Rollover Injuries in Residential Driveways: Age-related Patterns of Injury

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ABSTRACT. *Background.* **The major objective of the present study was to determine the severity of nonfatal injuries sustained by children (<16 years old) when a motor vehicle rolls over them. We also sought to determine whether younger children (<24 months old) demonstrated different patterns of injury and/or a worse outcome, compared with older children (>24 months old).**

Methods. **We reviewed the medical records of 3971 consecutive admissions to a single trauma service at an urban children's hospital between March 1990 and October 1994. During this time period, 26 (0.7%) children presented with rollover injuries incurred by motor vehicles in residential driveways. Outcome was measured by length of both intensive care unit admission and hospitalization.**

Results. **Two children died shortly after admission and were excluded from the remainder of the study. Younger children (<24 months old) had significantly higher injury severity scores and lower pediatric trauma scale scores. Both the duration in the intensive care unit and the length of hospitalization were significantly longer in younger children, compared with children >24 months old. One explanation for these observations was that younger children had a significantly higher incidence of both head and neck and extremity injury but a similar incidence and severity of chest and abdominal trauma, compared with older children. Injuries requiring operative intervention were rare.**

Conclusion. **Younger patients sustaining rollover injuries in the residential driveway have a worse outcome, in part, because of the head and neck or extremity injures that they incur. The majority of rollover injuries can be managed conservatively.** ***Pediatrics*** **1999;104(1). URL: http://www.pediatrics.org/cgi/content/full/104/1/e7;** ***pediatric trauma, driveway, pedestrian events, rollover injuries, injury severity score, pediatric trauma scale.***

ABBREVIATIONS. ICU, intensive care unit; ISS, injury severity score; PTS, pediatric trauma scale.

Injury resulting from vehicular trauma remains a major problem in the pediatric population. Traffic-related injuries account for nearly half of all injury deaths among children and adolescents in the United States.[1] Although less common, pedestrian injuries are an important cause of morbidity and mortality in children younger than 4 years and account for one third of all deaths in this age group. The residential driveway is a common location for pedestrian injuries, especially in children younger than two years (toddlers).[2,3] The major objective of the present study was to determine the severity of nonfatal rollover (wheels of the vehicle roll over the child) injuries sustained by children on residential driveways. We also investigated whether younger children (<24 months old) demonstrated different patterns of injury and/or worse outcome.

METHODS

We initially reviewed the medical records of 3971 consecutive admissions to a single trauma service at an urban children's hospital between March 1990 and October 1994 and identified pedestrian versus motor vehicle injuries that occurred only in driveways. The catchment region of Cardinal Glennon Children's Hospital is a 250 km radius that includes both urban (the city of St Louis, MO) and rural areas. This catchment region is shared equally with another urban, level 1 pediatric trauma facility. Only children sustaining injuries associated with a motor vehicle rolling over the child (opposed to a motor vehicle colliding with the child) were included. The objective of the study was to investigate the characteristics of children with nonfatal injuries; thus, children who died soon after admission were excluded from the study. Collected data included patient age, gender, length of admission to the intensive care unit (ICU), length of hospitalization, injury severity score (ISS)[4] (<10, minor; >15, serious; >25, severe; range of 1–75), pediatric trauma scale (PTS) score[5] (>9, minor; 5–8, serious; <4, severe; range of −6–12). ANOVA using a Scheffe post hoc test was performed on all groups with continuous data (such as age or length of hospitalization), whereas χ^2 or Fisher's exact test was used for analysis of nominal data. For nonparametric data (such as ISS and PTS score), the Mann-Whitney *U* test was used for statistical comparison. A P value $<.05$ defined statistical significance. StatView 4.5 (Abacus Concepts, Inc, Berkeley, CA) was used for all statistical analysis.

RESULTS

During the 4½-year period that was previously mentioned, 26 (0.7%) children were injured by motor vehicles in residential driveways located in the County of St Louis or in the surrounding rural areas. In all cases, the vehicle rolled over the child; no injury was the result of vehicular impact alone. Eighteen (69%) injuries resulted from a child being struck by a vehicle that was being backed up by an adult. In two instances, the child was rolled over twice. The remaining 8 (31%) injuries were caused by either an older child and/or sibling (<16 years of age) rolling over the child ($n = 4$) or the child engaging the vehicle into gear and then attempting to leave the vehicle ($n = 4$).

