Driveway Crush Injuries in Young Children: A Highly Lethal, Devastating, and Potentially Preventable Event

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Background/Purpose: The aim of this study was to investigate driveway-related injuries in children, identify associated risk factors, and evaluate outcome compared with other mechanisms of blunt trauma.

Methods: A 6-year review (1991 to 1996) of pediatric (age less than 18 years) pedestrian injuries treated at two urban trauma centers was conducted: one regional pediatric trauma center and one level I trauma center with pediatric commitment. Five hundred twenty-seven children injured in pedestrian accidents were identified from the trauma registry; 51 children (10%) sustained traumatic injuries as a result of being struck in their driveway. Data are reported as mean ± SEM.

Results: Children less than 5 years of age (n = 41) had an injury severity score (ISS) of 12.3 ± 2.3, 15 (37%) sustained closed head injury, 13 (37%) had torso trauma, 19 (46%) skeletal trauma, and eight (20%) died. Children ≥ 5 years old (n = 10) had an ISS of 10.7 ± 2.4, three (30%) sustained closed head injury, four (40%) torso trauma, six (60%) skeletal trauma, and none died. In contrast, all other pediatric pedestrian accidents analyzed over the same time period had a mortality rate of only 2% (11 of 476).

Conclusions: Pediatric driveway trauma carries a significant risk of head injury and a 10-fold increase in mortality in children under 5 years of age when compared with all other pediatric pedestrian accidents. More emphasis must be placed on injury prevention and public education to prevent this devastating mechanism of injury in these young, vulnerable children.

INDEX WORDS: Trauma, driveway, pedestrian, automobile.

AMONG CHILDREN under 18 years old, traumatic injury causes more deaths than all diseases combined and is the leading cause of disability.[1,2] Motor vehicles remain the most dangerous element in the child's environment accounting for 47% of injury deaths in 1986.[3] Pedestrian injury accounts for a significant proportion of these motor vehicle accidents and has been shown to be the leading cause of postinjury death affecting 5- to 9-year-old children.[4,5] Risk factors for auto versus pedestrian injury have been described previously and include age (5 to 9 years), male gender, minority race, low social class, and crowded neighborhoods.[3] The majority of injuries in this at-risk population are sustained when a child crossing a public road or "darting out" into traffic is struck by a rapidly moving vehicle. However, younger children appear to be vulnerable to a different scenario of driveway-related trauma in which the child is driven over by a slow moving vehicle in reverse.[6-8] The purpose of this study was to investigate driveway-related injuries in children treated at our institutions, identify associated risk factors, and evaluate outcome compared with other mechanisms of blunt trauma. Our study hypothesis was that driveway-related trauma in children causes a significant crush injury mechanism resulting in increased morbidity and mortality in younger children.

MATERIALS AND METHODS

Patients

All patients younger than 18 years of age admitted to the trauma service at Denver Health Medical Center (DHMC) or The Children's Hospital of Denver with the diagnosis of auto versus pedestrian accident over a 7-year period (1990 to 1996) were identified by the trauma registry at each institution. This list was then reviewed systematically for children involved in driveway-related trauma or backover accidents. The charts of those patients found to fit the requested profile were reviewed to determine the exact mechanism of injury and to ascertain the hospital course and outcome of the children involved.

DHMC functions as a level I regional trauma center with pediatric commitment for the city of Denver and the state of Colorado. The Children's Hospital functions as a designated pediatric regional trauma center for the same encatchment area. At DHMC, injured patients (pediatric and adult) are evaluated in the emergency department by the senior general surgery residents on the trauma service (postgraduate year ≥ 4) along with a senior emergency medicine resident (postgraduate year 3) and an attending emergency medicine physician. Twenty-four-hour attending adult and pediatric surgery coverage is available within 15 minutes and is provided by four adult and two pediatric academic trauma surgeons. All pediatric trauma patients are admitted to one of three trauma services and remain in the hospital for at least 24 hours of

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Presented at the 31st Annual Meeting of the Pacific Association of Pediatric Surgeons, Maui, Hawaii, June 9-13, 1998.

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0022-3468/98/3311-0031$03.00/0

Table 1. Demographics of Patient Groups

Population	Age	Male (%)	ISS	CHI (%)	LOS (d)	Mortality (%)
Driveway trauma (n = 51)	3.4 ± 0.4*	30 (59)	12.0 ± 1.9*	18 (35)*	6.9 ± 2.6	8 (16)*
Other auto v pedestrian (n = 476)	7.8 ± 0.6	309 (65)	7.5 ± 0.9	119 (25)	4.6 ± 2.4	11 (2)

Abbreviations: CHI, closed head injury; LOS, length of hospital stay.
*P < .05 compared with other auto versus pedestrian accidents.

observation. At The Children's Hospital, injured patients are also evaluated initially in the emergency department by a senior general surgical resident from the same residency program as those rotating at DHMC (postgraduate year ≥ 4) or pediatric surgery fellow (postgraduate year ≥ 6) along with an attending emergency medicine physician. Twenty-four-hour attending pediatric surgery coverage is available within 15 minutes and is provided by six pediatric surgeons. At both institutions, children are admitted to the pediatric intensive care unit (ICU) or pediatric ward (depending on the severity of injury), and pediatric consultation is available and provided by in-house pediatric residents, attending physicians, intensivists, and neonatologists. Pediatric anesthesiologists are also available 24 hours a day for children who require emergency surgery. In every case, the trauma surgical service remains the primary care team throughout the hospital stay.

