SPECIAL CRASH INVESTIGATIONS OF RESTRAINED CHILD OCCUPANTS

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Paper Number 302

ABSTRACT

This paper presents preliminary anecdotal crash information specific to child occupants involved in 27 on-going Special Crash Investigations cases in various stages of analysis, compiled to date. These investigations encompass collecting, documenting and analyzing all evidence necessary to reconstruct the events before, during and after the crash. None of the Restrained Child Occupant cases are in final form; therefore only limited information is available at this time. However, initial data collection involving a sampling of these 27 cases includes comparison examples of the following: both specific and general findings linking injury levels to crash severity, configuration of restrained and unrestrained child passengers, type of child restraint used, how the restraint was used and installed in the vehicle, and resultant injuries to the child occupants.

BACKGROUND

The National Highway Traffic Safety Administration's (NHTSA) National Center for Statistics and Analysis (NCSA) has conducted in-depth field crash investigations through its Special Crash Investigations (SCI) Office since 1972. The purpose of SCI is to examine the safety impact of new, emerging, and rapidly changing technologies as well as investigating potential or alleged vehicle defects. In addition, since late 2000, SCI has been actively pursuing special interest crashes involving restrained child occupants, which will enable the agency to assess injury outcomes to children in certain real-world crash environments.

NHTSA headquarters SCI staff receive notification of crashes involving restrained children under the age of 13. Crashes that meet SCI criteria are then assigned to one of three field teams for in-depth investigation. Details involving the crash and child occupants are then examined and documented in a case report. The criteria for case selection include: a child 0-12 years of age occupying a child restraint system attached to the vehicle, a child in a child restraint using both the vehicle and child seat Lower Anchors and Tethers for Children (LATCH) system, a child 0-12 years of age using the vehicles belt system only, or a child seated in a child safety seat with non-fatal air bag interaction.

Motor vehicle crashes remain a leading cause of death for children of all ages, and according to the Agency's Fatality Analysis Reporting System (FARS), there have been 1,580 passenger vehicle occupant fatalities among children under 5 years of age since 1999. Of these 1,580 fatalities, an estimated 793 (50 percent) were restrained by either a child seat or a vehicle safety belt system. The FARS data file contains limited information on all fatal traffic crashes within the 50 states, District of Columbia and Puerto Rico, and it is in part, due to this lack of detailed information, that the Agency is using its resources within other program areas to acquire and document restraint use data by children in all types of crashes.

NHTSA performs research, develops safety programs, and establishes safety performance standards in an effort to reduce the toll of deaths and injuries from motor vehicle crashes. The SCI program utilizes highly trained and skilled motor vehicle crash reconstructionists to perform detailed, in-depth investigations on a limited number of crashes involving new and rapidly changing occupant protection technologies.

The Agency is committed to understanding how child restraint systems perform in real-world crashes. This, coupled with the requirements initiated in the recent implementation of the Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act, has created the need for improved and updated real-world crash data and collection methods related to child occupants. The study of restrained child occupants detailed in this paper is a result of that effort.

INTRODUCTION

In late 2000, NHTSA's SCI teams initiated a study of special interest crashes involving restrained child occupants. This is an ongoing study, which will be continued over the next several years. This paper will report on the preliminary data gathered to date from a small number of crashes involving children in child restraints. Topics covered in this paper will range from the types of restraints used by child occupants of varying ages and sizes to how the respective restraint was used and installed in the vehicle.

These comprehensive investigations of real-world crashes involving child occupants will provide a unique, anecdotal data set useful to the agency as well as the whole automotive safety community for examining crash outcomes to children.

The SCI teams consist of three professional crash reconstruction teams representing the east, central, and western portions of the United States. These SCI teams perform extensive examinations of the vehicles, occupant kinematics, and crash scenes. Each team has staff who attended NHTSA's 32-hour Standardized Child Passenger Safety Training Program, and became certified Child Passenger Safety Technicians.

METHODOLOGY

Improved Data Collection Methodologies

New and updated data collection methodologies have been incorporated into the Agency's National Automotive Sampling System (NASS), Electronic Data Collection System (EDCS) beginning with the 2002 data collection year. The EDCS has been restructured with new and updated child seat and safety belt data collection variables and attributes along with the new Child Restraint Supplemental Interview Form for additional data collection which was pilot-tested by the SCI teams during late 2000. The new Child Restraint Interview consists of over 40 questions regarding how the child restraint was used and method of installation, history of the child restraint's use and what source of knowledge/instruction the parent/care giver relied upon for use and installation of the child restraint.

