

INJURIES TO CHILDREN ONE TO THREE YEARS OLD IN SIDE IMPACT CRASHES

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ABSTRACT

Children comprise more than 50% of the rear seat occupants in motor vehicle crashes. Side impact is a particularly harmful crash mode. The National Highway Traffic Safety Administration (NHTSA) has undertaken a study of real-world data to help characterize crash parameters and injury causation of children in side impact crashes. Although there is a paucity of data on children in motor vehicle crashes a detailed analysis of real-world crashes was conducted to determine any potential safety improvements that can be afforded this population of rear seat occupants.

A weighted query of the National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) showed that 9% of child involvements one to three years old were unrestrained, while the Fatality Analysis Reporting System (FARS) showed that 46% of the fatalities in that age group were unrestrained. A NASS-CDS query of side impact crashes with a change in velocity (ΔV) ≥ 30 kph was analyzed to determine which body regions were injured. Injury causations were reviewed to determine injury source and severity. Children injured in side impact crashes of this intensity seemed to exhibit a preponderance of head injuries in addition to those to the torso and extremities. Children on the near side in these crashes tended to suffer more severe injuries than far side occupants. Several case studies from the Crash Injury Research and Engineering Network (CIREN) were examined. The cases involved children aged one to three years old who were injured in forward facing child restraint systems (CRS) appropriate for their age. Observations were made about the influence on injury severity of relative seating position (near side, center, far side), crash severity, structural intrusion, and attributes of the child restraint systems. For these cases, the evaluation and applicability of existing countermeasures were considered qualitatively.

INTRODUCTION

Children comprise more than 50% of the rear seat occupants in motor vehicle crashes. The National Automotive Sampling System, in particular the Crashworthiness Data System [NASS-CDS: 1995, 1996, 1998-2005], estimates that more than 2.7 million children ages 0 to 12 years old were involved in motor vehicle crashes in a period covering ten years of data. Figure 1 shows that 53% of 0 to 12 year-olds were involved in frontal crashes followed by 27% in side impact crashes. Rollover and rear end crashes represented the remaining 11% and 9% of crashes, respectively.

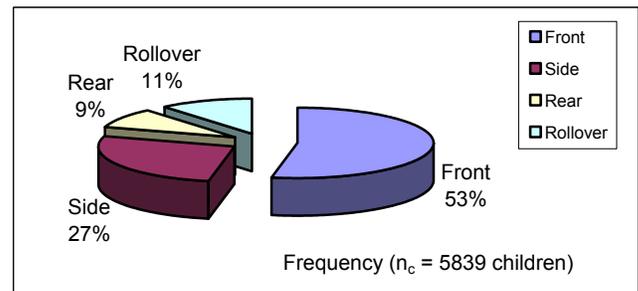


Figure 1: Distribution of crash configurations for all children 0 to 12 years old. Weighted N = 2,732,141 children. NASS CDS: 1995, 1996, 1998-2005

NHTSA has undertaken a study of real-world data to help characterize crash parameters and injury causation of children in side impact crashes. Despite limited data, the detailed analysis of real-world crashes will help to characterize potential safety improvements for rear seat occupants.

For the purpose of this study unweighted data are used. The authors do not draw any conclusions but report the findings based on the data sample. Therefore, in the absence of weighted estimates, the data should be considered a collection of anecdotal data.

National Automotive Sampling System - Crashworthiness Data System (NASS-CDS) and Fatality Analysis Reporting System (FARS)

The initial investigation used the National Automotive Sampling System, in particular the Crashworthiness Data System, and Fatality Analysis Reporting System (FARS). A weighted query of NASS-CDS [data years 1995, 1996, 1998-2004] shows that 13% of children aged 0 to 12 years old involved in crashes were unrestrained. In this time frame, children ages one through three years old had a lower unrestrained rate (9%). In contrast, the Fatality Analysis Reporting System (FARS data years 1994-2003) shows that 46% of side impact fatalities of children aged one through three years old were unrestrained. This implies that 9% of children in this age group who were unrestrained bore significantly more risk of death from side impact crashes than the 91% who were restrained. Continued efforts to encourage proper restraint of vehicle occupants, especially children, appear warranted.

Nonetheless, children are being injured and killed. Further investigations were undertaken to determine how children were being injured in side impact crashes. A NASS-CDS query was performed which identified cases of children aged 0 to 12 years old injured in side impact crashes. The crash parameters include rear seated occupants involved in non-rollover, side impact crashes. Side impact crashes were defined as vehicles with the General Area of Damage variable equal to “right” or “left.”

In order to focus on the more serious crash events, a subset of the NASS-CDS data was scrutinized for injury mechanisms and distributions. Children injured in side impact crashes with a change in velocity (ΔV) of 30 kph or more were included. For the children who are the focus of this paper (injured children aged one- to three-years-old), the 28 cases listed at $\Delta V \geq 30$ kph values constitute a relatively small percentage of the overall 117 injured one- to three-year-olds. However, when the data are weighted, these 28 children represent 60% of the one-to three-year-old children receiving a maximum injury of AIS 3 or higher.

At ΔV values of 30 kph or more, there were 552 injuries recorded for the 125 injured children aged zero to twelve years old for an average of 4.4 injuries per child. The injuries were categorized as head, neck, torso, upper extremity, and lower extremity. The distribution is shown in Figure 2. The preponderance of injuries (52%; n=287) was head injuries. Torso and lower extremities injuries each

represent 18% of the overall injuries. Upper extremities and neck injuries represent 7% and 5%, respectively.

The subset of data for children one to three years old tells a slightly different story in Figure 3. There were 104 injuries distributed over 28 children (for an average of 3.7 injuries per child).

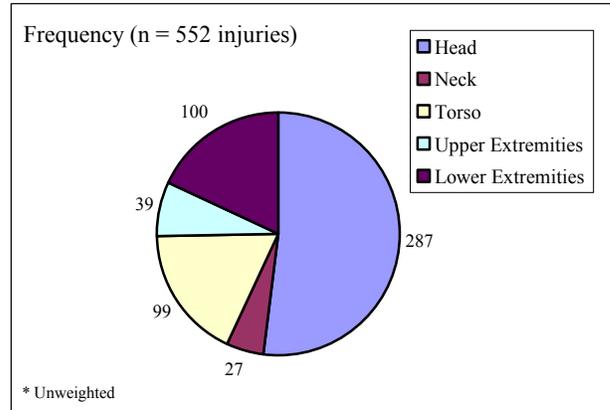


Figure 2: Distribution of injuries among body regions. Side impact crashes. Children 0 to 12 years old. $n_c = 125$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

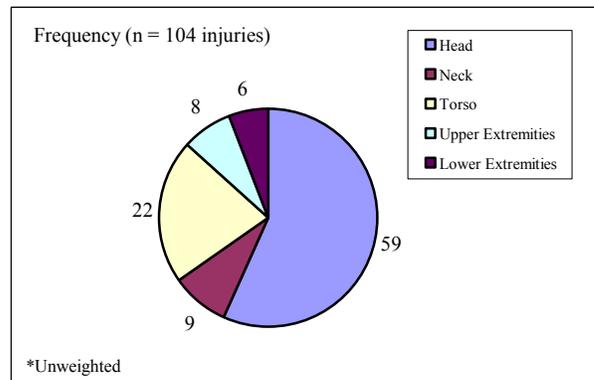


Figure 3: Distribution of injuries among body regions. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

The distribution of injury severity across injured body region is shown in Table 1. There were no AIS 6 injuries in this sample.

For the one to three year old subset, head injuries were slightly higher (57%) than the overall population set. The higher fraction of head injuries may be related to relatively high neck loading compared to larger children. According to Weber, there has long been a concern that a child’s cervical

spine could be separated as a result of the force on the head when the shoulders are held back in a crash[1]. The other factors to consider are the direction of the impact force, difference in restraint systems (internal harness, 3-point belts, etc.) and the proximity of the nearest surface (often the padded CRS itself).

The percentage of torso injuries is 21% which is similar in proportion to the overall child population. However, for the one to three year old subset, lower extremity injuries were less of an issue--only 6%. Neck injuries represented 9% while upper extremities represented 8% of the injuries for one to three year olds.

Of this injured group of 28 one to three year olds, half were known to be in a forward facing CRS. This population of children in forward facing restraints will be discussed in a later section.

The injuries to the 28 children can be categorized by the contact source that caused the injury. The injury contact sources are defined in the NASS-CDS Coding and Editing manual[1]. The groups are shown in Figure 4. While “flying glass” caused 19 of the 104 injuries (mostly to the head), direct contact with the vehicle interior (47 of the 104 injuries) was the most common injury source. Interior contacts included seat backs, sills, hardware, and other surfaces. Contact with the child seat represented 15 injuries. However, further review is required to determine whether the injury is caused by the child’s own CRS (possibly due to contact with an intruding component) or that of an adjacent occupant. Torso injuries were attributed to contact with interior objects/surfaces and other vehicle elements.

Table 1: Distribution of injury severity versus injured body region. Side impact crashes. $n_c = 28$ children. Children 1 to 3 years old. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004.

	AIS1	AIS2	AIS3	AIS4	AIS5	Total
Head	49	1	3	2	4	59
Neck	9	0	0	0	0	9
Torso	6	8	2	4	2	22
Upper Extremity	7	1	0	0	0	8
Lower Extremity	5	1	0	0	0	6
Total	76	11	5	6	6	104

Figure 5 correlates these same contact groups with the injury severity level using the Abbreviated Injury Scale (AIS). Minor injuries (AIS1) were attributed to flying glass, the vehicle interior, the child seat and the seat back. However, focusing on the moderate and serious-to-fatal injuries (for known sources), Figure 5 shows that the vehicle seat back and other interior surfaces are the prevailing sources of injuries. Table 2 provides the frequency distribution of injury sources.

The authors choose to compare moderate-to-fatal (AIS2+) injuries with serious-to-fatal (AIS3+) injuries. Moderate (AIS 2) injuries cover a broad spectrum of injuries that may or may not be a threat to life and/or result in long-term outcome issues. Therefore, the AIS2+ frequency count also includes $AIS \geq 3$ injuries.

