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Children in Motor Vehicle Collisions: Analysis of Injury by Restraint Use and Seat Location*

ABSTRACT: This study was a retrospective chart review of hospital records and autopsy reports of 499 children nine years old or younger involved in motor vehicle collisions from 1994 to 1998. The objective was to evaluate the frequency and severity of injuries as a function of age, restraint use, and seat position.

We found that 33% of the children were unrestrained and 20% were improperly restrained. Unrestrained children had the highest mean Maximum Abbreviated Injury Scores (MAIS) and Injury Severity Scores (ISS), accounted for 70% of the fatalities, and had the highest incidence of head injuries. Although most of the head injuries were superficial, 80% of the fatalities were the result of a head injury. Improperly restrained children had the highest frequency of abdominal injuries. Regardless of restraint use, the back seat was associated with fewer head injuries and lower mean MAIS and ISS scores compared to the front seat. Also, properly restrained children in the front seat had lower mean MAIS and ISS scores than unrestrained children in the back seat, suggesting that restraint use is more beneficial than seat position.

KEYWORDS: forensic science, motor vehicle collisions, pediatrics, child restraint systems, safety belts, injuries

In the United States, injuries sustained in motor vehicle collisions (MVCs) are the leading cause of severe injury and mortality in the pediatric population (1–6). According to the National SAFE KIDS Campaign (7), each year approximately 1,800 children 14 years of age and younger are killed as passengers in motor vehicles and more than 280,000 are injured.

The protection of infants and children by safety restraints has been mandated by state laws. However, the requirements of the laws vary from state to state with regard to the child's age, weight, and position in the vehicle. Despite these discrepancies, the laws have effectively increased the use of restraint devices among child occupants in motor vehicles. There are different restraint devices and requirements for children of different heights and weights (Table 1).

Despite these guidelines, proper restraint of the pediatric population continues to be an important issue. All states require protection for children younger than two years; however, there are inconsistencies in laws covering older children. A major concern is children in the four- to nine-year-old age group: these children have outgrown child restraint systems (CRSs) designed for younger children and are inappropriately placed in adult seat belts. Agran et al. (8) found that unrestrained children and those restrained by adult seat belts sustained similar numbers of fatal injuries. These findings suggest that restraints designed for adults are not as effective in preventing injury as restraints designed for children.

Another concern is the misuse of child restraint devices. When used properly, these devices can reduce the risk of fatal injury by 69% for infants less than one year old and by 47% for toddlers one to four years old (9). Although the proper use of restraint devices has been shown to reduce the number of injuries sustained in MVCs, studies have shown misuse rates to be as high as 80% (7,10–14).

Children traveling as unrestrained occupants in motor vehicles are another major concern. In 1997, the National Highway Traffic Safety Administration estimated that of children less than 15 years of age involved in a MVC, 46% were unrestrained, and, of those fatally injured, 63% were not restrained. Also, while 85% of infants were restrained, only 60% of toddlers were restrained.

When restrained infants or children are injured in MVCs, the most common sites of injury are the head and face, cervical spine, and abdomen. In the head and face, most injuries are minor; however, the majority of deaths result from head injuries (15–25). Head injuries are also the major cause of death for unrestrained children. The majority of cervical spine lesions are strains; however, fractures and dislocations also occur (5,15). Abdominal injuries are generally superficial contusions/abrasions and/or intra-abdominal hematomas/lacerations (3,23,26–27).