Specific information on the child restraint's design, installation features, (e.g., LATCH equipped, lock-offs, etc.), how the child restraint was used, harness strap(s) location, and LATCH features, are collected and documented, when used, for each child occupant. There are also questions aimed at determining the type of vehicle safety belt system used with the child restraint and/or the child; for example lap/shoulder combination, lap belt only, retractor/lock feature type, and how the vehicle safety belt was locked to secure the child restraint.

The Agency is attempting to create a depository of child occupant restraint information by combining comprehensive interview data with thorough crash scene data collection. This will provide the Agency and engineering community unique opportunities to better evaluate injury outcomes to restrained children involved in crashes.

SCI staff receive notifications of crashes involving vehicles that have an occupied child restraint in use. Screening of the crash is then conducted to determine if the crash meets the established selection criteria. Once selected, preliminary information is obtained to determine what type of investigation will be initiated, e.g., on-site or remote.

On-site child restraint investigations normally entail inspection of the case vehicle(s) and child restraints along with comprehensive interviews with crash victims and other involved parties. The crash scene is inspected and all related physical evidence is documented. The other (non-case) vehicle(s) are inspected and, when possible, medical records are reviewed during on-site investigations. Remote investigations typically only require that the crash meet the selection criteria with limited available information, e.g., police crash report only. Interviews may also be conducted with crash involved parties over-the-phone during a remote investigation, and photos from the vehicle owner, police and/or insurance company are obtained if possible.

PROCEDURES

In late 2000, SCI began collecting information relating to crashes involving restrained child occupants. Motor vehicle crashes involving vehicles having an occupied child safety seat installed are screened by the SCI staff to determine if the crash generally meets one or more of the following criterion:

(1) The vehicle and child restraint is equipped with a LATCH system which was in use;

(2) The child is restrained in a child safety seat;

(3) The child restraint is fastened in the vehicle; and

(4) The vehicle is towed due to disabling damage.

The variables to be examined in this study upon completion of each of the 27 cases will include: delta V and Collision Deformation Classification (CDC); vehicle make, model and year; vehicle safety belt system types (retractor and latch plate); vehicle

LATCH systems used; child's seating position; child's age, weight and height; child seat make, model, type, and harness design; child seat LATCH features; child's injury and injury severity.

In-depth information relating to the case child occupant's environment, (e.g., restraint use and installation, child restraint type used, orientation, harness strap positioning, seating location, vehicle safety belt type utilized to anchor the child restraint, top tether and lower anchorage systems utilized, etc.), is gathered by a thorough, hands-on examination of the child restraint and vehicle during on-site investigations. This data coupled with a newly developed, comprehensive Child Restraint Use Interview Form enables the highly skilled crash reconstructionists of the SCI teams to describe in detail how the respective child restraint was used and installed in the case vehicle in most instances.

The Child Restraint Use Interview Form consists of numerous questions pertaining to various child restraint types, (e.g., infant only, convertible, forward facing only, and belt-positioning booster seat) the parent/caregiver's knowledge of and familiarity with the child restraint, and its use and installation. There are also questions regarding information sources the parent/caregiver has used, (e.g., child seat checkpoints/clinics attended, vehicle and child restraint owner's manuals) which aided them in the child restraint's use and installation.

Table 1 provides a sample of questions asked of respondents along with possible response selections contained within the Child Restraint Use Interview Form when a child is using a belt-positioning booster and the vehicle lap and shoulder belt.

Table 1.
Sample of Child Restraint Use Interview Questions

Where was the shoulder belt positioned on the child?	__Over Shoulder Crossing Chest __Across face __Across the Neck	__Under the Arm __Off the Shoulder __Behind the Back	__Unknown __Other (specify)
Was the shoulder belt routed through a positioner clip/fabric on the booster seat?	__Yes __No __Unknown		
Describe the position of the lap belt	Low, across the child's lap/upper thighs	High, up across the waist/ stomach	__Other (specify) __Unknown

There are also questions pertaining to the use/installation of vehicle safety belt adaptations/add-ons as well as use of aftermarket belt-positioning devices. There are over 40 questions on the Interview Form. The responses to these questions are combined with crash scene documentation, vehicle documentation, and photos, enabling the investigators from the SCI Teams to reconstruct the pre and post crash child occupant scenario. This information is also automated into the Agency's NASS, EDCS. The EDCS was updated in 2002 with new child occupant restraint data collection variables along with the new Child Restraint Use Interview Form.

