J Neurosurg Pediatrics 4:414–419, 2009

Comparison of accidental and nonaccidental traumatic brain injuries in infants and toddlers: demographics, neurosurgical interventions, and outcomes

Clinical article

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Object. Nonaccidental trauma has become a leading cause of death in infants and toddlers. Compared with children suffering from accidental trauma, many children with nonaccidental trauma present with injuries requiring neurosurgical management and operative interventions.

Methods. A retrospective review was performed concerning the clinical and radiological findings, need for neurosurgical intervention, and outcomes in infants and toddlers with head injuries who presented to Albany Medical Center between 1999 and 2007. The Fisher exact probability test and ORs were computed for Glasgow Coma Scale (GCS) scores, hyperdense versus hypodense subdural collections, and discharge and follow-up King's Outcome Scale for Childhood Head Injury (KOSCHI) scores.

Results. There were 218 patients, among whom 164 had sustained accidental trauma, and 54 had sustained nonaccidental trauma (NAT). The patients with accidental traumatic injuries were more likely to present with GCS scores of 13–15 (OR 6.95), and the patients with NATs with of GCS scores 9–12 (OR 6.83) and 3–8 (OR 2.99). Skull fractures were present in 57.2% of accidentally injured patients at presentation, and 15% had subdural collections. Skull fractures were present in 30% of nonaccidentally injured patients, and subdural collections in 52%. Patients with evidence of hypodense subdural collections were significantly more likely to be in the NAT group (OR 20.56). Patients with NAT injuries were also much more likely to require neurosurgical operative intervention. Patients with accidental trauma were more likely to have a KOSCHI score of 5 at discharge and follow-up (ORs 6.48 and 4.58), while patients with NAT had KOSCHI scores of 3a, 3b, 4a, and 4b at discharge (ORs 6.48, 5.47, 2.44, and 3.62, respectively), and 3b and 4a at follow-up.

Conclusions. Infant and toddler victims of NAT have significantly worse injuries and outcomes than those whose trauma was accidental. In the authors' experience, however, with aggressive intervention, many of these patients can make significant neurological improvements at subsequent follow-up visits. *(DOI: 10.3171/2009.6.PEDS0939)*

Key Words • **decompressive craniectomy** • **head trauma** • **traumatic brain injury** • **infant** • **toddler** • **outcome** • **complications**

Traumatic injury is the leading cause of death in children, with NAT being a leading cause of traumatic death during infancy.[14] In the United States, NATs occur in 17 of 100,000 children younger than 2 years of age.[18] Subdural hematomas are found in 20–25/100,000 children between the ages of 1 and 3 years, with most cases the result of physical abuse.[15] It has been reported that minority groups tend to have a higher incidence of NAT.[18] Children who are the victims of NAT also tend to have worse outcomes compared with those who have suffered accidental trauma, with a reported 15–38% mortality rate.[11]

The goal of our study was to determine the incidence of accidental and nonaccidental head trauma in infants

Abbreviations used in this paper: CPS = Child Protective Services; GCS = Glasgow Coma Scale; KOSCHI = King's Outcome Scale for Childhood Head Injury; ICP = intracranial pressure; NAT = nonaccidental trauma; SDH = subdural hemorrhage; TBI = traumatic brain injury.

This article contains some figures that are displayed in color online but in black and white in the print edition.

and toddlers in the Capital District Region of upstate New York, and to compare patient demographics, radiological findings, need for neurosurgical intervention, and outcomes between the groups, and determine what statistical differences may exist between them.

Methods

After obtaining approval from the Institutional Review Board at Albany Medical Center, we performed a retrospective chart review of all infants and toddlers who were admitted with head injuries from January 1, 2002, through December 31, 2008. To detect possible differences in alleged child abuse from those of confirmed child abuse, records were also obtained and reviewed from CPS. Therefore, a case was only classified as abuse or NAT after it was thoroughly investigated and proven as such by CPS. A query was also performed through the New York State Trauma Registry to assure that our database included all cases of infant and toddler head injury that occurred during the assigned time frame. This comprehensive database was established in 1992 and includes patients with a high injury severity or who were brought to the emergency department and died there of a trauma-related injuries before admission as an inpatient. Patients with head injuries sustained from child abuse were identified using the International Classification of Diseases diagnosis codes.

