INJURY RISKS FOR CHILDREN IN CHILD RESTRAINT SYSTEMS IN SIDE IMPACT CRASHES

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ABSTRACT

Current efforts to enhance child restraint safety performance focus on protection afforded by child restraints in side impact crashes. Analyses of real world crashes can be used to identify relevant crash characteristics for incorporation into the design of test procedures. To this end, this paper assessed the injury risks for children restrained in CRS in side impact crashes as compared with frontal impacts and described the nature of their injuries using a large US population-based surveillance system. Injury risk for children on the struck side of the crash was significantly higher (8.9 injured children per 1000 crashes) than for children seated on the non-struck side of the crash (2.1 injured children per 1000 crashes) and children in frontal crashes (2.7 injured children per 1000 crashes). The most common injuries sustained in struck side impact crashes were to the face, head, and lower extremity. The ability to assess the injury potential for these body regions in a laboratory setting must be explored. The high risk of injury to those in struck side crashes suggests that regulatory and due care efforts should be placed on lowering the injury risk in this crash scenario.

Key words: child restraint systems, side impacts, regulations, epidemiology

THE PROTECTION OF CHILDREN in child restraint systems (CRS) in side impact crashes has received considerable attention recently as these crashes represent a significant burden on society. European data states that although side impact crashes are only 25% of all crashes, they represent over 40% of all injury costs associated with motor vehicle crashes. [Johannsen, Schoeneich et al., 2003] Analyses of the Fatal Analysis Reporting System of the United States (US) corroborate this finding: 42% of the fatalities of rear seat child occupants age 0-8 were in side impact crashes. [National Highway Traffic Safety Administration, 2003a]

To date, dynamic evaluation programs of CRS in side impacts have been limited to European and Australian initiatives. The EuroNCAP (European New Car Assessment Program) conducts tests in which a vehicle is impacted by a moving deformable barrier at 90°. An 18-month-old or 3-year-old anthropomorphic test device (ATD) seated in a CRS in the rear seat is evaluated and rated for head containment and head acceleration. [EuroNCAP, 2004] Australian efforts in New South Wales have focused on a sled test evaluation protocol in which the ATD is evaluated in a tethered CRS in a 20 mph 90° test configuration. Head excursion relative to a fixed door structure determines a particular CRS's ranking. [National Highway Traffic Safety Administration, 2003a; Paine, Griffiths et al., 2003] Neither of these programs is integrated into regulation.

These efforts have led to substantial emphasis in Europe and the US on understanding the need for and defining characteristics of an effective regulatory test procedure for CRS in side impact crashes. In Europe, research and development led by the International Organization for Standardization (ISO) TC 22/SC 12/WG 1 and supported by efforts by the Transport Research Lab (TRL) in the United Kingdom and the Technical University of Berlin (TUB) resulted in a proposed CRS test procedure characterized by a lateral sled test with a simulated intruding door. [Johannsen, et al., 2003; National Highway Traffic Safety Administration, 2003a]

In the US, the Transportation Recall and Accountability Act (TREAD) issued in 2000 called on the National Highway Traffic Safety Administration (NHTSA) to "simulate an array of accident conditions, such as side impact crashes…" as part of a more comprehensive program for evaluating the protection of children in CRS. [Fitzgerald, 2001] In response to the TREAD, NHTSA issued an Advanced Notice for Proposed Rulemaking (ANPRM) in June 2002, maintaining that substantial questions regarding the protection of children in CRS in side impact crashes remain and that a regulation at this time would be premature. These questions include: what are the injury mechanisms in side impact crashes; what crash characteristics lead to serious injury; what should be the characteristics of a regulatory procedure; and what ATD (and associated injury criteria) should be used in this procedure? [National Highway Traffic Safety Administration, 2003a] In June 2003, they rescinded the ANPRM stating that existing analyses failed to provide enough data to answer these questions. [National Highway Traffic Safety Administration, 2003b] In response to this need, this paper utilizes a large child-focused crash surveillance system to define the problem associated with CRS in side impact crashes. Specifically, the objectives of this work were to determine the injury risk for children restrained in CRS in side impact crashes as compared with those in frontal crashes and to delineate the nature of the injuries sustained in side impact crash scenarios.

