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RESTRICTING THE TIME OF INJURY IN FATAL INFLICTED HEAD INJURIES

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ABSTRACT

Objective: To determine the normal clinical progression of fatal head injuries in children. Such information can then be used to estimate the time of injury in cases with obscure histories and will thus aid investigations of nonaccidental trauma.
Method: A retrospective chart review design was used. One hundred and thirty eight accidental fatalities involving head injury were identified and 95 of these were used as the study group. Details of the cases were reviewed and cases in which a child either had a Glasgow Coma Scale (GCS) of 14–15 or was described as having a "lucid interval" or as being "conscious" were further studied.
Results: One "lucid interval" case was identified. This case involved an epidural hematoma. Three other cases that partially met the criteria for a lucid interval were also identified; one of these cases did not meet the criteria for inclusion in the study group. Review of head CTs revealed that brain swelling could be detected as early as 1 hour and 17 minutes post injury.
Conclusions: The children studied were in obvious serious medical condition from the time of injury until death. If a history purports a lucid interval in a fatal head injury case that does not involve an epidural hematoma, that history is likely false and the injury is likely inflicted. The time of most fatal head injury events can be restricted to the time period after the last confirmed period of wellness for the child. In addition, the presence of brain swelling on a head CT scan is not helpful in restricting the time of injury © 1997 Elsevier Science Ltd

Key Words—Child abuse, Head injury, Timing of injury, Lucid interval, Inflicted injury.

INTRODUCTION

WHEN ABUSED CHILDREN present to a medical facility for care, the accompanying history of injury is often false. The incorrect history may attempt to draw suspicion away from the person responsible for injuring the child or to make someone else seem responsible for the injuries. After the child's injuries are determined to be inflicted rather than accidental, a caregiver may insist that the injury event must have occurred at some time prior to when the child was in his or her care or as a result of a minor accidental injury. The question then arises: Can an infant or young child who experiences a fatal head injury look and act well post injury?

In fatal inflicted head injury (HI) cases, a reliable history is often available indicating that a "normal" child was transferred from one caregiver to another. For example, a parent may transfer care of an infant to a daycare provider and both adults may agree that the infant appeared normal at the time that care was transferred. Eye contact, reaching, grasping, playing, smiling, normal feeding, and other normal behaviors may be described. This normal appearance and behavior of the child may also be confirmed by more or less unconnected observers such as the parents of other children being brought for child care. If the time of injury can be reliably restricted to after the

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transfer from one caregiver to another, this information can be crucial in allowing the complex issues surrounding such a case to be properly managed.

Studying the clinical course of inflicted head injuries is difficult. The histories provided for children who experience inflicted injuries are often inaccurate and there is often a delay of care preventing documentation of the child's clinical state immediately after injury. In contrast, accurate data can be obtained in accidental fatal HI cases. Most accidental fatal head injuries are the result of motor vehicle accidents (MVA) and these events are usually witnessed and receive prompt emergency medical service (EMS) response. Data are recorded by objective witnesses and trained medical professionals from the time of the accident until the time of death. If lucid intervals commonly occur in inflicted fatal HI cases, review of accidental fatal HI cases should also reveal the frequent occurrence of such periods of well being post injury.

Lucid intervals do occur after some head injuries. In one study, 25.1% of patients with head injuries were found to have "talked at some time between trauma and subsequent deterioration into coma" (Lobato, Rivas, Gomez, Castaneda, Canizal, Sarabia, & Munoz, 1992). Lucid intervals following a traumatic event resulting in isolated epidural hematoma are well described in children (Schutzman, Barnes, Mantello, & Scott, 1993). Lucid intervals preceding death have also been described in patients who were found to have intracranial bleeds or cerebral contusions (Adams, 1990).

Fatal head injuries, however, often involve subdural or subarachnoid bleeding accompanied by brain swelling. In addition, subdural hematoma is reported as the most common type of craniocerebral injury resulting from child abuse (Tullous, Walker, & Wright, 1992; Hahn, Raimondi, McLone, & Yamanouchi, 1983). The literature indicates that a patient presenting with a subdural hematoma is "less likely" to have a lucid interval, as compared to a patient presenting with an epidural hematoma. The severe forces causing a subdural bleed are thought to preclude a return to consciousness in fatal cases (Tullous, Walker, & Wright, 1992). This retrospective study will investigate the likelihood of a lucid interval post injury after reviewing fatal HI cases. Armed with this data, the clinician can better restrict the time period during which an inflicted traumatic event occurred amidst a long and convoluted story that purposefully tries to mask the nonaccidental nature of the trauma.

The results of radiological studies are often central to the evaluation of fatal head injury cases and can sometimes be used to date injuries. This study will quantify the time period after injury at which brain swelling can become apparent on head CT scans. Thus, the usefulness of head CT scans in restricting the time at which a fatal head injury occurred will be determined.