As mentioned earlier, information and photographs from 27 ongoing special crash investigations representing the first 18 months of this special data collection program were analyzed for this paper. All of the crashes involve at least one child occupant, who occupied a child restraint system at the time of the crash. Of these 27 on-going investigations, 19 are being conducted as on-site with the remaining 8 being conducted as remote.

None of the 27 cases are final, and the information discussed herein is in various stages of investigation and completion. No cases, from which portions of this paper have been developed, are specifically identified; and none are currently available for public distribution.

Case Study Child Occupants

There were 44 children between the ages of 2 months and 10 years, who were occupants in the 27 cases. All child occupants involved in a special interest crash up to and including the age of 12 will be documented, not just the children selected for case study.

Child Occupant Specifics

Height and weight ranges are known for 19 of the 44 children involved in these cases. Specifics regarding the remaining 25 children are unknown at this time pending receipt of medical reports.

The breakdown of the 19 children for whom weight and height are known is shown in Table 2.

Table 2.
Age, Height and Weight for 19 Child Occupants

Age	Height (cm)	Weight (kg)
2mo.	58	2.8
4mo.	64	4.8
1	81	11
17mo.	62	11
2	80	13
2	80	16
2	90	18
2	92	14
2	95	15
3	92	17.5
3	95	17.5
3	100	17
3	105	18
4	97.5	15.7
4	100	13.5
5	102.5	18
5	120	21
5	120	20
9	120	30

Case Study Child Restraints

The child restraints discussed in this study are defined as follows**:**

Infant Only Restraint – Designed for use by infants from birth to about 9 kg, and intended to be used rear facing only with an integrated harness system. Some are manufactured with a separate base**.**

Convertible Seat – Designed for use rear facing by infants from birth to about 9 to 13.6 kg, depending upon the manufacturers recommendations. Designed to be used forward facing by children at least 9 kg up to about 18 kg, depending upon the manufacturers recommendation.

Shield Booster – Designed for forward facing use only, typically recommended for use by children weighing between 13.6 kg to 18 kg.

Booster Seat/Forward Facing Only with Harness – Designed for forward facing use only with an integrated harness. Typically recommended for use by children who weigh at least 13.6 kg up to about 18 kg.

Belt Positioning Booster – Designed to be used with the vehicle's lap and shoulder safety belt combination by children weighing 13.6 kg up to approximately 27 kg.

Integrated Seat – Built into the vehicle seat, designed to be used forward facing only. Some have a full harness and accommodate children over 9 kg up to about 18 kg.

Lap and shoulder belt – Recommended for use by children who are at least 8 years of age with a height of at least 120 cm.

Child Occupants

Forty-four children were occupants of the 27 cases included within this study. Children from birth up to 16 months are included in the age 1 category, and children 17 months up to 24 months are included in the 2-year-old category. Breakdowns of the child occupants by age are shown in Figure 1.

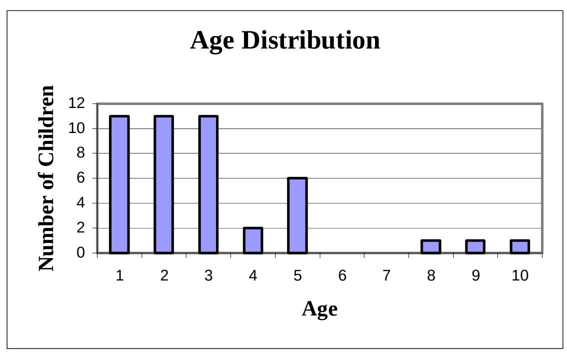

Figure 1. Age Distribution of the 44 Children.

Child Restraint Type Used

Of the 44 children, two were unrestrained, one 5-year-old and one 3-year-old. Five of the children were restrained using the vehicle's lap and shoulder safety belt only. One child was seated in an integrated seat, and one child was seated in a convertible seat used rear facing. Ten children were seated in convertible seats facing forward. Four infants were seated in infant only restraints, rear facing. Seven children were seated in booster seat/forward facing only seats with a harness. Two children were seated in a shield booster and five children were seated in high-back, belt-positioning boosters using the vehicle's lap and shoulder belt for restraint. The remaining seven children were restrained forward facing in unknown types of child restraints at this time. Figure 2 provides a breakdown of the child restraint types used by the children included in this paper.