METHODS

STUDY POPULATION AND DATA COLLECTION: Data for the current study were drawn from the Partners for Child Passenger Safety (PCPS) program, collected from December 1, 1998 to November 30, 2002. A description of the study methods has been published previously [Durbin, Bhatia et al., 2001]. PCPS consists of a large scale, child-specific crash surveillance system: insurance claims from State Farm Insurance Co. (Bloomington, IL) function as the source of subjects, with telephone survey and on-site crash investigations serving as the primary sources of data.

Vehicles qualifying for inclusion were State Farm™-insured, model year 1990 or newer, and involved in a crash with at least one child occupant ≤15 years of age. Qualifying crashes were limited to those that occurred in fifteen states and the District of Columbia, representing three large regions of the United States (East: NY, NJ, PA, DE, MD, VA, WV, NC, DC; Midwest: OH, MI, IN, IL; West: CA, NV, AZ). After policyholders consented to participate in the study, limited data were transferred electronically to researchers at The Children's Hospital of Philadelphia and University of Pennsylvania. Data in this initial transfer included contact information for the insured, the ages and genders of all child occupants, and a coded variable describing the level of medical treatment received by all child occupants (no treatment, physician's office or emergency department only, admitted to the hospital, or death).

A stratified cluster sample was designed in order to select vehicles (the unit of sampling) for the conduct of a telephone survey with the driver. In the first stage of sampling, vehicles were stratified on the basis of whether they were towed from the scene or not, and a probability sample of both towed and non-towed vehicles was selected at random, with a higher probability of selection for towed vehicles. In the second stage of sampling, vehicles were stratified on the basis of the level of medical treatment received by the child occupant(s). A probability sample from each tow status/ medical treatment stratum was selected at random with a higher probability of selection for vehicles in which a child occupant died, was admitted to the hospital, or evaluated in a physician's office or emergency department. In this way, the majority of injured children would be selected while maintaining the representativeness of the overall population. If a vehicle were sampled, the "cluster" of all child occupants in that vehicle were included in the survey.

Drivers of sampled vehicles were contacted by phone and screened via an abbreviated survey to verify the presence of at least one child occupant with an injury. Surveys were conducted only in English. All vehicles with at least one child who screened positive for injury and a 10% random sample of vehicles in which all child occupants screened negative for injury were selected for a full interview. The full interview involved a 30-minute telephone survey with the driver of the vehicle and parent(s) of the involved children. Only adult drivers and parents were interviewed. The median length of time between the date of the crash and the completion of the interview was six days.

The eligible population in the overall PCPS project consisted of all 430,308 children riding in 288,187 State-Farm™-insured vehicles newer than 1990 reporting a crash claim between December 1, 1998 and November 30, 2002. Claim representatives correctly identified 95% of eligible vehicles, and 73% of policyholders consented for participation in this study. Of these, 18% were sampled for interview and an estimated 81% of these were successfully interviewed. The mean age of the child in the sample was 7.0 years, compared with 7.2 years in the population.

For a subset of cases in which child occupants were admitted to the hospital or killed, in-depth crash investigations were performed. Cases were screened via telephone to confirm the details of the crash. Contact information from selected cases was then forwarded to a crash investigation firm (Dynamic Science, Incorporated, Annapolis, MD), and a full-scale on-site crash investigation was conducted using custom child-specific data collection forms.

Among 170 children for whom paired information on seating position (front versus rear) was available from both the telephone survey and crash investigations, agreement was 99% between the driver report and the crash investigator (kappa=0.99, $p<0.0001$). Among 164 children for whom paired information on restraint use was available from both the telephone survey and crash investigations, agreement was 89% between the driver report and the crash investigator (kappa=0.74, $p<0.0001$).

Separate verbal consent was obtained from eligible participants for the transfer of claim information from State Farm to CHOP/Penn, for the conduct of the telephone survey, and for the conduct of the crash investigation. The study protocol was reviewed and approved by the Institutional Review Boards of both The Children's Hospital of Philadelphia and The University of Pennsylvania School of Medicine.

VARIABLE DEFINITIONS: Seating location and restraint use of each child were determined from a series of questions in the telephone survey. Forward-facing child restraint systems (FFCRS) included forward-facing convertible seats with harnesses and combination child restraint/boosters, designed as a forward facing child safety seats when used with the harness. The harness types include t-shield, tray shield, five- point, and three- point harness. Most forward-facing convertible seats and combination child restraint/booster seats with harness are recommended to accommodate a child weighing between 9.1 kg (20 lb) and 18.1 kg (40 lb). For this study, parent responses to a series of validated survey questions determined the restraint type used, the child's seating position, and the child's weight.