METHODS

The study was designed as a retrospective medical chart review. The use of data from the Children's Hospital Trauma Database was approved by the Trauma Advisory Committee at the Children's Hospital and Health Center in San Diego.

Children 16 years old and younger who suffered fatal accidental injuries involving blunt head injuries from August 1984 to July 1995 were included. Cases were excluded for the following reasons: (1) unwitnessed injury; (2) no EMS response to the scene of the injury (SOI); (3) occurrence of a penetrating head injury or gun shot wound rather than solely a blunt head injury; (4) partial or complete brainstem or spinal cord transection documented on the autopsy report; or (5) no available documentation of the child's pre-hospital clinical course. An air or ground ambulance record, emergency department (ED) trauma run sheet, or investigative report prepared by the medical examiner's office containing clinical details from the SOI were considered acceptable forms of pre-hospital documentation. Data collected on each case included age, sex, mechanism of injury, initial clinical appearance, date and time of injury and death, Glasgow Coma

Scale (GCS) score and pupillary exam at the SOI and upon arrival to the first ED at which the child was examined, head computed topography (CT) scan findings, and autopsy findings. All data were collected, coded, and analyzed by a single reviewer.

Using the times of events recorded in each case's medical chart, the survival time after injury was calculated. The survival time was defined as the time interval from the earliest documented time post injury to the time at which the child was pronounced dead. The first documented time post injury might be the time of the event according to the medical examiners investigative report, the time that a ground or air ambulance arrived at the SOI, or the time that the ED was first contacted by the field responders.

All cases were specifically reviewed for the occurrence of a lucid interval post injury. A lucid interval was defined as a time when a child had a GCS score of 14–15, or when the terms "lucid interval" or "conscious" were used to describe a patient's clinical state.

The component and aggregate GCS scores at the SOI and in the ED were recorded for all cases with available data (see Appendix for Glasgow and Pediatric Coma Scales; Hahn, Chung, Barthel, Bailes, Flannery, & McLone, 1988). GCS scores were used to group cases according to the severity of HI as follows: severe HI, GCS score 3–8; moderate HI, GCS score 9–12; mild HI, GCS score 13–15. For each case, the GCS score at the SOI and upon arrival to the ED were compared to determine if any patients had a higher score in the ED than at the SOI. A GCS score increase of 4 points or greater was judged as clinically significant, indicating that the patient had experienced improvement in clinical status from the time of evaluation at the SOI to the time of evaluation in the ED.

When data in the chart conflicted regarding a patient's GCS score or pupil exam, the case was assigned the better score or more normal exam for purposes of the data analysis. For example, if the ED records indicated a patient as having "GCS of 7–10" the patient was assigned GCS score of 10. Similarly, in tabulating the pupillary exams a patient was counted as having reactive pupils even if only one pupil was documented to be reactive or if the pupils were noted to be sluggishly reactive. When exact pupillary sizes were recorded, a pupil size of 5 mm or greater was counted as dilated. Thus if the chart indicated left pupil 5 mm and nonreactive, right pupil 7 mm and nonreactive, this child was classified as having "fixed and/or dilated pupils." Pupillary exams that could not be coded as either reactive or fixed and/or dilated according to the above criteria were not included in the summary of pupillary exam data.

Head CT scans were retrospectively reviewed by a single pediatric radiologist for signs of brain swelling (compromise or effacement of the basal cisterns and poor gray-white differentiation) as well as intra-axial and extra-axial hemorrhages. Brain swelling was graded as none, mild, moderate, or severe for each case. The time from injury to head CT scan was calculated using the time of injury as defined above and the time that the head CT scan was performed according to the radiology reports.

Autopsies in all cases had been performed in the San Diego County Office of the Medical Examiner, and copies of the autopsy reports were reviewed by the authors. Examination of the brains had utilized standard methods for removal, fixation, slicing, and gross microscopic examination. Specific autopsy examination for diffuse axonal injury had not been consistently performed.

RESULTS

One hundred and thirty eight cases of accidental fatal HI were identified for review. Cases were excluded from the study group based on the following: seven cases with no EMS response at the SOI, one case of an unwitnessed injury, 23 cases with a near or complete spinal cord or brain stem transection documented by autopsy, 10 cases of gun shot wounds or other penetrating injuries. Of

Table 1. Formation of the Study Group

Total Fatal Cases of Accidental Head Injury, Aug. 1984–July 1995	138
Cases excluded by study group criteria	
Unwitnessed injury	1
No EMS response to scene of injury	7
Penetrating injury/gun shot wound	10
Spinal cord or brainstem partial or complete transection	23
Total cases excluded by study criteria	41
Cases Eligible for Study Group	97
No pre-hospital data available	2
Study Group Cases	95

the 97 remaining cases fitting the criteria for the study group, two cases had no available documentation of the child's pre-hospital clinical course. The study group thus consisted of 95 cases (see Table 1).