Statistical Analysis

Nominal data (eg, gender, mortality) were compared by Fisher's Exact test, and continuous data (eg, age, ISS) were compared by an analysis of variance (ANOVA) using Scheffe's F procedure for post-hoc comparisons. Data are reported as the mean ± SEM and P less than .05 was considered statistically significant.

RESULTS

The study population consisted of 527 children who had been involved in an auto versus pedestrian accident over the 6-year period ending December 1996. From this total, 51 (9.7%) were driveway-related accidents with the car rolling backwards over the child. The children in driveway-related injuries are compared with the other auto versus pedestrian population in Table 1. The patients in driveway-related trauma were significantly younger (3.4 ± 0.4 *v* 7.8 ± 0.6 years), had a higher mean ISS (12.0 ± 1.9 *v* 7.5 ± 0.9), a higher incidence of closed head injury (35% *v* 25%), and a higher mortality rate (16% *v* 2%).

The 51 patients sustaining driveway-related injuries were evaluated further by age group to identify the children at most risk (Fig 1). Children younger than 5 years accounted for the majority of cases of driveway-related trauma (41 of 51, 80%). Six children (12%) were between 5 and 9 years old, and four children (8%) were older than 9 years of age. The youngest age group (0 to 4 years) contained all of the children who died secondary to their injuries, yielding a mortality rate of 20%.

The demographics comparing these different age groups are described in Table 2. The severity of injury, measured by the ISS, decreased with increasing age. The incidence of head injury also decreased as the age group increased, whereas the incidence of torso injuries and skeletal injuries was comparable within the age groups. The mortality rate of 20% in the young 0- to 4-year-old patients is significantly increased compared with the overall mortality rate of 2% for all auto versus pedestrian accidents at our institutions.

The specific circumstances surrounding these driveway crush injuries are outlined in Table 3. The majority of driveway-related accidents (19 of 51, 37%) involved young children playing under or behind a vehicle parked in the driveway that began rolling backwards, crushing the unseen victim. Other children (10 of 51, 20%) were injured when they unknowingly walked behind a vehicle moving slowly in reverse. A few younger children (3 of 51, 6%) were actually struck when they were standing behind a parked vehicle. They apparently were not seen by the driver who proceeded to back the car down the driveway. A few injuries (3 of 51, 6%) were caused by a child accidentally dislodging the vehicle out of gear or, in one case, releasing the emergency brake. This resulted in the vehicle rolling backwards and injuring children playing in the driveway. Twenty-five percent (13 of 51) of the driveway-related accidents did not have specific descriptions of the injury mechanism.

Additional data concerning who was driving the automobile that struck the younger children (age 0 to 4 years) were obtained from a detailed chart review (Fig 2). The mother or father of the child were the responsible drivers for at least 14 (34%) of the driveway-related rollover accidents. Other family members involved were siblings in four cases (10%) and a grandmother in one incident

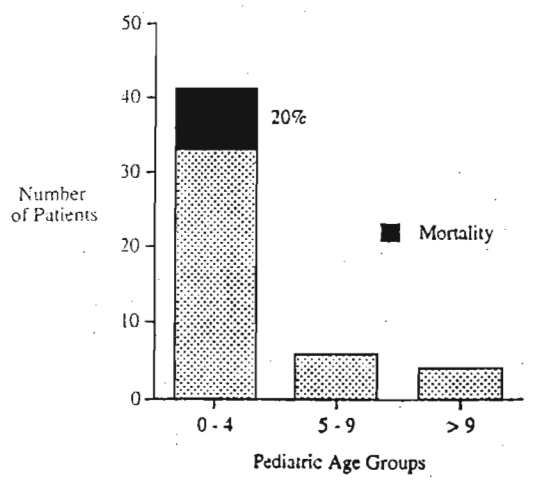

Fig 1. The incidence of driveway-related injuries with the associated mortality depicted by age group in 51 children.

Table 2. Demographics of Patients by Age Groups

Patient Variables	0-4 yr (41)	Age Group (n) 5-9 yr (6)	>9 yr (4)
Age	2.2 ± 0.1	6.0 ± 0.5	11.5 ± 1.6
Male (%)	22 (54)	6 (100)	2 (50)
Injury severity score	12.3 ± 2.3*	11.2 ± 4.6	9.0 ± 1.1
Head injury (%)	15 (37)*	2 (33)	1 (25)
Torso injuries (%)	13 (32)	2 (33)	2 (50)
Skeletal injuries (%)	19 (46)	3 (50)	3 (75)
Length of stay (days)	4.0 ± 1.3	24.7 ± 16.4	3.5 ± 1.5
Mortality (%)	8 (20)*	0	0

*$P < .05$ compared with other auto versus pedestrian accidents.