Several recent child safety seat models are designed to be used by children up to 27.2 kg (60 lb) [American Academy of Pediatrics, 2003; National Highway Traffic Safety Administration, 2003c]. However, few of them were included in our study period. In order to account for the weight limit of the new CRS and parents' tendency of rounding their child's weight, child's weight of 50 lbs or under was the inclusion criteria for the study sample.

Direction of first impact was derived from a series of questions regarding the vehicle parts that were involved in the first collision. Side impact crashes were defined as crashes in which the vehicle parts involved in the first collision were on the right or left plane of the vehicle. Struck side crashes were those crashes in which the child was on the struck side of the vehicle; non-struck side crashes were those in which the child was on the non-struck side of the vehicle (including the center seating position). Crash severity was determined by driver report of intrusion into the occupant compartment of the vehicle via the telephone survey. The presence of intrusion was reported as intrusion anywhere in the vehicle not just in the case occupants' seating location. Tow-away status of the vehicle was reported in the insurance claim file.

Survey questions regarding injuries to children were designed to provide responses that were classified by body region and severity based on the Abbreviated Injury Scale (AIS) score. [AAAM, 1990] The ability of parents to accurately distinguish AIS 2 or greater injuries from those less severe has been previously validated for all body regions of injury. [Durbin, Winston et al., 1999] Children were classified as injured if they had an injury likely to require medical attention: any injury with an AIS score of 2 or greater (brain injuries, all internal organ injuries, spinal cord injuries, and extremity fractures) or facial lacerations. Concussions, although AIS 2 injuries, were excluded as they are difficult to diagnose in a pre-verbal population.

STUDY SAMPLE: The study sample for these analyses included children who weighed ≤ 22.7 kg (50 lbs) and were restrained in a FFCRS. All booster seats when used without harnesses (high back, low back, and shield boosters) were excluded from the analyses. All children in FFCRS in side impact crashes were grouped together as the primary group of interest (target group) (459 children weighted to represent 7457 children) while those children in FFCRS in frontal impact crashes were considered the comparison group (1408 children weighted to represent 24,592 children). The target group was further divided into those seated on the struck-side (177 children weighted to represent 2648 children) and those on the non-struck side (282 children weighted to represent 4809 children).

DATA ANALYSIS: Because sampling was based on the likelihood of an injury, subjects least likely to be injured were underrepresented in the study sample in a manner potentially associated with the predictors of interest. The SAS-callable SUDAAN®: Software for the Statistical Analysis of Correlated Data, Version 8.0 (Research Triangle Institute, Research Triangle Park, NC, 2001) was used for the weighted analyses to account for the stratification of subjects by medical treatment, clustering of subjects by vehicle, and the disproportional probability of selection. The Pearson chi-square test was performed to assess differences in the distribution of categorical variables between frontal crashes and side impact crashes. The student's t test was carried out to determine whether the means of the continuous variables differed between frontal crashes and side impact crashes. Injury risks (overall and by body region) by impact direction (i.e. frontal, side, struck side, non-struck side) were then calculated. The statistical difference of injury risk between any two impact directions (i.e. frontal vs. side, frontal vs. struck side, frontal vs. non-struck side, struck side vs. non-struck side) were assessed by Pearson Chi-square test. Furthermore, the association between injury and various characteristics for children in side impact crashes was examined by Pearson Chi-square test. The last analyses were restricted to injured children in FFCRS in side impact. Due to the small sample size, the descriptive analyses only present the frequency counts for most characteristics.

RESULTS

The distribution of child, FFCRS, vehicle, driver and crash characteristics by crash direction is described in Table 1. In this table, side impact crashes include both struck-side and non-struck side crashes. All variables, except intrusion as expected, demonstrated similar distributions among the crash directions. Differences in gender and age although statistically significant were not clinically meaningful.

Table 2 shows the injury risk (overall and by body region) by impact direction (frontal, side , struck side, and non-struck side). Although children in side impact crashes were at elevated risk of injury (4.5 injured children per 1000 crashes) compared to those in frontal impacts (2.7 injured children per 1000 crashes), this difference was not statistically significant. Injury risk in struck side crashes (8.9 injured children per 1000 crashes) was significantly higher than non-struck side crashes (2.1 injured children per 1000 crashes, $p=0.02$) and frontal crashes (2.7 injured children per 1000 crashes, $p=0.04$). The most common injuries sustained in side impact crashes were to the face, lower and upper extremity and the head. There appeared to be a trend towards increased risk of facial injury among impact directions (i.e. the lowest risk in frontal impact, then non-struck side impact, and the highest in struck side impact). The increased risk of facial injuries in side impact crashes as compared with frontal impact crashes appeared to be explained solely by struck-side impacts.

