

Pediatric Restraint Use in Motor Vehicle Collisions

Reduction of Deaths Without Contribution to Injury

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Hypothesis: Restraint use for children in automobiles is mandated in every state, but injury patterns are unknown. Although use of pediatric restraints is associated with reducing morbidity and mortality, the injury distribution for specific anatomic sites may be altered in restrained vs unrestrained children.

Design: Review of trauma registry data, medical records, and autopsy findings.

Setting: Urban level I trauma center and tertiary care children's hospital.

Patients: All children aged 6 years or younger who were in motor vehicle collisions from June 1, 1990, through March 31, 1997.

Main Outcome Measures: Age, weight, restraint use

and type, collision data, Injury Severity Score (ISS), injury type, and outcome.

Results: We included 600 children. The restrained group showed a reduction in severe injuries for every anatomic site and had a lower mean ISS, fewer injuries, and more uninjured children. The restrained group also had a reduction in the incidence of hollow- and solid-organ abdominal injuries.

Conclusions: Age-appropriate restraint devices decrease mortality and reduce the incidence of significant injury in motor vehicle collisions for all anatomic sites in young children. In contrast to injuries attributed to restraint use in adults, specific restraint-related injury patterns were not seen in children.

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IN THE UNITED STATES, 41 967 fatalities and 3.4 million injuries were attributed to motor vehicle collisions (MVCs) in 1997. Motor vehicle collisions remain a primary cause of death and serious injury, especially in the younger population. Despite this, the fatality rate in 1997 remained at a low of 1.7 deaths per 100 million vehicle miles of travel. This value has not changed since 1992, compared with a rate of 2.4 deaths per 100 million vehicle miles of travel in 1987.¹ The use of restraint devices such as seat belts, child safety seats, and airbags has contributed appreciably to this decline.

The first mandatory child restraint law was implemented in Tennessee in 1978.² Since 1985, all states and the District of Columbia have enacted child restraint laws, albeit with coverage gaps existing in most states, which allow certain age groups to be unrestrained in motor vehicles.³

Ample evidence exists that adult use of seat belts reduces mortality and the number and magnitude of injuries after MVCs.^{4,5}

Properly positioned lap belts, when worn with shoulder harnesses, reduce craniofacial injuries, chest injuries, and extremity fractures.⁶⁻⁹ Although seat belt use in adults reduces overall injuries and mortality, certain injuries can result.⁵ Among these are mesenteric lacerations, intestinal rupture, Chance fractures of the thoracolumbar spine, and injury to the retroperitoneal and cervical vessels.¹⁰⁻¹⁴

Properly restrained children and infants also are less frequently and severely injured and have a lower mortality rate than their unrestrained counterparts.^{2,15-18} The use of child safety seats has reduced mortality by 47% for toddlers (aged 1-4 years) and by 69% for infants. The use of child safety seats is estimated to have saved the lives of 312 children younger than 5 years in 1997. Of these 312 children, 266 used child safety seats and 52 wore adult seat belts. From 1975 through 1997, the lives of an estimated 3894 children were saved by child restraints.⁴

Despite this demonstrated efficacy, injury patterns in restrained infants and

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SUBJECTS AND METHODS

Medical and trauma registry records of all patients aged 6 years or younger with injuries due to MVCs who were admitted to University Medical Center (level I trauma center) and Valley Children's Hospital in Fresno, Calif, from June 1, 1990, through March 31, 1997, were reviewed. Both hospitals are the primary receiving and referral centers for pediatric trauma patients in Fresno County and the surrounding 5-county region, with a catchment area of 1.5 million people. The medical records of all children undergoing evaluation and discharge from the emergency departments at both hospitals were reviewed to include those children with minor or no injuries. Autopsy records from the coroner's office were analyzed for all children who died before hospitalization during the same period. Age, weight, restraint use and type, collision data, Injury Severity Score (ISS), injury type, and outcome were documented for each individual.