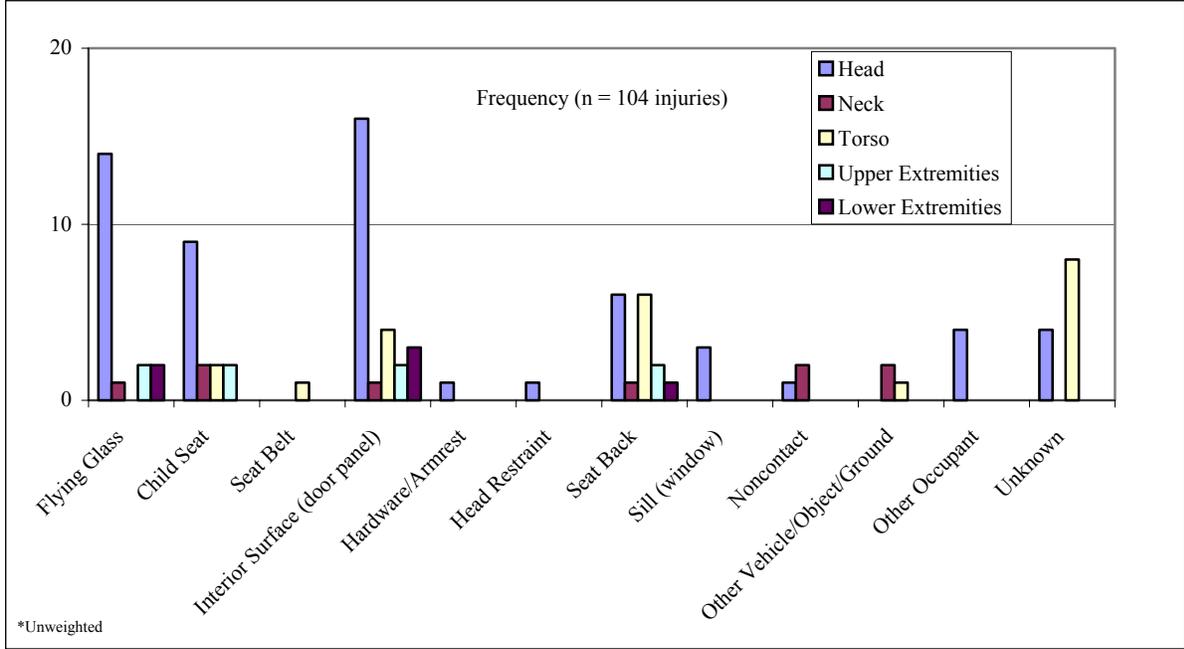


Figure 4: Distribution of injury sources among body regions. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

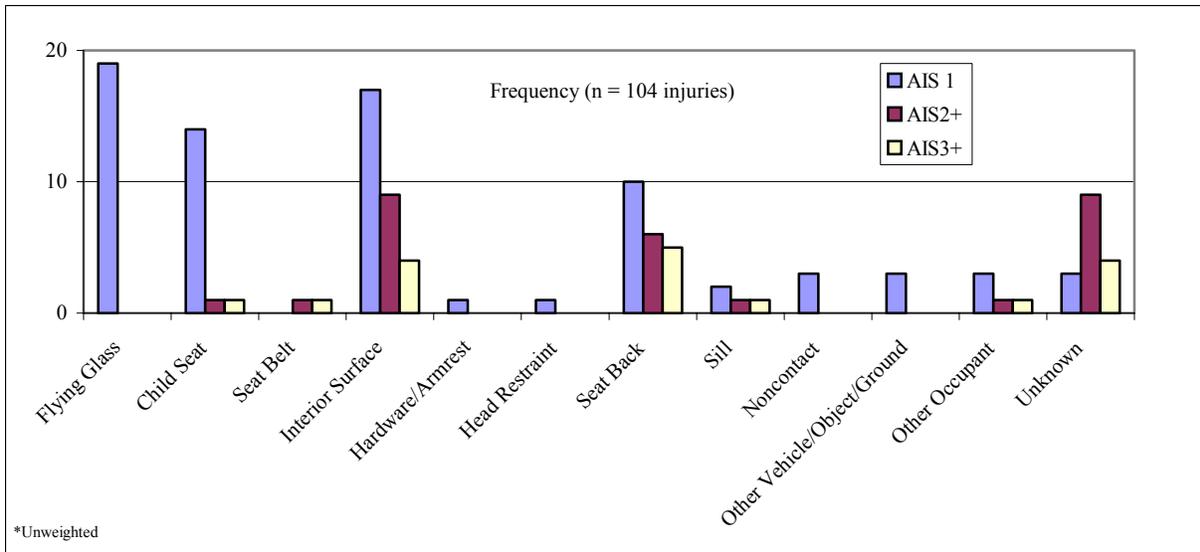


Figure 5: Distribution of injury sources among injury severities. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004. [Note: AIS2+ also includes AIS ≥ 3 injuries]

Table 2: Frequency distribution of injury sources. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

Source	n	Source	n
Flying Glass	19	Seat Back	16
Child Seat	15	Sill (window)	3
Seat Belt	1	Non-Contact	3
Int. Surface	26	Oth/Veh/Grd	3
Hrdw/Arm	1	Other Occupant	4
Head Rest	1	Unknown	12

The frequency of injured regions was also investigated as a function of the relative vehicle impact location. Side impacts were categorized relative to the seating position of the rear seated occupant in question; that is, near side, far side, center, or (in the case of unrestrained children not in a seat) "other." The distribution is shown in Figure 6. Note that these data include all restraint alternatives and will be evaluated in the next segment. The data seem to indicate that head injuries are always prevalent, but that far side occupants are less likely to suffer torso injuries. However, neck injuries are most prevalent with far side occupants then slightly less with near side occupants.

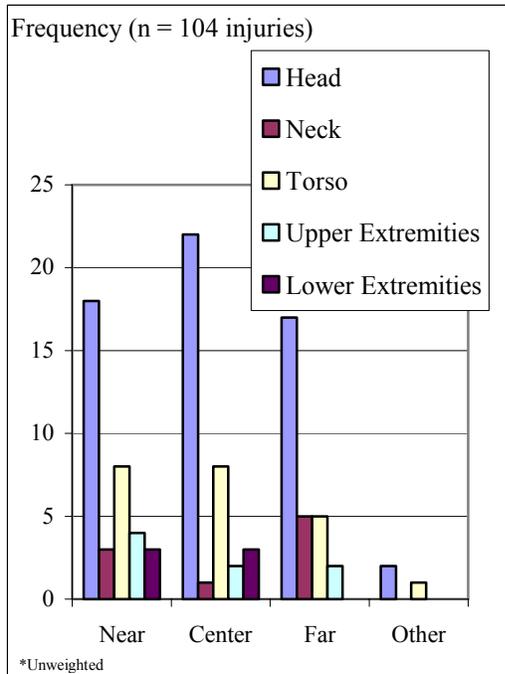


Figure 6: Distribution of relative impact location and injured body region. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

These data can also be looked at in terms of injury severity by relative impact location, as shown in Figure 7. It is encouraging that many of the injuries are at the AIS 1 level, but it becomes evident that a higher percentage of the injuries of near side and center seat occupants are at the higher AIS levels for this dataset. The most significant injuries (AIS 3+) are sustained by near-side and center seated occupants for this dataset.

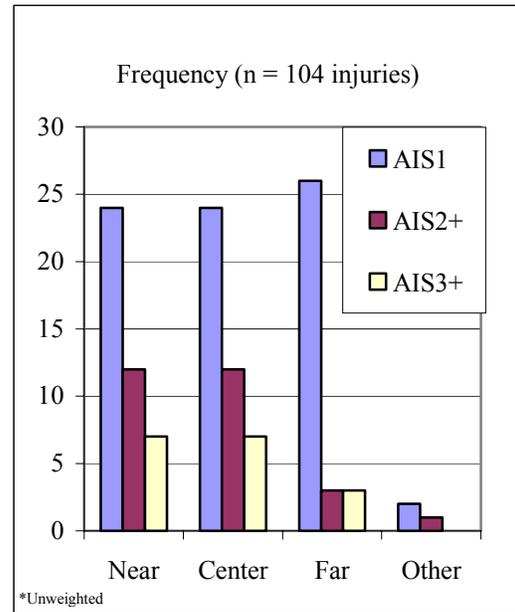


Figure 7: Distribution of relative impact location and injury severity. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004 [Note: AIS2+ also includes AIS ≥ 3 injuries]

The injury data can be segmented by restraint type. The restraints listed in this NASS-CDS dataset were booster seats, forward facing child restraint systems, lap and shoulder (3 point) safety belts, lap belts only, unrestrained, and other/unknown. The distribution of injured body region is shown in Figure 8. With the limited amount of data across these six alternatives, no clear differences in injury patterns emerge. As a result of this limited sample size of data, the children in forward facing restraints experienced a prevalence of injuries for all body regions. As you review the data, note that the forward facing children represent half of the overall sample. While they represent half of the sample population, there are only 40 (39%) injuries sustained. Thirty five (35) of these injuries are AIS1 and are mainly due to flying glass, child seat, forward seatback and other interior contacts. This sample of restrained children (14) are reviewed in a later section of this paper.

Head injuries are clearly represented within each restraint category. The prevalence of torso injuries is second to head injuries. Although the frequency of upper and lower extremity varies by restraint type, upper extremity injuries are primarily sustained by children in forward facing, lap belt only and other/unknown restraint categories. These data show that children in forward-facing restraints (in this dataset) seem to experience more neck injury than those children in other types of restraints. Given the limited data sample size, more data and further analysis must be conducted better understand the various complexities of the crash events.

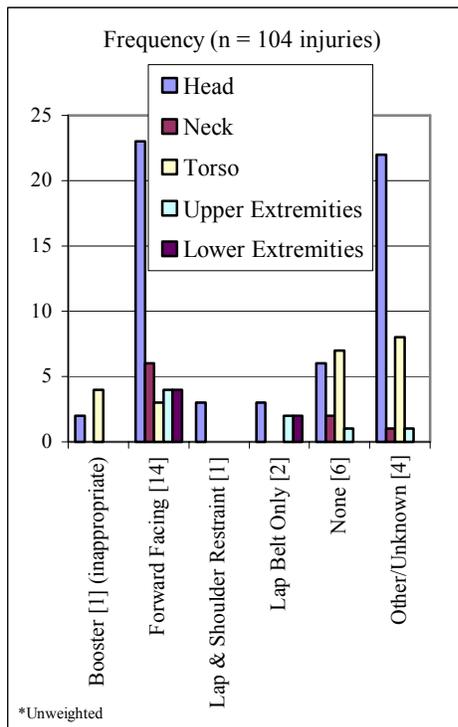


Figure 8: Distribution of restraint type and injured body region. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

Injury severity was also determined based on restraint type, as shown in Figure 9. In this plot, some differences between injury severity and restraint type are evident. While only one case of premature graduation to a booster seat was included, most of that case occupant’s injuries were more severe. In contrast, most of the injuries to children in forward facing restraints were AIS 1. The unrestrained and other/unknown cases had higher percentages of injuries above the AIS 1 level.