The average age of the study group patients was 8.5 years, with a standard deviation of 4.0 years. The youngest child in the group was 99 days old and the oldest was 16.2 years old. Only 4.3% of the study group (four cases) was younger than 2 years old at the time of injury. The sex distribution of the study group was 64.2% male and 35.8% female.

In all but two of the study group cases, the mechanism of injury was a variant of a MVA. The specific mechanisms of injury in the MVA cases were: child as a pedestrian 32.6%, child as a motor vehicle passenger 29.5%, child on a bicycle or tricycle 25.3%, child on a skateboard or roller-skates 9.5%, and child riding a three wheeler vehicle 1.1% (one case). There was also one child (1.1%) who was injured while doing stunts on his bike and one child (1.1%) who was stuck on the head by a large board in a hardware store (see Figure 1).

The median survival time was 6.1 hours, with a minimum survival time of 29 minutes and a maximum survival time of 139 days. In one case, the survival time could not be calculated

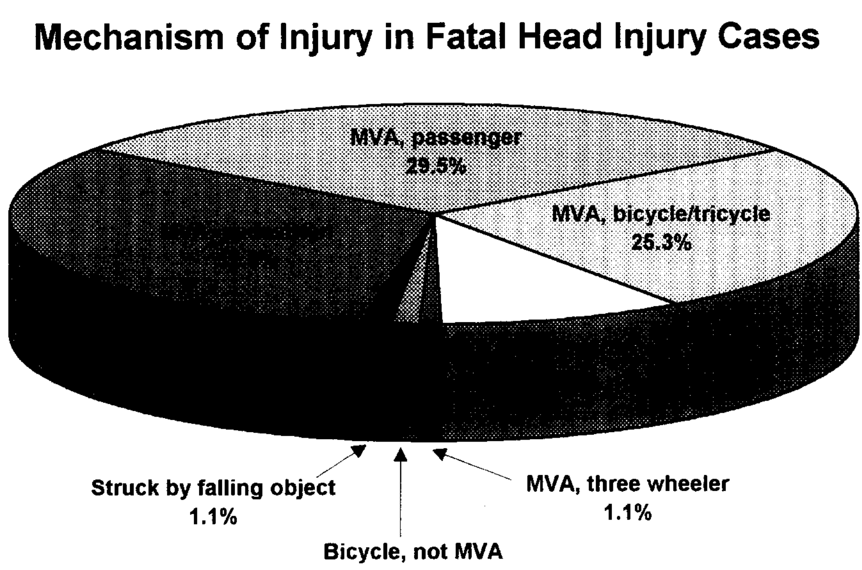

Figure 1.

because the time of the injury was not documented, however this child expired 9.5 hours after arrival in the ED.

Cerebral injuries incurred by the study group included the following: subarachnoid hemorrhage (75.8%), subdural hemorrhage (52.6%), epidural hemorrhage (14.7%), cerebral, cerebellar or brainstem contusion (54.7%), skull fracture (54.7%), and cerebral edema (47.4%). In only three of the study group cases was neither a subarachnoid, subdural, or epidural hemorrhage documented. Other significant injuries in each of these three cases included: Case A—intraventricular hemorrhage and flail chest; Case B—brain matter protruding from a skull fracture and open cortex laceration and contusion; and Case C—cerebellar contusion, cerebral edema and flail chest.

All cases were specifically reviewed for the occurrence of a lucid interval post injury. There was only one case in the study group in which a lucid interval occurred. The details of this case are given below.

Lucid Interval Case 1: An 11-year-old boy rode his bike ran into a parked car. At the SOI the child was evaluated as having a GCS score of 15 and bilaterally equal and reactive pupils. When the child arrived in the ED he was assigned a GCS score of 14; his verbal score was 4 because his speech was "somewhat confused." The head CT scan done approximately 45 minutes post injury revealed a large epidural hemorrhage, no other intracrainial hemorrhage, and no brain swelling. During the placement of a craniotomy, a surgical complication ensued. Autopsy reported diffuse subarachnoid hemorrhage and severe subarachnoid hemorrhage around the Circle of Willis as well as a 2.0 cm defect in the temporal lobe and a skull fracture status post craniotomy and ventriculostomy. No significant noncrainial injuries were found on the autopsy, however the child's heart, lungs, liver, kidneys, pancreas, spleen, and adrenal glands were not examined as they had been removed for organ donation. The autopsy reported the cause of death as blunt force trauma to the head with the contributing factor of intraoperative hemorrhage and cerebral laceration from a surgical drill. The child was pronounced dead 56 hours after the injury.

This case demonstrates the occurrence of a lucid interval concomitant with an epidural hemorrhage. The epidural hemorrhage was the only HI apparent on the initial CT which was taken prior to the occurrence of the surgical complication. If the surgical complication had not occurred this case may not have been a fatality. This was the only case of a fatal head injury associated with a lucid interval found in this study.

