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Initial Neurologic Presentation in Young Children Sustaining Inflicted and Unintentional Fatal Head Injuries

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ABSTRACT. ***Background.*** **It remains unclear if fatal brain injuries in young children are characterized by immediate rapid deterioration or can present after an initial period of lucidity. This issue has legal implications in child abuse, for which understanding the clinical course affects perpetrator identification.**

Objective. **To determine patterns of neurologic presentation on hospital admission in infants and toddlers who die of inflicted and unintentional injury.**

Design/Methods. **Data on children <48 months of age who sustained a fatal head injury from 1986–2002 were extracted from the Pennsylvania Trauma Outcomes Study. Only those with external-causes-of-injury codes for inflicted injury, falls, and motor vehicle crashes (MVCs) with a recorded Glasgow Coma Scale (GCS) on admission were included. The GCS was compared across mechanisms and age groups (0–11, 12–23, 24–35, and 36–47 months).**

Results. **Of the 314 fatally injured children, 37% sustained inflicted injury, 13% sustained a fall, and 49% sustained an MVC. At admission, 6.8% of all children had a GCS score of >7, and 1.9% presented with a GCS score of >12 (lucid). The incidence of admission a GCS score of >7 varied by mechanism. Overall, children with inflicted injury were 3 times more likely to present with a GCS score of >7 than those injured in MVCs (odds ratio [OR]: 3.6; 95% confidence interval [CI]: 1.2–10.3), but incidence of a GCS score of >7 did not differ between inflicted injuries and falls. Similarly, when considering only those children ≥24 months old, a GCS score of >7 did not differ by mechanism. In contrast, in those <24 months old, children who died as a result of inflicted injury were >10 times more likely to have a GCS score of >7 than those who died as a result of a MVC (OR: 9.36; 95% CI: 1.3–80.9).**

Conclusions. **The data suggest an age- and mechanism-dependent presentation of neurologic status in children with fatal head injury. Although infrequent, young victims of fatal head trauma may present as lucid (GCS score: >12) before death. Furthermore, children <48 months old sustaining inflicted injury are 3 times more likely to be assessed with a moderate GCS score (>7) than those in MVCs. This effect is amplified in the youngest children (<24 months old): those with inflicted injury were 10 times more likely to present with moderate GCS scores than those in MVCs. In addition, this youngest age group seems to be overrepresented in those who present as lucid (GCS score: >12 [5 of 6]). It is unclear whether these differences are the result of inadequate tests to evaluate consciousness in younger children or differences in biomechanical mechanisms of inflicted trauma.** ***Pediatrics*** **2005;116:180–184;** ***abuse, accidents, falls, head injuries, lucid interval.***

ABBREVIATIONS. PTOS, Pennsylvania Trauma Outcomes Study; ICD-9, *International Classification of Diseases, Ninth Revision*; MVC, motor vehicle crash; GCS, Glasgow Coma Scale; OR, odds ratio; CI, confidence interval.

Homicide is the leading cause of injury death in infancy, and half of infant homicides occur during the first 4 months of life.[1] The majority of infant homicides involve inflicted traumatic brain injury. It remains unclear if fatal head injuries in young children are characterized by immediate rapid deterioration or can present after an initial period of lucidity.[2–5] This issue has legal implications in child abuse, for which understanding the clinical course affects perpetrator identification. Because inflicted injuries are typically unwitnessed and perpetrators are unwilling to provide a truthful history, the timing between injury and first clinical presentation may be unknown, further confounding the description of the clinical course.

In an attempt to determine if fatal head injuries in abused children are obviously symptomatic immediately, previous researchers have focused on the presence of a lucid interval by studying children who sustained unintentional fatal head injuries, for which the injury event is typically well documented. Plunkett[3] reported 18 short falls that resulted in fatal head injuries and documented 12 lucid intervals. In this study the average age (5.2 years) was significantly higher than that associated with child abuse. It is notable that no children were <1 year of age, and for those children <4 years of age, the lucid intervals documented were limited to <15 minutes. Willman et al[2] reviewed 95 cases of accidental fatalities involving head injury through a retrospective chart review and identified 2 children with a lucid interval: 1 child died with an epidural hemorrhage, and 1 died as a result of abdominal exsanguination. In their study, as well, the average age (8.5 years) was significantly older than the typical child involved in

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abusive head injury. Only 2 infants were included in their study sample. Because of variability in myelination and the size of subdural spaces between infants and older children,[6] the generalizability of their results to the inflicted-head-injury population remains unclear.