(2%). Vehicles driven by neighbors caused three (7%) of the accidents, and 19 (46%) of the accidents were caused by unspecified drivers.

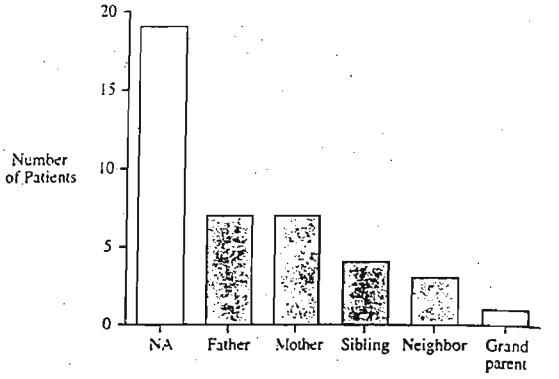

Fig 2. The driver of the vehicle involved with the driveway related accident for the 0- to 4-year-old age group. NA, driver unspecified.

DISCUSSION

It is difficult to imagine a more devastating event than running over your own child in the driveway and inflicting a mortal or morbid injury. The lifelong psychological implications for the parent or other relative involved are nearly beyond comprehension. The costs of such injuries involve more than time, money, and resources.[5] They result in disrupted lives and families, and take an enormous emotional toll on family, friends, and health care personnel.

Previous analyses have demonstrated that traffic-related pedestrian injuries are a significant cause of morbidity and mortality in the pediatric population, specifically emphasizing the risk of 5 to 9 year olds.[3-5,9] However, this study demonstrates a pattern of fatal nontraffic pedestrian injury that appears to be unique to children younger than 5 years and has not been described adequately or brought to the public's collective attention. When compared with other automobile versus pedestrian accidents, the mortality rate from driveway injuries is significantly higher and likely is related to the higher number of nonsurvivable severe head injuries sustained. The preponderance of head injury may be explained partially by the height of a child under 5 years old relative to the vehicle's bumper and the proportionately larger head-to-body ratio at this young age. Crush injuries to the head in children involve large dynamic and static forces that result in significant or fatal brain injury.[10,11] Unfortunately, children under 5 years of age are unable to recognize the environmental hazards present in such a driveway scenario. In addition, because of decreased visibility, such small children can easily end up out of the driver's view and, thus, not be seen by even the most conscientious driver. Such a visibility problem may be more of an issue with larger family cars, pick-up trucks, and the ever-popular sport utility vehicle.[6]

Table 3. Mechanism of Pediatric Driveway-Related Injuries

No. of Children	Mechanism of Injury	Mean Age (yr)
19	Playing under or behind parked vehicle	2.1 ± 0.2
10	Walking behind moving vehicle	4.9 ± 1.2
3	Standing behind parked vehicle	2.0 ± 0.3
3	Playing behind parked vehicle knocked out of gear by another child	3.5 ± 0.5
1	Released emergency brake, child fell out and was struck by rolling vehicle	6
1	Knocked vehicle out of gear, struck by rolling vehicle when trying to get out	8
1	Washing windows, trapped when vehicle rolled backwards	16
13	Not specified	2.7 ± 0.4

Interventions to prevent child pedestrian injuries must consider normal child behavior and driver awareness as it relates to the location of the events.[12] In the case of the driveway, potential areas of intervention include car design, restricted access to the driveway, as well as public education. One possible modification would be larger rearview mirrors resulting in fewer "blind spots" in which a small child could be overlooked. Because some of these backover driveway injuries were caused by another child, often a sibling, who unwittingly slipped the automobile out of gear, modifications to the steering column or gear shift could be made to lock the vehicle in gear when it is parked. Some newer automobile models do not allow any gear shifting until the brake pedal is depressed. This mechanism of injury precipitated by another child could also be averted by ensuring the parking brake is firmly set, although this can also be dislodged by an unsuspecting but curious child. Further locking features could also be added to the parking brake to make it relatively "childproof." It is encouraging that changes in vehicle design previously have been shown to be effective in reducing traffic-related pedestrian injuries.[13] Vehicular modifications with pediatric driveway crush injuries in mind thus may result in reduced injuries and fatalities. In addition, physical barriers (ie, fencing) to prevent children from gaining access to the residential driveway may have the potential to reduce driveway-related injuries.[8] This strategy of barrier protection previ-

ously has been proposed to prevent access to domestic swimming pools thus decreasing childhood drownings.[14]

The pivotal step in an intervention strategy to gain from these data is the need for parent and family education on the risk of pediatric driveway-related pedestrian accidents. All caregivers of these young children should be made aware of the significance of driveway-related injuries and of the necessary steps to avoid such a devastating traumatic event. Specific recommendations can be developed that parents should be encouraged to support. First, children should not be allowed to remain unsupervised in any vehicle.[15] Furthermore, small children should be forbidden from playing outside in the vicinity of a parked motor vehicle. These points of injury prevention education should be introduced to the child early and reinforced vigorously. Because children younger than 5 years old account for the overwhelming majority of these accidents resulting in such a high mortality, they deserve the most directed education on the subject. Only with this focused injury prevention and public awareness program can such horrific driveway-related childhood injuries be avoided.

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