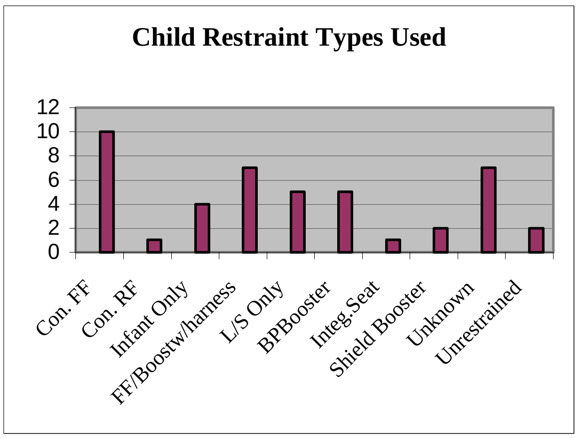

Figure 2. Types of Restraints Used by Child Occupants.

Child Restraint Placement

Forty of the 44 children included in this paper were seated in the rear rows of the vehicle. The four who were seated in the front seat were a 9-year-old and three, 3-year-olds. The 9-year-old was using the vehicle lap and shoulder safety belt, and one of the 3-year-olds was seated in a belt-positioning booster using the vehicle's automatic shoulder belt and manual lap belt. The other two 3-year-olds were seated in booster/forward facing only with harness seats. Only one front-seated child was riding in a pickup with no rear seat, the others were riding in vehicles with rear seating available. Figure 3 shows a comparison of front vs. rear seating positions.

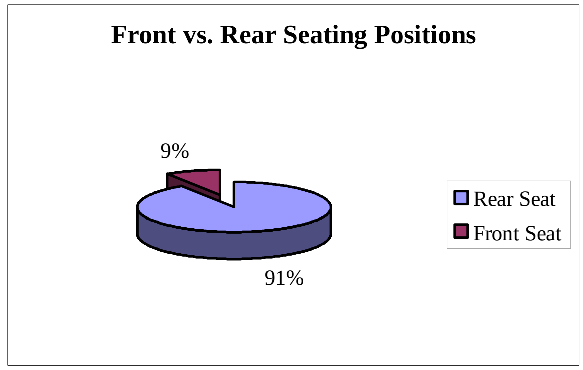

Figure 3. Percentage of the 44 Children Positioned in the Front Seat vs. the Rear Seat.

Child Restraint Installation

Vehicle Belt/LATCH Systems

Of the 42 restrained child occupants (44 total child occupants, two were unrestrained), 32 were restrained in a child restraint system with a harness or shield, which required use of the vehicle's safety belt system for installation. One child was using an integrated child restraint with a harness system. Of the 32 child restraints installed using vehicle's safety belt systems, three were installed using a lap belt only; the remaining 29 seats were installed using a lap and shoulder safety belt combination. None of the three center lap belts used for installation appeared to restrain the child restraint according to each respective manufacturer's recommendations. All three child restraints experienced some level of movement on the vehicle seat (i.e. child seat base was scuffed, child seat twisted/turned at final rest, etc.). Of the 29 lap and shoulder safety belt combinations, only six belts showed any signs of retaining the child restraint according to the vehicle and child restraint manufacturer's instructions. Indications of this were observations of child restraint indentations in the vehicle seat, signs of loading/stress on the belt webbing, parent/caregiver indicating that the child restraint did not move from its original position, post crash condition at inspection, etc. Hence, about 20 percent of the 29 lap and shoulder safety belt combinations appeared to be used according to manufacturer's recommendations when installing a child restraint within the vehicle.

LATCH Systems

Vehicle and Child Restraint Lower Anchors

Some of the vehicles included in these 27 cases were equipped with lower LATCH anchorages. However, none of the lower anchors were utilized for child restraint attachment. None of the child restraints included in this paper were lower LATCH compatible.

Tether Anchors and Attachments

Of the 32 known child restraint types requiring installation using the vehicle's safety belt system, eight were equipped with a top tether attachment. Of the eight top tether equipped seats, one top tether was used forward facing and one tether was used in the rear facing mode (as recommended by the manufacturer). For the remaining six seats where the top tether was available it was not used.

Child Restraint Use

As described previously, the majority of the 27 on-site and remote cases are in various stages of completion. Because of this it is not possible at this time to provide ample details regarding specific child restraint use and installation in each case. However, two separate sample cases are presented which provide some detail as to the data collected about the child restraint in the case, its use and installation, type of crash, and resultant child injuries.

