Delay in Arrival to Care in Perpetrator-Identified Nonaccidental Head Trauma: Observations and Outcomes

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BACKGROUND: **Children who sustained nonaccidental head trauma (NAHT) are at severe risk for mortality within the first 24 hours after presentation.**

OBJECTIVE: **Extent of delay in seeking medical attention may be related to patient outcome.**

METHODS: **A 10-year, single-institution, retrospective review of 48 cases treated at a large tertiary Children's Hospital reported to the New York State Central Registrar by the child protection team was conducted. The perpetrator was identified in 28 cases on the basis of confession or conviction. The medical and legal records allowed for identification of time of injury and the interval between injury and arrival to the hospital; this information was categorized as follows: <6 hours (without delay); 6–12 hours (moderate delay); and >12 hours (severe delay). The King's Outcome Scale for Childhood Head Injury (KOSCHI) score was recorded for each case.**

RESULTS: **All children were 3 years of age or younger (2.1–34 months) and predominantly male (68%; 19/28). On arrival, 61% of patients (17/28) presented with moderate or severe delay. A low arrival Glasgow Coma Scale (GCS) score ($P < 0.0001$) and extracranial injuries ($P < 0.0061$) correlated with worse clinical patient outcomes. Patients with an arrival GCS score <7 predominantly arrived without delay or with moderate delay. Patients presenting without delay or with severe delay were more likely to have a higher KOSCHI outcome score on discharge ($P < 0.0426$). Four of the 6 patients who died presented after moderate delay.**

CONCLUSION: **Patients presenting to medical care 6–12 hours after NAHT (moderate delay) appeared to have worse outcomes than those presenting earlier or later.**

INTRODUCTION

Compared with adults, the immature brain's response to traumatic brain injury—principally those with inflicted injuries—demonstrates particular vulnerability (7). The injury itself evolves quickly from a combination of threats including angular forces from shaking episodes, hypoxia, and blunt trauma (5, 7, 15). The severity of brain response to nonaccidental head trauma (NAHT) accounts for 86% mortality with more than half of the mortalities occurring within the first 24 hours. The acute period becomes increasingly important as only 17% of those mortality cases arrived within 3 hours and 31% after 6 hours post injury (with delay) (11). This time in presentation delay may represent an identifiable factor affecting outcomes, as seen in both adult and pediatric stroke (2, 16). Previous data reporting higher NAHT mortality after 6 hours and treatment guidelines in stroke suggest delay in arrival, in part, may help in recognizing those with an increased chance of survival >24 hours.

Despite the initial history and confession generally observed to be limited or erroneous (1, 18) and the unreliability of computed tomography (CT) scans in predicting the time of injury, Willman et al. (21) determined the time of injury to be restricted to the immediate time after the last observed "period of wellness" (21).

Key words
- Child abuse
- Decompressive craniectomy
- Hypoxic - ischemic stroke
- Inflicted head injury
- Shaken baby
- Traumatic brain injury

Abbreviations and Acronyms
CNS: Central nervous system
CPCT: Child protection consultation team
GCS: Glasgow Coma Scale
KOSCHI: King's Outcome Scale for Childhood Head Injury
NAHT: Nonaccidental head trauma

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In 1995 report, Starling et al. (18) found 97% of identified perpetrators were present at symptom onset. When analyzing the confessions of identified perpetrators further, Starling et al. (19) in 2004 found symptoms appeared immediately after injury and this was irrespective of the mechanism of shaking and/or impact as contributory. Though less reliable than time of injury reported in accidental head trauma cases, Vinchon et al. incorporated this method for demonstrating a trend of longer delay in arrival to medical care with NAHT versus accidental cases, but with sooner observation toward elevated intracranial pressure in the NAHT group (20), suggesting importance to examining time delay in relation to neurologic compromise. In this study, cases with identified perpetrators were included to identify documented time of injury and to hypothesize that the time delay in arrival to care played an important role in overall patient neurologic outcome upon discharge. An a priori temporal profile based on data from NAHT mortality reports and stroke treatment guidelines was evaluated against perpetrator-identified cases included here. This profile of delay in arrival to medical attention is labeled as follows: without delay (0–6 hours), moderate delay (6–12 hours), and severe delay (>12 hours).

