ARTICLE

Prehospital and In-Hospital Mortality

A Comparison of Intentional and Unintentional Traumatic Brain Injuries in Colorado Children

Marion R. Sills, MD, MPH; Anne M. Libby, PhD; Heather D. Orton, MS

Objectives: To describe the incidence and case-fatality rates of traumatic brain injury (TBI) in young children in Colorado, to compare these injuries based on intentionality and outcome (prehospital death, in-hospital death, or survival), and to model the association of intentionality with TBI-related mortality.

Methods: Cases were drawn from the 1994-2002 Colorado Traumatic Brain Injury Surveillance System. Incidence and case-fatality rates for intentional and unintentional TBI were calculated. We performed univariate comparisons based on the intentionality and outcome of the TBI. Multivariate logistic regression was used to estimate the association of intentionality and mortality, controlling for injury severity.

Results: Of the 1333 children aged 0 to 36 months with TBI, 340 had intentional and 993 had unintentional TBI. Incidence for intentional and unintentional TBI was 16.1 and 47.0 per 100 000, respectively. Children with intentional TBI had a higher case-fatality rate, in-hospital death rate, and injury severity. Intentional TBI deaths were twice as likely to occur in hospital than prehospital, whereas unintentional TBI deaths were twice as likely to occur prehospital. Intentionality was significantly associated with mortality, with the effect increasing with increasing age.

Conclusion: Intentionality—independent of severity—raises the mortality of TBI in young children.

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HEAD TRAUMA IS THE MOST common cause of death from physical abuse[1] and is the most common cause of traumatic death in children younger than 1 year.[2] Of the estimated 826 000 children who have experienced substantiated child maltreatment known to child protective services agencies nationwide in 1999, approximately 1100 died, 77% of who were younger than 3 years.[3] Abuse causes more than 95% of serious intracranial injuries during the first year of life and 85% during the first 2 years.[4,5]

Several regional and national databases provide sufficient data to estimate population-based traumatic brain injury (TBI) incidence-related estimates in 0- to 3-year-olds. Among children in this age group in the 1992-2000 National Hospital Ambulatory Medical Care Survey emergency department surveys,[6] an annual average of 96 000 visited emergency departments for TBI, as defined by the Centers for Disease Control and Prevention's (CDC) case definition.[7] (The CDC defines TBI by *International Classification of Diseases, Ninth Revision* [*ICD-9*] codes 800.0-801.9 [fracture of the vault or base of the skull]; 803.0-804.9 [other and unqualified and multiple fractures of the skull]; and 850.0-854.1 [intracranial injury, including concussion, contusion, laceration, and hemorrhage]. For death certificates, *International Classification of Diseases, 10th Revision* [*ICD-10*] codes were used to identify TBI: S01.0-S02.9 [open wound of head]; S02.0-S02.1, S02.3, S02.7-S02.9 [fracture of skull and facial bones]; S06.0, S06.2-S06.9 [intracranial injury]; S07.0-S07.1, S07.8-S07.9 [crushing injury of head]; S09.7-S09.9 [other unspecified injuries of head]; T01.0 [open wounds involving head with neck]; T02.0 [fractures involving head with neck]; T04.0 [crushing injuries involving head with neck]; T06.0 [injuries of brain and cranial nerve with injuries of nerves and spinal cord at neck level]; and T90.1-T90.2, T90.4-T90.5, T90.8-T90.9 [sequelae of injuries of head].) Statewide mortality data compiled by the Colorado Department of Public Health and Environment (CDPHE) (Denver) showed that 15% of all nonperinatal deaths among 0- to 3-year-olds in 1990 to 2002 were trauma

Author Affiliations: Departments of Pediatrics (Dr Sills) and Psychiatry (Dr Libby and Ms Orton), University of Colorado at Denver and Health Sciences Center, Denver.