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Two children (24 and 36 months old) died soon after admission as a result of massive head injuries and were excluded from the remainder of the study. Among the 24 survivors, there were 12 males and 12 females. Mean patient age was 44 (11–132) months, and 19 children were <60 months old (Fig 1).

The mean ISS and PTS scores were 23 (1–50) and 6.3 (0–12), respectively. Injuries sustained by younger (<24 months old) children, defined by both trauma indices, were more severe. Younger children had a higher mean ISS (mean rank 17.2 vs 9.2; $P = .006$) and lower mean PTS score (mean rank 7.8 vs 15.9; $P = .006$) (Figs 2 and 3).

Overall, length of ICU admission and hospitalization was 3.2 (0–22) and 8.0 (1–40) days, respectively. Younger (<24 months old) children had significantly longer lengths of ICU admission and hospitalization (Fig 4). With regard to injury patterns, younger children had a significantly higher incidence of both head and neck and extremity injury, but a similar incidence of chest and abdominal trauma, compared with older children (Fig 5). Tire marks were associated commonly with major underlying injuries in the thorax (4/6; 66.7%) and abdomen (4/5; 40%).

The 16 children sustaining injuries as a result of a vehicle driven by an adult were younger (32 ± 6 months vs 68 ± 12 months; $P < .01$), had higher ISSs (mean rank 15.5 vs 6.5; $P < .01$), and lower PTS scores (mean rank 9.7 vs 18.1; $P < .01$). Children sustaining injuries as a result of a vehicle driven by an adult, compared with children sustaining injuries associated with either a vehicle driven by an older child or caused by the patient engaging the vehicle into gear and jumping out, also had a longer course in the ICU (4.6 ± 1.3 days vs 0.4 ± 0.3 days; $P = .03$) and had an increased length of hospitalization (10.3 ± 2.3 vs 3.5 ± 0.7; $P = .05$). The previously mentioned observations may be the result of a higher incidence of head and neck trauma ($P < .05$) among the children who sustained injuried from a rollover by an adult-driven vehicle.

Specific injuries, sorted by anatomic region, are shown in Table 1. Of note, only one injury (frontal lobe laceration) required immediate operative intervention. Three children with hemo/pneumothorax were treated with tube thoracostomy and 5 children with pulmonary contusion were managed with a brief period of ventilatory support. All intraabdominal injuries were treated nonoperatively.

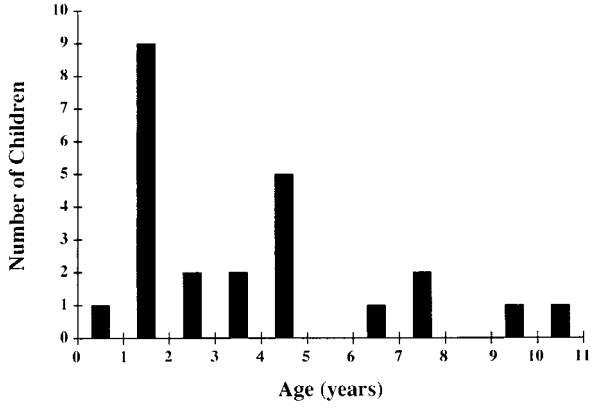

Fig 1. Age distribution of 24 survivors with rollover injuries sustained on residential driveways.

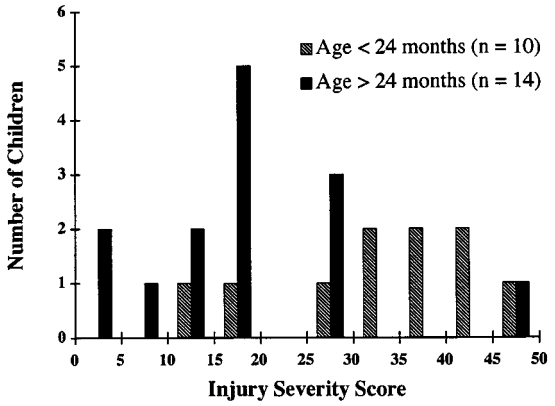

Fig 2. ISS of younger (<24 months) or older (>24 months) children with rollover injuries. The number (*n*) of children in each group is depicted beside the respective figure legend.