In this study, we build on this previous work and study a younger population. Specifically, we identify patterns of neurologic presentation for children <4 years of age who died as a result of inflicted and unintentional head injury.

METHODS

For the period 1986–2003, the Pennsylvania Trauma Systems Foundation Trauma Outcomes Study (PTOS) was reviewed to extract data on children <48 months of age who sustained a fatal head injury. PTOS is a statewide registry of clinical data from all 26 accredited trauma centers (adult and pediatric) throughout the state of Pennsylvania. A standardized set of data elements for cases that meet specific criteria is collected by trained trauma registrars in individual institutions and submitted to a central database. Inclusion criteria for the PTOS study are patients (all ages) admitted for treatment of a diagnosis of trauma including all intensive care admissions, all patients who were dead on arrival, all trauma deaths, and all admissions for at least 48 hours, including transfers. The diagnosis of trauma is defined as *International Classification of Diseases, Ninth Revision* (ICD-9) codes of 800 through 995. Cases are enrolled regardless of specific injury patterns. Specific exclusions include those patients with an isolated hip fracture, isolated asphyxiation, drowning, and poisoning. To minimize data errors, registrars attend mandatory training sessions semiannually, 1 of which focuses on interabstractor reliability. Audits are also performed regularly to monitor coding accuracy of the data submitted.

For this study, we selected those children <48 months of age with fatal head injuries from this database. Determination of fatal head injuries was based on ICD-9 coding of injuries. Only children who died with external-causes-of-injury codes (E codes) for inflicted injury (E967), falls (E880–E888), and motor vehicle crashes (MVCs) (E810–E819) with a recorded Glasgow Coma Scale (GCS) score on hospital admission were included. All 3 injury events were studied to determine the neurologic presentation of young children who sustained fatal head injuries from 3 varied mechanisms. MVCs, in particular, were chosen as a comparison to inflicted-injury events because the timing of the MVC relative to hospital presentation is well defined; thus, the occurrence of lucidity, if present, would be more likely to be documented. GCS scores were compared across mechanisms and age groups (0–11, 12–23, 24–35, and 36–47 months) by using the χ^2-test method. For the purposes of this study, relevant categorization of GCS scores was determined a priori (poor neurologic status: GCS score 3–7; moderate neurologic status: GCS score 8–12; good neurologic status [lucid]: GCS score 13–15).

RESULTS

Of the 314 fatally injured children identified, 37% (121) sustained inflicted injury, 13% (40) sustained falls, and 49% (153) were in MVCs. This distribution varied significantly by age ($P < .001$) (Fig 1).

Although most children had poor neurologic status on admission, 6.8% had an admission GCS score of >7, and 1.9% presented with a GCS score of 13–15 (lucid). Figure 2 demonstrates the distribution of GCS scores for each year of age.

The incidence of admission GCS scores varied by mechanism (Fig 3). Overall, children with inflicted injury were 3 times (odds ratio [OR]: 3.6; 95% confidence interval [CI]: 1.2–10.3) more likely to present with a GCS score of >7 than those in MVCs, but incidence of a GCS score of >7 did not differ between inflicted injury and falls (OR: 1.5; 95% CI: 0.4–5.5) (Table 1). When considering only children ≥24 months old, a GCS score of >7 did not differ by mechanism. In contrast, in those <24 months old, children who died as a result of inflicted injury were >10 times more likely to have a GCS score of >7 than those who died as a result of a MVC (OR: 10.6; 95% CI: 1.3–80.9). Thus, the influence of mechanism on the incidence of a GCS score of >7 varied by age.

Overall, 6 children were lucid (GCS score: >12) at admission, and children <24 months were overrepresented in this group (5 of 6). Moreover, 3 of 121 (2.5%) children with ultimately fatal inflicted injury were thought to be lucid at presentation to a Pennsylvania trauma hospital. All 3 were <24 months old (Table 2). Of the 6 children with a GCS score of >12 on admission, 4 sustained a subdural hematoma as part of their head injury.