Of the patients meeting the criteria for this review, we focused on age, sex, race, admission GCS score, findings on the admission brain CT scan (including review of bone anatomy to evaluate for fractures), treatment modality (observation, placement of an ICP monitor, craniotomy, craniectomy, subdural tap, or elevation of fracture), CPS workup, and outcome. Skull radiographs were not reviewed, as we believed that CT scans were more likely to reveal skull fractures. We used the KOSCHI scale as a measure of outcome (1 = death, 2 = vegetative, 3 = severe disability, 4 = moderate disability, 5 = good recovery).[8] We entered this information into a Microsoft Excel database, where we converted the raw data into percentages to summarize demographic variables and elucidate trends among the groups. In addition, we were specifically interested in comparing accidental and nonaccidental trauma on variables related to presentation and outcome. Chi-square, Fisher exact probability test, and ORs were computed for hypodense versus hyperdense SDH, presentation GCS scores, and discharge and follow-up KOSCHI scores.

Results

Three hundred and thirty-nine infants and toddlers ranging in age from 0 to 36 months were identified in the New York State Trauma Registry who were admitted to Albany Medical Center Hospital between 2002 and 2008. Of these 339 children, 218 had head injuries: 164 were sustained accidentally, and 54 were the result of NAT. Nonaccidental traumatic injuries were suspected in 95 children, but only 54 were proven cases of NAT. In the accidental trauma group, 56% were boys and 44% were girls, while in the NAT group, 59% were boys and 41% were girls (Table 1). Racial characteristics of the accidental trauma group were as follows: 79.8% Caucasian, 12.8% African American, 4.2% Hispanic, and 3% other. Of the children in the NAT group, 62.9% were Caucasian, 24% were African American, 7.4% were Hispanic, and 5.5% were other (Table 1). Patient age varied as follows: for the accidental trauma group, 41.4% of patients were 0–6 months of age, 17% were 7–12 months, 6.1% were 13–18 months, 23.1% were 19–24 months, 1.2% were 25–30 months, and 10.9% were 31–36 months. In the NAT group, 48.1% were 0–6 months, 27.7% were 7–12 months, 1.8% were 13–18 months, 18.5% were 19–24 months, 0% were 25–30 months, and 3.7% were 31–36 months of age (Fig. 1).

TABLE 1: Demographic information for infants and toddlers sustaining accidental and nonaccidental trauma, including sex and race*

Demographic Characteristic	% AT (164 children)	% NAT (54 children)
M	56	59
F	44	41
Caucasian	79.88	62.96
African American	12.8	24.07
Hispanic	4.27	7.41
other race	3.05	5.56

* AT = accidental trauma.

Admission GCS scores varied as follows: in the accidental trauma group 86.5% had GCS scores of 13–15, 7.9% had scores of 9–12, and 5.4% had scores of 3–8. In the NAT group, 46.1% had GCS scores of 13–15, 37% had scores of 9–12, and 14.8% had scores of 3–8 (Fig. 2). Patients with GCS scores at presentation of 13–15 (OR 6.95, 95% CI 3.46–13.96) were much more likely to have sustained accidental traumatic injuries, while nonaccidental injuries were more likely in patients with GCS scores of 9–12 (OR 6.83, 95% CI 3.09–15.07) and 3–8 at presentation (OR 2.99, 95% CI 1.09–8.2). Radiographic findings were as follows: in the accidental traumatic injury group 57.2% presented with a skull fracture, 14.5% with an SDH, 6.2% with an epidural hematoma, 6.7% with intraparenchymal hemorrhage, 7.7% with subarachnoid hemorrhage, and in 7.8% of children there were no significant CT findings. In the NAT group, 30.4% had a skull fracture, 52.1% had an SDH, 2.9% had an epidural hematoma, 7.2% had an intraparenchymal hemorrhage, 4.3% had a subarachnoid hemorrhage, and in 2.9% of children there were no significant findings on CT (Table 2). Patients who presented with hyperdense and hypodense SDHs were more likely to be part of the NAT group (OR 6.39, 95% CI 3.44–11.87). Specifically, patients with evidence of hypodense SDHs on head CT scans were significantly more likely to be in the NAT group (OR 20.56, 95% CI 6.74–62.7).