Sample Case No. 1. Case Type – Remote. The case vehicle impacted a tree head-on at approximately 64 kmph**.** This case involves an 18-month-old with a weight of 14 kg and height of 81 cm. The child was seated in a forward facing convertible seat, which was installed in the back-center seat of a 1994 Ford Tempo utilizing the vehicle's manual lap belt. The belt showed no visible signs of stress/loading during vehicle inspection. The convertible seat was equipped with a tray shield, used with the harness straps routed through the bottom/lowest positioning slots, shown in Figure 4.

The child restraint manufacturer's instructions stated that the harness straps must be positioned in the top set of slots when the seat was used forward facing.

Figure 4. Front of child safety seat. Harness straps threaded through lowest slots.

At impact, both harness straps pulled through the back of the plastic shell of the child restraint as shown in Figure 5.

Figure 5. Harness straps tore through back of the plastic shell of child restraint. Note: Circles highlight damaged shell.

The child in this case endured an AIS-5 life-altering flexion injury with a cervical spine (C2) body fracture/dislocation with a cord contusion. The child remained unconscious for a period of time post resuscitation and also suffered from a subarachnoid hemorrhage. These injuries were attributed to forward movement, flexion, non-contact, head motion. A perineal laceration was due to contact with the crotch strap on the child safety seat.

The other occupant of this vehicle, the adult driver, was using the automatic shoulder belt only, not the available manual lap belt. The driver sustained a critical (AIS-5) injury along with other multiple injuries. He too was found unconscious and incurred injuries consisting of a liver laceration, diaphragm rupture with herniation, a gallbladder and kidney laceration along with rib fractures.

Sample Case No. 2. Case Type – On-site. The case vehicle was involved in a sideswipe collision which resulted in the vehicle leaving the left side of the roadway, rolling over 2 ½ times, coming to rest on its left side roof area after striking a utility pole. The case involves a 4-month-old infant with a weight of 4.8 kg and height of 64 cm. The infant was seated rear facing in an infant only, rear facing seat with its removable base attached. The seat had a 3-point/V harness that could be adjusted in the back of the seat by routing the free end of the harness strap through a metal slide sewn to the other end of the harness strap. The right side (free end) of the harness strap was not threaded back through the adjustment slide. Instead, the free end of the harness strap was threaded through the adjustment slide only once, and subsequently tied in a knot with the adjustment slide piece of webbing.

The manufacturer's instructions stated that the free end of the harness strap was to be laced through the adjustment slide until the correct harness strap fit is obtained for the child occupant. The harness straps should then be locked together by threading the free end of the harness strap back through the adjustment slide; doing so keeps the free harness strap from separating from the slide and pulling through the back of the shell if any force were applied.

The infant seat was positioned in the back-left seat of a 1989 GMC Jimmy, secured with a lap and shoulder safety belt combination with a locking latchplate. Creases were noted on the seat belt webbing suggesting that the infant seat was secured. The vehicle belt webbing was cut to remove the child seat.

The infant seat's carrying handle was left in the "up position" when placed in the vehicle and the harness straps were located in the lowest position. See Figure 6.

Figure 6. Frontal view of infant seat with the carrying handle "up" and the free end of the harness strap placed across the top of the seat.

Figure 7 is a reenactment of how the harness straps were tied in the back of the seat.

Figure 7. Harness straps tied in a knot pre-crash.

The infant seat and base remained in the vehicle, but the infant was ejected from both the child restraint and the vehicle during the rollover event. The free end of the harness strap was not threaded back through the adjustment slide, but was instead tied/knotted to the adjustment slide end. The knot released at some point during the crash allowing the strap to pull through the back of the infant seat, releasing the child. As a result of the ejection and impact with the ground, this infant suffered fatal, AIS-5 injuries, e.g., a transtentorial herniation completely obliterating the basilar cistern, third and fourth ventricles and sulci.

There were two other occupants of this vehicle, the driver and the right-front seat passenger, both restrained using the lap/shoulder belt combination. The driver sustained multiple injuries; the most severe was categorized as a complex laceration of the right parietal area of the scalp moderate (AIS-2). The right-front seat passenger also sustained multiple injuries; the most severe was a fracture of the posterior aspect of the right, fifth rib, categorized as serious (AIS 3).

DATA ANALYSIS

Crash Types

Of the 27 SCI Child Restraint cases documented to date, 20, (74%) involved vehicle-to-vehicle impacts. Seven, (26%) were single vehicle crashes. The most common impact configuration involved the front plane, followed by the right plane, rollover configuration, left plane and back plane. Figure 8 shows a breakdown of crash configuration with respect to the highest severity impact.