Table 3 shows the associations between injury and crash, vehicle and passenger characteristics in side impact crashes. The bivariate analyses showed that tow-away status ($p<0.001$), crash severity ($p<0.001$), vehicle type ($p=0.13$, achieving marginally statistical significance), and vehicle model year ($p=0.07$, achieving marginally statistical significance) were statistically associated with injury. There was an increased injury risk in towaway (10.0 vs. 0.0 injured children per 1000 crashes) and intrusion crashes (11.9 vs. 3.4 injured children per 1000 crashes) compared to crashes of lower severity. All injured children in FFCRS in side impact crashes were in towaway crashes. Children in minivans had lower injury risks when compared to those in other vehicle types. Children riding in older vehicles had higher injury risks than those in newer vehicles. Of interest, the absence of an adjacent passenger (either between the case occupant and the side of impact or outboard to the case occupant relative to the side of impact) appears to contribute to an elevated risk of injury (5.1 vs. 0.9 injured children per 1000 crashes).

Characteristics of the injured children in side impact crashes are compiled in Table 4. All harness types and vehicle types were represented. It is noted that of the 19 injured children who were in vehicle-to-vehicle crashes, 8 were in crashes with a vehicle of elevated mass (either an SUV or a truck/bus).

DISCUSSION

These data provide real world support for the development of an appropriate test procedure for assessing side impact protection for children in FFCRS. The analyses demonstrated that while children in FFCRS do well in crashes in all impact directions, children restrained in FFCRS in struck side crashes are at a markedly elevated risk of injury when compared to children in frontal or non-struck side crashes. The high risk of injury to children in struck side crashes, similar to adults, suggests that regulatory and due care efforts should be placed on lowering the injury risk in this crash scenario.

Review of the nature of the injuries revealed that the most common body regions of injury in side impact crashes were the head, face, upper and lower extremities. The absence of chest injuries, a common injury sustained by adults in side impact crashes, and neck/back/spine injuries is of interest. Work by Langweider and colleagues [Langweider and Hummel, 1989; Langweider, Hell et al., 1996] utilizing German crash data identified the importance of head injuries in restrained children in side impact crashes – these injuries represented approximately 60% of the total injuries and 4/10 of the AIS2+ injuries. Injuries to the face were not examined separately in the German study. Further, by combining injuries to the shoulder and the arms, the upper extremity represented the second most common body region of injury in Langweider's study with primarily AIS 1 neck injuries third most common. Similar to our study, chest injuries were rare in the German study. A similar distribution of body region of injury was seen in a review of US Fatal Analysis Reporting System (FARS) crashes in which children restrained in CRS sustained fatal injury [Sherwood, Crandall et al., 2003].

Lower extremity injuries were more notable among children seated on the struck-side of side impact crashes. We have identified this common injury pattern in children in FFCRS in crashes of all severity and directions. [Arbogast, Cornejo et al., 2002] Injury to the lower extremity, however, is not a focus for any US regulation for child occupant protection. Further research should be directed to understanding these injury mechanisms as injury to this body region, although not often a threat to life, can have profound long-term implications for the child and their family if the injury adversely affects development and growth. Studies that build upon research conducted on lower extremity protection for the adult ATD's may be necessary.

The occurrence of upper extremity injuries coupled with the lack of injuries to the chest suggest importance should be placed on ensuring adequate biofidelity of the upper extremity- thoracic junction in the pediatric ATD's used to assess injury potential in side impact crashes. In the Hybrid III ATD's there is a direct connection between the spine and the shoulder. Loading the shoulder often results in high spinal accelerations. [Bolte, Hines et al., 2003] This is particularly important in perpendicular test procedures because the shoulder is stiff when loaded in this direction. If the load is applied in an oblique manner, the clavicle moves out of the way and the load is directed to the thoracic cage [Bolte, et al., 2003]. If this junction is not adequately biofidelic, test procedures may result in artificially high lumbar spine or chest loads that are not representative of real-world injury mechanisms and countermeasures might be directed inappropriately.