In two other cases, the criteria used in this study to identify lucid intervals were partially met, but as discussed below, lucid intervals did not in fact occur. In one case, the words "lucid interval" were written once on a flow sheet in the chart. Close review of this case, however, revealed that the child did not experience a period of normal consciousness. The term "lucid interval" had been misused. In another case, the child was fully conscious with a GCS of 15 upon arrival to the emergency room, however this child had only a minor head injury and the cause of death was abdominal exsanguination. As would be expected in auto accident victims, many children in the study had multiple body injuries in addition to their head injuries. Unlike in this case of fatal abdominal exsanguination, the severity of head injury was the primary cause of death in most cases in this study. There were no other cases of possible lucid intervals in the study group.

The cases excluded from the study group (two cases excluded due to lack of pre-hospital data and 41 cases excluded based on study group criteria) were also reviewed for any indication that lucid intervals might have occurred. There was one possible lucid interval case among the excluded cases and the details are as follows.

Lucid Interval Case 2: A 6-year-old girl was reportedly on her bike when she collided with an automobile. She was not wearing a helmet at the time of injury. She received no immediate medical attention and walked home after the injury incident. Apparently, she complained of a headache and was lethargic later during the evening on the day of the injury. The next morning her family could not arouse her from bed and EMS was called. GCS score of 3 was documented upon arrival of EMS the morning after the injury and when the child was first evaluated at the ED. Pupils were documented as fixed and dilated at both of these evaluations as well. A huge epidural hemorrhage was confirmed by a head CT scan. The head CT scan also showed a moderate amount of brain swelling. She died approximately 54 hours after the injury event. The autopsy report noted status post evacuation of an epidural hematoma, a linear skull fracture, and diffuse cerebral edema.

Table 2. GCS Scores at the Scene of Injury

	GCS Score Components		
Score	Eye	Verbal	Motor
1	79	80	56
2	3	6	11
3	2	0	7
4	5	2	9
5	NA	1	2
6	NA	NA	4
Totals	89	89	89

Interestingly, this child had a history of being sexually abused. There was no indication in the chart that any inflicted injury or abuse was suspected to be related to her death.

This case was excluded from the study group because although EMS was called and responded several hours after the injury, there was no EMS response at the SOI. As in Lucid Interval Case 1, Lucid Interval Case 2 illustrates a lucid interval associated with an epidural hemorrhage.

Glasgow Coma Scale scores were available at the SOI for 89 cases and upon arrival to the ED for 94 cases. All the cases with no documented GCS at the SOI were evaluated as having a GCS score of 3 upon arrival to the ED. The cases without GCS scores at the SOI included: (1) the case of fatal abdominal exsanguination referred to above; (2) one case of a child documented at the SOI to have reactive pupils, a pulse of 60 beats per minute and labored respirations at 40 breaths per minute; (3) one case of a child who was described as "unresponsive" with fixed pupils, no pulse, and no blood pressure at the SOI; (4) three additional cases where children received cardiopulmonary resuscitation before arrival to the ED. The one case with no GCS score in the ED had a GCS score of 3 at the SOI.

Of the study group cases with documented GCS scores, 89.9% had severe HI at the SOI and 97.2% had severe HI upon arrival to the ED. Moderate HI was documented in 9.0% of cases at the SOI and in 2.1% of cases upon arrival to the ED. The aggregate GCS scores for the patients with moderate HI at the SOI were as follows: three cases GCS score of 9; two cases GCS score of 10; two cases GCS score of 11; and one case GCS score of 12. One of these cases of moderate HI at the SOI was classified as a moderate HI upon arrival to the ED while all the others fell into the category of severe HI upon arrival to the ED. In the only other case of moderate HI upon arrival to the ED, the child fit the definition of severe HI with a GCS score of 6 at the SOI, but was then assigned a GCS score of 10, fitting the definition of moderate HI upon arrival to the ED. Mild HI was documented in 1.1% of cases (one case) at the SOI and in 2.1% of cases (two cases) upon arrival to the ED. These cases of mild HI at either the SOI or in the ED are Lucid Interval Case 1 and the case of fatal abdominal exsanguination mentioned above (see Tables 2, 3, 4, and 5, and Figure 2).