Data were analyzed for injury patterns, excluding minor injuries such as simple lacerations, contusions, and abrasions. Significant injuries included intracranial, spinal cord, and intra-abdominal or intrathoracic injuries and fractures. However, minor injuries were included to determine the total number of injuries per group.

Statistical analysis was performed using *t* test and χ^2 analysis, with a *P* value of less than .05 considered significant.

young children have not been described. We examined the severity and distribution of injuries resulting from MVCs in restrained and unrestrained children and infants.

RESULTS

During the 82-month study period, 541 children involved in MVCs underwent evaluation at University Medical Center and 45 at Valley Children's Hospital. Fourteen prehospital deaths were identified and also reviewed, for a total of 600 children in the study. Fifty-four percent were boys and 46% were girls. The restrained and unrestrained groups were comparable in mean age (3 years) and weight (14.8 kg). Overall, 19% of the children required hospital admission.

Fifty-three percent of the children were restrained. Of the 320 children in the restrained group, 141 and 154 were restrained in child safety seats and seat belts, respectively. Another 25 children had restraint devices, but the restraint type could not be identified. For the other 280 children, 262 were not restrained, and restraint use was unknown in 18. We did not attempt to identify whether restraints were used appropriately.

With the exception of back fractures, the restrained group showed a reduction in severe injuries for every anatomic site (**Table 1**). The mean ISS (3 vs 8) and the number of children with severe injuries (ISS \geq 16, 21 vs 38) was lower in the restrained group, even when

stratified with respect to child safety seat and seat belt use ($P < .001$).

Twenty-six children (restrained vs unrestrained groups, 9 vs 16; status unknown in 1 child) suffered 27 abdominal injuries. The total number of abdominal injuries for restrained and unrestrained children was 7 and 20, respectively ($P = .009$, χ^2). The spleen was the most frequently injured abdominal organ (in 13 patients; restrained vs unrestrained groups, 4 vs 8; status unknown in 1 child). The second and third most frequently injured abdominal organs were the liver and kidney, with 5 instances each.

Restrained children had a lesser incidence of solid-organ injuries compared with unrestrained children (2% vs 6% [$P = .005$, χ^2]). Likewise, there was a statistically significant, albeit small, difference in the incidence of hollow-organ injuries between restrained and unrestrained children (1% vs 2% [$P = .007$, χ^2]).

The total number of injuries, including minor and severe, was decreased in the restrained group (206 injuries in 320 children vs 217 injuries in 262 unrestrained children [$P < .001$]). In addition, the percentage of uninjured children was higher in the restrained group (36% vs 18% in the unrestrained group) (**Table 2**). Restraint use was also associated with a decreased incidence of death (restrained vs unrestrained groups, 8 [4 in seat belts and 4 in child safety seats] vs 18 [$P < .001$]). Of the 18 deaths in the unrestrained group, 10 occurred when children were ejected ($P < .001$, χ^2).

Twenty-one percent of unrestrained children were ejected from their vehicles. Ejections occurred in 24 (42%) of 57 unrestrained children involved in rollover collisions. Lateral impact collisions resulted in the highest mean ISS for restrained and unrestrained children (**Table 3**).

COMMENT

The widespread enactment of child restraint laws in the United States has increased the use of child safety seats and seat belts and decreased the rate of pediatric injuries and deaths due to MVCs. After Tennessee enacted the nation's first child restraint law in 1978, restraint use rose from 8% to more than 30% in the state. Analysis of accident reports from Tennessee's Department of Safety during that period showed that the mortality rate for children younger than 4 years was halved. Furthermore, the number and severity of injuries were reduced in restrained children. The analysis concluded that the use of child safety seats effectively prevented death and reduced injury.²