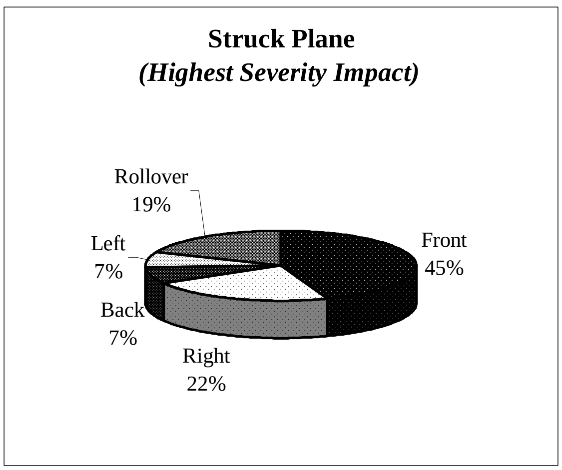

Figure 8. Case Vehicles Highest Severity Struck Plane as a Percentage.

Vehicle Types

The SCI Child Restraint cases reflect the overall popularity of minivans and sport utility vehicles (SUV) with families transporting children, making up nearly 45% of the total. Passenger cars made up 51.9% of the case vehicles included in this study. Minivans made up 25.9%. Sport utility vehicles accounted for 18.5%, while pickup trucks accounted for 3.7%. Figure 9 shows the breakdown of vehicle types.

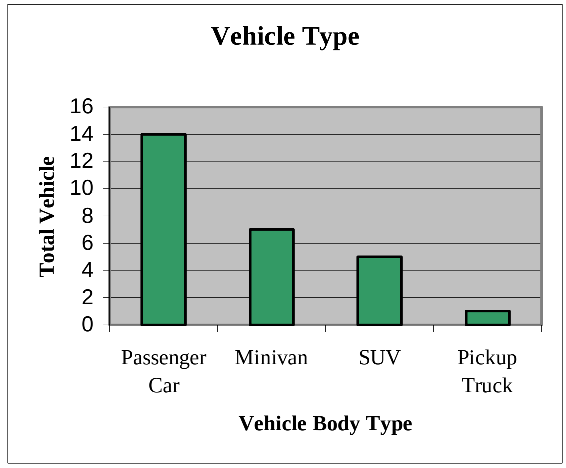

Figure 9. Case Vehicle Body Type.

Crash Severity

SCI uses delta v as a measure of crash severity. Delta v is derived from WinSMASH, a Windows based collision reconstruction program. WinSMASH makes use of detailed measurements of structural deformation of each vehicle to arrive at an estimate of the energy required to produce the measured vehicle damage. Since WinSMASH is a two dimensional program that simplifies the characteristics of vehicle-to-object and vehicle-to-vehicle interaction, many crash conditions fall out of the range of the WinSMASH reconstruction program. These conditions include rollovers, sideswipes, severe override/underride crashes, non-horizontal collisions, and collisions with large trucks, pedestrians, bicyclists, motorcyclists, and yielding objects such as guardrails and uprooted trees.

A delta v was calculated for the case vehicle in 18 of the 27 SCI Child Restraint cases. A rollover was defined as the most severe impact in five of the 18 cases. In three cases, the crash investigation is in its very early stages and the delta v data are not yet known. In one case, the case vehicle severely impacted and underrode the side of a tractor-trailer, primarily impacting the greenhouse area (upper portion of the passenger compartment) of the case vehicle. The crash configuration is not applicable to WinSMASH. The severity was simply defined as "severe."

The range of recorded delta v's in the 18 cases where it is known is reported in Figure 10.

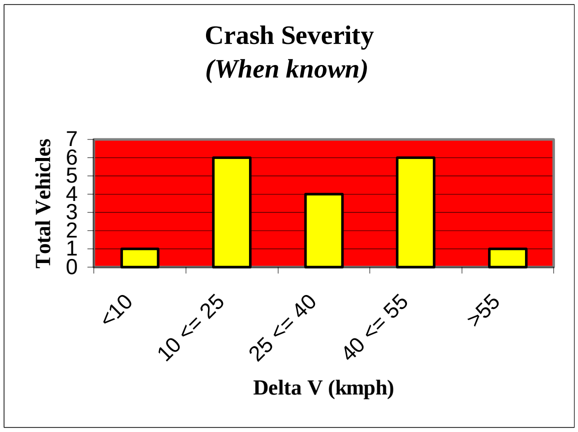

Figure 10. Total Velocity Change When Known.