Of the known restraint types, the most serious (AIS3+) injuries were sustained by a single child inappropriately restrained in a booster seat. This child sustained multiple significant injuries.

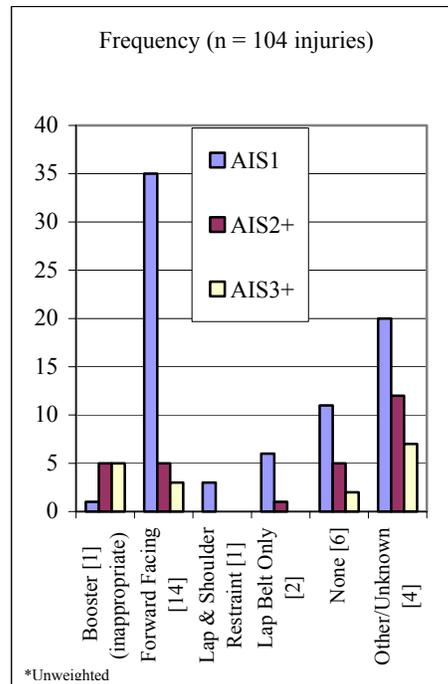


Figure 9: Distribution of restraint type and injury severity. Side impact crashes. Children 1 to 3 years old. $n_c = 28$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004 [Note: AIS2+ also includes AIS ≥ 3 injuries]

Next, it is useful to compare the injury severity distributions for some broad categories of impact speed, ΔV . Figure 10 shows the distribution of AIS level for crashes that occurred over 10 kph increments and those designated as “unknown”. Note that these are all ΔV ’s, including “unknown” values. When accounting for all ΔV ’s there are 117 injured one to three year old children who sustained a total of 335 injuries. For approximately one-third of the injuries the ΔV is unknown. Of those cases with a known ΔV , again, no clear pattern emerges. While this is surprising in that the impact speed would be expected to have a stronger influence on injury levels, there are enough confounding factors (e.g., the precise location of the intrusion relative to the occupant) that it is not unreasonable to find limited correlation in a relatively small sample.

Minor injuries (AIS 1) occur at each level of impact speed. Moderate to severe injuries (AIS 2+) seem to occur over a broad range of speeds from 20 – 49 kph. The more severe injuries (AIS3+) seem to occur at ΔV of 40-49 kph.

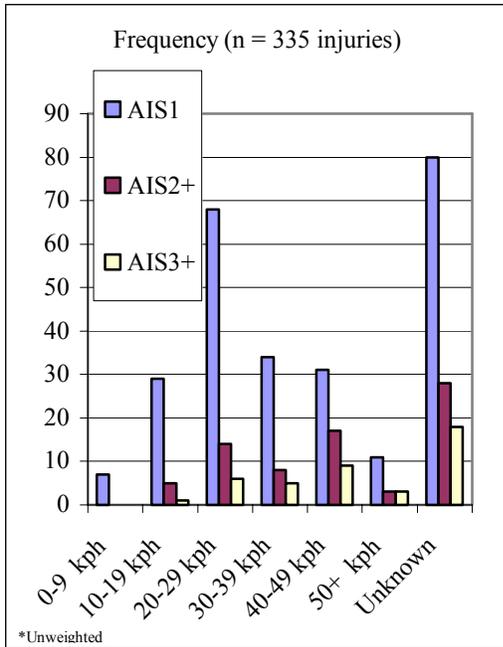


Figure 10: Distribution of ΔV and injury severity. Side impact crashes. Children 1 to 3 years old. $n_c = 117$ injured children. NASS CDS: 1995, 1996, 1998-2004

Finally, another important aspect of the crash problem is the impact angle or Principle Direction of Force (PDOF). In NASS-CDS, the angles are given as clock angles (e.g., head on force is defined as “12 o’clock”). The dataset was queried to determine the distribution of PDOF for side impact crashes with children in the rear seat. The distribution is shown in Figure 11. If data are grouped by degrees from the longitudinal axis (that is, both 10 o’clock and 2 o’clock represent 60° from longitudinal), then the average impact angle is approximately 70°. If they are grouped by degree from lateral (i.e., 2 o’clock, 4 o’clock, 8 o’clock and 10 o’clock are 30° from lateral), then the average angle from lateral is approximately 30°.

The kinematics of a side impact crash will depend on both the magnitude of the impulse from the bullet vehicle as well as its relative direction. The principal direction of force for side impact crashes tends to be slightly forward of lateral. Figure 12 is a polar coordinate plot depiction of the clock angles of force (12 o’clock being a head-on direction) for side impact crashes in the NASS-CDS database. Side impact crashes are defined as those for which the general area of damage was given as “right” or “left.” In the 394 cases of a side impact crash with a one- to three-year-old occupant in the back seat, the most common angles were 10 o’clock and 2 o’clock.

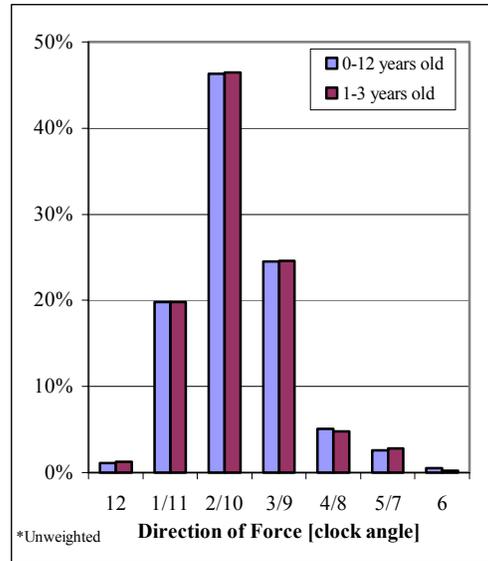


Figure 11: Distribution of Principle Direction of Force. Unweighted side impact crashes (General Area of Damage = Right Side or Left Side). $n_{c\ 1-3} = 394$ children and $n_{c\ 0-12} = 1618$ children. NASS CDS: 1996 - 2005.

The data demonstrates that there is typically a longitudinal component in side impact crashes with children. Similar findings were demonstrated in the side impact case studies conducted by Arbogast, et al [3] and Nagabhushana, et al [4].

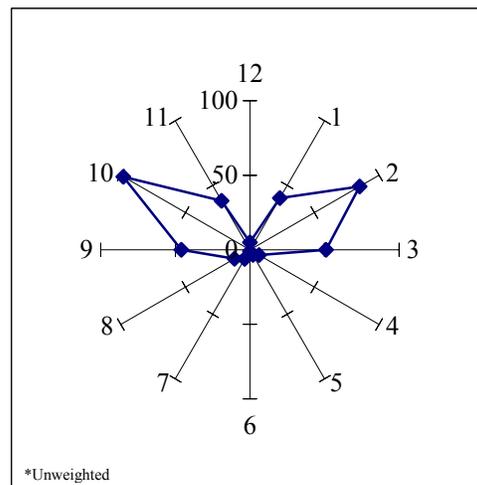


Figure 12: Distribution of principal direction of force [clock angle]. Side impact crashes (General area of damage of “left” or “right”) with a rear seat child occupant aged 1 to 3 years old. $n_c = 394$ children. NASS CDS: 1996-2005.

Analysis of Fourteen Children in Forward-Facing CRS

Previously, 28 children ages one to three years old were identified as the subset of children in side impact crashes. Half (14) of these children were restrained in forward-facing restraints. The restraint status of the remaining fourteen children was as listed below. One child was restrained in a booster seat. One was secured with a three-point belt. Two children were restrained with a lap belt only. Nearly half (six) of the 14 children were unrestrained. However, the restraint type was unknown for four children. A similar analysis of the previous section

was undertaken to better understand the forward-facing restrained population.

Figures 13 and 14 are the equivalents of Figures 4 and 5 for the restricted (forward facing) dataset. As a general trend, the injuries decrease by more than a factor of two, implying the forward facing child restraints afford significant protection. Certain contact surfaces such as interior surfaces, seat backs, head restraints, and unknown are greatly reduced or virtually eliminated as injury sources. Those injuries that do occur seem to be less severe.

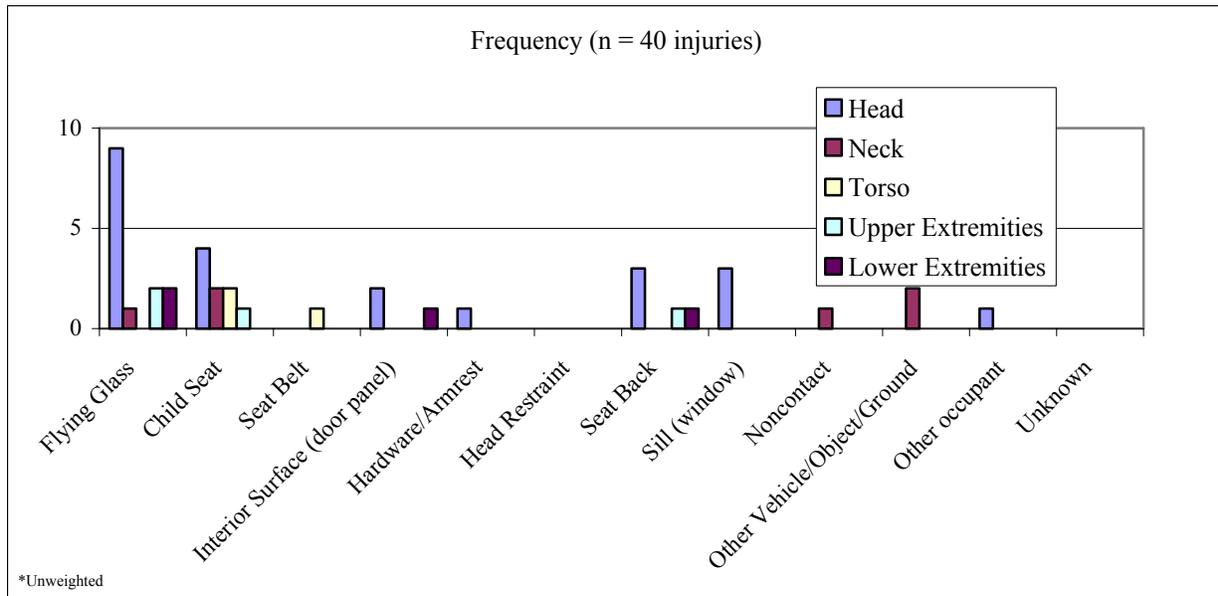


Figure 13: Distribution of injury sources among body regions. Side impact crashes. Children 1 to 3 years old in forward-facing child seats. $n_c = 14$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