DISCUSSION

Whether children can be lucid after sustaining a fatal head injury has important implications in the investigation of child abuse. Historically, infants and toddlers who have sustained fatal inflicted trauma are assumed to have been immediately and obviously symptomatic.[4,5] With a large sample of age-relevant cases, our data suggest that although infrequent, young victims of fatal head trauma may present as lucid (GCS score: 13–15) before death. In this series, ~2% of children <4 years of age were recorded as having a GCS score of 13–15 on arrival to a trauma hospital. By using PTOS data, our study only included children who were admitted to a Pennsylvania trauma hospital and did not capture data on children who died at the scene of the injury or at a local hospital before transfer to a trauma

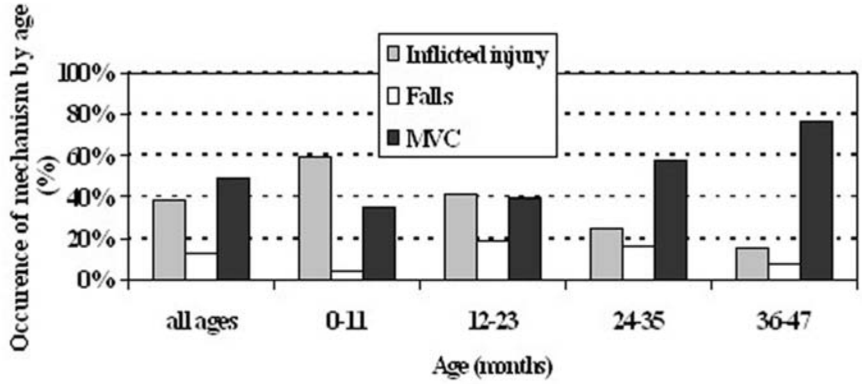

Fig 1. Distribution of injury mechanism (inflicted injury, falls, and MVCs) according to child age.

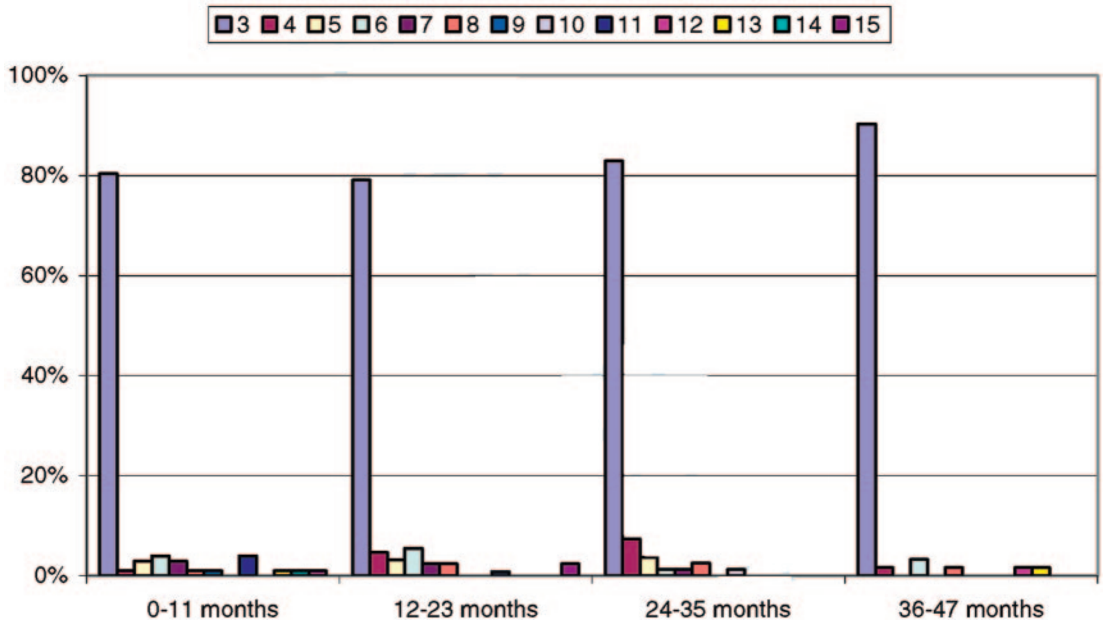

Fig 2. Distribution of GCS score according to child age.