Only two cases demonstrated an increase in GCS score judged to be clinically significant when comparing the evaluation at the SOI and in the ED. In one case, a 4–point difference of GCS score was entirely a function of an increase in the motor component of the GCS score; a motor score of 1 given at the SOI and a motor score of 5 given in the ED. Additional ED documentation indicates that the patient was withdrawing from pain rather than localizing pain and should have been given a motor score of 4 rather than 5 in the ED, and would thus only have had a 3–point increase in GCS score. In the second case of a 4–point increase in the GCS score, the child's score increased from 6 (Eye 1, Verbal 1, Motor 4) at the SOI to 10 (Eye 3, Verbal 3, Motor 4) in the ED. This child's

Table 3. GCS Scores Upon Arrival in the ED

	GCS Score Components		
Score	Eye	Verbal	Motor
1	89	90	72
2	1	1	8
3	1	1	6
4	3	1	4
5	NA	1	2
6	NA	NA	2
Totals	94	94	94

autopsy reported cranial injuries as follows: epidural, subdural, and subarachnoid hemorrhages; midline hemorrhage of the pons; brain edema; contusions of brain with subcortical hematoma; and fracture of the skull. This is the only case of an increase in GCS score that is judged to be clinically significant and indicative of an improvement in clinical status between the evaluation at the SOI and in the ED. In six additional cases there were 1 and 2 point increases in GCS scores between the SOI and the ED and in all but one of these cases the increase was solely a function of an increase in the motor component of the GCS score in the ED.

Documentation of either reactive or fixed and/or dilated pupils was available at the SOI for 73

Table 4. Comparing Aggregate GCS Scores at the SOI and in the ED

Score	Scene of Injury	Arrival to ED
3	56	74
4	10	7
5	6	4
6	6	4
7	1	1
8	1	0
9	3	0
10	2	1
11	2	1
12	1	0
13	0	0
14	0	1
15	1	1
Totals	89	94

Table 5. Severity of Head Injury According to GCS Score

	Scene of Injury		Arrival in ED	
	n	%	*n*	%
Severe HI (GCS 3–8)	80	89.9	90	95.7
Moderate HI (GCS 9–12)	8	9.0	2	2.1
Mild HI (GCS 13–15)	1	1.1	2	2.1

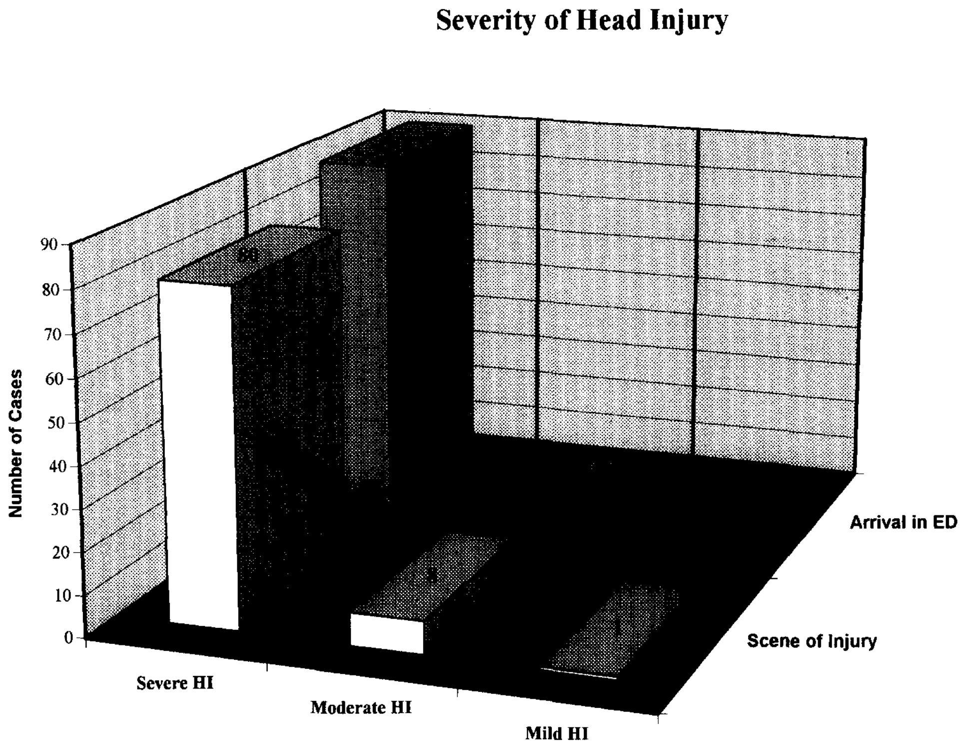

Figure 2.

cases and upon arrival in the ED in 85 cases. Reactive pupils were documented at the SOI in 32.9% of these cases and upon arrival to the ED in 21.2% of these cases. Bilaterally fixed and/or dilated pupils were documented at the SOI in 67.1% of these cases and upon arrival at the ED in 78.8% of these cases.

