The Crash Problem for Advanced Restraints

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ABSTRACT

In response to evolving sensor and occupant retention technologies, the National Highway Traffic Safety Administration (NHTSA) will soon begin cooperative research to develop test procedures for advanced occupant restraints. It is believed that these restraints will be real-time adaptive to a variety of crash types and severities, as well as address such problems as improving belt effectiveness in front-front crashes to higher than the current 50% fatality reduction level and possibly making the belts and air bags better suited for rollover and offset crashes. The research will address: identification of potential improvements in current restraints, identification of minimum performance and objective testing, as well as performance metrics, and calculation of benefits inherent in such improvements. To complete these tasks, the identification of a target crash population, estimations of the effectiveness of advanced restraints from test and evaluation, and benefits calculation based upon the target population and the effectiveness estimates is necessary. This paper serves as an initial analysis of the advanced restraint system target population.

The Crashworthiness Data System (CDS) of the National Automotive Sampling System (NASS) was chosen for the initial work owing to its complete crash, vehicle, occupant, and injury reporting in the U.S. In addition, in order to maintain a focus on recent vehicle designs and performance, the most recent eight years of data were used for an occupant population that contains only belted drivers and passengers. By analyzing this population, attention was focused on the current performance of restraints in order to identify opportunities for restraint improvement. Restrained occupants with Maximum Abbreviated Injury Scale (MAIS) groupings of 3+ (serious injuries and higher) were quantified. Disaggregations of the primary direction of force, impact area, and injury types, among others, were computed across all crash types in order to develop an understanding of the requirements for advanced restraint prototype designs.

INTRODUCTION

NHTSA is interested in developing research on objective performance tests for advanced integrated safety systems and is now focusing attention on two projects in this area: crash imminent automatic braking, and advanced restraints. The first of these projects assumes the current state of the art in restraint technology and seeks to leverage crash avoidance sensor technology to make restraints perform better, while the second is focused more on using the sensors to accomplish real-time adaptation in the restraints. Although these projects are not directly linked, the advanced restraints project will use many data techniques identified in the imminent braking project, which include using data set queries of the NASS CDS data to build and study target crash scenarios. These scenarios will then be used to identify opportunities for intervention and corresponding benefits. This paper reports on the initial steps of this effort, determining the crash target population for advanced restraints.

The advanced restraints data analysis project is deemed a continuation of the work started in support of the imminent braking project. As basis for that effort, a 36 crash typology was developed using the General Estimates System (GES) of the NASS (Najm and Smith, 2007). The NASS GES is a sample of police-reported crashes occurring on public roadways in the United States and, with weighting factors for the samples, provides overall crash frequency data.

In the previous work, the 36 GES crash types were ranked according to frequency, economic cost, and occupant functional years lost. However, a large portion of these crashes were damage only crashes, which are of little interest in developing advanced restraints. For this reason, a new approach was sought to characterize pre-crash and crash scenarios that could form a basis for the injury reduction benefits analysis.

Table 1 (tables and figures are presented at the end of the paper) shows an initial taxonomy of crash configurations disaggregated by vehicle or object contact. Note that the object type struck for frontal impacts may be either a wide or narrow object and it is important to distinguish these. Frontal, left side, and right side are for planar crash events. The rollover event has been disaggregated by initiation type and does not rely on vehicle damage.

Advanced restraint systems could incorporate sensors such as vision and radar that provide data in the crash timeline before the vehicle-vehicle contact occurs. In this way the system could see, anticipate, and provide the best protection to the occupants. This action likely follows a crash avoidance segment where driver braking, roadway geometry, vehicle characteristics, and vehicle handling are critical. However, in the case of advanced restraints, although interest exists in the vehicle characteristics, issues of handling become more obscure owing to the foregone notion that a crash will occur and the restraint should mitigate rather than avoid the crash. For this reason, NASS CDS was consulted to build the scenarios summarized in Table 1. NASS CDS is a sample of tow-away crashes with injuries occurring on public roadways in the United States. Variables and attributes describe more complete occupant demography than that seen in GES, as well as a listing of injuries by body region, type, severity, and location on the given body region, as well as injury source.

The approach taken in this initial effort was to develop and evaluate the problem definition by first determining the most common and the most harmful crashes for belted occupants and then to present these results in scenarios detailing the sequence of events. This paper presents the initial data analysis effort that could lead to advanced restraint scenario creation. Such scenarios will eventually be used as the basis for countermeasure development, testing, and, finally, benefits analysis.