There are also different age-related patterns of injury among children restrained in adult seat belts. Agran et al. (16) found that the majority of restrained infants and toddlers sustained head injuries consisting of superficial contusions, abrasions, and lacerations. Spinal strains, extremity injuries, and chest/abdominal injuries were infrequent in this age group. When in adult restraints, these children, due to their proportionately larger head size and higher center of gravity, tend to rotate out of the restraint and become airborne, thus becoming a projectile moving headfirst toward an impact site (16). Although the majority of restrained school-aged children also sustained minor head injuries, there was a

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TABLE 1—*General guidelines: pediatric car safety.*

Age, years	Weight, kg	Restraint
< 1	< 9	Rear-facing CRS
1–3	9–18	Forward-facing CRS
4–9	18–27	Booster seats
≥10	> 27	Safety belts

greater occurrence of extremity injuries and chest/abdominal injuries. The frequency of the latter injuries is due to the center of gravity for these children being closer to the umbilicus, and iliac crests that are not fully developed to serve as anchor points for the lap belt, which causes the belt to slide up over the abdomen (16).

Seating position can affect injury severity and the pattern of injuries. The rear seat is the safest place for a child in a MVC regardless of restraint status (15,24–25, 28–31). Studies have found that children in the rear seat are less likely to be injured than children in the front seat (28,32–33). Braver et al. (31) demonstrated a 36% reduction in the risk of fatal injury for passengers aged twelve or younger in the rear seat as compared to those in the front seat. This reduced risk was observed when comparing restrained occupants in the front and rear seats, as well as when comparing unrestrained occupants in these seat positions.

The objective of the present study was to evaluate the frequency and severity of injury as a function of age, restraint use, and seat position. Analyses were performed on children zero to three years old and four to nine years old because of anatomical differences and recommended types of restraint for these groups. Data were gathered from hospital records and autopsy reports. Statistical tests were used to analyze the data.

Methods

This study was based on a retrospective chart review of the hospital medical records and autopsy reports of children involved in MVCs from January 1, 1994 to December 31, 1998. Data were obtained on children nine years old and younger who were treated at Kosair Children's Hospital and/or had an autopsy performed at the OCME in Louisville, Kentucky. Only children who were passengers in a vehicle at the time of the collision were included in this analysis. Cases obtained from Kosair Children's Hospital included all records with International Classification of Disease (ICD) codes: E810–813, E815–816, E818–819, E822–823, E825. These ICD codes use fourth-digit subdivisions to identify the injured person. Only cases with the fourth-digit 0.1 (passenger in motor vehicle other than motorcycle) were included in the study. Cases obtained from the OCME were obtained by searching the computer files for the correct age and MVC as the cause of death.

For each case included in the study, a medical chart and/or autopsy report was reviewed and a data sheet completed by the investigator. The parameters investigated included: age, sex, height, weight, injuries, restraint use, and seating position.

Restraint use was documented as proper restraint use, misuse, and no restraint use. Proper restraint use was defined by the guidelines in Table 1. Restraint use was classified as misuse in the following situations: if a child was in a restraint device inappropriate for his/her size, if a rear-facing CRS was used in the front seat, if the child was not properly secured in the CRS, if the CRS was not properly secured in the vehicle, if the shoulder portion of the three-point restraint was placed behind the child's back, if a lap-belt only restraint was used in the front seat, if two passengers were sharing one restraint device, or if the medical chart or EMS sheet indicated that the restraint use was improper. Seat position was categorized as front and back seat.

The pattern of injury was documented using the body regions denoted in the Abbreviated Injury Scale (AIS). The AIS was created by the Committee on Medical Aspects of Automotive Injury of the American Medical Association to establish uniformity in injury data collection. It is used by crash investigators and medical and paramedical personnel to compare injury severity among different patients and between groups of patients. This system recognizes seven body regions as locations of injury. The anatomical sites were: external, head and face, neck, thorax, abdomen and pelvic contents, spine, and upper and lower extremities and bony pelvis. The specific injuries at each location were identified.

