Traffic Safety Facts
Research Note

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Examination of Rollover Crash Mechanisms and Occupant Outcomes

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Objective

In response to the growing concern surrounding rollover incidence and its consequences, the present analysis seeks to answer the following questions:

- Which are the most prevalent rollover crash attributes?
- What is the injury outcome for rollover crash occupants?

Background

A void in real-world rollover data compilation was filled in 2002 with the release of "Characteristics of Fatal Rollover Crashes" (DOT HS 809 438.) Using the Fatality Analysis Reporting System (FARS), DOT HS 809 438 examined an important segment of the rollover population. It was shown in the referenced report that, generally, those without restraint and subject to ejection are the most vulnerable.

This Research Note seeks to expand on the findings of the DOT HS 809 438 by using the National Automotive Sampling System (NASS) – Crashworthiness Data System (CDS.) Combining the crash investigation elements with the injury reporting inherent to this data base, a more exact description of the crash is possible.

In 2003, NHTSA has declared the issue of passenger vehicle rollover a priority, owing to its prominence in fatal crash statistics. The agency has been active in the implementation of the Rollover Resistance Rating for new vehicles and in the development of a dynamic rollover test.

While, the number of quarter turns is not always accepted as a measure of rollover severity, it has been used in prior works such as Rains and Kanianthra (SAE 1995.) In this analysis, it will be used as a comparative measure aimed at discerning rollover crash attributes and associated injury vulnerabilities. Based on previous reporting, the unbelted occupant is the most vulnerable to ejection and fatality; however, even the belted occupant is at risk because some current seatbelts, and most retractors, are primarily designed to withstand the exigencies imposed by a planar crash. Further, the complexity of the rollover crash suggests that vehicle integrity, in particular roof strength, in conjunction with, restraint use must provide adequate protection to minimize occupant injury. The concern is accentuated by recent roof crush testing (Federal Highway Administration, Test 03005 A&B, 2003) in which each roof strike appeared to weaken the loading capacity of the roof. The examination of the most frequently occurring types of rollover crashes and their associated injury outcomes in relation to quarter turns, as reported in real-world data bases, is proposed to further understand rollover crashes.

Introduction

From 1995 through 2001, an estimated 17.1 million (weighted) crashes, involving passenger vehicles towed from the scene due to damage sustained in the crashes, occurred on roadways in the United States. Of these 17.1 million crashes, 4.5 million were single vehicle events. Approximately 28 percent of these single vehicle crashes resulted in rollovers, as reported in the NASS – CDS. Among all rollover crashes (1.6 million), 81 percent were single vehicle encounters.

Among rollover crashes reported in NASS - CDS, approximately 55 percent ended in one or two quarter turns contacting either the near side of the roll or the roof. Generally, these crashes

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occurred when the vehicle left the roadway and encountered a tripping mechanism such as soft dirt or loose gravel. In contrast, it was noted that untripped rollover crashes comprised only a small fraction of all rollover crashes and were differentiated from the tripped cases by the absence of any tripping mechanism.

Under the circumstances encountered during a rollover crash, occupant vulnerability increased with the omission of restraint use. For those completely ejected, 97 percent were unrestrained. Among injured occupants, the proportion of serious injuries was greater for those involved in rollover crashes.

Table 1
Percentage of Vehicles in Single Vehicle Rollover by Body Type and Type of Rollover (Sample sizes given in parentheses. Total column given in thousands, weighted)

Vehicle Body Type	1 Quarter Turn (Lateral)	2 Quarter Turn (Lateral)	3+ Quarter Turn (Lateral)	End-over-End	Unknown Num. of Quarter Turns	(in '000) Total
Pass. Car	13 % (n=144)	42 % (n=499)	40 % (n=719)	1 % (n=43)	4 % (n=107)	632 50 %
SUV	13 % (n=108)	41 % (n=127)	40 % (n=384)	0 % (n=6)	6 % (n=58)	330 26 %
Van	31 % (n=38)	22 % (n=25)	42 % (n=78)	1 % (n=2)	3 % (n=7)	44 3 %
Pickup	22 % (n=95)	35 % (n=134)	39 % (n=328)	0 % (n=10)	4 % (n=32)	261 21 %
Total	16 % (n=385)	39 % (n=785)	40 % (n=1,509)	1 % (n=61)	5 % (n=204)	1,268 100 %

Note: Slight differences may exist in percentage calculations owing to rounding.
Source: NCSA, NHTSA, NASS-CDS,1995-2001

Definitions and Constraints

In order to amplify the scope of rollover crash understanding, the NASS – CDS was queried. CDS is a nationally representative sample of tow-away crashes based on Police Accident Reports (PAR). Upon selection, a comprehensive crash scene and vehicle review combines with the occupant demography and injury account to form the case file.