METHODOLOGY

The creation of initial scenarios was approached in two ways that were merged for a final result. A top-down approach was used on the CDS data to step-wise disaggregrate the belted driver data into crash types to find the most common types and focus on those, then assess the most common injury types and counts. In coordination with this, a bottom-up approach was used on the injury data to better understand the causation of injury. Finally, the two approaches were merged to establish and select the most common injury types from which scenarios are used to develop advanced restraints performance requirements.

Top-Down Damage and Injury

A general query was first made of the NASS CDS to estimate the total tow-away crash population and the corresponding restraint usage characteristics to date. Next, vehicles were disaggregated by model year, with the retention of vehicles of model year 1998 and later. The model year served as the surrogate for modern restraint systems, including three-point lap and shoulder belts, presence of pretensioners, load limiters, the advent of the second generation, depowered air bags, and more advanced seat belt and air bag technology. This was done to preserve homogeneity in the restraints available within the late model vehicles.

CDS crash variables were selected to capture vehicle attitude, crash severity, and direction of force. The most severe event is normally based upon vehicle deformation processed through an algorithm to produce delta-V. Delta-V is a measure of crash energy transfer and deemed to form part of a composite crash severity indicator to be studied during this project. However, the algorithm yielding delta-V may fail owing to extreme planar conditions and in all rollover crashes. For planar events, if a researcher is able to provide a quantitative or qualitative value, it will be reported as an estimated delta-V. The decision to report quantitative or qualitative severity is dependent upon the degree of confidence that the NASS CDS researcher is able to assert. In the case of rollover crashes, crash severity may not be calculated using the existing crash algorithm and the estimated crash severity will always take on a qualitative value.

The top-down analysis was based on a model of zone of impacts for the most severe event, as seen in Figure 1. Planar crash events occurred from one o'clock through 12 o'clock and rollover crashes were identified with zero, as seen in Figure 1. For rollover crashes, the type of damage distribution was consulted to ascertain whether the rollover crash was the most severe event. A composite variable was then formed for rollover crashes by consulting both the type of damage distribution and rollover initiation type. The rollover initiation type was further summarized to characterize tripped versus untripped rollover crashes.

The vehicle analysis was an iterative process and yielded commonalities based upon Collision Deformation Classification (CDC). The elements of interest included the principal direction of force

(PDOF), damaged vehicle plane, specific horizontal location, specific vertical location, and the extent of damage. The restriction on the extent of damage was loosened owing to the case representation across the zones of deformation.

The first analysis conducted was for damage to the frontal plane pursuant to force with an, 11, 12, or 1 o'clock direction. This would indicate a head-on collision with full frontal or offset frontal damage. The full frontal crash with a 12 o'clock direction of force was found to be the most prevalent; however, the aggregate of the left frontal and right frontal offset crashes exceeded the full frontal crashes. Further, examination of the cases indicated that everything below the belt line on the vehicle body was prevalently damaged. Finally, an array of extent zones from one to five appeared in the initial analysis. Owing to the integration of injury parameters into this selection process, the extent zone was not specified in subsequent queries. Thus, the database query yielded 12FDEW (**12** o'clock direction of force, **F**rontal damage plane, **D**istributed damage, **E**verything below the belt line, and **W**ide distributed damage) as a prevalent CDC where the extent zone was omitted to generalize the injury search.

This methodology was generalized to consider all crash types at the MAIS 3+ level, as shown in Figures 2 through 4. MAIS 3+ subsumes MAIS 3 (serious), MAIS 4 (severe), MAIS 5 (critical), and MAIS 6 (maximum) injuries. Further, comparison of these figures focusing on frontal crashes shows that MAIS 3+ head injuries trailed thoracic injuries. Abdominal injuries were also examined and summarized in Figure 4. The prevalence of the frontal injuries was seen in the plots for thoracic and abdominal injuries. Comparable head and thorax injury frequencies were seen for tripped rollovers. Frontal crashes resulting in MAIS 3+ head injuries were disaggregated by the specific horizontal location. Frontal offset injuries were the most prevalent for head and thorax injuries. These results are pending further case review.