Among the study group, 30 cases had head CT scans available for review. The shortest documented time interval between injury and a head CT scan demonstrating severe brain swelling was 1 hour and 17 minutes. Among the study group cases with head CT scans performed less than 3 hours post injury, six (26.1%) had severe brain swelling, 10 (43.5%) had moderate brain swelling, and six (26.1%) had mild brain swelling. Only one case (4.3%) in which a head CT scan was

Table 6. Correlating Brain Swelling on Head CT Scans With the Time Interval From Injury to Head CT Scan

	Time Interval from Injury to CT	
Brain Swelling on CT	<3 hours	>3 hours
None	1	
Mild	6	2
Moderate	11	3
Severe	6	1
Totals	24	6

performed within 3 hours after injury showed no brain swelling. This case is described above as Lucid Interval Case 1. Head CT scans performed greater than 3 hours post injury demonstrated various degrees of brain swelling as well (see Table 6).

DISCUSSION

It is evident that the vast majority of children who die of blunt head injuries do not behave normally immediately after the injury event (89.9% had GCS score < 8 and 67.1% had fixed and/or dilated pupils at the SOI). Likewise, few cases show clinical improvement during the time period immediately following injury that might be interpreted as a lucid interval. The child whose GCS score increased from 6 at the SOI to 10 in the ED showed the most improvement of all the cases in the study group. Even in this case, the increase in GCS score is probably at least in part a function of the poor inter-rater reliability of the GCS score tool or the failure of the pre-hospital personnel to recognize subtle neurologic signs. As demonstrated by the other cases of increased GCS score, the motor component of the GCS score seems to be particularly subject to inter-rater variability. This variability of the motor score is probably in part due to the fact that painful procedures, such as needle sticks, may elicit a child's best response to pain but might not occur until the child is in the ED.

Review of all the cases in the study group as well as all the cases excluded from the study group (138 total fatal cases of accidental HI reviewed), revealed the possible occurrence of lucid intervals in only a few select cases. In Lucid Interval Cases 1 and 2, lucid intervals were associated with epidural hematomas. As presented above, an epidural hemorrhage was the only finding related to the traumatic event in both Lucid Interval Case 1 and 2. With timely and proper treatment, a child with an epidural hemorrhage and no other serious HI would not be expected to die. If there had been no surgical complication in Lucid Interval Case 1 and no delay in presentation to a medical facility in Lucid Interval Case 2, these cases may not have been fatal cases. In another case, the word "lucid" was used in the chart but review of the case revealed that this was a misapplication of the term. In the only other case where a child was fully conscious post injury, the cause of death was fatal abdominal exsanguination and the child had suffered only minor head injuries. In summary, there were no cases identified in which children died from head injuries involving entities other than pure epidural hematoma where the child experienced a normal state of consciousness post injury.

It should be noted that Lucid Interval Case 1 was not the only case in the study group in which an epidural hematoma occurred. In fact, 14.7% of the study group (14 cases) had epidural hematomas, and only one of these cases of epidural hematomas (7.1% of the total number of epidural hematoma cases) was found to be associated with a lucid interval. Lucid Interval Case 1 was the only case of epidural hematoma where both the epidural hematoma and any concurrent head injuries were mild enough to allow a normal state of consciousness post injury.

The results of this study suggest that a fatal HI that does not involve an epidural hemorrhage must have occurred after the last known time that the child exhibited normal behavior. For a baby, normal behavior may be demonstrated by the ability to feed, the ability to respond to surroundings, the ability to demonstrate age-appropriate volitional motor activity, or the ability to be consoled. For an older child, normal behavior can be demonstrated by normal speech, eating, or playing. The time of the injury event in a fatal HI without an epidural hemorrhage can be restricted to after a confirmed period of such normal behavior. Given the obvious serious medical condition of the vast majority of the study group immediately after injury, one would expect any competent caretaker to call for medical assistance within moments of any similar HI. A delay in presentation to a medical facility after such an injury is likely a clue that nonaccidental trauma needs to be investigated rather than an indication that the child was is no apparent need of medical attention until some time after the injury.

The rarity of lucid intervals in this series requires an explanation. As mentioned in the introduction, other studies have found larger percentages of patients who "talk and die" or have lucid intervals. Based upon communications from the physicians involved in the care of the patients in this series, we hypothesize that the rarity of lucid intervals is related to improvements in the care of head injured patients in our hospital since 1985. Since that time, we have been fortunate to have a rapid response system in the field and have been aggressively managing head-injured patients in the hospital (personal communication, B. M. Peterson, 1997). Thus only those patients with the most severe injuries die. Those with less severe injuries, some of whom are capable of talking post injury, do not die. Thus as medical management continues to improve we would expect even fewer fatal cases to involve lucid intervals.