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related and that these occurred at an annual rate of 19.8 per 100 000.[8,9] Of the trauma-related deaths among 0- to 3-year-olds, 26% were homicides, an annual incidence of 5.0 per 100 000.

Several previous studies have quantified the mortality of intentional TBI and unintentional TBI among US children, although, to our knowledge, only 2 have included prehospital deaths. Of these 2, 1 study prospectively examined North Carolina children aged 0 to 2 years who were hospitalized in an intensive care unit or who died of TBI.[10] They found incidences of intentional and unintentional TBI of 17.0 and 15.3 per 100 000, respectively, and case-fatality rates of 22.4% and 30.5%, respectively. The other study retrospectively examined 0- to 19-year-olds in Minnesota sustaining TBI that resulted in either hospitalization or death; this population had a mortality incidence of 9.3 per 100 000 and case-fatality rate of 12.8%.[11] This study reported "battering" to be a predictor of "severe TBI" but did not give age-specific or cause-specific mortality or case-fatality rates. A study of children aged 0 to 6.5 years admitted to the hospital for TBI found a case-fatality rate of 13.0% for abused children and 1.7% for children with accidental injuries.[1] Among records of injured children aged 0 to 4 years in the National Pediatric Trauma Registry (1988-1997) who either died in the emergency department or were hospitalized, the case-fatality rates for intentional and unintentional trauma (not TBI specific) were 12.7% and 2.6%, respectively.[12]

Neither these previous studies nor our population-based database queries differentiated between the discrete contribution of intentionality (intentional vs unintentional) and that of severity of injuries in relation to the outcome of TBI mortality.

In our recent article, we examined the association between intentionality and the financial cost of TBI and found that inpatients with intentional TBI stayed in the hospital 52% longer (2 days) and had a mean total bill 89% higher ($4232 more) than did inpatients with unintentional TBI.[13] We now turn our attention to the role of intentionality in the gravest human cost of TBI: mortality. Our study included prehospital deaths, so it more accurately depicts the scope of mortality from early childhood TBI than do studies excluding prehospital deaths.

METHODS

DATA SOURCE

Abstracts of patient records for children aged 0 to 36 months were drawn from the annual 1994-2002 Colorado Traumatic Brain Injury Surveillance System database, compiled by the CDPHE. In 1991, the Colorado Board of Health made hospitalized head injuries a reportable condition; since then, the CDPHE has maintained a statewide, population-based surveillance system of all fatal and hospitalized TBIs. Most children in the database (94%) are Colorado residents.

Cases of TBI were identified using the *ICD-9*[14] and *ICD-10* codes that make up the CDC definition of TBI.[7] The CDC's definition of TBI includes cases of head injury that do not involve documented brain injury, such as skull fractures. Causes of death recorded include hospital codes as well as additional codes assigned by the local county's coroner or medical examiner.

VARIABLE DEFINITIONS

The main variable of interest was mortality and was categorized as prehospital death, in-hospital death, or survival. Cases classified as prehospital death were never admitted to the hospital as a result of the fatal TBI—this group includes patients declared dead in the emergency department—while cases classified as in-hospital death were admitted but died before hospital discharge. Cases that were discharged from the hospital were classified as survivors. Prehospital and in-hospital death cases were combined to represent mortality and were compared with cases that survived. In our subgroup analysis of all deaths in the data set, we refer to the mortality variable as location of death, which has 2 possible values: prehospital death and in-hospital death. Because records were not longitudinal, we could not account for a survivor's death in a subsequent episode of care.