METHODS

A retrospective review of charts of all patients evaluated by the medical child protection consultation team (CPCT) and reported to the New York State Central Register over a 10-year span, with approval from the Institutional Review Board, was conducted. The total number of NAHT patients registered included 48 cases. Inclusion criteria enlisted cases where the perpetrator was specifically identified by the Child Protection Services of Nassau and Suffolk Counties and the boroughs ofBrooklyn and Queens and considered a primary suspect in trial for criminal investigation or was convicted by the local/state law enforcement agencies (8). Fourteen cases were excluded because of failure to identify the perpetrator or lack of availability of the chart for review at the time of the study. Twenty-eight cases met the criteria and were included in this study.

Symptom onset and reported time of injury was identified as the time of injury ictus similar to previous studies evaluating identified perpetrator confessions (18, 19, 21). The recorded pediatric emergency department (ED) triage time was identified as the arrival time to medical care. The elapsed time was then categorized into the following temporal classification: 1) No delay 0–6 hours, 2) Moderate delay 6–12 hours, and 3) Severe delay >12 hours. Categorization of time is based on delay in pediatric acute ischemic stroke studies evaluating demonstrating diagnosis and treatment importance within 6 hours (our no-delay group listed in our current study) (2, 16). Only admission Glasgow Coma Score (GCS) scores were recorded from initial ED trauma assessments or emergency medical services' evaluations as modified childhood GCS scores were not identified in all cases included in this study.

Outcomes were assessed on the basis of the following variables: serial imaging, in-hospital morbidity, and neurosurgical interventions. Outcomes were graded on discharge using the King's Outcome Scale for Closed Head Injury (KOSCHI) where a score of 1 = death, 2 = vegetative state, 3 = severe disability, 4 = moderate disability, and 5 = good recovery (4). These outcome scores were collected from archived discharge summaries and recorded and single-blinded from delay in arrival classification of respective cases.

Statistical assessments were performed by the Feinstein Institute Biostatistics Unit. Univariate analyses were performed and included the following variables: patient age, gender, admission delay, neuroimaging findings, operative intervention, GCS, KOSCHI score, and extracranial injuries. A multivariate analysis was not performed due to the limited number of cases included in the study. For statistical purposes, scores were graded in nonparametric ranks to preserve the order of the scoring. A Kruskal–Wallis test or Mann–Whitney test was used to test all univariate analyses, and a side-by-side box plot was generated to illustrate statistical findings. The GCS and KOSCHI score analysis was compared for spearman correlation. A P value of less than 0.05 was considered significant. SAS 9.2 statistical software (SAS Institute, Inc., Cary, North Carolina, USA) was used for all data evaluation.

RESULTS

Patient and Perpetrator Characteristics

We reviewed 28 children with a diagnosis of nonaccidental head trauma in which the perpetrator was specifically identified. This population presented predominantly infantile with an age ranging from 2–34 months, 93% (26/28) younger than 2 years of age (Table 1). Patients most often arrived via ambulance and

Table 1. Demographic Characteristics of Perpetrator—Identified NAHT

Characteristic	Value
Number of patients	28
Gender	
Female	10 (36%)
Male	18 (64%)
Age (months)	33.6 (range 14–54)
<2 years	26 (93%)
GCS (admission)	
<7	17 (61%)
>8	11 (39%)
Radiology	
Subdural hematoma	25 (89%)
Uncal herniation	5 (18%)
Bihemispheric brain edema	1 (4%)
Retinal hemorrhages	25 (89%)
KOSCHI (discharge)	
Home/foster	12 (43%)
Rehabilitation	10 (36%)
Mortality	6 (21%)

GCS, Glasgow Coma Scale; KOSCHI, King's Outcome Scale for Childhood Head Injury.

accompanied by at least 1 caretaker, typically 1 parent. In all cases, we evaluated the patient immediately on arrival. The history obtained during evaluation indicated erroneous injury had occurred in a majority of the cases. Notation of the time of symptom onset, which was specifically based on the first observation of symptom(s) obtained from the provided history, was identified in 100% of the cases. All of the perpetrator-identified cases had an eventual confession and/or conviction that confirmed the time described of injury ictus but not necessarily the initial mechanism of injury provided.