Figures 2 through 4 clearly show the predominance of frontal crashes as the largest part of the overall MAIS 3+ injury problem. Consequently, the next step was to look in more detail at these frontal crashes to determine how the belted drivers are being injured, in what body regions. Analysis of the mortality rate and injury costs dictated the body regions of interest in defining the crash problem (Eigen and Martin, 2005). The frequency counts for these major body region injuries in frontal crashes are shown in Figure 5. Here, the size of the relative injuries are shown, with the largest being thorax injuries, followed by head, neck, and abdomen.

Bottom-Up Injury and Damage

Using the results of Figure 5, the bottom-up approach to CDS analysis starts with the most common type of injury and seeks to find clues as to how these came about in a kinematic sense to lay a basis for scenario development. The accuracy of this task was corroborated using the Biomechanics Tab (BioTab) found in the Crash Injury Research and Engineering Network (CIREN) database. For example, within the 20,197 weighted cases describing the various types of head injuries, 75% were due to head contact within the vehicle interior and 4% of the head injuries occur despite the lack of contact with the vehicle interior or other occupants (0.6%). Furthermore, injury from contact of the head could be due to one kind of kinematics, while injury without contact may be due to another kind of kinematics. This is assuming that the selection of non-contact by the researcher does not imply that there is a lack of physical evidence supporting contact with the vehicle interior. To avoid misinterpretation and ambiguity in describing the injury causation when incorporating the contact information, the injury parameters from CDS associated with certain and probable confidence were considered. This information was used to supplement and support a similar query using the BioTab. These two databases concurrently provided valuable and accurate clues to vehicle and occupant motions prior to and during the crash event.

Figure 5 shows the major body regions injured in frontal crashes, with the thorax region being the largest problem. Nevertheless, the head region was selected for this initial study. The choice of the head injury in frontal crashes as a focus for the initial bottom-up analysis stemmed from an examination of the relationship between the injured body region and the injury source.

The sources of injury to the head, such as contact with the A-pillar or B-pillar were more distinct than thoracic injuries occurring from the usual contact with the steering hub, rim, and wheel combination and also the belt web or belt buckle. Further, contact with the injury sources specified for thoracic injuries did not involve as much excursion by the driver as that of the head region using the given injury sources of Figure 6. Thus, the motivator for the selection of the head injury data for initial analysis was to understand why and how the belted driver was able to contact the pillars. In addition, the sample size for the head exceeded that of the neck or abdomen.

Thus, more cases were available for preliminary analysis using the head region.

Figure 6 displays several sources of injury for the head and the thorax by total weighted cases. Of note in this figure is the fact that roof contact in frontal crashes resulted in MAIS 3+ head injuries with such a high frequency. 82% of these head injuries in which the roof was stated as an injury source was made with high confidence by the researcher. The specific reasons for this result need to be evaluated before a scenario for such crashes can be detailed.

The second phase of injury analysis identified the top ten head injury types by frequency. Table 2 shows the weighting totals for these head injuries.

Next, the causation of these head injuries was investigated for two reasons. The first was to better understand the circumstances that will result in the head injury. This was performed as a means of validating and supporting the injury source data in NASS CDS. The second reason was to provide a means of aggregating similar injuries, where possible. This step alleviated one of the problems of case limitations from a query focusing only on model year 1998+ vehicles by increasing the cases that were available for analysis. This enabled the explanation of the injury causation in connection with the relationship between the injury and vehicle-level CDS parameters to be understood more comprehensively.

The following example uses both intracerebral and subdural cerebrum hematoma/hemorrhage injuries, vault skull fractures, and orbit fractures to illustrate the caution needed in steps for aggregation. The causation of these four prevalent head injury cases, acquired from Table 2, were examined to justify aggregation. This step must not be overlooked as the injuries vary by mechanisms, which is dependent upon the occupant kinematics in response to the vehicle collision (Takhounts et. al., 2003).

Hematoma/hemorrhage in the intracerebral region is typically due to bleeding directly into brain tissue, pushing the tissues against the bones of the skull. This type of injury encapsulates 31% of the hematoma/hemorrhage category. However, research has shown that 8-13% of all strokes result from intracerebral hemorrhage (Liebeskind, 2006). Although this percentage is relatively small, it is still considered in the analysis of this injury. One should be careful to examine other data in NASS CDS, such as the crash or accident summary to determine whether the intracerebral hemorrhages were due to the crash or the stroke. This detailed selection criteria will prevent the use of cases in which the injury precipitated the crash. A similar analysis should be performed during the study of injuries in other body regions.