The severity of injury was coded using the Abbreviated Injury Scale (AIS-1990 revision), and the Injury Severity Score (ISS). The AIS rates injuries as they represent a threat to life and classifies injuries by body region using a six-point severity scale. The AIS is scored as follows: AIS-1 (minor); AIS-2 (moderate); AIS-3 (serious); AIS-4 (severe); AIS-5 (critical); AIS-6 (untreatable/fatal). Using this system, a Maximum Abbreviated Injury Score (MAIS) that represents overall injury severity was assigned to each case. For children with multiple injuries, the MAIS is the single highest AIS code; for children with only one injury, the AIS is also the MAIS. The Injury Severity Score (ISS) developed by Baker et al. (34) was used to assess overall injury severity. The ISS is the sum of the squares of the highest AIS code in each of the three most severely injured body regions ($AIS_1^2 + AIS_2^2 + AIS_3^2$). Injuries coded with AIS-6 are assigned an ISS of 75, the highest ISS score possible.

The Statistical Package for the Social Sciences (SPSS-8) software was used to analyze the data for specific age groups. These were defined as 0–3 years and 4–9 years based on the recommendation for different restraints for these two groups. Chi-square tests were used to determine if proportions of victims with various outcomes differed according to restraint use and seat position (35). The outcomes investigated included: survival status, multiple external injuries, head injury, neck injury, thorax injury, abdominal injury, spine injury, upper extremity injury, and lower extremity injury. If the sample sizes were too small for the Chi-square test, exact tests were used as recommended by Dawson and Trapp (35). The data were also stratified by seat location and the aforementioned tests involving restraint use were performed again for 0–3 year olds and for 4–9 year olds. The results were considered significant if the p-value was 0.05 or less and considered of borderline significance (weak evidence) if the p-value was between 0.055 and 0.10.

Kruskal-Wallis and Mann-Whitney tests were used to determine the statistical significance of the ordinal measures MAIS and ISS versus restraint and seat position. These tests were performed for 0–3 year olds and 4–9 year olds.

Results

The study population consisted of 499 infants and children nine years old or younger who were treated at Kosair Children's Hospital and/or had an autopsy performed at the OCME. The distributions for survival status, gender, age, restraint use, and seat position are illustrated in Table 2.

When analyzing age and restraint use, infants and toddlers (0–3 years of age) had a higher percentage of misuse, and school-age children (4–9 years of age) had a higher percentage of no use. When restraint use was analyzed by seat location, the highest percentages of proper use were in the back seat, and the highest percentages of misuse were in the front seat for both age groups. Re-

TABLE 2—*Demographic data of the entire study population.*

	Number	Percentage
Survival Status		
Alive	474	95.0
Dead	25	5.0
Gender		
Male	233	46.7
Female	266	53.3
Age (years)		
0–3	167	33.4
4–9	332	66.4
Restraint Use		
Proper	210	42.1
None	166	33.3
Misuse	102	20.4
Unknown	21	4.2
Seat Position		
Front	172	34.5
Back	268	53.7
Unknown	59	11.8

TABLE 3—*Restraint use rates for 0–3 year olds and 4–9 year olds.*

	0–3 Years *n*, %	4–9 Years *n*, %
All seats		
Proper	68 (40.7)	142 (42.8)
Misuse	44 (26.3)	58 (17.5)
No Use	50 (29.9)	116 (34.9)
Unknown	5 (3.0)	16 (4.8)
Front Seat		
Proper	7 (13.7)	43 (36.4)
Misuse	17 (33.3)	32 (27.1)
No Use	27 (52.9)	43 (36.4)
Back Seat		
Proper	49 (55.1)	85 (49.1)
Misuse	24 (27.0)	23 (13.3)
No Use	16 (18.0)	65 (37.6)

garding no use, 0–3 year olds had a higher percentage in the front seat and 4–9 year olds had similar percentages in the front and back seats (Table 3).

Zero to Three Year Olds

The effects of restraints on the frequency of injury to different body regions for 0–3 year olds are presented in Fig. 1. Figure 1 demonstrates the results for all seat locations. Unrestrained infants and toddlers had the highest incidence of fatalities ($p = 0.032$), head injuries ($p = 0.005$), spinal injuries ($p = 0.008$), and multiple external injuries ($p = 0.011$) as compared to properly and improperly restrained children.