Fracture location also varied by group. Of those with accidental injuries, 60% had parietal fractures, 6.36% had frontal, 10.9% had orbital, 10% had temporal, 10% had occipital, and 2.7% had multiple fractures. Fractures among those with NAT were 43.8% parietal, 14.2% frontal, 9.5% orbital, 19% temporal, 0% occipital, and mul-

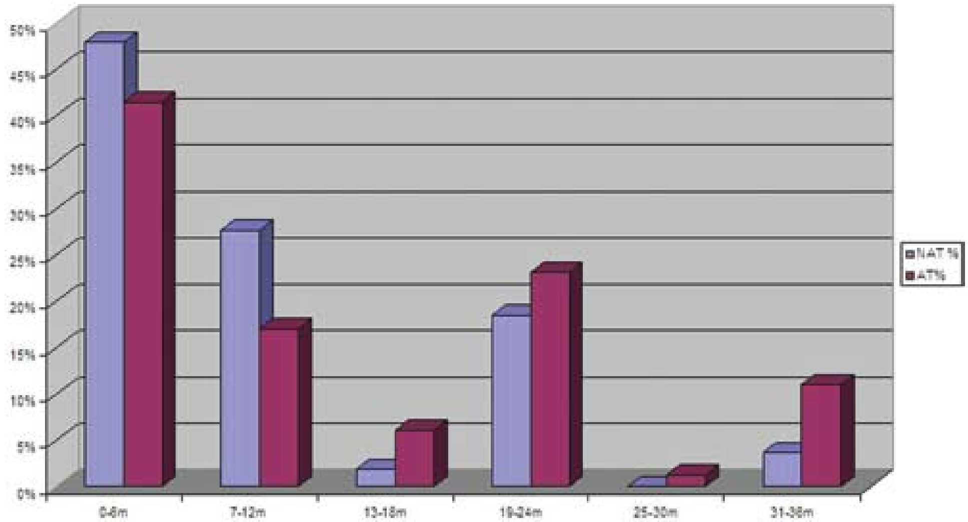

Fig. 1. Bar graph demonstrating the percentage of infants and toddlers presenting with accidental (AT) and nonaccidental trauma represented in 6-month blocks for ages 0–36 months.

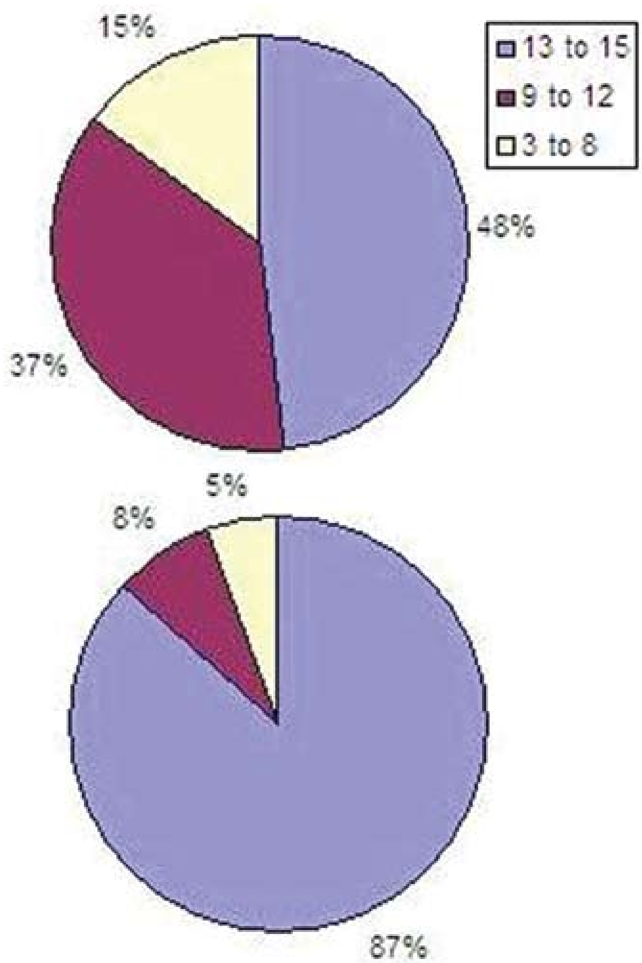

Fig. 2. Pie graphs showing the percentage of infants and toddlers presenting with GCS scores of 13–15, 9–12, or 3–8. *Upper:* The breakdown of GCS scores among infants and toddlers who have sustained accidental trauma is shown. *Lower:* The breakdown of GCS scores among infants and toddlers who have sustained NAT is shown.

tiple fractures were noted 14.2%. Subdural hemorrhage type also varied by group: of those with SDH in the accidental trauma group, 85.7% were hyperdense and 14.2% were hypodense, while in NAT group 41.6% were hyperdense and 58.3% were hypodense (Fig. 3). Based on these results, we estimated the sensitivity of hypodense SDH at 84% and its specificity at 80% for the diagnosis of NAT; the predictive positive value was 60% and the positive likelihood ratio was 4.1. We estimated the sensitivity of hyperdense SDH at 38% and its specificity at 76% for the diagnosis of NAT; the predictive positive value was 22% and the positive likelihood ratio was 1.6.