The key independent variable was intentionality, a dichotomous variable that categorized cases as either intentional or unintentional based on the presence of an *ICD-9* or *ICD-10* code indicative of intentionality, excluding codes for self-intentional injury. (We defined an intentional injury on the basis of *ICD-9* and *ICD-10* codes. The *ICD-9* codes included: 995.5x [child maltreatment syndrome], E967x [child battering and other maltreatment], or E968x [assault by other and unspecified means, including nonaccidental violence]. The *ICD-10* codes included: T748 [maltreatment syndromes] and Y07 [other maltreatment syndromes].) Among unintentional cases, the dichotomous variable motor vehicle collision (MVC) categorized cases as either MVC or non-MVC based on the presence of an *ICD-9* or *ICD-10* code indicative of an MVC. (Our definition of MVC was based on the *ICD-9* codes E810-E829 [E-codes]. We excluded *ICD-10* codes from our definition, because they were indistinguishable from *ICD-9* V-codes. For example, the *ICD-10* code for a passenger injured in a collision with another motor vehicle, V19.5, is identical to the *ICD-9* code for a history of congenital anomalies.) We used the term *etiology* for 3 mutually exclusive categories: intentional TBI, unintentional MVC-related TBI, and unintentional non-MVC–related TBI. Although falls accounted for twice as many TBIs as did MVCs, we chose not to look at falls separately, because MVCs represent (arguably) unintentional trauma prima facie, whereas mechanisms described as falls could, in truth, have been either intentional or unintentional TBI. (Our definition of MVC was based on the *ICD-9* codes E880-E888 [E-codes].)

Age was calculated, in months, from the hospital admission date or death date minus the birth date. Sex was indicated by a variable that was equal to 1 if the child was male. Race/ethnicity was categorized as white/non-Hispanic, black/non-Hispanic, Hispanic, and Other. Year, indicating the year of the patient's hospital discharge or death, was also collected. We included year in the model to adjust for temporal trends occurring during the 9-year span of the data set.

Severity of injury was measured using the *ICD* Injury Severity Score (ICISS).[15] The ICISS is based on injury code–specific survival risk ratios (SRRs) (range, 0-1) derived from the National Trauma Data Bank. The more severe injuries (ie, lower SRRs) have lower ICISS scores. The ICISS is the product of all the SRRs for each of an individual patient's injuries; the addition of any injuries that are nontrivial (ie, have an ICISS <1) will always lower the ICISS score. The predictive value of the ICISS repeatedly has been found to be superior to, or comparable with, that of other injury severity measures.[16-22]

Slight modifications were made to the ICISS methods to avoid the potential bias introduced by differences in the method of diagnostic-code assignment between groups of patients. The Colorado Traumatic Brain Injury Surveillance System's diagnosis assignment varied as follows: all patients who died (both

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prehospital and in-hospital) received diagnostic codes from the county's coroner or medical examiner, whereas all children who were hospitalized (survivors, in-hospital deaths, and prehospital deaths that were pronounced dead in an emergency department) received hospital billing codes for their diagnoses. As a result, prehospital death codes differed from codes for all inpatients in 2 ways. First, prehospital deaths had fewer diagnoses, averaging 2.3 diagnostic codes per patient compared with 6.6 and 3.6 for in-hospital deaths and survivors, respectively. Second, 56% and 27% of prehospital death *ICD-9* codes were 3 and 4 digits compared with 15% and 37% of codes for all inpatients. Since cases of prehospital death had fewer codes and fewer digits per code, ICISS scores were biased upward compared with inpatient cases.

To reduce the bias from the coding associated with the different settings, we narrowed the scope of diagnosis codes that would generate an ICISS. For each case we used the most nonspecific *ICD-9* code (ie, fewest digits ≥3) that still had a corresponding SRR. For each code, we first tried to match to an SRR based on just the first 3 digits; for those codes that didn't have a corresponding SRR, we tried to match on the first 4 digits, and finally, for those that did not have a corresponding SRR, we matched on all 5 digits. We also restricted our score to include only the 5 most severe diagnoses per patient.

ANALYSIS

Univariate comparisons of variables between patients with intentional and unintentional TBI were performed using *t* tests or χ^2 statistics. Because of the possibility of nonnormal data, nonparametric tests, such as the Wilcoxon test, were also used to compare continuous variables. In each case, the *t* test and nonparametric test results agreed, and therefore, the *t* test results are presented.