A male preponderance among perpetrators was not found here, as we identified 54% (15/28) of the perpetrators as female. Under further review of our cohort, we observed female patients associated equally between male and female perpetrators (1:1 ratio of male-to-female perpetrators in female NAHT), whereas we found male patients more likely injured by female perpetrators (10/18; 56%). Female perpetrators were often biological mothers and in select cases were involved in the care of multiple children. The nonsignificant lack of male preponderance among perpetrators observed here and in our group's recent report is different than previously reported male predator predominance.

Admission Characteristics

Admission GCS scores of less than 7 were identified in 61% of these patients (see Table 1). We found these patients to have undergone a neurosurgical operation (11/17; 65%) including subdural tap, craniotomy, and/or craniectomy, which was not statistically different from the 39% of perpetrator-identified NAHT patients who presented with at least a GCS score of 8 who had undergone a neurosurgical operation 64% (7/11) of the time as well (see Table 1). Not surprisingly, we did observe admission GCS scores highly correlative to patient discharge outcomes in our cohort (coefficient 0.831; $P < 0.0001$).

When reviewing radiologic and ophthalmologic examinations, we found subdural hematomas as a copredominant sign in 89% (25/28) of this cohort. We did identify uncal herniation (5/28; 18%) and bihemispheric brain edema (1/28; 4%) present in select cases (see Table 1). The other predominating sign on admission included numerous retinal hemorrhages (25/28; 89%).

Discharge Outcomes

We employed the KOSCHI scale to assess outcomes at the time of discharge from the hospital and questioned whether delay in arrival was associated with inpatient discharge outcomes. Overall, patients with low KOSCHI scores of 2, 3a, or 3b discharged to rehabilitation facilities represented the dominant proportion of our cohort. We observed patients with higher scores discharged home or to a foster home with multiple home care services in 36% of the patients (see Table 1). Twenty-one percent (6/28) of our NAHT patients died.

When evaluating specifically for delay in arrival association, eleven (39%) patients presented without delay versus seventeen (61%) patients with moderate (8; 29%) or severe (9; 32%) delay. Comparative analysis between this temporal delay to arrival classification and KOSCHI scores on discharge demonstrated a significant association ($P < 0.0426$). Specifically, patients arriving in moderate delay associated with worse clinical outcomes on discharge from the hospital compared with those who arrived without delay or in severe delay (Figure 1). We questioned if the strong correlation between GCS scores and KOSCHI discharge scores played a role here, but a significant association could not be identified between GCS and delay in arrival classifications. We predicted that discharge outcomes, despite presentation delay, may be worsened when associated with non−central nervous system (CNS) injuries. Seven out of 28 patients (25%) were identified with non-CNS injuries; this group of patients correlated with lower KOSCHI scores ($P < 0.006$, Figure 2). None of the non-CNS injuries were identified as the cause of death.

Operative Characteristics and Decompressive Craniectomy

The operative treatments included subdural taps, craniotomies, and craniectomies, which were in some cases performed acutely and in other cases performed a few days after intracranial pressure was proven intractable. When we reviewed operative procedures versus nonoperative management, we identified a significant association ($P < 0.0112$) with KOSCHI scores (Figure 3). Those who underwent a craniectomy were observed with lower outcomes. These cases were also identified with low GCS score presentations on arrival.