Examination of risk factors for injury highlights the extreme importance of intrusion as a causal factor for injury. 20/28 (71%) of the children who sustained an AIS2+ injury were in crashes with intrusion into the occupant compartment. Survey data of this nature cannot identify the location of the intrusion relative to the child occupant – this level of specificity can only be obtained through review of in-depth investigations. This supports efforts by others that claim that an appropriate test procedure MUST replicate an intrusion scenario [Paton, Roy et al., 1998; Steffens, 2002]. A recent analysis by the Insurance Institute for Highway Safety which examined 92 crashes of children in child restraints (of all impact directions) included 7 side impact crashes with AIS3+ injuries: 6/7 crashes had substantial intrusion [Sherwood, et al., 2003], further supporting the need to delineate the intrusion scenarios that need to be replicated in dynamic test protocols. The role of intrusion is not an exclusive pediatric phenomenon; intrusion has been implicated in injury mechanisms for adults in side impact crashes [National Highway Traffic Safety Administration, 2003a].

Analyses examining the crash partners for the children injured in vehicle-to-vehicle crashes identified that 8/19 were in crashes with a vehicle of elevated mass (either an SUV or a truck/bus). This percentage is higher than what one would expect given the percentage of these vehicles within the fleet. In these crashes injuries were to the face (n=5), upper extremity (n=2), head (n=1), and lower extremity (n=1). Efforts to account for this type of loading in countermeasure development have been led by the Insurance Institute for Highway Safety's development of a raised, contoured side impact barrier and Transport Canada's extensive set of vehicle to vehicle side impact crashes with a mid-size SUV as the bullet vehicle [Arbelaez, Dakin et al., 2002]. Our results suggest protection of children in CRS in this mode of loading is of importance and worth further study.

LIMITATIONS

This research is conducted on crashes involving State Farm Insurance Co. policyholders only. State Farm is the largest insurer of automobiles in the United States, with over 38 million vehicles covered; therefore, its policyholders are likely representative of the insured public in this country. The surveillance system is limited to children occupying model year 1990 and newer vehicles insured in 15 states and the District of Columbia. Our study sample represents the entire spectrum of crashes reported to an insurance company including property damage only, as well as bodily injury crashes. While our sample included a significant number of vehicles with intrusion into the occupant compartment, it is possible that we do not have a representative sample of the most severe crashes

Nearly all of the data for this study were obtained via telephone interview with the driver/ parent of the child and is, therefore, subject to potential misclassification. On-going comparison of driver-reported child restraint use and seating position to evidence from crash investigations has demonstrated a high degree of agreement. In addition, our results on age-specific restraint use and seating position are similar to those of other recently reported population-based studies of child occupants. [Edwards and Sullivan, 1997; Wittenberg, Nelson et al., 1999] Therefore, it is unlikely that errors in reporting restraint use or seating position would substantially alter the results of this study.

Data on the injuries sustained have been obtained via a validated telephone survey – more specific details from medical records may provide insight regarding the mechanisms of injury. Thus, it is important to note, however that these comparisons only look at injury risk and do not assume similar mechanisms of injury. For example, although the injury risk in frontal crashes and non-struck side crashes are similar, the mechanisms and patterns of injuries sustained in those impact directions may be different. Further the injury risks presented are for AIS2+ injury. These surveillance data cannot detect if those in frontal crashes are sustaining primarily AIS3-4 injuries while those in non-struck side crashes are experiencing only AIS2 injuries. These differences will be explored in further work utilizing in-depth field investigations. Side impact crashes as defined in the PCPS surveillance system include those crashes in which the point of first contact is on the lateral plane of the vehicle. Understanding the role of impact angle and specific horizontal location of impact are obtained through review of the in-depth cases only. This analysis focused only on forward facing child restraints and excluded booster seats and rear facing restraints. These other restraints may demonstrate different injury risks and patterns than those studied in this manuscript.

CONCLUSIONS

Children restrained in FFCRS in struck side crashes are at a significantly elevated risk of injury compared to both frontal and non-struck side collisions. Injury mitigation efforts should focus on reducing injuries to the head, face, and extremities. The ability to assess injury potential for these body regions in a laboratory setting should be explored. The highest risk of injury was to those in struck side crashes suggesting that regulatory and due care efforts should be placed on lowering the injury risk in this crash scenario. These results identify the importance of intrusion as a causative factor for moderate/serious injury and indicate that test procedures assessing the performance of CRS in side impact replicate an intrusion scenario.