After Michigan's passage of a mandatory restraint law in 1982, restraint compliance for children younger than 4 years increased 4-fold. Police reports for MVCs documented an overall 25% reduction in the number of injured children. In collisions with minimal vehicle damage, the number of injured children decreased by 50%. Children in more severe collisions had a 22% decrease in injuries, although specific injury patterns were not examined in the study.¹⁹

A review of crash data from police reports provided to the National Highway Traffic Safety Adminis-

Table 1. Comparison of Significant Injuries by Anatomic Site*

Anatomic Site	Restrained	Unrestrained	P	Child Safety Seat	P	Seat Belt	P
Craniofacial	14	34	<.001	11	<.001	3	<.001
Brain	23	44	<.001	15	<.001	8	<.001
Cervical	0	4	<.001	0	<.001	0	<.001
Chest	2	10	<.001	0	<.001	2	<.001
Abdomen	7	20	<.001	1	<.001	6	<.001
Upper extremity	0	11	<.001	0	<.001	0	<.001
Lower extremity	4	17	<.001	1	<.001	3	<.001
Pelvis	1	6	<.001	0	<.001	1	<.001
Back	2	0	.10	0	.09	2	.09
Total	53	146	<.001	28	<.001	25	<.001

*Unless otherwise indicated, data are given as number of injuries.

tration showed that seat belts and child safety seats reduced injuries in children younger than 15 years.¹⁷ The use of child safety seats reduced injury by 60% for children aged 0 to 4 years; however, lap or shoulder harnesses were only 38% effective in decreasing injuries in older children. The overall injury rate was 4.76 (per 1000 collisions per year), with the lowest rate (2.91) for infants and the highest (4.78) for children aged 3 years. In every age group, the relative risk of injury in unrestrained children was 1.5 to 2.5 compared with restrained children. Specific injuries were not reviewed.¹⁷

Agran et al²⁰ described the types of injuries sustained by 191 children aged from infancy to 14 years who were restrained with seat belts. For children from birth through 3 years of age restrained with a seat belt, 87% suffered only minor injuries. The head was the most commonly injured region, with most injuries consisting of contusions and lacerations. Torso, extremity, and spinal injuries were infrequent. Eighty-two percent of children aged 4 to 9 years received minor injuries in that study. Similarly, most injuries were superficial contusions and lacerations to the head and face. This group also sustained "whiplash" (9%), extremity injuries (25%), and abdominal injuries (21%) that were inconsequential.²⁰

In California, the pediatric restraint law passed in 1983 mandates that children younger than 4 years and weighing less than 18 kg (40 lb) travel in child safety seats. Seat belts are required for all older occupants in the vehicle.³ Agran et al¹⁵ reviewed the injuries of 505 children younger than 4 years involved in MVCs before and after passage of the law. The children underwent evaluation in 9 large emergency departments in an urban county in California. The law appeared to enhance compliance, since restraint use increased from 26% before to 50% after its enactment. The total number of children injured as a result of MVCs and who underwent evaluation in the 9 emergency departments did not change, although the percentage of injured children declined from 70% before to 57% after the law's implementation. Head injuries decreased by 17%, but no significant reductions were noted for torso and extremity injuries.¹⁵

In our study, only slightly more than half of the children were restrained, despite having mandatory restraint laws in effect for longer than 7 years. The restrained children not only sustained fewer injuries, but

Table 2. Children Without injuries

	No. of Children	No. (%) Uninjured	P*
Unrestrained	262	45 (17)	...
Restrained	320	114 (36)	<.001
Child safety seat	141	66 (47)	<.001
Seat belt	154	40 (26)	<.001

*Compared with the unrestrained group.

Table 3. Comparison of Impact Site With Mean ISS, Deaths, and Ejections*

	No. of Injuries	Mean ISS†	No. of Deaths	No. of Ejections
Lateral impact				
Restrained	91	5	3	0
Unrestrained	66	12	3	13
Frontal impact				
Restrained	107	2	0	0
Unrestrained	83	6	2	11
Rear impact				
Restrained	40	1	0	0
Unrestrained	27	3	0	2
Rollovers				
Restrained	41	3	1	1
Unrestrained	57	8	1	24

*ISS indicates Injury Severity Score.