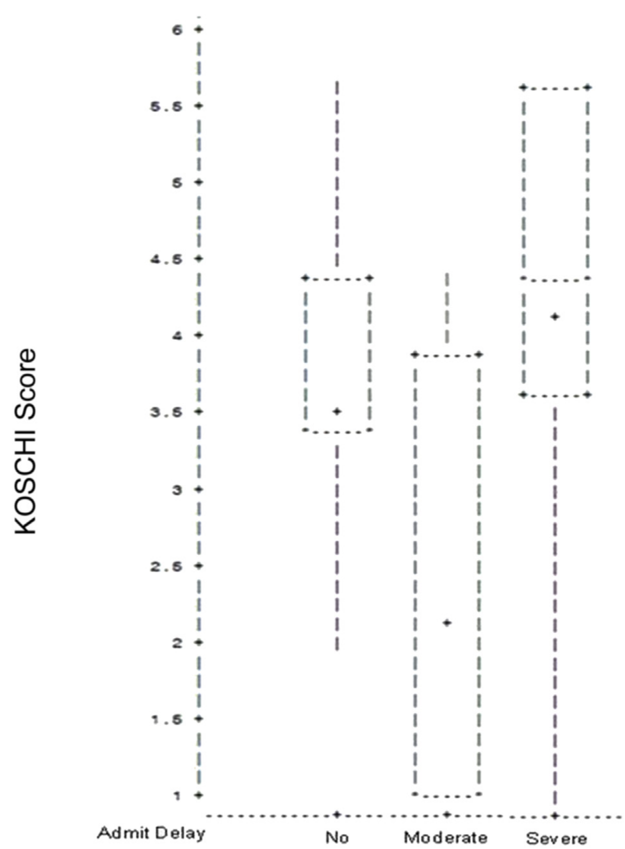

Figure 1. Classification of admission delay demonstrated a significant difference in discharge King's Outcome Scale for Childhood Head Injury scores ($P < 0.0426$).

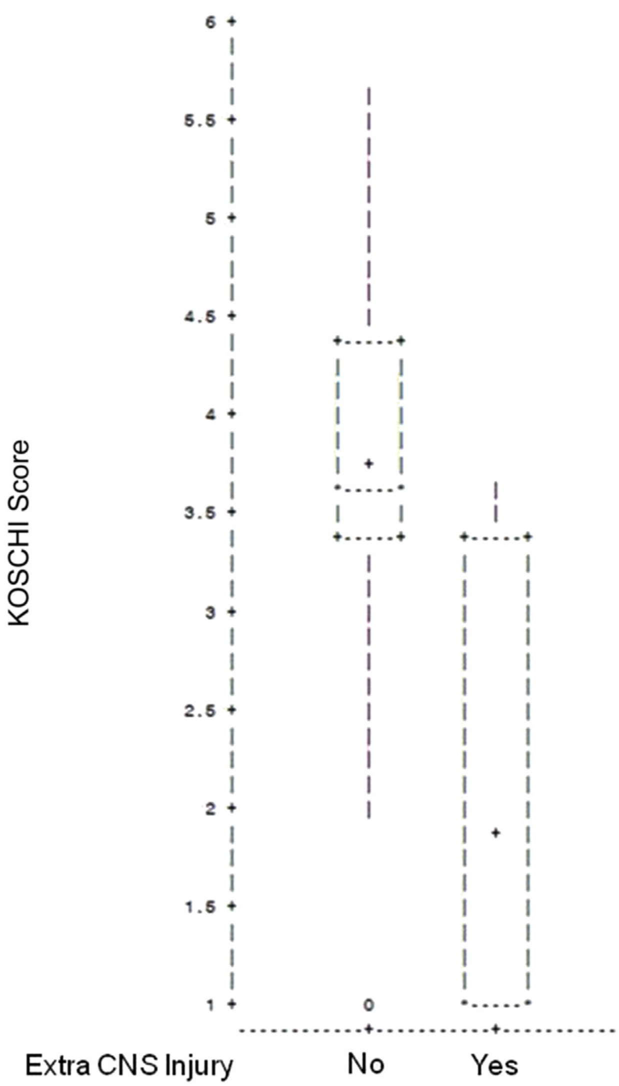

Figure 2. Isolated head injury versus those presenting with additional extra–central nervous system injuries demonstrated a significant difference in King's Outcome Scale for Childhood Head Injury discharge scores ($P < 0.0061$).