In the front seat, abdominal injuries were incurred most often in improperly restrained children ($p = 0.030$). Also, unrestrained children in the back seat had a higher incidence of multiple external injuries ($p = 0.044$).

When seat position was tested, the back seat, regardless of restraint use, was associated with a reduced incidence of head injuries ($p = 0.026$).

Four to Nine Year Olds

The effects of restraints on the frequency of injury to different body regions for 4–9 year olds are presented in Fig. 2. Figure 2 demonstrates the results for all seat locations. Unrestrained school-aged children had the highest incidence of fatalities ($p = 0.054$), head injuries ($p = 0.003$), and multiple external injuries ($p < 0.0005$). Improperly restrained children sustained the highest frequency of abdominal injuries ($p < 0.0005$).

In the front seat, unrestrained children had the highest incidence of multiple external injuries ($p = 0.026$). A similar result was also found in the back seat ($p = 0.015$). Also, in the back seat, improperly restrained children had the highest frequency of abdominal injuries, while unrestrained children had the lowest frequency ($p = 0.002$). There was weak evidence that unrestrained children had a higher frequency of head injuries as compared to properly and improperly restrained children ($p = 0.088$).

When seat position was tested, the back seat, regardless of restraint use, was associated with a reduced frequency of head injuries ($p = 0.040$).

Injury Severity

Most of the children (52%) in the study population sustained minor (MAIS 1) injuries, and 17% of the children sustained no injuries. Thirteen percent of the children sustained injuries considered seri-

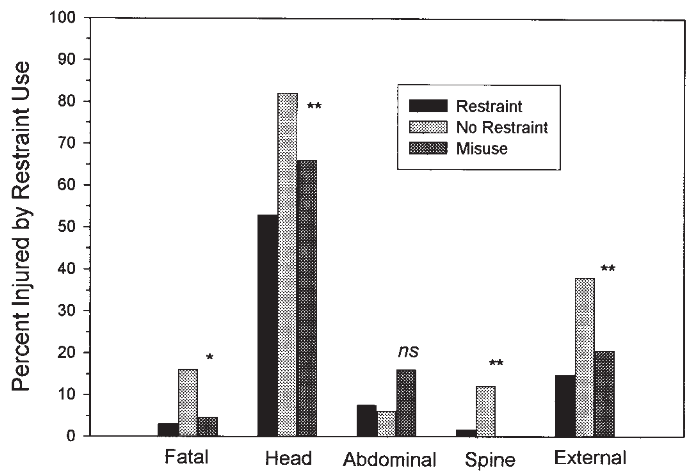

FIG. 1—*Occurrence of injuries by restraint usage for all seat locations for 0–3 year olds: * p-value ≤ 0.05; ** p-value ≤ 0.01; ns = not significant.*

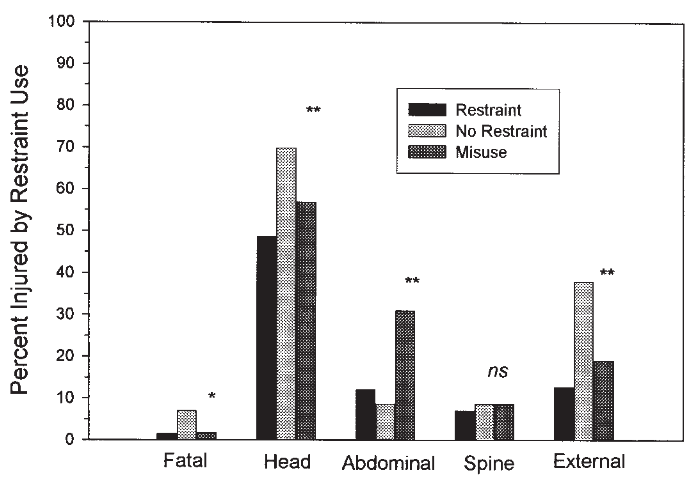

FIG. 2—*Occurrence of injuries by restraint usage for all seat locations for 4–9 year olds: * p-value ≤ 0.05; ** p-value ≤ 0.01; ns = not significant.*