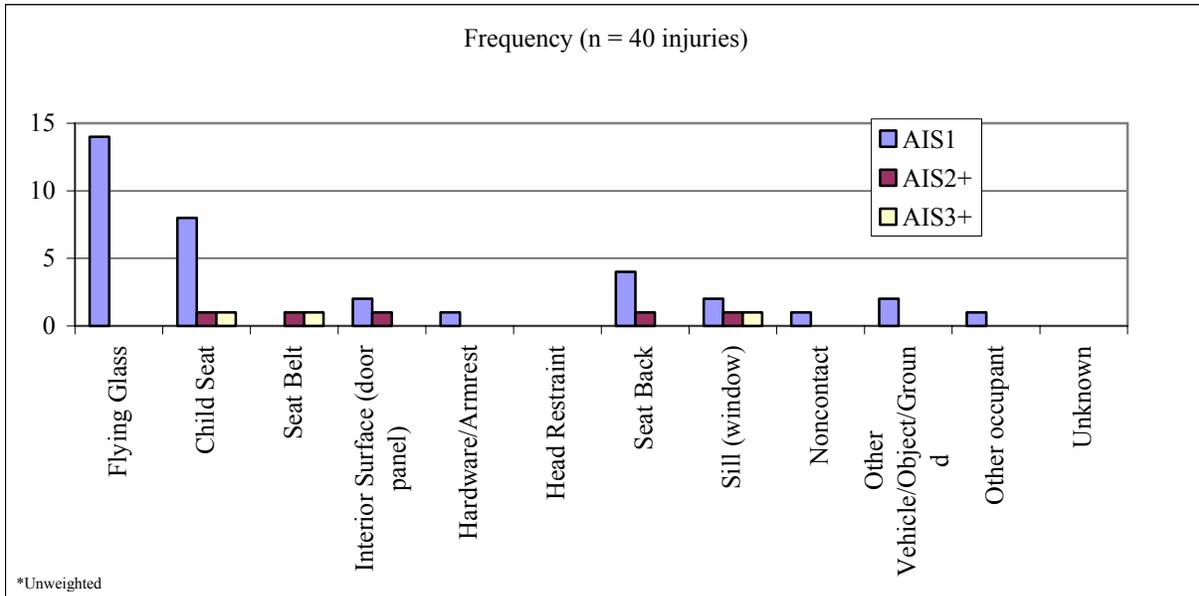


Figure 14: Distribution of injury sources among injury severities. Side impact crashes. Children 1 to 3 years old in forward-facing child seats. $n_c = 14$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004 [Note: AIS2+ also includes AIS ≥ 3 injuries]

Figures 15 and 16 are equivalent to Figures 6 and 7 for the reduced dataset. A comparison of these figures indicates that children in the forward facing restraints are more protected from torso injuries, at least on the near side and in the center when compared to all other restraint alternatives. Figure 16 shows that occupants in forward facing restraints, in the center seat, sustained only minor (AIS1) injuries.

For this dataset the injuries decreased from 104 for 28 children to 40 injuries for 14 children. The reduction in severe injuries of AIS3+ decreased from 17 to 3. The 40 injuries sustained by this sample are mostly AIS1 (35). These injuries were mainly due to sources such as flying glass, the child seat, the seat back, interior surfaces, the window sill, and “other” structures. For the children aged one to three years old identified in this data, the forward facing child restraints seem quite effective.

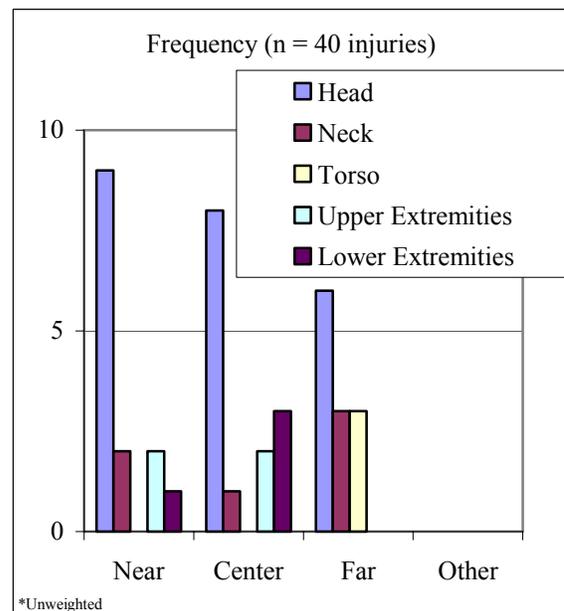


Figure 15: Distribution of relative impact location and injured body region. Side impact crashes. Children 1 to 3 years old in forward-facing child seats. $n_c = 14$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004

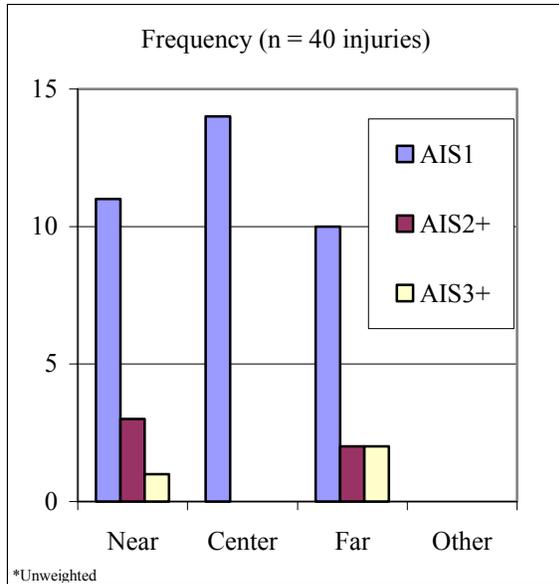


Figure 16: Distribution of relative impact location and injury severity. Side impact crashes. Children 1 to 3 years old in forward-facing child seats. $n_c = 14$ children. $\Delta V \geq 30$ kph. NASS CDS: 1995, 1996, 1998-2004 [Note: AIS2+ also includes AIS ≥ 3 injuries]

Crash Injury Research Engineering Network (CIREN) Case Studies

The patterns of injury distribution in the NASS-CDS data indicated that this issue of injuries to children from one to three years old in side impact crashes requires closer scrutiny. While the NASS-CDS data gives relevant data, the Crash Injury Research Engineering Network (CIREN) contains more in-depth injury and biomechanical information, although on fewer cases. CIREN currently consists of eight trauma centers which carefully examine injury in various serious motor vehicle crashes. The additional data (such as an evaluation of whether or not the child restraint system was installed properly) becomes useful in understanding injury mechanisms and discussing potential countermeasures.

To ensure the most complete evaluation, CIREN cases were examined in which restraint type was optimal (i.e., forward facing CRS's were chosen), although proper installation was not required. A query of CIREN was run that searched for children aged one through three years (twelve to 47 months) who were restrained in a forward-facing child restraint system, injured in a side impact crash and sustained a Maximum AIS level (MAIS) ≥ 2 . Nine cases (in eight separate crashes) were returned and are listed in Table 3[5]. These cases can be accessed as follows:

Table 3: CIREN cases. Side impact crashes injury severity of AIS 2 or more. Children 1 to 3 years old.

Case	Age [months]	ΔV (kph)	Near/Far/Center	Injury	Installation Annotation
376028346	29	35	Far	AIS 2 spine	No locking clip
874037095	28	48**	Far*	AIS 2 arm fracture	Unknown
377037327	24	42	Far	AIS 2 maxilla fracture	"Highly unlikely" to be appropriate
470047788	33	Unknown	Center	AIS 2 concussion/cuts	Appropriate
33088	46	19	Near	AIS 3 orbit fracture	No locking clip
377039617	31	Unknown	Near	AIS 3 brain hemorrhage	No locking clip, belt in wrong slots
690040270	46	48**	Near*	AIS 3 lung contusion	Appropriate
874034767	40	80	Near	AIS 4 lung contusions	"Proper"
426032502	24	Unknown	Near*	AIS 4 brain hematomas	Appropriate

*other occupants in the same row **Different case occupants from the same crash

Discussion of Injury Patterns and Potential Countermeasures

Near side cases - Five of the nine cases were near side impacts. These crashes have all the vehicle kinematics of center and far side crashes, but also have the most opportunity for direct or indirect contact with intruding vehicle structure. All five of these cases had significant intrusion in the vicinity of the case occupant. They all produced an AIS3+ injury to either the head (including two cases with brain injuries) or the torso (two cases with lung contusions). The Injury Severity Score (ISS) of each child in a near side crash was higher than the other four case occupants.

Four of the five cases experienced right side lateral impacts (See Appendix). Of the five near side cases the principle direction of force (PDOF) was primarily a “pure” lateral impact (three at 80° and one at 270° impact). Only one crash case experienced an impact with a proportionate longitudinal component (PDOF of 50°). This is not consistent with the NASS-CDS results nor analytical results from other researchers. According to Arbogast et al.[3], a longitudinal component is typically present in most side impact crashes. This difference is likely due to the limited sample size available for case selection in CIREN.

Interestingly, both child restraint systems which were not properly restrained (that is, no locking clip or automatic locking retractor [ALR] was used) resulted in head injury while both lung contusion cases were deemed to have had “appropriate” CRS installation. It appears that improper installation may allow sufficient translation and rotation of the CRS to promote head contact and subsequent injury. While proper installation is always preferable, the advantages of more rigid interfaces between the CRS and the vehicle, such as LATCH, should be further evaluated. According to Arbogast et al.[3], it is suggested that rigid (ISOFIX) LATCH may reduce the risk of rotation.