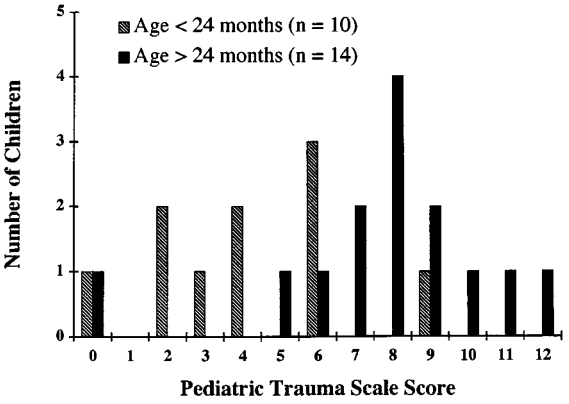

Fig 3. PTS scores of younger (<24 months) or older (>24 months) children with rollover injuries. The number (*n*) of children in each group is depicted beside the respective figure legend.

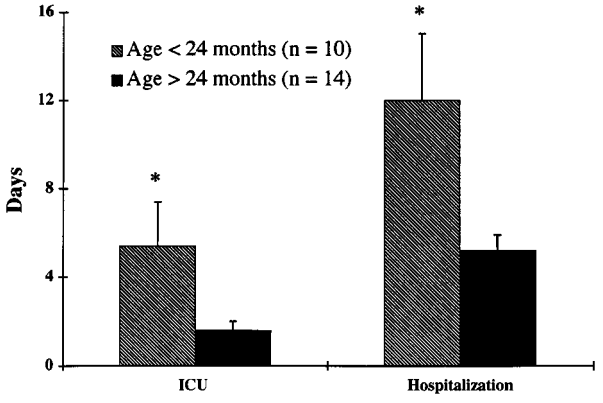

Fig 4. The effect of patient age upon either the duration of ICU admission or length of hospitalization. The number (*n*) of children in each group is depicted beside the respective figure legend. *$P <$ .05 versus children >24 months of age.

DISCUSSION

The residential driveway is an important site of pediatric trauma involving motor vehicles. Injuries sustained by children in this location are different from the typical high velocity motor vehicle–pedes-

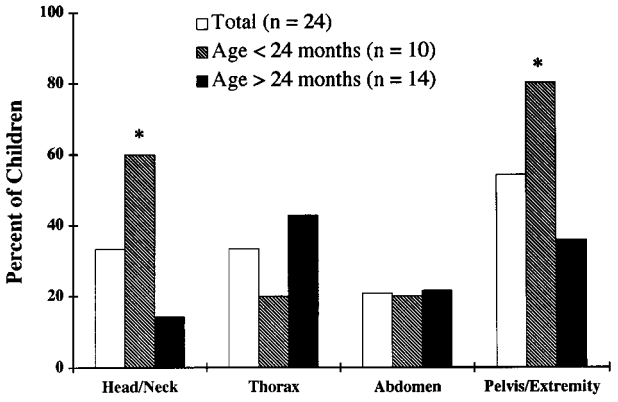

Fig 5. The distribution of rollover injuries of all (total), younger, or older children. The number (*n*) of children in each group is depicted beside the respective figure legend. *$P < .05$ versus children >24 months of age.

trian event. The mechanism of injury is a crushing force by the vehicle rather than a sudden blunt impact or deceleration force.[6] The potential lethal nature of these injuries has been appreciated recently.[2] The patients in the current series emphasize the severity and typical pattern of nonlethal injuries sustained in the residential driveway.

Our data suggest that younger children (toddlers) sustaining rollover injuries have more severe injuries and worse outcomes. One explanation for this observation is that younger children have a higher incidence of both head and neck and extremity injury but a similar incidence of significant chest and abdominal trauma. Perhaps younger children are less mobile and therefore are less able to pull or crawl away from a moving tire. In addition, the impact of a given size tire will be distributed across more organ systems in a small child, compared with a larger child.