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Table 1: The distribution of child, driver, vehicle, and crash characteristics by crash types among children weighing 50 lbs or under in forward facing child restraint systems (n=1868)

			FFCRS in frontal crashes (n=1408)	FFCRS in side impact crashes (n=460)	P values
Child's Characteristics					
	Gender weighted % (unweighted n)				P=0.065
		Boys	49.0 (695)	55.9(246)	
		Girls	51.0 (713)	44.1 (214)	
	Mean Child's age (yrs) (S.E.)		2.15 (0.04)	1.98 (0.07)	P=0.038
	Mean Weight (lbs) (S.E.)		30.6 (0.24)	30.1 (0.48)	P=0.35
	Seat Positions weighted % (unweighted n)				
		Front row	3.1 (48)	0.91 (10)	
		Rear rows	96.9 (1360)	98.1 (449)	
		Front row struck side	---	0.59 (4)	
		Rear rows struck side	---	34.9 (173)	
		Front row non-struck side	---	0.32 (6)	
		Rear rows non-struck side	---	64.2 (276)	
	Seated next to another passenger weighted % (unweighted n				P=0.58
		Yes	16.7 (271)	15.0 (78)	
		No	83.3 (1137)	85.0 (382)	
FFCRS characteristics					
	Combination seat weighted % (unweighted n)				P=0.10
		Yes	23.6 (292)	29.5 (121)	
		No	76.4 (1110)	70.5 (337)	
	Harness type weighted % (unweighted n)				P=0.67
		T-shield	17.2 (258)	18.8 (82)	
		Tray shield	21.0 (316)	21.3 (103)	
		5-point	46.6 (568)	47.3 (195)	
		3-point	0.00 (1)	0.11 (2)	
		Unknown	15.3 (173)	12.5 (47)	
Vehicle Characteristics					
	Vehicle Type weighted % (unweighted n)				P=0.20
		Passenger Car	52.6 (790)	49.9 (250)	
		Large van	1.9 (27)	1.8 (98)	
		Pickup truck	4.9 (68)	3.2 (14)	
		SUV	19.6 (247)	15.53 (72)	
		Passenger Van	21.0 (276)	29.6 (115)	
	Vehicle Model Year weighted % (unweighted n)				P=0.84
		1990-1993	18.4 (305)	20.3 (105)	
		1994-1996	31.0 (461)	30.0 (157)	
		1997-2003	50.7 (642)	49.4 (198)	
Driver's Characteristics					
	Mean driver's age (yrs) (S.E.)		32.7 (0.34)	33.1 (0.56)	P=0.55
	No Restraint Use weighted % (unweighted n)		4.1 (76)	2.7 (22)	P=0.31

	Relation to Children weighted % (unweighted n)				P=0.32
		Parents	93.0 (1214)	94.8 (378)	
		Non parents	7.0 (76)	5.2 (31)	
Crash Characteristics					
	Tow-away weighted % (unweighted n)				P=0.22
		Yes	40.0 (860)	45.1 (294)	
		No	60.0 (548)	55.0 (166)	
	Collision type weighted % (unweighted n)				P=0.71
		Vehicle	78.6 (1154)	81.3 (388)	
		Object	20.6 (237)	17.9 (63)	
		Ground	0.8 (17)	0.77 (9)	
		Unknown	0 (0)	0 (0)	
	Vehicle Crash partner weighted % (unweighted n)				P=0.44
		Passenger car	44.2 (636)	43.9 (201)	
		SUV	7.7 (113)	6.1 (31)	
		Van	6.7 (90)	9.2 (33)	
		Truck/Bus	14.9 (219)	12.8 (75)	
		Miscellaneous	0.8 (8)	1.2 (3)	
		Unknown	4.3 (88)	8.1 (45)	
		Non -vehicle	21.4 (254)	18.7 (72)	
	Crash Severity weighted % (unweighted n)				P<0.001
		Intrusion	5.9 (194)	18.1 (163)	
		No intrusion (Non-drivable)	35.6 (682)	31.0 (152)	
		No intrusion (Drivable)	58.6 (532)	50.9 (145)	

Note: Due to missing data, the unweighted n by subgroup does not add up to the total unweighted N