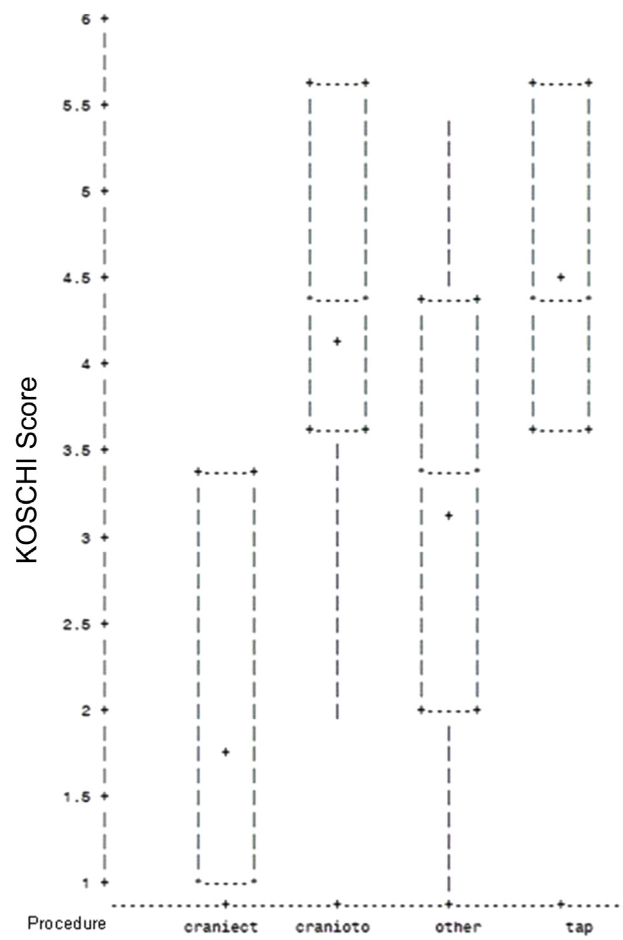

Figure 3. Operative procedures were found to have a significant difference in King's Outcome Scale for Childhood Head Injury discharge scores ($P < 0.0112$). However, subgroup analysis did not demonstrate significant differences in operative procedures.

We questioned the effect of a decompressive craniectomy in relation to the identified presentation delay. Six patients (21%) underwent a craniectomy as part of their life-sustaining care. The time of operation from hospital admission appeared heterogeneous, ranging from hours to 3 days post injury ictus, and the indication for decompression was based on declining clinical examination suggestive of worsening intracranial pressure or via direct measurement with escalating intracranial pressure to above 20 cm H_2O and deemed intractable to medical management. We hypothesize that the significant association of temporal delay classification with discharge KOSCHI scores would suggest differences in outcome within those who underwent a craniectomy despite their presenting CT findings (**Figure 4**). Given the small sample size ($n = 6$), we could identify no significant conclusions. However, we did observe an obvious trend. We found patients who arrived without delay (2/6) versus those who arrived in moderate delay (4/6) to survive and proceed to discharge to a rehabilitation facility versus the latter group (moderate delay) who all died (**Table 2**).

DISCUSSION

This is the first study to examine the extent of time delay from NAHT to hospital admission. Here, we evaluated only NAHT cases with a known perpetrator to accurately pinpoint a time of injury and assess a temporal profile of delay to seeking medical care. Our results demonstrate how identifying delay in arrival to medical attention relates to clinical outcomes on discharge. We further identified categories of this time delay in seeking medical attention and observed its effect on surgical cases and outcomes.