In contrast, both cases with lung contusions were identified as having appropriate CRS installation as well as significant impact velocity. One CRS was specifically identified as a shield booster. Both case occupants also experienced head injuries and additional internal injuries.

In two of the cases, there were other occupants in the rear seat with the child, but in both cases they were other children restrained in CRS and were not cited as a possible injury source. In contrast, the NASS-CDS study did note some injuries resulting from

contact with other occupants. Nonetheless, beyond proper restraint of all rear seat occupants, there are few options for reducing occupant-to-occupant injury mechanism.

Center case - One of the nine cases was a center seat occupant. This young girl suffered head injuries and lower extremity abrasions as the driver’s seat was displaced back into her occupant area. This example illustrates that center seat occupants are not immune to the effects of intrusion resulting from external load forces. Her ISS score was lower than all near side occupants, but higher than all far side occupants. The intruding driver’s seat reinforces the point that every surface in the vehicle interior is a potential injury source. Reducing the likelihood of collapsing forward seats may reduce intrusion into the rear occupant compartment.

Far side cases - The remaining three of the nine CIREN cases were children on the opposite side of the vehicle from the impact. These were all MAIS 2 cases, although the NASS-CDS data in Figure 6 demonstrates that this need not be the case. None of the children in these cases was demonstrably well-restrained. It is possible that there is a connection between the MAIS 2 requirement in the original CIREN query and the propensity for insufficient restraint.

The primary injuries varied from case to case. One child had primarily head injuries. Another had spine injuries. The last had upper extremity injuries. This diversity shows that substantial contact can occur away from the direct intrusion.

Individual Case Analysis

Case-33088

This case involves a 3-year old (46 months), 15 kg (33 lbs.) and 102 cm (40 in.) female seated in the second row right of a 1998 Honda Accord that was involved in a right side collision with a 1997 Dodge Ram pick-up truck. The principal direction of force (PDOF) was 50° (two o’clock) with a ΔV calculated at 19 kph (12 mph). The case vehicle damage was mainly confined to the upper rear portion of the second door, upper rear wheel and right C-pillar area (slight override). The case occupant was restrained in a convertible booster CRS by the internal harness. There was potential slack between the vehicle manual 3-point belt and restraint of the CRS due to non-use of a locking clip or use of the automatic locking retractor mode. The occupant was near-side to the impact and moved forward and to the right with respect to the vehicle. The occupant contacted the

upper portion of the intruding door panel (9 cm) with her right malar eminence (cheek bone) as evidenced by door panel scuffing and contusion/abrasion to the malar eminence. This direct compression on the malar eminence resulted in a right zygoma fracture, right maxillary sinus fracture and a right lateral orbit wall fracture. The occupant's MAIS was 3 with an ISS of 10.

Case-376028346

This case involves a 2 year-old (29 months), 17 kg (37 lbs.) male seated in the third row left of a 1997 Dodge Caravan that was involved in a right side collision with a 1991 Hyundai Sonata sedan. The PDOF was 80° (three o'clock) with a ΔV calculated at 35 kph (22 mph). The case vehicle damage was distributed down the right side of the vehicle starting behind the front wheel and extending to the rear wheel, vertical damage extended past the midline. The lower sill or rocker panel was fully engaged. The case occupant was restrained in an appropriate forward facing CRS by the internal harness, but the vehicle 3-point belt was improperly routed to restrain the CRS. The occupant was far-side to the impact and moved right and slightly forward with respect to the vehicle. The improper belt routing allowed the CRS to move right prior to fully engaging the 3-point belt. The neck/cervical spine underwent lateral extension as the occupant's head moved to the right. This extension placed the brachial plexus under tension causing nerve injury within the plexus. The occupant's MAIS was 2 with an ISS of 4.

Case-377037327

This case involves a 2-year old (24 months), 17kg (37 lbs.) and 91 cm (36in.) female seated in the second row right of a 1990 Honda Accord that was involved in a left side collision with a 1991 Toyota 4-Runner SUV. The PDOF was 280° (nine o'clock) with a ΔV calculated at 42 kph (26 mph). The case vehicle damage was distributed across both doors on the left side with B-pillar engagement and minimal rocker panel engagement. The case occupant was restrained in an appropriate forward facing CRS by the internal harness, but the vehicle 3-point belt was likely not locked. The occupant was far-side to the impact and moved left with respect to the vehicle. Slack in the 3-point belt allowed the CRS to rotate to the left. The occupant contacted the center second row seat back as evidenced by a large fabric scuff. The occupant contacted the seat back with the left side of her face. This compression fractured her left maxilla and nose. The occupant's MAIS was 2 with an ISS of 8.

Case-377039617

This case involves a 2-year old (31 months), 17 kg (37 lbs.) and 94 cm (37 in.) female seated in the second row right of a 1994 Honda Civic that was involved in a right side collision with a 1999 Kenworth tractor and trailer. The PDOF was 80° (three o'clock) with a barrier equivalent speed calculated at 28 kph (17 mph). The case vehicle damage was distributed across the upper portion of both right side doors and over the rear wheel (slight override). The case occupant was restrained in a forward facing CRS by the internal harness which was not routed through the upper slots. There was potential slack between the vehicle manual 3-point belt and restraint of the CRS due to non-use of a locking clip or use of the automatic locking retractor mode. The occupant was near-side to the impact and moved forward and to the right with respect to the vehicle. The occupant contacted the upper portion of the intruding door panel (11 cm) with the right side of her head just superior to the ear and anterior. The broken window glass lacerated her scalp and face (glass in wound) and the compression of the intruding door resulted in a very small right frontal subarachnoid hemorrhage of the cerebrum. The occupant's MAIS was 3 with an ISS of 10.

Case-426032502

This case involves a 2-year old (24 months), 9 kg (20 lbs.) and 90 cm (36 in.) male seated in the second row left of a 1994 Acura Legend that was involved in a left side collision with a 1993 International tractor and trailer. The PDOF was 270° (nine o'clock) with a barrier equivalent speed calculated at 41 kph (25 mph). The case vehicle damage was distributed across both left side doors (horizontally and vertically) and over the rear wheel (significant crush). The case occupant was restrained in a forward facing CRS by the internal harness. The CRS was properly restrained to the vehicle by the 3-point belt. The occupant was near-side to the impact and moved to the left with respect to the vehicle. The occupant contacted the upper portion of the intruding door panel (50 cm) with the left side of his head in the temporal region. The intruded door panel also loaded the left side of the CRS. The compressive contact of the upper door on the occupant's head produced a subdural hematomas in the left cerebrum and cerebellum. The left scalp was contused and lacerated. The occupant's thorax and abdomen was compressed by the reinforced side of the CRS causing lung contusions on the lower lobe of the left lung and a small spleen laceration. The occupant's MAIS was 4 with an ISS of 29.

Case-470047788

This case involves a 2-year old (33 months), 15 kg (33 lbs.) and 97 cm (38in.) female seated in the second row center of a 1998 Ford Contour that was involved in a left side collision with a 1985 International tractor and trailer. The PDOF was 280° (nine o'clock) with a barrier equivalent speed calculated at 37 kph (23 mph). The case vehicle damage was distributed across both left side doors and over the front wheel with rocker panel and roof engagement (significant crush). The case occupant was properly restrained in a forward facing CRS by the internal harness. The CRS was properly restrained to the vehicle by the 3-point belt. The occupant was center to the impact and moved to the left with respect to the vehicle. The occupant contacted the intruding door panel (28 cm) with the left side of her head just superior to the eyebrow and across the temple resulting in a laceration and concussion. The occupant's MAIS was 2 with an ISS of 8.

Case-874034767

This case involves a 3-year old (40 months), 16 kg (35 lbs.) and 97 cm (38 in.) male seated in the second row right of a 1997 BMW 318 that was involved in a right side collision with a 1997 Cadillac Seville. The PDOF was 80° (three o'clock) with a ΔV calculated at 80 kph (50 mph). The case vehicle damage was distributed from behind the right front wheel to past the rear wheel. The rocker panel and doors were fully engaged. The case occupant was restrained in a backless booster CRS by the available manual 3-point belt. The occupant was near-side to the impact and moved forward and to the right with respect to the vehicle. The occupant contacted the intruding door panel (60 cm) with his right thorax and head resulting in bilateral lung contusions and a concussion. The intruding door panel also loaded the CRS compressing the occupant's pelvis resulting in a fracture. The occupant's MAIS was 4 with an ISS of 24.

Case-690040270 (Occupant #1)**Case-874037095 (Occupant #2)**

This case involves two children in the same vehicle. The occupants are in a 1994 Toyota Corolla that is involved in a right side collision with a 1988 Ford Ranger compact pick-up truck. The PDOF was 80° (three o'clock) with a ΔV calculated at 48 kph (30 mph). The case vehicle damage was distributed across the both right side doors and over the rear wheel (slight override).

Occupant 1 is a 3-year old (46months), 16kg (36 lbs.) and 111 cm (44 in.) male seated in the second row

right. Occupant 1 was restrained in a booster seat with a shield using the manual 3-point belt. The occupant was near-side to the impact and moved forward and to the right with respect to the vehicle. The occupant contacted the upper portion of the intruding door panel (40 cm) with the front right side of his head just superior to his hairline resulting in a scalp laceration. The intruded door panel loaded the CRS and compressed occupant 1's thorax as he contacted the CRS's shield resulting in a right lung contusion with hemo and pneumothorax. The upper abdomen was also compressed resulting in a small liver laceration and small kidney laceration. The occupant's MAIS was 3 with an ISS of 17.

Occupant 2 is a 2-year old (28 months), 15kg (34 lbs.) female seated in the second row left. Occupant 2 was restrained in a forward facing CRS using the internal harness. The CRS was properly restrained in the vehicle using the manual 3-point belt. The occupant was far-side to the impact and moved forward and to the right with respect to the vehicle. Occupant 2's arm contacted the shielded booster (occupant 1) to her right resulting in a right distal ulna fracture 2 cm proximal to the wrist joint. The occupant's MAIS was 2 with an ISS of 5.

LIMITATIONS OF STUDY

This study used data from NASS-CDS years 1995, 1996, 1998-2004. Due to the small sample size, the authors did not segment the data to evaluate vehicle type, older versus recent model year, etc.