Passenger vehicle (passenger car, sport utility vehicle, van, and pickup truck) crashes reported in CDS from 1995 through 2001 were considered in this study.

Rollover Crash Mechanism

Percentage of Rollover Crashes, by Crash Configuration and Fleet Composition

From 1995 through 2001, single vehicle rollovers accounted for 81 percent of all rollovers. As seen in Table 1, passenger cars experienced 50 percent of single vehicle rollovers. Polk vehicle registration data aggregated over 1995 through 2001, yielding vehicle years, indicated that 65 percent of the 1.54 billion vehicle years belonged to passenger cars. The remaining fifty percent of the single vehicle rollover crashes were attributable to light trucks; however, this vehicle class comprised 35 percent of the vehicle fleet. The vehicle years were aggregated in response to the small CDS sample size. It was not dictated by the fleet composition, which experienced rapid changes over this period.

Rollover Initiation Object

The predominant tripping mechanism inducing rollovers in single vehicle crashes tends to be ground (61 percent of single vehicle rollover crashes.) In CDS, if the rollover initiation type has been identified as a fall-over, neither tripped nor untripped, or turn-over, an untripped situation, rollover initiation object aggregates these attributes. It should be noted that these are very different types of rollover crashes. Further, the rollover initiation type fall-over constitutes most of the entries found in this aggregated attribute. Please reference the Section "Rollover Initiation Type" for disaggregation of these two attributes.

Among multi-vehicle rollover crashes, the vehicle is the predominant tripping mechanism, accounting for 47 percent. Thirty-four percent of multi-vehicle rollover crashes occur owing to tripping on the ground.

Number of Quarter Turns

In the single vehicle rollover crash, most vehicles come to rest at two quarter turns. This can be a promising sign once the rollover has occurred for several reasons. First, if the roof meets the required standard, it should withstand the mass of the vehicle. Second, the roof has not been debilitated with repeated strikes since the vehicle undergoes two quarter turns and comes to rest. Finally, since undue force has not been exerted during the first roof strike the windshield will generally be intact. This is significant because the windshield is an important structural element for roof integrity / strength, as shown by the work of Henderson and Paine (1998.) Most of these benefits are severely curtailed if the occupant omits restraint use.

Sixty-four percent of multi-vehicle rollovers last up to two quarter turns, as compared to 55 percent in the single vehicle case. Since only 19 percent of rollover crashes involve more than one vehicle, fewer conclusions may be drawn than from the single vehicle scenario. Additionally, single vehicle rollovers are very complex and unique events; the presence of more vehicles, in the multi-vehicle rollover case, serves to further obfuscate the event and hamper reconstruction of the crash relevant to injury and damage.

Rollover Initiation Type

The results for this variable are included for completeness; however, data prior to 1997 are subject to recodification based on methodologies proposed by Hertz (1999). Of specific concern and warranting additional study are the vehicles that experience off-paved road excursion and rejoin the paved roadway. Upon publication, CDS data sets are not revised, therefore, the work of Hendriks (1998) and Hertz (1999) provide an update to the attributes relevant to this variable. The summarization below is limited to 1998 through 2001.

The trip–over (tripped rollover) is the rollover initiation type most commonly experienced (71 percent) during single vehicle rollover crashes, per Table 2. This scenario is enacted by a sudden sideways slowing or stopping and induced by contact with a curb, pothole, wheel rim / pavement contact, or pavement / soil dug into by a vehicle's wheels. At each of the quarter turn levels the trip-over is predominant. The fall–over is the second most prevalent event occurring in 13 percent of the single vehicle rollover crashes. As defined by the CDS coding manual, in fall-over, the vehicle is tipped by a slope so that its center of gravity is outboard of its wheels. It should be noted that this definition is true for a vehicle not in motion. For a moving vehicle, the dynamics of the vehicle are controlled by gravity and centrifugal forces.