Treatment modalities varied among patients in the 2 groups, and are summarized in Table 3. Outcome was assessed using KOSCHI scores, and follow-up duration ranged from 3 to 18 months (Table 4). The overall mortality rate in our series was 0.6% among patients who sustained accidental trauma and 3.7% for those with NAT. Accidentally injured patients were much more likely to have a KOSCHI score of 5 at discharge and at follow-up, with ORs of 6.48 (95% CI 3.31–12.66) and 4.58 (95% CI 2.23–9.4), respectively. Scores of 3a, 3b, 4a, and 4b at discharge were more likely in the NAT group, with ORs of 6.48 (95% CI 1.15–36.4), 5.47 (95% CI 1.26–23.7), 2.44 (95% CI 1.01–

TABLE 2: Radiographical findings on initial brain CT scans in infants and toddlers who sustained accidental and nonaccidental trauma*

Radiographic Finding	% AT (164 children)	% NAT (54 children)
skull fracture	57.2	30.4
SDH	14.5	52.1
EDH	6.2	2.9
IPH	6.7	7.2
SAH	7.7	4.3
no finding	7.8	2.9

* EDH = epidural hematoma; IPH = intraparenchymal hematoma; SAH = subarachnoid hemorrhage.

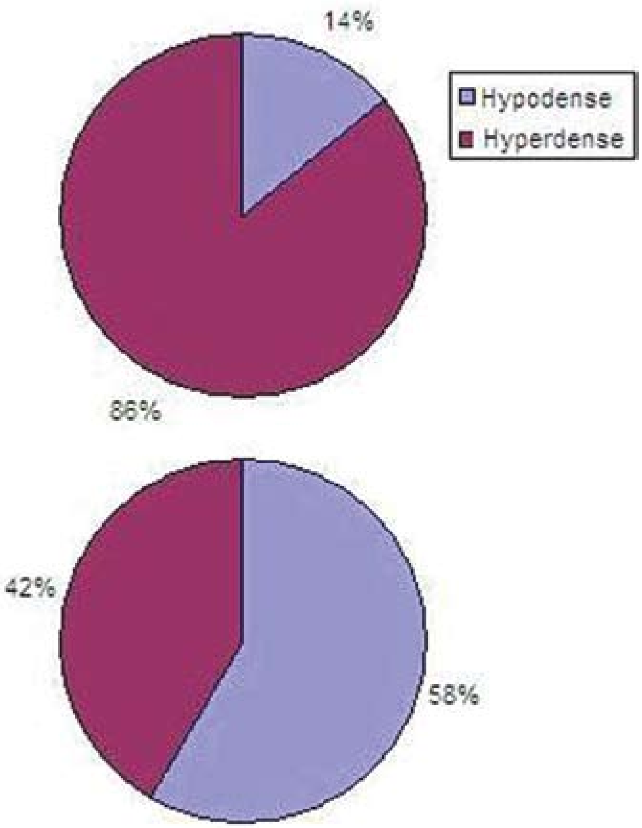

Fig. 3. Pie graphs showing the percentage of infants and toddlers presenting with hyperdense or hypodense subdural fluid collections. *Upper:* The breakdown of subdural collections among infants and toddlers who have sustained accidental trauma is shown. *Lower:* The breakdown of subdural collections among infants and toddlers who have sustained NAT is shown.

5.86), and 3.62 (95% CI 1.51–8.64), respectively. At follow-up, KOSCHI scores of 3b and 4a were also more likely in the NAT group, with ORs of 13.04 (95% CI 1.4–119) and 5.09 (95% CI 1.8–14.6), respectively.