Multivariate logistic regression was used to estimate the effect of intentionality and other variables on mortality. A full model was obtained by adding covariates in a forward selection process, keeping variables that significantly improved the model fit based on χ^2 tests of differences between log-likelihoods (–2LL) of nested models. Interactions between age, severity, and intentionality were also tested for inclusion. Severity was ultimately considered a confounder on the relationship between intentionality and mortality because the effect of intentionality changed by more than 10% on inclusion of severity in the model. Therefore, severity was simply included as a covariate in the final mortality model.

Among the subpopulation of children who died, we performed additional logistic regression models to examine relationships between each covariate of interest and location of death (prehospital death vs hospital death).

Analyses were conducted using SAS Version 8.01 (SAS Institute Inc, Cary, NC). The study was reviewed by the institutional review board of the University of Colorado Health Sciences Center (Denver) and granted an exemption based on anonymity of subjects.

RESULTS

From 1994 to 2002, Colorado recorded 1333 cases of TBI among children younger than 3 years. Of those, 340 cases were considered intentional and 993 were unintentional, with 241 of these unintentional TBIs caused by MVCs. **Table 1** provides descriptive statistics comparing intentional and unintentional TBI cases. Incidence figures for intentional TBI and unintentional TBI in our sample were calculated using the average annual observed cases divided by the average annual population of children aged 0 to 3 years in the study period; these figures were 16.1 (95% confidence interval, 11.0-21.2) and 47.0 (95% confidence interval, 38.2-55.7) per 100 000, respectively, based on US census population estimates for 0- to 3-year-olds in Colorado.[8,9] The case-fatality rates for intentional TBI and unintentional TBI in our sample were 16.8 (95% confidence interval, 12.8-20.8) and 10.7 (95% confidence interval, 8.8-12.6) per 100, respectively.

Table 1. Characteristics of Patients Younger Than 3 Years With TBI by TBI Intentionality

	Intentional TBI (n = 340)	Unintentional TBI (n = 993)	*P* Value
Outcome, No. (%)			
Survived/discharged from hospital	283 (83.2)	887 (89.3)	<.001
Prehospital death	21 (6.2)	73 (7.4)	
In-hospital death	36 (10.6)	33 (3.3)	
Total deaths	57 (16.8)	106 (10.7)	
ICISS, mean (SD)	0.63 (0.24)	0.83 (0.23)	<.001
25th percentile	0.49	0.80	
50th percentile	0.64	0.92	
75th percentile	0.82	0.97	
Age, mo, mean (SD)	7.9 (8.6)	15.5 (11.1)	<.001
25th percentile	2	6	
50th percentile	4	14	
75th percentile	10	25	
Female, No. (%)	139 (40.9)	410 (41.3)	.90
Race/ethnicity, No. (%)			
White/non-Hispanic	162 (47.7)	548 (55.2)	<.001
Hispanic	112 (32.9)	236 (23.8)	
Black/non-Hispanic	28 (8.2)	49 (4.9)	
Other	38 (11.2)	160 (16.1)	
Insurer, No. (%)			
Commercial insurance	131 (38.5)	434 (43.7)	<.001
Medicaid	108 (31.8)	195 (19.7)	
Managed care, public or private	46 (13.5)	171 (17.2)	
Public	13 (3.8)	55 (5.5)	
Uninsured	26 (7.7)	90 (9.1)	
Other	16 (4.7)	48 (4.8)	
Mechanism, No. (%)			
MVC	NA	241 (24.3)	<.001
Fall	8 (2.4)	568 (57.2)	

Abbreviations: ICISS, *International Classification of Diseases* Injury Severity Score; MVC, motor vehicle collision; NA, not applicable; TBI, traumatic brain injury.