Table 2
Percentage of Vehicles in Single Vehicle Rollover by Rollover Initiation Type and Type of Rollover
(Total column given in thousands, weighted)

Rollover Initiation Type	1 Quarter Turn (Lateral)	2 Quarter Turn (Lateral)	3+ Quarter Turn (Lateral)	End-over-End	Unknown Num. of Quarter Turns	(in '000) Total
TRIP-OVER	12%	43%	45%	0%	0%	**562** 71%
FLIP-OVER	23%	47%	30%	0%	0%	**44** 6%
TURN-OVER	71%	19%	10%	0%	0%	**27** 3%
CLIMB-OVER	19%	29%	52%	0%	0%	**9** 1%
FALL-OVER	19%	62%	19%	0%	0%	**104** 13%
BOUNCE-OVER	32%	47%	21%	0%	0%	**31** 4%
COLLISION W/VEH	6%	82%	12%	0%	0%	**7** 1%
OTH ROLLOVER TYPE	2%	69%	28%	0%	0%	**4** 0%
END-OVER-END	0%	0%	0%	0%	100%	**4** 0%
Total	**128** **16%**	**357** **45%**	**304** **38%**	**0** **0%**	**4** **0%**	**793** **100%**

Note: Slight differences may exist in percentage calculations owing to rounding.
Source: NCSA, NHTSA, NASS-CDS, 1998-2001

Fifty-one percent of multi-vehicle rollover crashes occur as a result of the collision with another vehicle. This indicates that another vehicle rather than a roadway element serves to precipitate the event. This is followed by the trip-over in 38 percent of the multi-vehicle rollovers.

Direction of Initial Rollover

Approximately, 45 percent of vehicles roll to the right and 55 percent to the left in single vehicle crashes. A nearly equal proportion exists in multi-vehicular configurations.

Tripping Location on the Vehicle

For most rollover crashes, the wheels / tires are the point where the initial tripping force occurs (67 percent for single vehicle rollovers and 42 percent for multi-vehicle.) This also holds true regardless of the number of quarter turns. The non-contact force is associated with 17 percent of single vehicle rollovers including fall-over, which occurs in 13 percent of single vehicle rollover crashes. Non-contact forces describe a roll precipitated by centrifugal or gravitational forces. At three or more quarter turns, roughly 57 percent of tripping is attributable to wheel / tire engagements. Wheel rim contact is associated with tripped rollover while the tire force only is related to untripped rollover.

Although 42 percent of the multi-vehicle rollover crashes are initially tripped at the wheels / tires, 35 percent are attributable to the side plane. Further, the side-plane incidents are concentrated at one quarter turn (45 percent) indicating a potentially lower severity crash. The side plane refers to any side plane other than the wheels and tires that precipitates rollover.

Behavioral Elements

In reconstructing rollover crashes, it is important to understand the behavioral elements attributable to the event. Examination of the pre-event movement prior to the recognition of critical event and quarter turn frequency, with regard to driver inputs, as described in CDS, are included.

In single vehicle, non-planar events approximately 49 percent of the drivers sought to negotiate a turn. Forty-one percent seem to have failed to continue on their straight path. The remaining pre-event movements were seen to occur very infrequently and included: an absence of driver, decelerating in traffic lane, accelerating in traffic lane, starting in traffic lane, stopped in traffic lane, passing or overtaking another vehicle, disabled or parked in travel lane, leaving a parking position, entering a parking position, turning right, turning left, making a U-turn, backing up (other than for parking position,) changing lanes, merging, successful avoidance maneuver to a previous critical event, other movement, or unknown.

In multi-vehicle, non-planar events, 60 percent of the drivers failed to continue in a straight path. Sixteen percent were attempting a left turn movement prior to the rollover event. These were noted as the highest frequency multi-vehicle pre-event movements.

Occupant Demography

Owing to the small sample size of occupants involved in rollover crashes, the crash configurations were collapsed into one data set. The attributes of interest were on-scene disposition of the occupant, restraint use, ejection, and injury severity.

On-Scene Occupant Disposition

The severity of rollover crashes is suggested by the following comparisons. Fifty-six percent of occupants receive some form of treatment, as compared to 40 percent of planar crash occupants. Further, for rollovers with more than two quarter turns, the number of occupants receiving no treatment experiences a sharp decline from 24 to 11 percent.

Occupant Restraint Use

The data supports the advocacy for manual restraint use. Although the Occupant Protection Standard (FMVSS 208) does not require a safety belt test under rollover conditions, the safety belt does provide the intended result of retaining most restrained occupants within the vehicle. By virtue of restraint use, these occupants generally walk away from the rollover sequence. Additionally, these occupants experience crashes of higher severity with regard to the recorded quarter turns and are not ejected. It is found that most of the occupants classified at the various treatment levels are restrained.