Hematoma/hemorrhage in the subdural region is due to swelling in the area between the cerebrum/brain surface and the parietal bone/skull (Jasmin, 2004 & WebMD, 2004). The bleeding can be either minor or severe, causing a slow or rapid increase in pressure within the skull (Meagher, 2005).

All cerebrum hematoma/hemorrhages are the result of one or more blood vessels breaking in the cerebrum tissue. As a result, the influx of blood in the confined region of the brain, where the damage occurred, causes swelling and an increase of pressure within the skull. For example, the head of an occupant may be subjected to a hard blow or impact to the A-pillar during the frontal planar crash. Or, due to inertial effects of the crash, the occupant may suffer an AIS 1 neck injury such as whiplash. This minor neck injury may initiate the vibration of the brain within the skull, resulting in an AIS 3+ head injury (University of Virginia Health System, 2004). This rapid movement of the brain within the skull can also result in cerebrum hematoma/hemorrhages due to bruising, swelling, or tearing of the brain tissue. Without further specifying the type of cerebrum hematoma/hemorrhage (intracerebral small, subdural small, or subdural NFS), the results of this analysis showed that aggregation of these three groups of cerebrum injuries were possible since they all resulted in swelling and an increase of pressure within the brain.

Vault comminuted fractures are bones of the skull that are broken, splinted, or crushed/shattered into a number of pieces (MedicineNet.com, 2003). The bones of the vault skull include: parietal, frontal, squamous temporal, and the squamous part of the occipital (The Johns Hopkins Hospital Center for Craniofacial Development and Disorders, 2000).

Orbit fractures, are any or combination of open (where a broken bone penetrates the skin), displaced (where the fragments are not perfectly aligned), or comminuted fractures of the bone around the eye (The Medical Center Online, 2006). Non-deployment of the air bag increases the occupant contact with the steering wheel, resulting in the orbit fracture (Duma and Jernigan, 2003).

Following the analysis and aggregation, where applicable, three injury groupings resulted for this example: Cerebrum Hematoma/hemorrhage, Vault skull fracture comminuted, and Orbit fracture open/displaced/comminuted. The vault skull and orbit fractures could not be aggregated because the causes and locations of these injuries differed.

The next step is to aggregate injuries to infer kinematics at the occupant level. For example, suppose in frontal crashes, a severe brain injury with a face injury indicates a head contact causation. On the other hand, a brain injury without a facial injury indicates a non-contact head injury. While these are both head injuries, the restraint countermeasure could be quite different, so they must be separated.

To further strengthen the comprehension of the injury causation following an aggregated grouping scheme, the most prevalent CDC value among the head injuries was obtained. Without application of the extent, this CDC value corresponded to 12FDEW. Next, the most prevalent accident type for 12FDEW was chosen to constrain the given data set to a particular vehicle impact description for a detailed causation description.

Table 3 displays the parameters that are needed to better describe the transition from injury to CDC (occupant to vehicle level) for each of the head injuries, utilizing the outcome of the CDC query and vehicle maneuver constraint.

Beginning with the occupant, the presence of alcohol or drugs is noted as it may affect the biophysical response to insult (Couper and Logan, 2004). This may provide additional locations of contact within the vehicle interior for the restrained occupant, who is under the influence of the substance. Thus, this parameter should be analyzed to determine whether it contributes any new information.

Next, the injury source parameter is examined as it initiates the transition to the vehicle level by connecting the occupant and injury with the vehicle interior. The accuracy of this step is fundamental for the transition to be made successfully. Thus, a combination of the evidence supporting the occupant contact with the vehicle interior, such as scuff mark(s), tissue contact(s), tooth mark(s), and bent structure(s), along with the researcher's level of certainty that the evidence supports the injury sources noted will aid in the selection of the appropriate cases for analysis.

In certain cases, the occupant sustains multiple injuries, in addition to the MAIS 3+ injury initially selected. Such instances require that these injured body regions, regardless of the injury severity, should be included in the analysis along with the corresponding injury source only if they meet the accuracy requirement. Thus, evidence supporting the injury source must also be substantiated by the researcher through their certainty level when determining the relationship between the injury and the injury source.