TABLE 4—*Assessment of injury by the abbreviated injury scale for 0 to 9 year olds.*

Body Region Injured	Total, *n*, %	AIS = 1 *n*, %	AIS = 2 *n*, %	AIS = 3 *n*, %	AIS ≥ 4 *n*, %
Head	299 (60)	194 (65)	51 (17)	15 (5)	39 (13)
Neck	16 (3)	13 (81)	1 (6)	2 (13)	… (0)
Thorax	36 (7)	13 (36)	… (0)	13 (36)	10 (28)
Abdomen	62 (12)	41 (66)	14 (23)	5 (8)	2 (3)
Spine	33 (7)	14 (42)	9 (27)	8 (24)	2 (6)

ous or worse as indicated by a MAIS ≥ 3, and the majority of these injuries occurred to the head and thorax. The head was the most frequently injured body region, with 60% of the children sustaining a head injury. Although 65% of head injuries were superficial, 80% of the fatalities were due to head injuries. The distribution of injuries by body region and MAIS are depicted in Table 4.

Zero to Three Year Olds

In the crude analysis, properly restrained infants and toddlers had the lowest mean MAIS and ISS as compared to unrestrained and improperly restrained children. When the analysis was stratified by seat location, the mean MAIS and ISS for properly restrained, unrestrained, and improperly restrained occupants were not significantly different.

Four to Nine Year Olds

In the crude analysis, properly restrained children had the lowest MAIS and ISS means as compared to unrestrained and improperly restrained children. A similar result was obtained for the front seat. In the back seat, unrestrained children had the highest MAIS and ISS means as compared to properly restrained and improperly restrained children.

Discussion

The object of the present study was to document local experience with restraint use and outcome in a pediatric population hospitalized for injuries sustained in MVCs. We were particularly interested in examining injury patterns in the 0–3 year old and 4–9 year-old age groups because of differences in anatomy and recommended and/or mandated forms of restraint.

Although Kentucky has mandated child restraint since 1982, one third (33%) of the study population was unrestrained when a collision occurred. Johnston et al. (33) and Edwards et al. (36) reported similar findings. Our finding that 4–9 year olds were less frequently restrained than 0–3 year olds, suggesting an inverse relationship between age and restraint use, has been well documented (2,6,8,33,37). Restraint misuse has been reported to be as high as 80% (7,13–14). We found that 20% of our study population had been improperly restrained. The discrepancy may be due to the lack of detailed information in the medical chart and/or autopsy report regarding the use of restraints; frequently, the only information available was “restrained.” We placed these children in the properly restrained group; however, some may have been improperly restrained. The highest percentage of misuse occurred among the 0–3 year olds. Weinstein et al. (38) also found this to be true and attributed the high rate of CRS misuse to the more complicated nature of the restraint system as compared to seat belts.

Previous studies have documented the safer environment afforded by the rear seat location (25,29–31,39). We found that the majority of children in both age groups were seated in the rear and were properly restrained. However, despite broad dissemination of information about the relative safety of the rear seat, the majority (53%) of unrestrained infants and toddlers were in the front seat.

The well-established protective effect of restraints is confirmed in this study. Unrestrained children accounted for 70% of the fatalities. Similarly, Osberg and Di Scala (26), Johnston et al. (33), and Agran et al. (40) found the highest percentage of fatalities to be associated with unrestrained children. When risk as a function of seat location was examined, Braver et al. (31) discovered that regardless of restraint use, the back seat was associated with a lower risk of dying than the front seat. We found no significant differences regarding fatalities and seat location. These findings may be due to the limited number of cases and/or incomplete information in the medical charts and/or autopsy reports regarding seat position.