It has long been theorized that risk takers generally succumb to rollover. This may be at least partially supported by elevated incidence of unrestrained occ-

Table 3
Percentage of Occupants Involved in Crashes by Restraint Use and Number of Quarter Turns (Totals given in thousands, weighted. Sample sizes given in parentheses.)

Safety Belt Use	Quarter Turns (Column Percentage) 0	1	2	3+	End-over-End	Unk Num	(in '000's) Total
No	27% (n=17,465)	35% (n=544)	34% (n=888)	34% (n=1,783)	67% (n=71)	51% (n=232)	**7,277** 28%
Yes	71% (n=28,564)	64% (n=684)	65% (n=959)	66% (n=1705)	32% (n=38)	48% (n=187)	**18,340** 70%
Unknown	2% (n=1,053)	1% (n=22)	1% (n=50)	1% (n=45)	2% (n=5)	1% (n=16)	**459** 2%
Total	23,480 (n=47,082)	447 (n=1,250)	1053 (n=1,897)	983 (n=3,533)	16 (n=114)	102 (n=435)	**26,080** 100%

Note: Slight differences may exist in percentage calculations owing to rounding.

Source: NCSA, NHTSA, NASS-CDS, 1995-2001

upants in rollover crashes. Among planar crash occupants, 27 percent failed to use a safety belt (were unrestrained), as compared to 35 percent of the rollover (other than zero quarter turn) crash occupants, per Table 3.

Ejection

As noted previously, those who were belted fared better than those unrestrained occupants. Further, ejection incidence was found to be far lower among those restrained. Although testing has not subjected restraint systems to the forces imparted during a rollover crash, they have been shown to retard the outward motion of the occupants.

As seen in Table 4, those unrestrained occupants who remained within the vehicle (30 percent of the rollover population) will have benefited from the integrity of the occupant compartment but will have sacrificed potential injury mitigation afforded by restraint use. The data suggested that the restrained occupants were able to withstand rollover without being ejected at a greater frequency than those who were unrestrained. Of the partially and completely ejected occupants, 81 percent were unrestrained, as compared to the 18 percent who were protected by a safety belt. Among completely ejected occupants subjected to rollover, 97 percent were unrestrained. In support of restraint use were the 69 percent of all CDS-reported rollover occupants who by virtue of their restraint use were retained within the vehicle. The percentage of occupant retention during rollover was exceedingly high for a technology not directly addressing this situation.

Table 4
Percentage and Number of Occupants Involved in Rollover Crashes by Ejection Status and Restraint Use (Total column given in thousands, weighted)

Ejection Status	Restraint Use (Row Percentage) No	Yes	Unk.	(in '000's) Total
No Ejection	30 %	69 %	1 %	**2,355** 92%
Complete Ejection	97 %	3 %	0 %	**142** 6%
Partial Ejection	49 %	51 %	0 %	**69** 3%
Ejection - Unknown Degree	87 %	12 %	1 %	**2** 0%
Total	34 %	65 %	1 %	**2,567** 100%

Note: Slight differences may exist in percentage calculations owing to rounding.

Source: NCSA, NHTSA, NASS-CDS, 1995-2001

Maximum Injury Severity

The Maximum Abbreviated Injury Scale (MAIS) describes the highest abbreviated injury severity score (AIS); based on mortality risk, sustained by an occupant. The scale ranges from minor (AIS 1) through maximum (AIS 6) injuries and unknown (AIS 7.) Ten percent of all occupants injured in rollover were seriously, including fatally, injured, as shown in Table 5. Another 15 percent of occupants sustained MAIS injury in the moderate range. Since most rollover crashes resulted in two quarter turns or less, thereby safeguarding the integrity of the vehicle, it was not surprising that rollover injuries were predominantly of lower injury severity. This did not mean that rollovers were benign in nature. Most planar crashes were also of low injury severity, per Table 6. In rollover

crashes, however, 49 percent of occupants experiencing three or more quarter turns sustained minor injuries. When examining the percentage of occupants involved in rollover crashes, injury patterns indicated the potential detriment to the occupant involved in a rollover versus a planar crash. As a percentage, MAIS scores for rollover occupants tended to be greater than those for planar crash occupants.