Injury Severity vs. Crash Severity

The Abbreviated Injury Scale (AIS) is an anatomical scoring system first introduced in 1971. AIS provides a reasonably accurate method for ranking the severity of an injury. Injuries are ranked on a scale of AIS-1 to AIS-6, with 1 being "minor", 5 "critical", and 6 a generally unsurvivable injury. This represents the 'threat to life' associated with an injury.

The SCI researcher acquires injury information primarily by obtaining detailed medical records from the hospital (provided the parent or guardian signs a medical release form). Absent medical records, injury information can be documented during the interview process.

There were a total of 18 instances in the study where both the case vehicle's delta v and the restrained child occupant's highest reported AIS were known. A distribution of the delta v vs. highest severity AIS is shown in Figure 11.

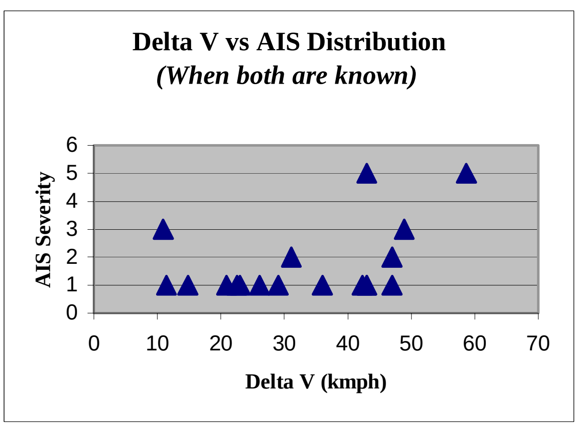

Figure 11. AIS Severity Level by Delta V.

Two-thirds of the case occupants in the distribution (12 of 18) sustained AIS-1 (minor) or no injuries including one-half (4 of 8) of those in the higher severity >40 kmph crashes. This would seem to point to the effectiveness of child safety seats in preventing serious injury.

Two children, both 3-years old, sustained AIS-2 injuries while seated in the front-right seating position of the vehicles – contrary to the rear seat position recommended by the NHTSA. One of these children, restrained in a booster/forward facing only seat with a harness, interacted with the air bag and instrument panel. The other child, seated in a high back, belt-positioning booster seat using the vehicle's automatic shoulder belt and manual lap belt for restraint, was involved in a severe offset head-on collision with a heavy truck in which the driver was fatally injured.

In both cases of AIS-3 injuries to the restrained child occupant, the child was seated on the same side of the vehicle as the primary impact (i.e. left-rear seating position, left side impact). In one case the child was seated in an integrated forward facing child seat in the second-left position of a minivan. The vehicle was struck on the left side, rear of the B-pillar. The left interior surface intruded onto the occupant's lower extremities causing the AIS-3 injury. The other case involved an child seated in a forward facing booster seat with shield in the back-right seat. This vehicle was struck in the right doors by the front of the other vehicle in an intersection collision. The right-rear door intruded onto the child's upper torso causing the AIS-3 injury.

Two restrained child occupants sustained AIS-5 injuries. In one case, the restrained child occupant was seated in a booster/forward facing seat with harness straps in the second-left seating position of the vehicle. The vehicle was struck in the rear plane and the driver's seat back collapsed rearward onto the child. The rear aspect of the driver's head contacted the front aspect of the child's head causing a critical brain injury to the child. The two other children seated in the second-center and second-right seats sustained only AIS-1 injuries.

In the other case, the restrained child occupant was seated in a forward facing convertible child seat in the back-center seating position. The harness straps were incorrectly threaded through the lower slots (straps should utilize the upper slots for forward facing configuration), which led to the straps tearing through the plastic shell during this high severity (59 kmph delta v) frontal impact. The release of the harness tension allowed the child to move violently forward in the child seat, leading to the AIS-5 spinal injury. This case is described earlier in this paper as Sample Case 1.

Injury Severity vs. Crash Configuration

There were 21 crashes included in the study where both the highest severity impact plane and the restrained child occupant's highest reported AIS were known. A distribution of the crash configuration vs. the highest AIS severity average is reported in Figure 12.