For the purpose of this study unweighted data are used. The authors do not draw any conclusions but report the findings based on the data sample. Therefore, in the absence of weighted estimates, the data should be considered a collection of anecdotal data.

The NASS-CDS data, by their nature, are limited in detail of the description of injury mechanisms. The CIREN data are limited by the relatively small number of cases. While neither set is complete in every aspect, together they do suggest common themes in the injury mechanisms of one to three year old children in side crashes.

The CIREN inclusion criteria are based on serious injury resulting from automobile crashes. The typical CIREN case involves significant impacts and usually multiple events. Such cases are often deemed catastrophic, but as we have seen all occupants in these cases survived and some with only AIS2 injury.

DISCUSSION

The NASS-CDS and CIREN databases give useful information about the injury patterns of children one to three years old in side impact crashes. The authors chose to investigate subgroups of data with more severe crashes and injury levels and identified some important trends. Head injuries were prevalent in these severe crashes. Further, while restraint is crucial in minimizing overall injury due to the severity of the crash, the loads applied by the restraint resulted in injury, usually in the torso.

In the side impact cases reviewed for this paper the majority of the significant injuries resulted from contact with an intruding door surface. The upper door in the area of the window sill was often the source for direct head contact. Upper and mid-door contacts were noted often with the door intrusion loading the occupant's CRS and resulting in thoracic injury. Although the door intrusion was not directly coded as the source, without these loading conditions energy transfer would not have been as significant. These injury scenarios where the intruding door contacts the CRS will have the injury contact typically assigned to the CRS. For the occupants in these cases, increased padding of the upper door area and/or within the CRS might have mitigated the severity of the injury sustained. Along with increased padding, methods to decrease the door panel intrusion by transferring more of the impact force longitudinally to the surrounding structures (pillars and rocker panel) of the door could help decrease the amount of intrusion into the occupant's position.

Interaction between vehicles was seen as a contributing factor in several of the more severe cases reviewed. Improved classification and/or measuring techniques are required to better research this issue in future cases. This study required analysis of photographs to estimate underide or override characteristics due to a lack of hard-coded fields for side plane impacts in the current NASS-CDS investigation process. The side impact data reviewed indicated injurious impact angles with more oblique approach than pure lateral.

Incorrect or poor CRS installation is not a new problem, but continues to be a possible contributing factor for injury in side impact crashes. Many of the cases reviewed produced evidence of poor CRS installation, which either leads to increased motion of the CRS or increased excursion of the child from the CRS. The increased CRS movement and/or child excursion can be of sufficient amount to place the

child in contact with a rigid structure. The threat of injury is increased even farther when the occupant is put in motion due to poor restraint and rigid structures are intruding resulting in even less ride-down space.

DISCLAIMER

The views expressed in this paper are not necessarily those of the National Highway Traffic Safety Administration.

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REFERENCES

- [1] Weber, K., "Crash Protection for Child Passengers: A Review of Best Practice," University of Michigan Transportation Research Institute Research Review, July-September 2000, Vol. 31, No. 3.
- [2] United States Department of Transportation, National Highway Traffic Safety Administration, "National Automotive Sampling System, Crashworthiness Data System, 2000 Coding and Editing Manual", NHTSA, Washington, D.C..
- [3] Arbogast, K., Ghati, Y., Yoganand, G., Menon, R., Tylko, S., Tamborra, N., and Morgan, R., "Field Investigation of Child Restraints in Side Impact Crashes," *Journal of Injury Prevention*, 6:351-360, 2005.
- [4] Nagabhushana, V., Park, J., Kuznetsov, A., and Morgan, R., "Side impact Risk for Small-Size Children Final Report," Volume 1 and II, NHTSA Technical Report No. DOT HS 810699, U.S. Department of Transportation, *In press*.
- [5] CIREN cases may be accessed at: <http://www-nrd.nhtsa.dot.gov/departments/nrd-50/ciren/CIREN.html>

Appendix: Summary of CIREN Case Studies

Case	Age [months]	ΔV [kph]	PDOF	Child's ISS	Near/Far/Center	Injury	Proposed Injury Causation and Possible Countermeasures
376028346	29	35	80	4	Far	AIS 2 spine	Causation: Lateral flexion of the cervical spine with tension on the brachial plexus produced a nerve root injury. More like a whiplash effect rather than contact between neck and CRS, exacerbated by improper CRS installation causing excessive CRS movement. Countermeasures: Secure CRS installation
874037095	28	48**	80	5	Far*	AIS 2 arm fracture	Causation: contact between arm and sibling's CRS Countermeasures: CRS padding
377037327	24	42	280	8	Far	AIS 2 maxilla fracture	Causation: Head contact with back of front seat, exacerbated by improper CRS installation causing excessive CRS movement.. Countermeasures: Interior padding, secure CRS installation
470047788	33	Unknown	280	8	Center	AIS 2 concussion Facial lacerations	Causation: Intruded door panel (28cms) made contact with occupant's face causing complex laceration and concussion. CRS restrained and appropriate. Countermeasures: Interior padding, airbags
33088	46	19	50	10	Near	AIS 3 orbit fracture	Causation: Head contact with intruding door (9cms), exacerbated by improper CRS installation causing excursion and/or rotation. Countermeasures: Interior padding, secure CRS installation, airbags covering door portion
377039617	31	Unknown	80	10	Near	AIS 3 brain hemorrhage	Causation: Head contact with intruding upper door panel (11cms), exacerbated by improper CRS installation causing excessive CRS movement Countermeasures: Interior padding, secure CRS installation, airbags covering door portion.
690040270	46	48**	80	17	Near*	AIS 3 lung contusion AIS 2 liver laceration AIS 2 scalp avulsion	Causation: Head contact with intruded window sill (40 cms), thorax contact with booster shield reinforced by the intruded door. Countermeasures: Interior padding, airbags, more appropriate CRS selection.
874034767	40	80	80	24	Near	AIS 4 lung contusions AIS 2 pelvic fracture AIS 2 loss of consciousness	Causation: Thorax and head contacted intruded door panel (62cms), pelvis pinned by intruded door panel and CRS, resulting in fracture Countermeasures: Interior padding, airbags, appropriate CRS selection.
426032502	24	Unknown	270	29	Near*	AIS 4 brain hematomas, AIS 3 lung contusion, AIS 2 spleen laceration	Causation Head contact to upper portion of intruded door panel (50 cms) and thorax contact with CRS reinforced by the intruded door panel. Countermeasures: Interior padding, CRS padding, airbags

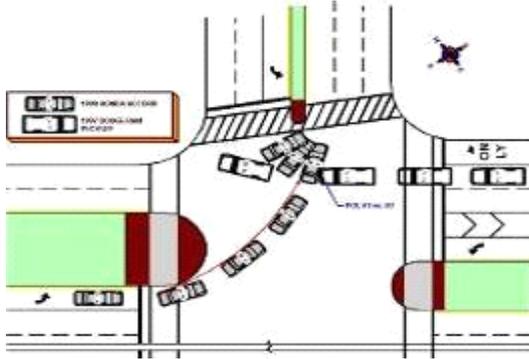
*Other occupant in the rear seat **Two different occupants in the same crash

Case Number: 33088

Vehicle Exterior:



Scene Diagram:



The collision between Vehicle 1 and Vehicle 2 occurred when the driver of the northbound Vehicle 1 attempted to turn left at the intersection as Vehicle 2 was traveling southbound through the intersection. Vehicle 2 struck Vehicle 1's right side plane with its front end. After the impact, Vehicle 1 rotated clockwise to final rest position in the intersection, facing north. The final rest position of Vehicle 2 was in the intersection, facing southwest. Vehicle 1 was towed from the collision scene due to the damage sustained in this collision. Vehicle 2 was driven from the collision scene.

Near-Side Occupant

Case Vehicle Information:

V1: Honda-Accord, 4-door sedan, hardtop-1998

DOF: 2 O'clock

Delta-V: Total: 19 Km/h (12 Mph)

Lateral: 14 Km/h (9 Mph)

Longitudinal: 12 Km/h (7 Mph)

Location of Impact: Right Side

Maximum Intrusion: >=8 to <15 cm, Second Right

Max. Intrusion Corresponding Component (s):

(1) C-pillar (2) Second seat back (3) Door panel (side)

Vehicle 2 Information:

V2: Dodge-Ram, Large pickup-1997

Case Occupant Information:

46mo old, Female, height-40" and Weight-33 lbs

Seating Position: Second right

Restrain Status: Lap and shoulder belt

Child Seat Type: Booster seat

Was Occupant Injured due to Intrusion? Yes

Components:

- (1) C-pillar
(2) Door panel (side)

Other Occupant (s) in Case Vehicle:

DRIVER: 21yr old, Female , MAIS 1

Restrain Status: Lap and shoulder belt

Front right: 21yr old, Female, MAIS 1

Restrain Status: Lap and shoulder belt

Case Occupant Associated Injuries:

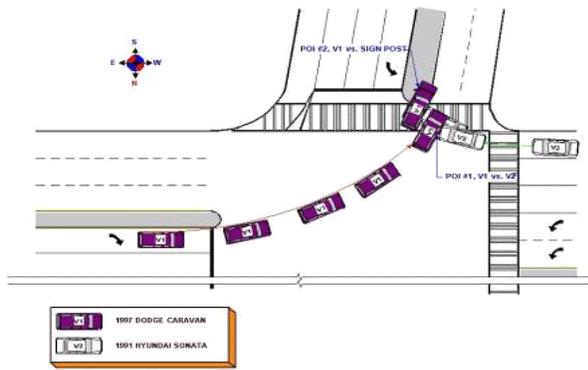
Table with 3 columns: Body Region, Injury Source, Injuries. Rows describe facial injuries from the right side interior surface.

Case Number: 376028346

Vehicle Exterior:



Scene Diagram:



The collision between the two vehicles occurred when the driver of Vehicle 1 attempted to make a left turn at the intersection and Vehicle 2 was traveling through the intersection. Vehicle 2 struck Vehicle 1's right side plane with its front end (angle configuration). After the impact, Vehicle 1 was pushed sideways with the left side leading and contacted a sign post with the left side of the vehicle. Vehicle 1 came to a final rest position, facing southwest in the median of the south leg of the intersection. Vehicle 2 came to a final rest position, up against the right side of Vehicle 1, facing southeast. Vehicles 1 and 2 were towed from the collision scene due to the damage sustained in this collision.