Table 5
Percentage of Injured Occupants, by Injury Severity and Crash Attitude

Injury Severity (MAIS)	Crash Attitude	
	Planar	Rollover
Minor	86 %	74 %
Moderate	9 %	15 %
Serious - Maximum	5 %	10 %
All Known Injured	100 %	100 %

Note: Slight differences may exist in percentage calculation owing to rounding.
Source: NCSA, NHTSA, NASS-CDS, 1995-2001

Among CDS crashes, 70 percent of occupants were restrained, as compared to 28 percent who were unrestrained, per Table 3. Upon disaggregation, however, 64 percent of rollover occupants were restrained and 35 percent were unrestrained. Although a very high incidence of crashes resulted in low MAIS scores, this may have been a masking effect of the restrained in relation to the unrestrained occupant outcomes. Among rollover crashes, as compared to planar crashes, a slightly lower percentage of MAIS 1 injuries existed. As a percentage, MAIS readings for rollover occupants tended to be greater than those for planar crash occupants.

Table 6
Percentage and Number of Rollover Occupants, by Maximum Injury Severity and Number of Quarter Turns

MAIS	Quarter Turns (Column Percentage)				End-over-End	Unknown Number	(in '000's) Total
	0	1	2	3+			
0 No Inj.	51 %	39 %	53 %	26 %	2 %	12 %	12,840 50 %
1 Minor	39 %	47 %	34 %	49 %	54 %	38 %	10,060 39 %
2 Moderate	4 %	7 %	6 %	11 %	8 %	17 %	1,206 5 %
3 – 6 Serious – Max.	2 %	4 %	3 %	9 %	32 %	10 %	669 3 %
7 Unknown/Severe	4 %	3 %	4 %	5 %	5 %	23 %	1,088 4 %
Total	23,290 100 %	438 100 %	1,041 100 %	979 100 %	16 100 %	100 100 %	25,860

Note: Slight differences may exist in percentage calculation owing to rounding.
Source: NCSA, NHTSA, NASS-CDS, 1995-2001

Injuries by Body Region

Thirty-three percent of all reported injuries occurring in non-planar crashes affected the head. Another one percent were assessed as neck injuries. Rains and Kanianthra (SAE 1995) suggested, that headroom reduction increased head injury risk, however, they did not discount the risks associated with vertical occupant excursion. It may be reasoned that the neck may first have loaded the roof, and rebounded off the roof thereby creating a two-pronged insult. Neck injuries of lower severity may have been overlooked or may not have manifested themselves until after examination. Similarly, non-life threatening neck injuries may have been overlooked in severely injured occupants. These considerations may be attributable, at least in part, to the necessity to immediately treat more severe, potentially life-threatening injuries in the emergency room. The initial examinations may allow less severe injuries to remain unidentified until further examination or never become documented for CDS.

Restrained occupants sustain nearly half of the injuries to extremities, as seen in Table 7. The compression of the occupant compartment and flailing of members may partially explain the head / face and extremity injury frequency that is evident for the unrestrained occupants. For restrained occupants, the thorax most frequently sustains serious injury. In contrast, the head and face of unrestrained occupants are the most vulnerable to serious injury. On average for these rollover data, three injuries are recorded for unrestrained and six for restrained occupants. Of injuries to unrestrained occupants, 23 percent are at least of AIS 2 severity, as compared to 10 percent for the restrained occupants.

Table 7
Percentage of Injuries Sustained by Occupants Involved in Rollover Crashes by Injured Body Region, Restraint Use, and Injury Severity

Injured Body Region	Safety Belt Use	Injury Severity (Row Percentage) AIS 1	AIS 2	AIS 3-6	AIS 7	(in '000) Total
Head/Face	No	76%	13%	11%	1%	981
	Yes	89%	7%	3%	0%	882
	All	82%	10%	7%	0%	1,872
Upper & Lower Extremities	No	82%	13%	5%	0%	1,017
	Yes	93%	6%	2%	0%	1,372
	All	88%	9%	3%	0%	2,398
Spine	No	71%	23%	6%	0%	283
	Yes	91%	7%	2%	0%	342
	All	82%	14%	4%	0%	628
Thorax	No	66%	6%	27%	1%	221
	Yes	77%	7%	14%	1%	233
	All	71%	7%	21%	1%	455
Abdomen	No	67%	20%	11%	1%	130
	Yes	74%	18%	7%	1%	95
	All	70%	19%	9%	1%	227
Unspecified	No	99%	0%	1%	0%	57
	Yes	98%	0%	2%	0%	37
	All	99%	0%	1%	0%	94
Neck	No	91%	3%	3%	3%	23
	Yes	99%	1%	0%	1%	37
	All	96%	2%	1%	1%	60
Total	No	77%	14%	9%	0%	2,712
	Yes	90%	7%	3%	0%	2,998
	All	84%	10%	6%	0%	5,734