The injury mechanism was recorded in 96% of cases. The 2 most common categories were MVCs (18%) and falls (44%). Among children with an intentional injury, 93% had data related to the perpetrator of the abuse; in 28% of cases, the perpetrator was the father, stepfather, or mother's boyfriend; in 6% of cases, it was a nonrelated caregiver; and in 3%, it was the mother, stepmother, or father's girlfriend. (Perpetrator was determined from the fourth digit of E-code 967.)

Our univariate analyses found several significant differences between the intentional TBI group and the unintentional TBI group (Table 1). Children with intentional TBI were younger, had a higher case-fatality rate, had a higher in-hospital death rate, had a lower (more severe) mean ICISS, and more often reported Hispanic

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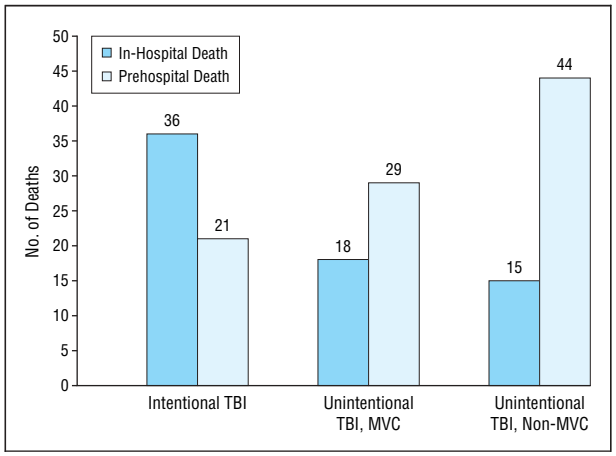

Figure 1. Location of death for traumatic brain injury (TBI)–related deaths, by etiology. MVC indicates motor vehicle collision.

Table 2. Multivariate Logistic Regression Model of Mortality Resulting From TBI for 1333 Children*

	Odds Ratio (95% Confidence Interval)
Intentionality (referent group = unintentional TBI)†	
4-Month-olds (25th percentile)	2.05 (1.22-3.43)
10.5-Month-olds (50th percentile)	2.64 (1.70-4.12)
23-Month-olds (75th percentile)	4.33 (2.37-7.89)
ICISS severity level	0.64 (0.32-1.27)
MVC	2.88 (1.85-4.48)

Abbreviations: ICISS, *International Classification of Diseases* Injury Severity Score; MVC, motor vehicle collision; TBI, traumatic brain injury.
*Model was adjusted for sex, race, and year of hospital discharge.
†Statistically significant interaction between intentionality and age.

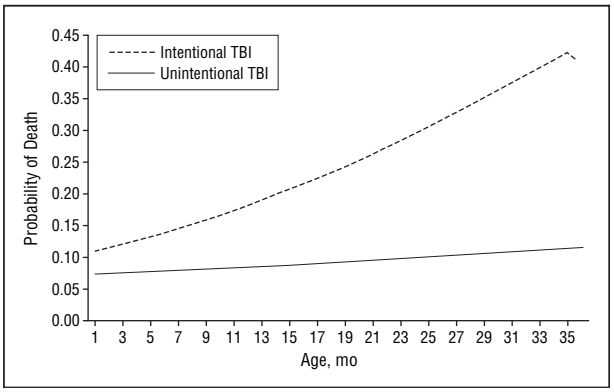

Figure 2. Probability of traumatic brain injury (TBI)–related death by age and intentionality.

Table 3. Logistic Regression Models of Prehospital Death vs In-Hospital Death for 163 Children*

	Odds Ratio (95% Confidence Interval)
Intentionality (referent group = unintentional TBI)	0.25 (0.12-0.52)
MVC	1.62 (0.71-3.72)
Age, mo	1.05 (1.02-1.08)
Female	1.03 (0.52-2.03)

Abbreviations: MVC, motor vehicle collision; TBI, traumatic brain injury.
*One model was run for each covariate and each model was adjusted for year of hospital discharge. The odds ratios for each covariate listed in this table represent findings from a separate model involving that covariate, the year of hospital discharge, and the outcome prehospital vs in-hospital death.

origin and Medicaid insurance. Among intentional TBIs, there were nearly twice as many in-hospital deaths as prehospital deaths, whereas for unintentional TBIs, this ratio was reversed. The high rate of prehospital deaths among unintentional TBIs was most marked for MVC-related TBI deaths, which represented 29% of all unintentional TBI prehospital deaths (**Figure 1**).