Discussion

The incidence of nonaccidental or inflicted TBI in the infant and toddler population has been reported previously as 17–19 cases per 100,000 persons for children 0–2 years of age.[3,9,18,19] The reported proportion of accidental trauma and child abuse associated with head injuries in infants has varied between 17 and 56% of cases, according to the age and severity of the selected population.[11,13,25] Various authors have reported an apparent predominance of male victims of child abuse[3,9] and noted an increased prevalence of abuse among minority populations.[19] Interestingly, we did not find a statistically significant male predominance in either the accidental trauma or the NAT group, nor did we see a greater frequency of cases in the minority populations. In fact, in both the accidental trauma and NAT groups, Caucasians were by far the predominantly represented race. Accordingly, in the most recent US Census, the Capital Region (City of Albany and surrounding areas) showed a majority of Caucasians (63% Caucasian, 28.1% African American, 5.5% Hispanic or Latino of any race, and 2.6% Asian).[24]

Conventional reporting of incidence rates for childhood injuries uses age brackets of 0–1, 1–4, 5–9, and 10–14 years for age-specific rates. Agran and colleagues[1] argued that even single year of age rates for children younger than 4 years may not reflect variations in risk because of rapid developmental changes in the infant and toddler years. Using 3-month age brackets, these authors showed that the incidence of “assault and neglect” cause-of-injury codes for 1996–1998 hospital discharges and death certificates in California was highest at 0–2 months of life, declined slightly at 3–5 months, and then declined precipitously thereafter.[4] In the present study we chose to examine our groups in 6-month brackets and found that most injuries were sustained within the first 6 months of life in both groups; this finding mirrors the trend described by Agran et al. However, we did not see a sharp decline in the number of cases after age 6 months. In-

TABLE 3: Summary of treatment modalities initiated for infants and toddlers who sustained accidental and nonaccidental trauma*

Treatment Modality	% AT (164 children)	% NAT (54 children)
craniotomy	3.0	20.3
craniectomy	0.6	12.9
STD	0.6	25.9
VPS	0.0	0.0
elevate fracture	0.6	0.0
ICP monitor	1.8	1.8
SDT + craniotomy	0.6	7.4
observation	92.6	31.4

* SDT = subdural tap; VPS = ventriculoperitoneal shunt.

TABLE 4: Outcome data based on KOSCHI scores for infants and toddlers who sustained accidental and nonaccidental trauma

KOSCHI Score	At Discharge (%)	At Follow-Up (%)
AT (164 patients)		
1	0.6	0.6
2	0.0	0.0
3a	1.2	0.0
3b	1.8	0.6
4a	8.5	4.2
4b	7.3	6.7
5	80.4	87.8
NAT (54 patients)		
1	1.8	3.7
2	0.0	0.0
3a	7.4	0.0
3b	9.2	5.5
4a	16.6	16.6
4b	24.0	12.9
5	38.8	61.1

stead, we found a large proportion of injuries still occurring in both the 7–12 and 19–24 month age groups.

There is a broad consensus regarding the higher morbidity and mortality rates associated with child abuse than with accidental trauma. Similarly, in the present study, we found that outcomes were significantly worse in children with nonaccidental versus accidental traumatic injuries, as indicated by the likelihood of lower KOSCHI scores at both discharge and follow-up among children in the NAT group. Higher KOSCHI scores were more common at discharge and follow-up in the accidentally injured group. This pattern of outcomes is probably due to the fact that there were much fewer serious injuries sustained in the accidentally injured group, based both on CT scan findings and presenting GCS score. Other authors have reported that as many as 30% of NAT cases are not diagnosed initially by medical providers, leaving children vulnerable to repeated injury.[16] This may explain why the children in the NAT group were more likely to present with hypodense SDHs. In the accidentally injured group, the presenting GCS scores were significantly better overall, with many more patients presenting with GCS scores of 13–15, while many more children in the NAT group presented with GCS scores of 9–12 and 3–8.

Traditionally, nonaccidental traumatic injury in infants and toddlers has been described as shaken baby syndrome.[5] The terminology used in the literature varies broadly between shaken baby syndrome, inflicted TBI, nonaccidental head injury, abusive head trauma, and NAT. Only shaken baby syndrome (typically defined by the triad of SDH, retinal hemorrhage, and encephalopathy) proposes a mechanism of injury wherein the shaking leads to tearing of the bridging veins.[2] This reported mechanism of injury has been questioned and has undergone scientific review and experimentation using models/dummies, animals, and cadavers.[7,12,22,23] Based on the results of these studies, it has been difficult to prove that shaking is sufficient to produce SDH.[22] As a result of this, together with the fact that the terminology describing this type of injury continues to evolve, we have concluded that it is important to avoid terminology that assumes mechanism. We therefore refer to these injuries simply as nonaccidental trauma.