†For mean ISS, deaths, and ejections, restrained vs unrestrained groups, P<.05.

the injuries were less severe. This finding was true regardless of the restraint type. Furthermore, the fatality rate was significantly lower in the restraint group.

When examining the percentage of children without any injuries, restrained children were twice as likely to be uninjured. Child restraints appeared to be the most effective in providing protection, since 47% of the children who were in child safety seats did not receive any injuries. This finding lends support to extending the age and weight limit before a child starts wearing a seat belt.

Children aged 4 to 6 years constitute a unique category. These children have outgrown child safety seats and are often secured in seat belts designed for adults.

Agran et al²¹ examined injury patterns and severity of injury in 131 restrained children aged 4 to 9 years. Seventy percent sustained head and facial injuries; however, most of the craniofacial injuries were considered to be insignificant. Upper torso and extremity injuries were uncommon in this age group. Lower torso injuries primarily occurred in frontal collisions regardless of the child's location in the vehicle. The most serious injuries occurred in children who were seated near the impact site in lateral collisions. We noted a similar finding. Irrespective of restraint use, the group of children who were involved in lateral collisions had not only the maximum number of deaths but also the highest mean ISS.

Another study¹⁶ compared outcomes for unrestrained (n=290) vs seat-belted (n=123) children aged 4 to 14 years who were injured in MVCs. Children who died before hospitalization or were discharged from the emergency department were excluded. Unrestrained children were more severely injured, required more services, and had higher mortality rates. Unrestrained children were more likely to have head, facial, cervical, thoracic, and extremity injuries, whereas restrained children had more severe abdominal injuries.¹⁶ This is in contrast to our study, in which restrained children sustained a decreased incidence and severity of abdominal injuries.

The importance of child restraints to reduce pediatric mortality and morbidity due to MVCs needs continued emphasis and education of the public. In a report from the Centers for Disease Control and Prevention, there was a close association between parent and resultant child restraint use.²² Primary care providers, such as pediatricians and family practitioners, must impress on parents the importance of automobile restraint use not only for children but also for all of the vehicle's occupants. In addition, obstetricians can encourage their pregnant patients to purchase and properly use child restraint devices after the birth of their infants.

Trauma surgeons and trauma nurse coordinators can also play a role in injury prevention. They can ensure that parents of injured children not only are provided with an appropriate-sized child safety seat at the time of the child's discharge, but that the parents are educated on proper use of the device. Preemptive measures, such as the distribution of child safety seats, are most likely cost-effective if the devices can prevent severe injuries in the event of a collision.

Although all states have laws requiring children to be restrained, the laws vary by state. States also differ as to primary or secondary enforcement of child restraint laws. In addition to various age, weight, and height requirements, the laws differ with respect to the child's position in the vehicle. As an example, in Texas it is legal for a child older than 14 years to be unrestrained in the rear seat of a vehicle. In addition, an adult seat belt will suffice legally (although not medically) past 2 years of age.³ Strong and uniform child restraint legislation with strict primary enforcement is needed to help reduce the morbidity and mortality of children in this country.

In our study, the use of child restraints reduced the rate of fatalities due to MVCs. Child safety seats and seat belts were effective in reducing the number and severity

of injuries. For child safety seats, all types of injuries were reduced. Seat belt use also decreased the number and severity of injuries overall. Although the absolute number of thoracolumbar fractures was higher in children who used seat belts, this did not reach statistical significance. In contrast to the injury pattern seen in restrained adults, associations between restraint use in children and specific injuries were not seen.

Despite previous suggestions of increased abdominal injury secondary to restraint use, our study did not support this finding. In addition to restraint use being associated with a reduction in solid-organ injuries, the use of restraints did not result in an increase in hollow-organ injuries.

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