Table 2 presents the results from a multivariate logistic regression model with mortality as the dependent variable. Children with an MVC-related injury were 2.9 times more likely to die than those whose injury was not MVC related. There was also a significant interaction between age and intentionality of the TBI. Therefore, the effect of having an intentional TBI was reported for 3 different ages: 4 months, which was the 25th percentile age for the sample; 10.5 months, which was the median age for the sample; and 23 months, which was the 75th percentile age for the sample. For 4-month-olds, having an intentional TBI doubled the likelihood of death. This likelihood increased with age, with the chance of death being more than 4 times higher for those children with an intentional TBI compared with those with an unintentional TBI among 23-month-olds. **Figure 2** further demonstrates this interaction, showing that the probability of death increased with increasing age for children with intentional TBI but stayed relatively constant with age for children with unintentional TBI. Although the majority of the intentional TBI cases in this study were younger than 1 year (78%), there was a higher occurrence of death among the older intentional TBI cases. Thirty-one percent of the intentional TBI cases between the ages of 1 and 3 years died while only 13% of children younger than 1 year with an intentional TBI died.

We wanted to further investigate the differences between prehospital deaths and in-hospital deaths. However, there was an insufficient number of deaths in the sample (n=163) to achieve adequate statistical power for detecting significant main effects in a multivariate logistic regression model. Therefore, we present logistic regression models of location of death (prehospital vs in-hospital), including only a single main-effect variable in each model while controlling for the year of hospital discharge. **Table 3** presents results from these models. Adjusting only for year of hospital discharge, intentional TBI deaths were significantly less likely to occur prehospitalization. Deaths from MVC were not significantly more or less likely to occur in a prehospital location. There was a significant positive correlation between ICISS and prehospital death ($\rho=0.67$; $P<.001$), so this relationship was not modeled using logistic regression in this subgroup analysis.

Figure 1 shows a graphic display of the relationships among etiology (intentional, unintentional, non-MVC TBI,

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and unintentional MVC TBI), and location of death. Even removing MVC cases, which represent those with a confirmed source of injury that are mutually exclusive from intentional TBI cases, intentional TBI and unintentional TBI show a reversed relationship with location of death. Unintentional TBI cases more frequently died prehospital and intentional TBI cases more frequently died after hospital admission.

COMMENT

The case-fatality rates we report for intentional TBI and unintentional TBI—16.8% and 10.7%, respectively—show lower case-fatality rates in both categories than did the Keenan et al[10] study (22.4% for intentional TBI and 30.5% for unintentional TBI), which may be related to their selection of higher-severity TBI cases, using the intensive care unit as their primary source of cases. The other 2 studies both showed lower case-fatality rates than ours: the Reece and Sege[1] study of children aged 0 to 6 years admitted to the hospital for TBI had rates of 13% for intentional TBI and 1.7% for unintentional TBI, and the National Pediatric Trauma Registry study found rates of 12.7% for intentional injuries and 2.6% for unintentional injuries.[12] Our higher figures may be related to the older age group included in the Reece and Sege study and to the non-TBI included in the National Pediatric Trauma Registry study. The intentional TBI–related incidence figure we calculated—16.8 per 100 000—is comparable with the Keenan et al[10] finding of 17.0 per 100 000.

The finding of higher probability of death from intentional TBI with increasing age might be related to underreporting of more minor intentional TBIs in the older age groups. This might be related to a lower degree of parental concern about minor injuries in a toddler as opposed to an infant, resulting in fewer minor intentional TBIs being brought to medical attention. This may also be related to underdiagnosis of less severe intentional TBI among children with TBI in an age group considered older than the "typical" age for intentional TBI.