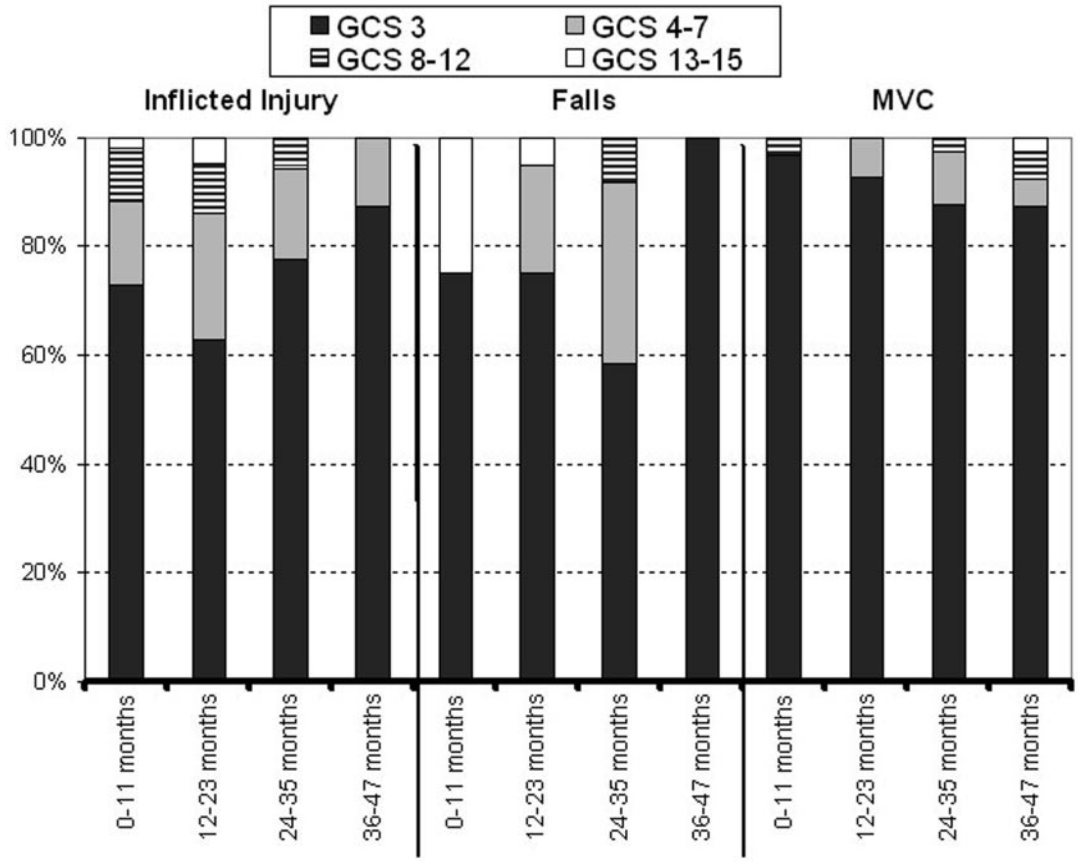

Fig 3. Distribution of GCS score according to child age and injury mechanism.

hospital. Therefore, our findings most likely overestimate the true percentage of children who seem to be lucid after fatal injury.

In our study, children <48 months old sustaining inflicted injury were 3 times more likely to be assessed with a moderate GCS score (>7) than those in MVCs. These results from a large sample support similar conclusions from single case reports.[4,5] In MVCs resulting in fatal injuries, the event is often a single, well-defined, high-energy impact. Inflicted injuries are typically more complex loading events that may include multiple purely inertial (shaking) as well as impact conditions, may encompass a wider magnitude range than MVCs, and may be repeated

TABLE 1. Percentage of Children With GCS Scores of >7

Age Group	Inflicted Injury, % (*n*)	MVCs, % (*n*)	Falls, % (*n*)	Inflicted Injury vs MVCs/Inflicted Injury vs Falls, OR (95% CI)
Overall	10.7 (13/121)	3.3 (5/153)	7.5 (3/40)	3.6 (1.2–10.3)/1.5 (0.4–5.5)
0–23 mo	12.6 (12/95)	1.4 (1/72)	8.3 (2/24)	10.6 (1.3–80.9)/1.6 (0.3–7.6)
24–47 mo	3.8 (1/26)	4.9 (4/81)	6.2 (1/16)	0.8 (0.08–7.2)/0.6 (0.03–10.3)

TABLE 2. Children With GCS Scores of >12 ($n = 6$)

Mechanism (Age Group)	Head Injury	Hospital Length of Stay, d
MVCs		
36–47 mo	Closed skull fracture, SAH, SDH, EDH	3
Falls		
0–11 mo	Closed skull fracture, SAH, SDH, EDH	1
12–23 mo	Closed skull fracture, intracranial hemorrhage	9
Inflicted injury		
0–11 mo	Intracranial hemorrhage	1
12–23 mo	SDH	2
12–23 mo	SDH, MMA/intracranial hemorrhage	47

SAH indicates subarachnoid hematoma; SDH, subdural hematoma; EDH, epidural hematoma; MMA, middle meningeal artery.

at intervals of hours, days, or weeks. It remains unclear if repeated mild head injuries exacerbate or modulate the response compared with a single, more severe injury event.[7–9]