Previous reports have identified unlocked motor vehicles set in motion by children themselves as a potentially preventable cause of such injuries.[7,8] Unlocked vehicles account for one third of all injuries in the present series. Clearly, if the vehicles had been locked by the driver or if they had been equipped with automatic locking systems, these events could have been avoided. Education of drivers through education programs and public service announcements may be beneficial.

The ISS scores in the current study are higher than those reported by Agran et al.[9] However, a major difference between the two groups is that 51% of the patients reported by Agran et al were treated and released from the emergency department. This difference may be explained by the fact that their data represented the experience of several hospitals, whereas our patients were evaluated and treated at a single level 1 trauma center. Presumably, those patients in our catchment area who were treated and discharged from an emergency department were never referred to our institution. In a report by Winn et al,[3] 61% of all pedestrian events involving toddlers (<24 months old) occurred on residential driveways. The 9% mortality, 51% hospitalization rate, and mean ISS of 10 are similar to findings from the previous report by the same group.[9] Between October 10, 1988 and August 18, 1994, 67 trauma centers that provide care for children submitted data to the Pediatric Trauma Registry staffed by Tufts University.

TABLE 1. Major Injuries Sustained

Age <24 Months	Age >24 Months
Head and neck	
Basilar skull fracture and CHI	Scalp laceration
Depressed skull fracture and frontal lobe laceration (operative repair)	Basilar skull fracture and sixth cranial nerve palsy
Open basilar skull fracture	
Intracranial hemorrhage	
Subarachnoid hemorrhage	
Left orbital floor fracture	
Thorax	
Right pulmonary contusion	Left pulmonary contusion
Left pulmonary contusion	Left pulmonary contusion, rib fractures, and pneumothorax (CT placement)
	Right pulmonary contusion, rib fractures, and pneumothorax (CT placement)
	Right pulmonary contusion and pneumothorax (CT placement)
Abdomen	
Rectal and vaginal laceration	Grade II splenic contusion
Grade II liver laceration	Grade II liver laceration
	Grade I liver and grade II splenic contusions
Pelvis and extremities	
Right supracondylar and humeral fractures	Left humerus fracture
Bilateral femur fractures	Bilateral pelvic fracture
Multiple left foot fractures	Left femoral head fracture
Right femur fracture	Right distal femur fracture
Left femur fracture	Left femur fracture
Right humerus fracture and right iliac wing fracture	
Pelvic fracture	
Left humerus and bilateral femur fractures	

CHI indicates closed head injury; CT, chest tube.

During this period, which is similar to the current study, 255 patients of a total of 42 029 children in the registry sustained a pedestrian injury at home. Of these 255 children, 6 were dead at the scene and another 5 died shortly after admission to the hospital for an overall fatality rate of 4%. The mortality rate of the current study was 2/26 = 7.6%.

Two thirds of the injuries in the present series were the result of the adult-initiated motion of a vehicle, usually while backing up, striking a pediatric pedestrian. Prevention of this type of injury in the residential driveway is imperative. Physical separation of a residential driveway from the play area of children by fencing has been reported recently to result in a 50% reduction in the risk of driveway events.[10] Public education and organized injury prevention programs (eg, the national Safe Kids campaign) must make parents, teachers, and other responsible adults aware of the hazards and risks of residential driveway events. Parents should be encouraged to walk around the car before leaving an area in which children may have been.

Making motor vehicle manufacturers aware of not only of the hazards but also of the injury patterns described in the present report may result in constructive automobile or truck design changes. In cases in which the child was the driver, perhaps the ignition was left on or the key was left in the ignition. Safety designs to prevent a driver from leaving the key in the ignition or leaving the ignition on may decrease the opportunity for another child to become the driver. The use of audible signals when any vehicle is driven in reverse and the alteration of the design of rear bumpers may also be valuable. Finally, on-board front and back radar may become an important adjunct as research continues and costs become more reasonable.

Physicians evaluating children injured in driveway vehicle events should be aware of the pattern of injuries among survivors and the differences in injuries in relation to the patients' ages. Although in our study the majority of the injuries were nonlethal, rapid evaluation and management remain critical to improve survival rates and quality of life after driveway events. Additional evaluation of the epidemiology of driveway events involving children may result in additional important advances in the prevention of these, often devastating, injuries.

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