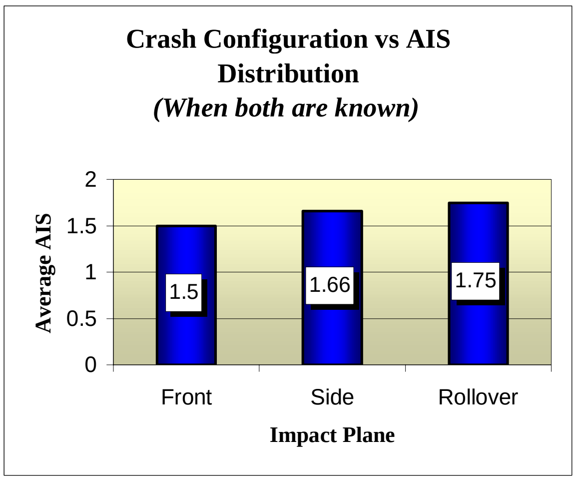

Figure 12. Average Highest AIS Injury by Impact Plane.

The distribution included 22 restrained child occupants in 20 impact crashes. There were a total of 10 frontal, six side, and four rollover configuration crashes. Since only one rear-impact crash has been documented to date, it was not included in this distribution.

Based on the preliminary data collection, child safety seats appear to be effective in preventing serious injuries in frontal and rollover configuration crashes. Twelve of 16, (75%) of the restrained child occupants in frontal or rollover crashes in child safety seats sustained AIS-1 or no injuries. In side impacts, the injury outcome of the restrained child occupants appears to be related to the seating position of the child in relation to the impact plane of the vehicle with both "seriously" injured child occupants seated on the struck side of the vehicle. Rear-impact configuration crashes are too rare in our current study to reach any type of finding or conclusion.

The average highest AIS injury severity for the restrained child occupants in frontal crashes was 1.5. Of the 12 restrained child occupants in frontal collisions, nine, (75%) sustained AIS-1 or no injuries. Only 1 child sustained an AIS-3 or higher injury in a frontal crash. This crash is described in Sample Case 1 and involved incorrect routing of the child safety seat's harness straps.

The average highest AIS injury severity for the restrained child occupants in side crashes was 1.66. Of the six restrained child occupants in side collisions, four, (67%) sustained AIS-1 or no injuries. However, two of the six, (33%) sustained AIS-3 or "serious" level injuries. As mentioned previously, these two children were seated on the struck side of the vehicle and were contacted by intruding interior surfaces.

The average highest AIS injury severity for the restrained child occupants in rollover crashes was 1.75. Of the four restrained child occupants in rollover crashes, one occupant sustained higher than an AIS-1 injury. This crash is described in detail earlier in this paper as Sample Case 2 and involved incorrect fastening of the child safety seat's harness straps leading to the ejection of the child. It should be noted that adult fatalities were present in two of the three rollover crashes in which the child occupants sustained AIS-1 or no injuries. The disparity between the adult and child occupants in these crashes seem due to the child restraint keeping the child occupants inside the vehicle during the rollover sequence while several of the unrestrained adult occupants were ejected from the vehicle.

FINDINGS

The SCI Restrained Child Occupant study is in its early stage, therefore conclusions cannot and should not be drawn from this data. Nonetheless, data derived to this point appear to have several indications. Namely, child occupants restrained in child safety seats as a whole sustained relatively low levels of injury in the wide severity range of crashes investigated to date**.** The majority of child restraints identified in these cases appear not to have been installed according to the vehicle or child restraint manufacturer's recommendations. The majority of the children involved in these 27 cases were riding in the rear seat as opposed to the front seat, and child safety seats seem particularly effective in frontal and rollover collisions. However, with only 27 cases initiated to date, the pool of crashes at the present time is not large enough to draw direct conclusions.

Special Crash Investigations will continue to collect and analyze data on crashes involving children over the next several years in order to provide the agency with a unique, anecdotal child occupant data set. The information gathered will provide the agency with scientific information of various crash scenarios with resultant injury outcomes to restrained child occupants, from which limited clinical assessments can be made.

DATA AVAILABILITY

Completed SCI cases are available to view on the National Highway Traffic Safety Administration (NHTSA) Special Crash Investigations Internet web site at the following web address:

http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/SCI.html

Copies of completed SCI cases are also available to purchase on compact disc (CD) for a nominal cost by sending a written request to the following address:

Marjorie Saccoccio
DTS-23
Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142-1093
TEL: 617-494-2640
FAX: 617-494-2429

Acknowledgments of thanks are due to the Special Crash Investigations Teams at Veridian Engineering, Indiana University, and Dynamic Science, Inc.

REFERENCES

1. Joint Committee on Injury Scaling, comprised of representatives of the American Medical Association (AMA), American Association for Automotive Medicine (AAAM), and the Society of Automotive Engineers (SAE)