Table 2: The distribution of overall and body region specific injuries (AIS2+) for frontal and side impact crashes (overall, struck side and non-struck side) among children weighing 50 lbs or under in forward facing child restraint systems (n=1868)

	FFCRS frontal impact (n=1408) weighted % (unweighted n)	FFCRS side impact (n=460) weighted % (unweighted n)	FFCRS struck side impact (n=177) weighted % (unweighted n)	FFCRS non-struck side impact (n=282) weighted % (unweighted n)	P values Front vs side Front vs struck side Front vs non-struck Struck vs non-struck
Overall Injury	0.27 (63)	0.45 (28)	0.89 (18)	0.21 (10)	P=0.15 P=0.04 P=0.41 P=0.02
Head Injury*	0.04 (8)	0.04 (3)	0.08 (2)	0.02 (1)	P=0.88 P=0.59 P=0.41 P=0.34
Face Injury	0.10 (25)	0.30 (17)	0.59 (10)	0.15 (7)	P=0.059 P=0.08 P=0.46 P=0.11
Neck/Spine/ Back Injury	0.01 (3)	0 (0)	0 (0)	0 (0)	P=0.085 P=0.09 P=0.09 --
Chest Injury	0.02 (3)	0 (0)	0 (0)	0 (0)	P=0.10 P=0.11 P=0.11 --
Abdomen Injury	0 (0)	0.01 (1)	0.04 (1)	0 (0)	P=0.32 P=0.32 -- P=0.32
Upper Extremity Injury	0.06 (14)	0.04 (3)	0.04 (1)	0.04 (2)	P=0.54 P=0.64 P=0.65 P=0.94
Lower Extremity Injury	0.08 (19)	0.09 (7)	0.15 (4)	0.06 (3)	P=0.69 P=0.35 P=0.71 P=0.29

*Note: head injury excludes concussions, which may be difficult to diagnose in the pre-verbal population

Table 3: The association between injury risk (AIS2+) and crash, vehicle and adjacent passenger characteristics for children in FFCRS in side impact crashes (n=460).

Characteristics		Injury weighted % (unweighted n)	P value
Tow-away	Yes	1.0 (28)	P<0.001
	No	0 (0)	
Crash severity	Intrusion	1.9 (20)	P<0.001
	No intrusion (Non-drivable)	0.34 (8)	
	No intrusion (Drivable)	0 (0)	
Vehicle type	Passenger Car	0.63 (18)	P=0.13
	Large van	0 (0)	
	Pickup truck	0.42 (1)	
	SUV	0.52 (6)	
	Passenger Van	0.14 (3)	
Vehicle model year	1990-1993	0.96 (9)	P=0.07
	1994-1996	0.53 (12)	
	1997-2003	0.19 (7)	
Seated next to another passenger	Yes	0.09 (1)	P=0.02
	No	0.51 (27)	

Table 4: The frequencies of child, driver, vehicle, and crash characteristics among children with AIS2+ injury weighing 50 lbs or under in forward facing child restraint systems in side impact crashes (n=28)

			FFCRS in side impact crashes (n=28)
Child's Characteristics			
	Gender		
		Boys	13
		Girls	15
	Mean Child's age (yrs) (SD)*		2.42 (1.43)
	Mean Weight (lbs) (SD)*		30.2 (7.6)
	Seat Positions		
		Front row	1
		Rear rows	27
	Seated next to another passenger		
		Yes	1
		No	27
FFCRS characteristics			
	Combination seat		
		Yes	7
		No	21
	Harness type		
		T-shield	2
		Tray shield	9
		5-point	14
		Unknown	3
Vehicle Characteristics			
	Vehicle Type		
		Passenger Car	18
		Pickup truck	1
		SUV	6
		Passenger Van	3
	Vehicle Model Year		
		1990-1993	9
		1994-1996	12
		1997-2003	7
Driver's Characteristics			
	Mean Driver's age (yrs) (SD)*		30.7 (8.8)
	Restraint Use		
		Yes	25
		No	3
	Relation to Children		
		Parents	24
		Non parents	2
Crash Characteristics			
	Tow-away		
		Yes	28
		No	---
	Collision type		
		Vehicle	19
		Object	9
	Vehicle Crash partner		
		Passenger car	5
		SUV	3
		Van	3

	Truck/Bus	5
	Unknown	3
	Non –vehicle crash	9
Crash Severity		
	Intrusion	20
	No intrusion (Non-drivable)	8
	No intrusion (Drivable)	---