Evaluation of time of arrival is not novel. Literature in both adult and pediatric stroke has proven its association to outcomes and its

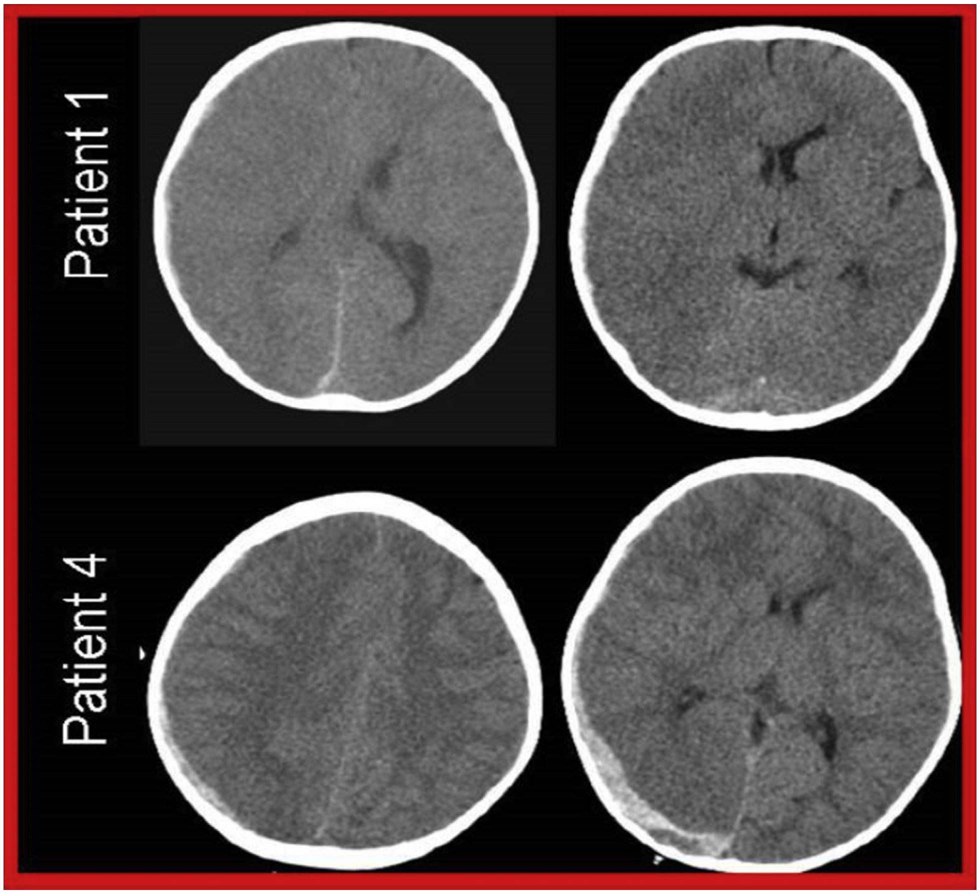

Figure 4. Comparison of presenting neuroimaging in 2 selected cases of admission without delay (*top row*) versus admission with moderate delay (*bottom row*).

pragmatic role in intervention success. NAHT includes observable ischemia, witnessed by a hypodensity on CT, and in only select cases on immediate arrival. Interestingly, a case series identified abnormal cerebral hypodensities presenting earlier than 6 hours after ictus rather than the well-described 24-hour appearance of an ischemic stroke—associated hypodensity (6). Physiological modeling of NAHT suggests that the combination of hypoxia with a momentous angular velocity associated with inflicted trauma may augment a secondary injury and represent a difference in the brain response to accidental versus nonaccidental head trauma (15). Clinical examples of this early progression are seen as Graupman and Winston reviewed all

Table 2. Decompressive Craniectomies in Perpetrator-Identified Nonaccidental Head Trauma

Patient	Age (months)	Admit Delay	Initial Glasgow Coma Scale Score	Days until Craniectomy	KOSCHI Outcome Score
1	11	Acute	6	3	3A
2	24	Acute	5	0	3A
3	10	Moderate	3	0	1
4	17	Moderate	3	0	1
5	18	Moderate	8	0	1
6	27	Moderate	3	0	1

KOSCHI, King's Outcome Scale for Childhood Head Injury.