Our finding of a higher overall mortality among intentional than unintentional TBIs, despite no difference in the prehospital death rate, may represent the effect of delayed care, although we could not determine this from these data. To our knowledge, the only study to examine the association of abuse and delayed care found no effect.[23] The finding may also be related to the accumulated morbidity of repeat injuries. Because our analysis did not involve longitudinal data for each child, we cannot support this hypothesis, although previous literature shows that children diagnosed with maltreatment have a high rate of previous injury.[24-26]

The primary limitations to our study are those intrinsic to retrospective research in this area. First, it has been shown that intentionality is underdocumented in *ICD-9* codes. If the resulting underascertainment did introduce bias, it would make us more likely to misclassify intentional cases as unintentional, which would weaken the effect of intentionality in our model.[27,28] (The "gold standard" for an abusive homicide in the Herman-Giddens et al[27] study was the ruling of the North Carolina State Child Fatality Prevention Team.) Second, prehospital deaths, in-hospital deaths, and survivors in our study population may have received different degrees of diagnosis ascertainment. Prehospital deaths generally receive codes only from the county coroner and, in some cases, the emergency department; in-hospital deaths receive codes from both the coroner and hospital staff, and survivors receive hospital codes only. In any case of suspected abuse, the county's child protective services and police departments would be involved; for in-hospital deaths and survivors, the hospital's social worker might be involved as well. It is not clear which group would receive closer scrutiny in terms of ascertainment of intentionality. It was clear that the 3 groups' *ICD* codes differed in number as well as length; our "Methods" section describes how we quantified and minimized the bias from this difference.

Our study contributes to the literature in 3 ways. First, we investigated etiology with a focus on intentional and unintentional TBI. We further parsed out unintentional TBIs that were attributed to MVCs. Second, we acquired both prehospital death cases of TBI and cases admitted to the hospital, so as not to restrict our study population to inpatients. Children with intentional TBI were more likely to die in the hospital than prehospital, whereas children with unintentional TBI were more likely to die prehospital than in-hospital. Thus, it is important to include prehospital cases when determining who is at heightened risk for mortality. Third, we used an extensively validated severity scoring system to adjust for severity when modeling the association of intentionality and TBI mortality. By making some minor adjustments, we were able to demonstrate the unique and significant contribution of intentionality to TBI mortality, independent of severity.

The higher mortality for hospitalized intentional TBI, independent of severity, may indicate inpatient physicians may need to treat intentional TBI more aggressively than they would for an unintentional TBI of similar apparent severity. While intentional TBI is more common among the youngest children (<1 year), the likelihood of death increases with age and is higher among toddlers. These cases represent ages in which special attention should be paid to preventive efforts, expanding the "never shake" messages for the infants to include additional messages and resources that may be more relevant to parents and caretakers of toddlers. Further investigation of the disproportionately high rate of in-hospital death among those with intentional TBI may help health care professionals and policy makers address means of improving survival and other outcomes in these children.

Our finding that intentional cases have a significantly higher chance of death from a TBI adds the dimension of the human cost of child abuse to our earlier portrayal of the financial burden of intentionality in TBI. Intentional injuries represent a potentially preventable injury and cause of death, consistent with numerous studies that have shown that preventive strategies do help reduce child abuse.[29-32] (The Rubin et al[29] article examines the literature on various prevention strategies, including, for example, 18 home visitation studies.) Our studies demonstrating the significant financial and, now, hu-

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man costs of childhood abuse underscore the urgent need for the further development and implementation of child abuse prevention programs.

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Corresponding Author: Marion R. Sills, MD, MPH, Department of Pediatrics, University of Colorado at Denver and Health Sciences Center, 1056 E 19th Ave, B-251, Denver, CO 80218 (sills.marion@tchden.org).
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