Note: Slight differences may exist in percentage calculation owing to rounding.
The "All" category includes the unknown restraint category, however, it is not explicitly included in the table.
Source: NCSA, NHTSA, NASS-CDS, 1995-2001

Conclusions

In this review of NASS – CDS data over the years 1995 through 2001, rollover crash mechanisms and their related injury patterns are summarized. Although the single vehicle rollover is a highly complex crash mode, the multi-vehicle rollover becomes less clear with the added dimension of a planar component. For this reason, only single vehicle *crash mechanisms* are considered in the summation. Owing to the small sample size, however, injuries of single and multiple vehicle *crash configurations* are aggregated within the study and for the summarization that follows. Based on the data examined in this report, it possible to address the questions posed in the Section "Objectives" regarding: prevalent rollover crash attributes and injury outcomes for occupants of rollover crashes.

Which are the Prevalent Rollover Crash Attributes?

The tripping mechanism generally inducing rollover was the ground with initial tripping force exerted at the wheels / tires. The trip-over type of rollover was found to be the most prevalent. Most rollovers ended in one or two quarter turns. Slightly more than half of the single vehicle crashes rolled to the left, driver side leading. As the counterpoint, it was noted that the turn-over (untripped) rollover type was the least frequent type of rollover crash.

What is the Injury Outcome for the Rollover Occupants?

The occupant data were sorted in relation to restraint use and crash configuration. It was noted that among rollover crash occupants, the percentage that were unrestrained was higher than the analogous percentage among planar crashes. Also, unrestrained occupants were at the greatest risk for injury and ejection. Further, MAIS readings for rollover occupants were proportionally higher than those for planar crash occupants. The head and extremities were injured with greatest frequency. It can be concluded that there would have been a larger number of severe injuries were it not for the benefits of safety belt use.

The research is on-going and subsequent phases will be published in the form of research notes and technical reports. The next phase will contemplate the issues discussed below.

Issues Identified with Current Parameters and Rationale for Future Modifications

In examining the data for all occupants and their vehicles, issues were encountered. These issues existed in comparing the injury outcomes and vehicle damage and included: crash configuration, impact orientation, occupant biomechanics, seating position, and clinical case analysis.

Crash Configuration

The crash configuration should be considered in this type of

analysis. The bulk of the rollovers are attributable to single vehicle events. However, the presence of other vehicles introduces issues beyond those within the traditional single vehicle rollover. It may also be useful to determine whether the case vehicle that does roll acts as the bullet or struck vehicle.

Impact Orientation

Additionally, the issue of near side versus far side leading rollovers must be considered in tandem with the quarter turn progression. Consideration to the occupant position and his relation to the leading side may be useful. First, for purposes of comparison, planar crashes of near side and far side may be used. Further, the occupant on the far side of the roll initiation generally sustains the most severe injuries.

Occupant - Biomechanics

Crash injury outcomes should be reported separately for children and adults. The biomechanical responses of children are different from those of adults. First, vehicle hardware is designed for adults. Secondly, child safety seats are retrofit items that are meant to work in concert with a wide variety of restraint hardware found in the vehicle fleet. Finally, children lack soft tissue and bone development. They will not be fully developed, in general, until the child reaches 12 years of age.

Occupant – Seating Configuration

Crash severities for front and rear seated occupants are different. Further, crash severity estimates can be biased by presence of vehicles with many occupants. The representation of the vehicle fleet suggests that there are many seating positions other than the front that might be occupied, however, consideration for mass, human and cargo, distribution should be considered. For normalization of the data analysis, it is suggested that the driver and right front passenger would serve to balance impact orientation reporting.

Clinical Case Analysis

Finally, based upon this update, CDS variables and attributes should be revised to capture more specific elements of rollover crashes. Of specific interest is the further definition of the rollover object to which an attribute might be ascribed. For instance, the width of a curb or the type of ground could be aggregated in a statistical analysis, however, for an engineering analysis the disaggregated elements may be crucial. These descriptors could lead to better understanding of the true sequence of a rollover crash and eventual test design based upon these concepts. Some of these descriptors might be found via clinical review for cases with copious supplementary information. Currently, however, the existing CDS variable set does not require this type of reporting.

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For additional copies of this research note, please call 1 800 934 8517 or fax your request to 202 366 3189. For questions regarding the data reported in this research, contact Ana María Eigen [202 366 2903]. This research note and other general information on highway traffic safety may be accessed by internet users at: http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/AvailInf.html