mortality cases due to nonaccidental head trauma at their institution (11). They identified a predominant proportion of cases arriving within 12 hours after injury, and approximately half of those died within the first 24 hours (11). Studies employing in vivo models of the immature rodent brain demonstrate a greater dependency toward glutamate excitotoxicity. A blockade of glutamate receptors directly or the partial uncoupling of mitochondria (earlier than 6 hours) may delay progression of deleterious molecular events seen after NAHT (13). Measurement of glutamate levels clinically after NAHT in children have shown exorbitant levels peaking as early as 24 hours post injury impact (17). We classified a temporal profile of this time delay in arrival. Our results promote the concept of further studies needed to evaluate cerebrospinal fluid biomarkers in a temporal profile and in the setting of NAHT.

We identified those NAHT patients who arrive in moderate delay (6–12 hours) to associate with worse outcomes versus those who arrived without delay (0–6 hours) or those who arrive with severe delay (>12 hours). Patients who arrived with severe delay were associated with higher GCS scores due to less severe NAHT, and for this reason are found to have better outcomes than those who arrived in moderate delay. For example, this paradoxical relationship may be explained by 2 possible reasons: 1) the gravity of the injury is extremely underestimated in light of fear of what has happened or in fear of consequences resulting in loss of chances to help the child achieve intracranial pressure control sooner, and 2) the child is well, without symptoms, and the injury is a possible repetitive etiology of a now more chronic condition. Nonetheless, our report is observational and by no means offers a cause-and-effect relationship. Furthermore, our single institutional and retrospective design is not without the following possible influences including 1) regional bias, 2) a small cohort of patients with identified perpetrators retrospectively reviewed, 3) a sampling bias of the 10-year demographics, 4) a selection bias in our single institutional multidisciplinary care, 5) studying a probability-based diagnosis based on objective findings, and 6) the concern for obtaining legal confirmed documentation of presenting histories that is not used here as a surrogate or in replace of medical/scientific certainty. However, there are similar factors to comparable studies including victims more likely presenting as males and the victims of male perpetrators with worse outcomes compared with female perpetrators, as our working group has previously reported (8). Larger and prospectively designed studies are needed to definitively confirm findings reported in this study.

We questioned the effectiveness of operative interventions such as decompressive craniectomies and hypothesized that it may depend on this time of presentation classification. Recently, Oluigbo et al. (14) described the impact of NAHT versus other etiologies of head trauma on mortality following a decompressive craniectomy, further suggesting timing of intervention for NAHT patients may vary greatly from general head trauma (14). Here, we identified all moderate-delay NAHT patients who underwent a decompressive craniectomy associated with mortality. Conversely, we found the other 2 patients who received a decompressive craniectomy and arrived without delay associated with a hospital discharge to rehabilitation facilities. This evidence suggests delay to medical attention is a clear opponent to the reduction of mortality, despite several treatment modalities. Kan et al. (12) reported 31.4% mortality in their childhood head trauma institutional review, which included NAHT patients (12). Therefore the delay profile we identified here may account for select cases that develop worse clinical outcomes.

We did not evaluate whether delay in arrival to medical attention could assist in the diagnosis of NAHT. However, identification of a subdural hematoma and retinal hemorrhages has aided the diagnostic process (3, 5, 6, 9, 10). Undoubtedly, public health efforts on awareness and avoidance are the most effective methods to avoid this infant presentation. In addition to public health efforts as the first line of defense, we suggest that recognition of presentation delay can help identify those patients likely to progress to better outcomes.

CONCLUSION

This is the first report to examine the extent of delay in arrival of NAHT patients and as it relates to discharge outcomes. Infants arriving in moderate delay resulted in poorer clinical outcomes compared with those arriving with no delay (0–6 hours) or with severe delay (>12 hours), despite an operative intervention. Identifying a delay in arrival profile may aid in the identification of NAHT patients who may have a chance at better outcomes than what has been previously predicted for all NAHT children within 24 hours.

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