Our data indicate that the initial neurologic presentation of children with fatal head injury also depended on age. In the youngest children (<24 months old), those with inflicted injury were 10 times more likely to present with a moderate GCS score than those in MVCs. In addition, this youngest age group seems to be overrepresented in those who present as lucid (GCS score: 13–15 [5 of 6]). For those >24 months old, there was no difference in GCS scores among the 3 injury mechanisms. This result can be interpreted in several ways. It may suggest that inflicted injuries in infants occur more frequently, or that there are distinct responses of an infant's and toddler's brain to traumatic loading. Studies that examine the biomechanical, neurologic, and physiologic responses of the young child's brain across the age range are necessary to fully explain these results.

Alternatively, the overrepresentation of the youngest infants in the moderate-GCS-score group may simply reflect the inadequacy of the GCS in assessing neurologic damage or mental clarity in the very youngest patients. The GCS relies on motor and verbal skills that cannot be assessed accurately in infants and toddlers. For example, the motor component of the GCS assesses localization of pain, which does not typically develop in a child until ~18 months of age. The verbal response options are inappropriate for preverbal children, greatly limiting the reliability of the overall scale. Additionally, spontaneous eye opening and/or nonspecific movements in response to pain can be seen in infants who have suffered severe traumatic brain injury affecting the cortex, which can result in the assigning of an erroneously high GCS score.[10] To overcome these limitations, a number of pediatric-appropriate scales have been developed. Some of them do not overcome the challenges of finding practical but accurate ways to assess infant neurologic function and remain inappropriate for intubated patients.[11–13] Although appropriate scales have been developed for use in infants and toddlers, their prognostic ability has not been tested.[10] Despite progress to create and validate appropriate coma scales for young children, none have been broadly adopted by clinicians, and the GCS remains the scale used in most trauma centers, including those in Pennsylvania. However, because in this series the majority of patients who died as a result of inflicted injury were infants, the imprecision of GCS at younger ages may confound our findings.

Although our data suggest that a small percentage of infants and toddlers with fatal head injury can present as lucid to a trauma center, it does not imply that these children were completely asymptomatic. The GCS does not measure common symptoms of head injury such as vomiting, irritability, or subtle changes in alertness. It is possible that some children with GCS scores of 13–15 had clinical signs of head trauma not assessed by that scale.[14]

Specific clinical presentation among a sample of children with fatal head injuries is variable. Researchers have suggested that an infant's response to traumatic loading differs from that of an older child[6] and that the acceleration magnitude varies by the mechanism.[15,16] Little research has been conducted that correlates specific clinical presentations of young children with neuropathological findings and how that varies by age and injury mechanism. Future work should focus on making these linkages to determine if those fatal cases that present with a lucid interval demonstrate unique pathology from the overwhelming majority of children who are immediately obviously symptomatic.

These analyses were conducted on a specific population of young children with fatal head injuries from Pennsylvania's statewide trauma registry. This registry has been used previously to study injury events (the rates and injury characteristics of firearm injuries in adolescents and young adults[17] and risk of pulmonary embolism after head injury in adults[18]). Of Pennsylvania's 67 counties, 51 have a trauma center in the county or an adjoining county. These 51 counties include 84% of Pennsylvania's population. We hypothesize that the majority of those children with fatal head injuries not contained in the Pennsylvania Trauma Systems Foundation database died at the scene and did not enter the health care system. This consideration would only serve to emphasize the rarity of a lucid interval, because it would increase the underlying population of children with fatal head injuries from which our 6 children with GCS scores of 13–15 are drawn.

A population-based database such as that used in this study provides an appropriate sample to be able to conduct relevant statistical analysis. Data in the database were deidentified and abstracted from medical records, preventing the review of the actual medical details, confirmation of the injury mechanism, and determination of the nuances of the clinical time course of an individual patient. Future studies should utilize multicenter networks such as the Pediatric Emergency Care and Applied Research Network (PECARN) to identify substantial numbers of young children with fatal head injuries in which detailed clinical data and injury-mechanism information can be obtained.

CONCLUSIONS

Our data suggest that on rare occasion, an infant or toddler can sustain a fatal head injury yet present as lucid to hospital clinicians before death. Whether this is because of differences in pathologic injury, neurologic responses unique to the infant brain, or limitations of the bedside methods used to assess neurologic function in young children cannot be determined by this study. Because fatal head injury is a relatively rare event in infancy, improved understanding about the clinical course of infants and toddlers after fatal head injury will be served best by cooperative, multicenter work.

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