Case Occupant Associated Injuries:

Body Region	Injury Source
Spine	Other non contact injury source

Far-Side Occupant

Case Vehicle Information:

V1: Dodge-Caravan, Minivan-1997

DOF: 3 O'clock

Delta-V: Total: 35 Km/h (22 Mph)

Lateral: 35 Km/h (22 Mph)

Longitudinal: : 6 Km/h (4 Mph)

Location of Impact: Right Side

Maximum Intrusion: >=30 to <46 cm, Front Right

Max. Intrusion Corresponding Component (s):

- (1) B-pillar

Vehicle 2 Information:

V2: Hyundai-Sonata, 4-door sedan, hardtop-1991

Case Occupant Information:

29mo old, Male, height-U" and Weight-37 lbs

Seating Position: Third left

Restrain Status: Lap and shoulder belt

Child Seat Type: Convertible seat

Was Occupant Injured due to Intrusion? No

Other Occupant (s) in Case Vehicle:

DRIVER: 27yr old, Male, MAIS 1,

Restrain Status: Lap and shoulder belt

Second left: 5yr old, Female, MAIS 1

Restrain Status: Lap and shoulder belt

Second right: 6yr old, Female, MAIS 1

Restrain Status: Lap and shoulder belt

Injuries

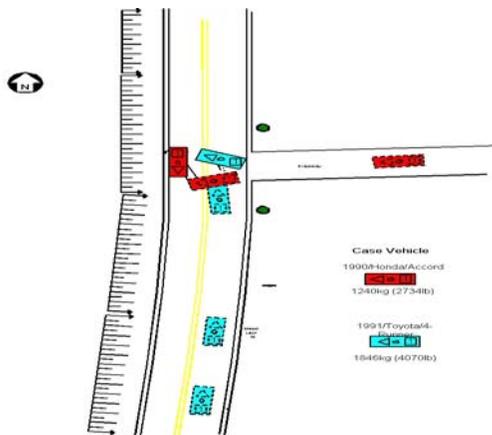
(AIS 2): Cervical Spine Brachial plexus

Case Number: 377037327

Vehicle Exterior:



Scene Diagram:



Vehicle #1 (Case vehicle, 1990 Honda Accord 4 door) was traveling westbound on a negative 1 percent driveway intending to travel southbound. Vehicle #2 (1991 Toyota 4-Runner Utility) was traveling northbound on a two lane positive 6 percent grade (slightly curved to the left) roadway with a posted speed limit of 40mph. As V1 entered the roadway, it intended to make a left turn to travel southbound when it was impacted on the left side by the front of V2. V1 and V2 both traveled in a north-west direction before traveling to final rest. The roadway was dry and it was sunny and clear at the time of the crash.

Case Occupant Associated Injuries:

Body Region	Injury Source	Injuries
Face	Seat, back support	(AIS 2): Maxilla fracture closed
Face	Seat, back support	(AIS 2): Facial Skin laceration major
Face	Seat, back support	(AIS 1): Nose fracture closed
Face	Seat, back support	(AIS 1): Eyelid contusion

Far-Side Occupant

Case Vehicle Information:

V1: Honda-Accord, 4-door sedan, hardtop-1990

DOF: 9 O'clock

Delta-V: Total: 42 Km/h (26 Mph)

Lateral: 41 Km/h (25 Mph)

Longitudinal: 7 Km/h (4 Mph)

Location of Impact: Left Side

Maximum Intrusion: >=30 to <46 cm, Front Left

Max. Intrusion Corresponding Component (s):

- (1) Side panel - forward

Vehicle 2 Information:

V2: Toyota-4-Runner, Compact utility-1991

Case Occupant Information:

24mo old, Female, height-36" and Weight-37 lbs

Seating Position: Second right

Restrain Status: Lap and shoulder belt

Child Seat Type: Unknown child safety seat type

Was Occupant Injured due to Intrusion? No

Other Occupant (s) in Case Vehicle:

DRIVER: 35yr old, Female, MAIS 2

Restrain Status: Lap and shoulder belt

Front right: 28yr old, Female, Not Injured

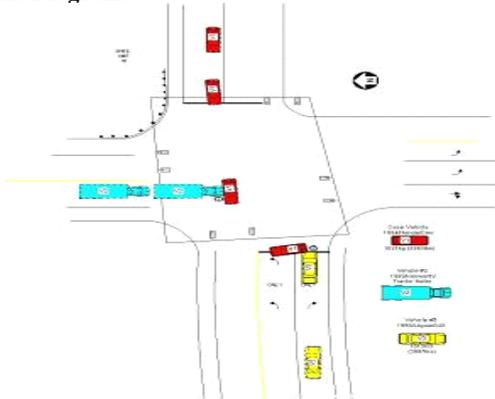
Restrain Status: Lap and shoulder belt

Case Number: 377039617

Vehicle Exterior:



Scene Diagram:



This crash occurred in the afternoon hours. The roadway was dry with adverse weather conditions. This crash occurred at a four legged intersection properly controlled by overhead traffic control standards. The case vehicle was initially traveling westbound in the outer travel lane on a three lane- roadway. The non-case vehicle, a 1999 Kenworth Tractor-trailer, was traveling southbound in the inner travel lane. Both vehicles entered a four-legged intersection resulting in an angle collision between the case and non-case vehicles. The initial impact caused Vehicle #1 to rotate clockwise resulting in an impact (second event) with a stopped 1998 Jaguar XJ8.

Case Occupant Associated Injuries:

Body Region	Injury Source	Injuries
Face	Flying glass	(AIS 1): Facial Skin laceration minor
Head	Right side interior surface	(AIS 3): Cerebrum subarachnoid hemorrhage
Head	Right side interior surface	(AIS 1): Scalp laceration minor

Near-Side Occupant

Case Vehicle Information:

V1: Honda-Civic/CRX/Del Sol, 4-door sedan, hard-top-1994

DOF: 3 O'clock

Delta-V: Total: U Km/h

Lateral: U Km/h Longitudinal: U Km/h

Location of Impact: Right Side

Maximum Intrusion: >=15 to <30 cm, Front Right

Max. Intrusion Corresponding Component (s):

- (1) Door panel (side)

Vehicle 2 Information:

V2: Kenworth-Median/Heavy Truck, 1999

Case Occupant Information:

31 mo old, Female, height-37" and Weight-37 lbs

Seating Position: Second right

Restrain Status: Lap and shoulder belt

Child Seat Type: CSS

Was Occupant Injured due to Intrusion? Yes

Components:

- (1) C-pillar
- (2) Door panel (side)
- (3) Window frame

Other Occupant (s) in Case Vehicle:

DRIVER: 38yr old, Female, Not Injured

Restrain Status: Lap and shoulder belt

Case Number: 426032502

Near-Side Occupant

Case Vehicle Information:

Vehicle Exterior:



V1: Acura-Legend, 4-door sedan, hardtop-1994

DOF: 9 O'clock

Delta-V: Total: U Km/h

Lateral: U Km/h Longitudinal: U Km/h

Location of Impact: Left Side

Maximum Intrusion: >=46 to <61 cm, Second Left

Max. Intrusion Corresponding Component (s):

(1) Door panel (side)

Vehicle 2 Information:

International H-Med/Heavy Truck, 1993

Case Occupant Information:

24mo old, Male, height-35" and Weight-20 lbs

Seating Position: Second left

Restrain Status: Lap and shoulder belt

Child Seat Type: Convertible seat

Was Occupant Injured due to Intrusion? Yes

Components: (1) Door panel (side)

Other Occupant (s) in Case Vehicle:

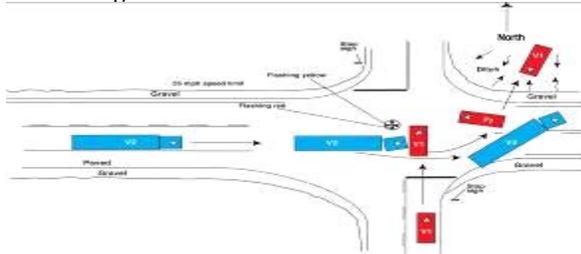
DRIVER: 35yr old, Female, MAIS unknown

Restrain Status: Lap and shoulder belt

Second right: 4yr old, Male, MAIS 1

Restrain Status: Lap and shoulder belt w/CRS

Scene Diagram:



V1 (case vehicle), a 1994 Acura Legend, 4-door sedan was traveling north in the northbound lane of a two-lane, two-way bituminous roadway and was approaching a four-leg intersection. V2, a 1993 International tractor-trailer (one trailer) was traveling east in the eastbound lane of the intersecting, two-lane, two-way bituminous roadway. It was daylight, clear weather, and the roadways were dry and free of defects. V1 came to a stop at the four-leg intersection. For an unknown reason, the driver of V1 pulled into the intersection with the intention of moving straight across the intersection and was struck on the left-side by the front of V2. V1 moved laterally and rotated counter-clockwise and exited the northeast corner of the intersection. V1 came to rest off the roadway facing southwest.

Case Occupant Associated Injuries:

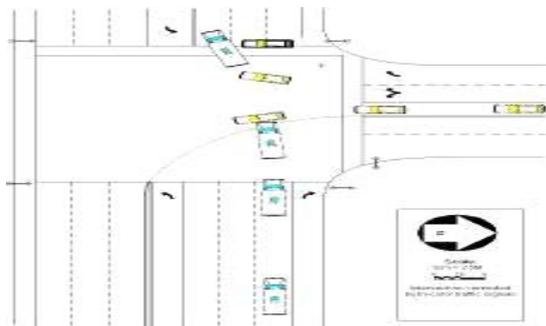
Body Region	Injury Source	Injuries
Abdomen	Left side interior surface	(AIS 2): Spleen laceration minor
Face	Left side interior surface	(AIS 1): Gingiva (gum) contusion
Head	Left side hardware or armrest	(AIS 4): Cerebellum hematoma/hemorrhage
Head	Left side interior surface	(AIS 4): Cerebrum hematoma/hemorrhage
Head	Left side hardware or armrest	(AIS 1): Scalp abrasion
Head	Left side hardware or armrest	(AIS 1): Scalp contusion/subgaleal hematoma
Head	Left side hardware or armrest	(AIS 1): Scalp laceration minor
Thorax	Left side interior surface	(AIS 3): Lung contusion unilateral
Upper Extremities	Left side interior surface	(AIS 1): Upper Extremity Skin abrasion

Case Number: : 470047788

Vehicle Exterior:



Scene Diagram:



This crash occurred at the three leg intersection of two urban roadways. The east/west roadway consists of seven, undivided, lanes of travel. The north/south roadway consists of five, undivided, lanes and connects to the north side of the larger east/west street. The incident occurred during daylight hours under clear, dry conditions. The case vehicle (V1) was traveling southbound approaching the intersection in the left turn lane intending to turn left. The opposing vehicle (V2) was traveling westbound in the number one lane. As V1 maneuvered into the intersection it was struck on its left side by the front of V2. V1 was pushed directly right to its final rest while V2 skidded straight to its final rest.