Although the results of this study indicate that the injury event must have occurred after the last period of confirmed well-being, the exact age of an injury upon presentation is difficult to determine. Head CT scans can be helpful in distinguishing relatively new (up to 3 days) from old (greater than 7 days) cerebral injury. Unfortunately, these imaging techniques cannot predict the exact age of an injury. Although some literature indicates that brain swelling usually takes at least 18–24 hours to develop, other literature reports that brain swelling can occur almost immediately after injury (Bruce, Alavi, & Bilaniuk, 1981; Barkovich, 1995). Perhaps this discrepancy in the literature can be explained by the fact that the signs of brain swelling on CT are subtle and can be easily missed. As shown in this study, brain swelling can occur almost instantaneously after an injury, or at least as fast as we are able to transport a child from the SOI to the CT scanner. Although radiology can offer black and white pictures to help in the evaluation of HI cases, it can not provide a precise answer regarding the time of the injury.

The average age of the study group (8.5 years) was significantly older than the average age of children suffering inflicted head injuries. The children with inflicted head injuries are often victims of the shaken baby syndrome and are usually less than 2 years old. The older age of the study group partly reflects the fact that older children are more likely to be involved in the activities associated with fatal accidental head injuries such as bike riding and walking in traffic. The most important effect of this age discrepancy is that the less myelinated infant brain with larger subdural spaces may respond differently to injury than the brain of an older child or adult (Kirschner, & Wilson, 1994). It is hypothesized that this larger subdural space may allow for a lucid period before an evolving subdural hematoma would produce symptoms. Unfortunately, only four children in this study (4.3% of the study group) were less than 2 years of age at the time of injury. Thus, this study can not reliably comment on the possibility of a different response to blunt HI in some children in this younger age group. Even so, none of the four children less than 2 years of age were among the lucid interval cases identified in this study. A larger population of fatal accidental HI cases would have to be reviewed in order to identify a sufficient number of children under 2 years of age to fully examine the effect of age on the clinical response to blunt HI.

Diffuse axonal injury is thought to be highly associated with persistent unconsciousness from the moment of injury (Adams, 1990). Diffuse axonal injury can be documented at autopsy by utilizing special brain sampling techniques and histochemical methods. Unfortunately, standard procedures of searching for diffuse axonal injury were not utilized during the autopsies in this study. The prevalence and significance of diffuse axonal injury could not be examined by this study.

The limitations of this study also include its retrospective design and its less than ideal sample size. This study should serve as a starting point to prove the hypothesis that children who die of blunt head injuries rarely, if ever, have a normal clinical appearance post injury.

CONCLUSION

Unless an epidural hematoma is present, children who die of blunt head injuries probably do not experience lucid intervals. In cases of fatal HI where the history claims that the child looked well following the injury and only later began to act abnormal, the story must be questioned and nonaccidental trauma must be suspected. Except in cases involving epidural hematomas, the time of injury in a fatal head injury case can be restricted to after the last confirmed period of normal consciousness for the child. Even in cases involving epidural hematomas, the presence of significant subarachnoid hemorrhage or subdural hemorrhage makes a lucid interval unlikely.

Brain swelling evident on a head CT scan can occur as early as 1 hour post injury. The appearance of brain swelling on a head CT scan is not useful in restricting the time of injury in fatal HI cases.

It is the hope of the authors that studies similar to this can be done at other institutions. Such a multicentered study approach would allow analysis of a larger number of cases and would enhance the certainty of the results. Drawing cases from a larger population would also allow specific analysis of cases involving infants. Future studies might be able to examine nonfatal cases of head injuries and determine the likelihood of a lucid interval occurring post injury and before life saving treatments in these cases.

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REFERENCES

Adams, J. H. (1990). Brain damage in fatal non-missile head injury. In R. Braakman (Ed.), *Handbook of clinical neurology* (p. 47). New York: Elsevier Science Publishers.

Barkovich, J. A. (1995). Destructive brain disorders of childhood. In J. A. Barkovich (Ed.), *Pediatric neuroimaging* (pp. 107–175). New York: Raven Press.

Bruce, D. A., Alavi, A., & Bilaniuk, L. (1981). Diffuse cerebral swelling following head injuries in children: The syndrome of "malignant brain edema." *Journal of Neurosurgery*, **54**, 170–178.

Hahn, Y. S., Chung, G., Barthel, M. J., Bailes, J., Flannery, A. M., & McLone, D. G. (1988). Head injuries in children under 36 months of age: Demography and outcome. *Child's Nervous System*, **4**, 34–40.

Hahn, Y. S., Raimondi, A. J., McLone, D. G., & Yamanouchi Y. (1983). Traumatic mechanisms of head injury in child abuse. *Child's Brain*, **10**, 229–241.

Kirschner, R. H., & Wilson, H. L. (1994). Fatal child abuse—The pathologist's perspective. In R. M. Recee (Ed.), *Child abuse: Medical diagnosis and management* (p. 325–357). Philadelphia, PA: Lea & Febiger.

Lobato, R. D., Rivas, J. J., Gomez, P. A., Castaneda, M., Canizal, J. M., Sarabia, R., Cabrera, A., & Munoz, M.J. (1992). Head-injured patients who talk and deteriorate into coma. Analysis of 211 cases studied with computerized tomography. *Journal of Nuerosurgery*, **75**, 256–61.