The anatomical region most frequently injured in a MVC is the head (14–16,22,24). We found that 60% of the injuries occurred to the head, and 65% of these injuries were superficial contusions, abrasions, or lacerations. While only 18% of the head injuries were serious or worse (AIS ≥ 3), 20 of the 25 fatalities were the result of a head injury. Agran et al. (15) and the National SAFE KIDS Campaign (22) also found the highest frequency of fatal injuries to be associated with the head. We also found that restrained children in the front and rear seats sustained fewer head injuries than unrestrained children in these seat positions. Osberg and Di Scala (26) had similar findings. Regardless of restraint use, the back seat was associated with a lower risk of sustaining a head injury compared to the front seat.

Numerous studies have documented a greater occurrence of abdominal injuries in restrained children as compared to unrestrained children (16,23,26,41). In the present study, restraint misuse accounted for the highest frequency of abdominal injuries. This finding was statistically significant for the 4–9 year olds. The 4–9 year olds also suffered more abdominal injuries than the 0–3 year olds. Agran et al. (15) described similar findings and proposed that this may be attributed to 4–9 year olds being inappropriately placed in restraint systems designed for an adult body. Although restrained children suffered a higher frequency of abdominal injuries than unrestrained children, unrestrained children had higher ISS means. Therefore, the risk of sustaining an abdominal injury from the misuse of a restraint device is less than the risk of sustaining multiple serious injuries from riding unrestrained.

Abdominal contusions have been suggested to be pathognomonic for abdominal visceral injury (26). We found 18% of restrained children to have abdominal contusions, and of these only 11% had associated intra-abdominal injuries. There were five cases of restrained and seven cases of unrestrained children with intra-abdominal injuries with no accompanying abdominal contusion.

The proper use of booster seats is one method to establish an improved fit for children restrained in adult seat belts. As a result, the child may be better protected against injuries incurred from the improper fit of the restraint. The National SAFE KIDS Campaign noted that only 5% of 4–9 year olds use booster seats (7). In the present study, only 0.9% of the 4–9 year olds used a booster seat.

Injury severity was documented using the AIS and the ISS. Sixty-nine percent of the study population sustained no injuries or minor injuries (AIS 1). Weinstein et al. (38) noted similar findings. In the crude analysis, properly restrained children had the lowest MAIS and ISS means, and unrestrained occupants had the highest. This finding was consistent for both the 0–3 and 4–9 age groups. Niemcryk et al. (37) and Newgard and Jolly (41) reported similar results. Gotschall et al. (14) and Weinstein et al. (38) found improperly restrained children had higher MAIS and ISS means than properly restrained children and lower MAIS and ISS means than unrestrained children. These findings suggest that the proper use of restraints affords the best protection, followed by improper use of restraints and, lastly, no restraint use. Regardless of restraint use, the back seat was associated with lower MAIS and ISS means than the front seat. Agran et al. (29) also found this to be true. When comparing unrestrained children in the back seat and properly restrained children in the front seat, the back seat no longer affords greater protection (31,39). We found that properly restrained 0–3 year olds and 4–9 year olds in the front seat had lower MAIS and ISS means than unrestrained children in the back seat.

Limitations

The design of the present study was a retrospective chart review, with its inherent limitations. Police accident reports were reviewed to verify the information obtained from the medical and autopsy reports. Only 75 police accident reports were available, and these did not add anything to the clinical information. Frequently, detailed information regarding the type of restraint used and whether it was used correctly was not available.

Children involved in MVCs who were uninjured and did not go to the hospital were not included in this study. Therefore, our results cannot determine the likelihood of a child sustaining an injury when involved in a MVC, nor can we determine the protective effect of different restraint devices and seating positions. Rather, our results provide a detailed description of the frequency and severity of specific injuries sustained by pediatric passengers involved in MVCs with injuries of a severity to require hospital evaluation or that otherwise entered the health care system.

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