Case Occupant Associated Injuries:

Body Region	Injury Source	Injuries
Face	Left side window sill	(AIS 2): Facial Skin laceration major
Face	Left side window sill	(AIS 1): Facial Skin laceration minor
Head	Left side window sill	(AIS 2): Cerebral Concussion
Head	Left side window sill	(AIS 1): Scalp laceration minor
Lower Extremities	Seat, back support	(AIS 1): Lower Extremity Skin contusion
Upper Extremities	Seat, back support	(AIS 1): Upper Extremity Skin abrasion

Center Occupant

Case Vehicle Information:

V1: Ford-Contour, 4-door sedan, hardtop-1998

DOF: Unknown

Delta-V: Total: U Km/h

Lateral: U Km/h Longitudinal: U Km/h

Location of Impact: Left Side

Maximum Intrusion: >=30 to <46 cm, Front Left

Max. Intrusion Corresponding Component (s):

(1) B-pillar (2) Roof side rail

Vehicle 2 Information:

International H-Med/Heavy Truck, 1985

Case Occupant Information:

33mo old, Female, height-38" and Weight-33 lbs

Seating Position: Second middle

Restrain Status: Lap and shoulder belt

Child Seat Type: Convertible seat

Was Occupant Injured due to Intrusion? Yes

Other Occupant (s) in Case Vehicle:

DRIVER: 47yr old, Male, MAIS 5

Restrain Status: Lap and shoulder belt

Second right: 37yr old, Female, MAIS 2

Restrain Status: Lap and shoulder belt

Case Number: 690040270

Near-Side Occupant

Case Vehicle Information:

Vehicle Exterior:



V1: Toyota-Corolla, 4-door sedan, hardtop-1994

DOF: 3 O'clock

Delta-V: Total: 48 Km/h (30 Mph)

Lateral: 47 Km/h (29 Mph)

Longitudinal: 8 Km/h (5 Mph)

Location of Impact: Right Side

Maximum Intrusion:

(1) >=30 to <46 cm, Front Right

(2) >=30 to <46 cm, Second Right

Max. Intrusion Corresponding Component (s):

(1)Door panel (side) (2)Door panel (side)

Vehicle 2 Information:

V2: Ford-Ranger, Compact pickup-1988

Case Occupant Information:

46mo old, Male, height-44" and Weight-35 lbs

Seating Position: Second right

Restrain Status: Lap and shoulder belt

Child Seat Type: CSS

Was Occupant Injured due to Intrusion? Yes

Other Occupant (s) in Case Vehicle:

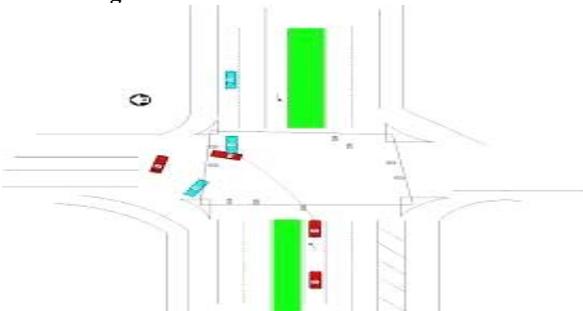
DRIVER: 82yr old, Female, MAIS 1

Restrain Status: Lap and shoulder belt

Second left: 3yr old, Male, MAIS 2

Restrain Status: Lap and shoulder belt w/CRS

Scene Diagram:



This crash occurred in the afternoon hours. The roadway was wet with adverse weather conditions. This crash occurred at a four legged intersection properly controlled by overhead traffic control standards. The case vehicle was initially traveling eastbound in the left hand turning lane (lane 3) on a six lane-divided roadway. The non-case vehicle was traveling westbound in the outer curb lane. The case vehicle attempted a left hand turn and was struck by the non-case vehicle within the intersection.

Case Occupant Associated Injuries:

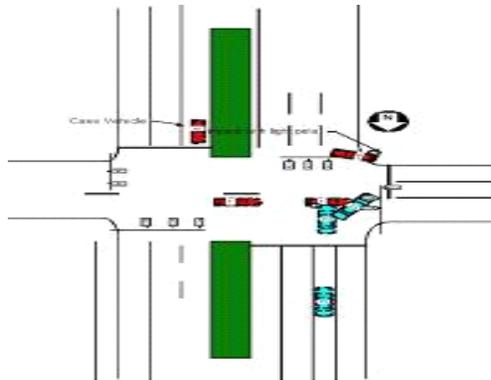
Body Region	Injury Source	Injuries
Abdomen	Child safety seat	(AIS 2): Liver laceration minor
Abdomen	Child safety seat	(AIS 2): Kidney contusion minor
Abdomen	Child safety seat	(AIS 1): Adrenal gland contusion minor
Face	Right side window sill	(AIS 1): Facial Skin laceration minor
Head	Right side window sill	(AIS 2): Scalp laceration major
Lower Extremities	Right side interior surface	(AIS 1): Lower Extremity Skin contusion
Thorax	Child safety seat	(AIS 3): Lung contusion unilateral

Case Number: 874034767

Vehicle Exterior:



Scene Diagram:



Vehicle #1 (case vehicle, 1997 BMW 318i) was initially traveling northbound and attempted a left turn at a four legged intersection. Vehicle #2 (non-case Vehicle, 1997 Cadillac Seville) was initially traveling southbound in the opposite direction of the case vehicle. Vehicle #1 entered the intersection and was struck on the passenger side by the front of the non-case vehicle. After impact Vehicle #1 rotated clockwise and traveled to final rest after impacting a light standard. It should be noted that the roadway was dark with no street lights and the surface was dry and the weather was clear at the time of the crash.

Case Occupant Associated Injuries:

Body Region	Injury Source	Injuries
Face	Right side interior surface	(AIS 1): Facial Skin laceration minor
Face	Right side interior surface	(AIS 1): Gingiva (gum) laceration
Head	Right side interior surface	(AIS 1): Scalp contusion/subgaleal hematoma
Lower Extremities	Child safety seat	(AIS 2): Pelvis fracture closed
Thorax	Right side interior surface	(AIS 4): Lung contusion bilateral

Near-Side Occupant

Case Vehicle Information:

V1: BMW-3Series, 4-door sedan, hardtop-1997

DOF: Unknown

Delta-V: Total: 80 Km/h (50 Mph)

Lateral: 79 Km/h (49 Mph)

Longitudinal: 14 Km/h (9 Mph)

Location of Impact: Right Side

Maximum Intrusion: >=61 cm, Second Right

Max. Intrusion Corresponding Component (s):

(1) Door panel (side)

Vehicle 2 Information:

V2: Cadillac-Seville, 2-door sedan, hardtop, coupe-1997

Case Occupant Information:

40mo old, Male, height-38" and Weight-35 lbs

Seating Position: Second right

Restrain Status: Lap and shoulder belt

Child Seat Type: Booster seat

Was occupant Injured due to Intrusion? Yes

Components:

(1) Door panel (side)

Other Occupant (s) in Case Vehicle:

DRIVER: Female, MAIS unknown

Restrain Status: Lap and shoulder belt

7yr old, Male, MAIS unknown

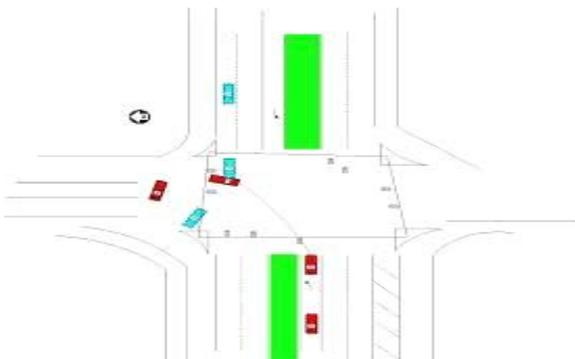
Restrain Status: Unknown

Case Number: 874037095

Vehicle Exterior:



Scene Diagram:



This crash occurred in the afternoon hours. The roadway was wet with adverse weather conditions. This crash occurred at a four legged intersection properly controlled by overhead traffic control standards. The case vehicle was initially traveling eastbound in the left hand turning lane (lane 3) on a six lane-divided roadway. The non-case vehicle was traveling westbound in the outer curb lane. The case vehicle attempted a left hand turn and was struck by the non-case vehicle within the intersection.

Far-Side Occupant

Case Vehicle Information:

V1: Toyota-Corolla, 4-door sedan, hardtop-1994

DOF: 3 O'clock

Delta-V: Total: 48 Km/h (30 Mph)

Lateral: 47 Km/h (29 Mph)

Longitudinal: 8 Km/h (5 Mph)

Location of Impact: Right Side

Maximum Intrusion:

(1) >=30 to <46 cm, Front Right

(2) >=30 to <46 cm, Second Right

Max. Intrusion Corresponding Component (s):

(1)Door panel (side) (2)Door panel (side)

Vehicle 2 Information:

V2: Ford-Ranger, Compact pickup-1988

Case Occupant Information:

28mo old, Female, height-U" and Weight-33 lbs

Seating Position: Second left

Restrain Status: Lap and shoulder belt

Child Seat Type: CSS

Was Occupant Injured due to Intrusion? No

Other Occupant (s) in Case Vehicle:

DRIVER: 82yr old, Female, MAIS 1

Restrain Status: Lap and shoulder belt

Second right: 3yr old, Male, MAIS 3

Restrain Status: Lap and shoulder belt w/CRS

Case Occupant Associated Injuries:

Body Region	Injury Source	Injuries
Upper Extremities	Other restraint system component	(AIS 2): Ulna fracture closed
Upper Extremities	Other restraint system component	(AIS 1): Upper Extremity Skin laceration minor