Schutzman, S. A., Barnes, P. D., Mantello, M., & Scott, R. M. (1993). Epidural hematomas in children. *Annals of Emergency Medicine*, **22**, 535–41.

Tullous, M., Walker, M. L., & Wright, L. C. (1992). Evaluation and treatment of head injuries in children. In B. P. Fuhrman, & J. J. Zimmerman (Eds.), *Pediatric critical care* (Chapter 100, pp. 1165–1182). St. Louis, MO: Mosby Year Book Inc.

RÉSUMÉ

But: Déterminer la progression clinique normale des lésions crâniennes fatales chez les enfants. Cette information peut alors être utilisée pour évaluer le moment du traumatisme dans les cas, présentant de sombres histoires, ce qui facilitera les enquêtes des traumatismes non-accidentels.

Méthode: Une revue rétrospective de dossiers a été utilisée. Cente trente huit morts d'enfants accidentelles incluant un traumatisme crânien ont été identifiées, dont 95 ont été utilisées comme groupe d'étude. Les détails des dossiers ont été passés en revue et les cas où l'enfant présentaient un GCS de 14-15 ou avait été décrit comme ayant eu "un intervalle lucide" ou ayant été "conscient" ont été appeofondis.

Resultats: Un cas d'"intervalle lucide" présentait des haematomes épiduraux. Il n'y avait pas de cas où un enfant avait présenté un "intervalle lucide" avant de mourir d'un traumatisme crânien, excepté dans ces cas sélectés. Le passage en revue des CT de la tête a révélé que l'oedème cérébral pouvait être détecté aussi tôt qu'une heure et 17 minutes après le traumatisme.

Conclusions: Mis à part ces cas sélectés d' "intervalle lucide", les enfants étudiés présentait une condition médicale grave évidente depuis le traumatisme jusqu'à la mort. Quand une histoire contient un "intervalle lucide" dans un cas fatal de traumatisme crânien, qui n'implique pas un haematome épidural, cette histoire est probablement fausse et le traumatisme probablement infligé. Dans la plupart des cas, le moment où le traumatisme crânien fatal a été infligé, peut être attribué à la période après la dernière période confirmée de bien-être de l'enfant. En plus, la présence d'un oedème cérébral sur un CT scan n'est pas utile pour déterminer le moment où le traumatisme a été infligé.

RESUMEN

Objetivo: Determinar cuál es la progresion clinica normal de lesiones mortales en la cabeza producidas en ninos/as. Esta información podrá utilizarse entonces para estimar el momento en el que se produjo la lesión en casos con historias poco claras, y ayudará en la investigación de lesiones no accidentales.
Método: Se utilizó un diseno retrospectivo de revisión de expedientes. Se identificaron 138 casos de muertes accidentales provocadas por lesiones en la cabeza; 95 de ellos formaron el grupo objeto de estudio. Se revisaron las circunstancias de cada caso, y se estudiaron más detenidamente aquéllos en los cuales el nino/a habia tenido un GCS de 14-15, o se describia que habia tenido un "período de lucidez" o había estado "consciente".
Resultados: Hubo un caso con "período de lucidez" entre los casos con hematomas epidurales. No hubo ningún caso en el que el nino/a tuviera un período de lucidez antes de morir a causa de la lesión en la cabeza, exceptuando esos casos elegidos. La revision de los CT de la cabeza reveló que, una hora y diecisiete minutos después de producirse la lesion, ya se podia detectar una tumefacción cerebral.
Conclusiones: Excepto en los casos seleccionados con "intervalo de lucidez", los ninos/as estudiados estuvieron en un estado médico claramente grave desde el momento de la lesion hasta su fallecimiento. Cuando una historia clinica de una lesion mortal en la cabeza incluya un período de lucidez, los hechos pueden situarse en el período de tiempo posterior al último momento en que se haya confirmado que el nino/a estaba bien. Por otra parte, la presencia de una tumefacción cerebral en un examen CT de la cabeza, no sirve de ayuda para precisar el momento en que se produjo la lesión.

Appendix. Glasgow and Pediatric Coma Scales

	Child	Infant
	Eye Opening	
1	None	None
2	To Pain	To Pain
3	To Voice	To Speech
4	Spontaneous	Spontaneous
	Verbal Response	
1	None	None
2	Incomprehensible	Moans to Pain
3	Inappropriate Words	Cries to Pain
4	Confused	Irritable Cries
5	Oriented	Coos, Babbles
	Motor Response	
1	None	NA
2	Extension (Pain)	Abnormal Extension
3	Flexion (Pain)	Abnormal Flexion
4	Withdraw (Pain)	Withdraw (Pain)
5	Localizes Pain	Withdraws to Touch
6	Obeys Commands	Normal Spontaneous Movement