Traumatic brain injury continues to result in significant rates of death and disability in infants. It is estimated that 1200–1400 children are shaken each year, with injury resulting in death in 25–30% of these cases, with most of the surviving infants left with permanent disability, including blindness, seizure disorder, mental retardation, and cerebral palsy.[21] Duhaime et al.[10] published a series on 100 head injured children under the age of 2 years, and reported a 15–38% mortality rate, 50% permanent cognitive deficits, and only a 30% chance of a full recovery. A study from a group in Oxford showed a 24.6% mortality rate, with 20 of 45 surviving children suffering long-term disability including cerebral palsy, seizures, visual problems, and speech, language, and behavioral problems.[17] Worse outcomes were associated with lower admission GCS scores and were more often seen in children with multiple injuries. In our series, we had a mortality rate of 3.7% in the NAT group, compared with 0.6% in the accidental trauma group. Although the mortality rate in the present study was not as high as in studies in only shaken baby populations, we did observe that NAT cases were the most severe, with higher mortality rates than in cases of accidental trauma.

One major difference between the accidental trauma and NAT groups was the requirement for neurosurgical interventions in the NAT group. Indeed, only ~ 7% of the children in the accidential trauma group required any operative intervention, compared with ~ 69% in the NAT group. Nearly 21 and 13% of the children in the NAT group required a craniotomy or craniectomy, respectively, reflecting the overall greater severity of their injuries at admission. Children in the accidental trauma group most commonly presented with a skull fracture (in 57% of cases), compared with the NAT group whose most common radiographic finding was SDH (52% of cases). Differentiating between the mechanism of injury required to produce either a skull fracture or an SDH is important, as the first requires a direct impact to the skull while the second may involve a direct impact, but is more likely to require an inertial force, either an acceleration or deceleration with significant force to tear the bridging cortical veins.[6] Almost 60% of the patients in the NAT group presented with a hypodense SDH, necessitating drainage in ~ 30% of them. We showed that the sensitivity and specificity for hypodense SDH is much greater than hyperdense SDH in patients with nonaccidental injuries.

With regard to SDH, a certain diagnostic challenge is presented when imaging studies reveal a mixed density subdural fluid collection. It is important to be cautious in interpreting such a finding as evidence of a hyperdense on hypodense injury, because a mixed density collection may represent a single injury that is hyperdense, with fresh blood surrounding clot and serum. It has also been hypothesized that mixed density collections may result from a tear in the arachnoid membrane, leading to leakage of CSF into the blood filling the subdural space.[26] Managing subdural fluid collections in infants can be challenging, especially with regard to initial choice of treatment. At our institution we usually perform subdural taps in infants through the open coronal suture. Depending on the characteristics of the fluid, we will either perform serial taps until it clears, or we will proceed to bur hole/craniotomy drainage. Miyake et al.[20] published a report concerning the management of subdural collections, and in it they classified the fluid collections as follows: Type I collections were the result of an arachnoid tear, Type II had an inner membrane, Type III had both an inner and outer membrane, and Type IV were true SDHs. For Types I and possibly Type II, taps were the appropriate management, while for most Types II and III collections, an external drainage system was necessary. Type IV collections required bur hole drainage.[20]

Limitations and Future Research

In any retrospective review dealing with accidental and nonaccidental trauma, it is very difficult to determine with complete certainty whether all cases that were truly nonaccidental in nature were identified. That is, despite vigorous workups by clinicians, social workers, and law enforcement officials, some cases will be incorrectly dis-missed as accidental. We have strived to be as accurate as possible with our assessment by basing our data not only on International Classification of Diseases codes, but also on the official outcomes of CPS investigations. Future research involving local and regional hospitals would increase the sample size and allow a more comprehensive assessment of accidental and nonaccidental traumatic injuries in infants and toddlers.

Conclusions

Infants and toddlers with TBIs resulting from NAT tend to have more serious injuries at presentation than those with accidental trauma. A hypodense SDH in an infant or toddler is moderately suggestive for NAT and should warrant consideration of a child abuse evaluation. Outcomes are also significantly worse among children in the NAT population, although the mortality rate in the present study was much lower than that previously reported in the literature. This finding may represent a population with a lower than expected incidence of NAT, or the difference resulting from a low rate of actual shaking among the patients in our series. Nonaccidental trauma remains a serious problem in infants and toddlers, and neurosurgical interventions are more frequently required in the management of nonaccidental rather than accidental TBIs.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Acknowledgments

The authors thank Dr. Miriam Nuno and Dr. Dan Mayer for their assistance with the preparation of this manuscript.

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Manuscript submitted January 22, 2009.
Accepted June 22, 2009.
This paper was presented at the World Federation of Neurological Surgeons Annual Meeting in Boston, Massachusetts, in September 2009.
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