Next, information regarding the gender, age, height, and weight of the occupant is needed to determine whether the injuries are dependent upon these factors. This is similar to the BioTab's description of other contributing factors that affect the injury causation, mechanism, and severity. Whether these four parameters are related to the injury and injury source through the occupant's seat back position, seat track position, and seat belt anchorage position should also be investigated.

Afterward, all vehicle intrusions and all severe events and corresponding CDC, where applicable, should be included in the analysis. This step clarifies whether or not occupant contact with the vehicle interior occurred on account of the intrusion(s). It is also necessary to include the information describing any pre-event movement that initiated the crash, critical pre-crash event that resulted in the crash, and any avoidance maneuver that the occupant performed leading to the crash.

Finally, to complete the transition from the given injury to the given vehicle-level crash, the heading angle and its corresponding other angle, which describes the vehicle configuration and location of the damage to the vehicle with respect to the North direction is necessary. Inclusion of this parameter is important as different geometry configurations for the given CDC may result in different injury and injury combinations.

From these parameters, the injury causation or scenario can be developed and used to explain the occupant positioning and movement that generated the injury as it relates to the CDC in the event of an imminent collision in time sequence. Through the listed parameters of Table 3, a causation describing the possible series of events that may result in one of the head injuries is possible.

As an aside, this process of injury selection led to vehicle-to-occupant case selection substantiation, as well as providing a complete case overview from the injury-to-vehicle perspective. This method will be applied to all other body regions for occupants in all seating positions (front and back seat passengers).

Although the listed parameters are sufficient to describe the injury causation resulting from the crash, there are other parameters not included in the NASS CDS database that would enhance and provide a more comprehensive scenario description to be used in vehicle testing situations and also to draw more definitive conclusions. For instance, examination of the seat belt material properties in conjunction with the retractor locking mechanism by body type and vehicle model may serve to be useful in understanding the excursion of the driver. Perhaps some combinations of the airbag properties, seat belt properties and retractor types function better than other system combinations (Ridella et. al., 2003). This information, along with the parameters declared in Table 3, may prove to be useful in explaining why occupants in similar crashes sustain different injuries.

Merging top-Down and Bottom-up Data

The research reported in this paper serves as the foundation for merging the top-down data with the bottom-up data into scenarios. This next step will be done first for frontal crash head injuries. The transition from the injury to the vehicle level will be possible through the use of the Collision Deformation Classification. This will both enable and ensure the proper alignment of the two methods prior to the merger.

SUMMARY

The objective of the advanced restraints research was to develop a set of crashworthiness scenarios that capture the timeline of events leading up to and during crashes that result in injury. These scenarios would contain a description of the conditions and events of the crash such that performance requirements for advanced restraints may be specified and benefits computed. Initial study of this problem suggested the use of CDS pre-crash variables and the sequence of harmful events. This would be used in the development of a chronology of what the vehicle sensors would detect and occupants would experience leading up to, and during the crash.

A framework for a top-down approach to the problem has been developed and preliminary analyses performed for model year 1998 and later vehicles in 1997 and later CDS data. Areas of damage and principal direction of force were analyzed. These results showed that the predominant types of crashes where belted drivers are getting injured are frontal and rollover crashes. Frontal crashes were analyzed in more detail showing four predominant injury areas in rank order: thoracic, head, neck, and abdomen.

Head injuries in frontal crashes were examined in more detail to develop a framework for a bottom-up problem definition approach, which would later be extended to all crash types. The most common types of head injuries were found to be cerebrum hematoma/hemorrhage, vault skull fracture, and orbit fractures. These injuries were caused by contact with the A-pillar, B-pillar, roof, and steering hub, rim, and wheel combination.

A taxonomy for crashworthiness scenarios was developed and presented based on an evaluation of all types of crashes. However, the research stopped short of creating the detailed crashworthiness scenarios.

Subsequent Study

Even at this early stage of the research it is clear that many data sources will be needed to develop useful scenarios, not just NASS CDS. Such sources include data from the CIREN, the Fatality Analysis Reporting System (FARS), and NHTSA Special Crash Investigations (SCI), all of which will certainly be needed. In addition, European data will be considered, if available, in the way that CIREN or SCI would be used to supplement the understanding of scenarios found in nationally representative data sets. The specific approach to this data integration will be considered in the context of the cooperative research program that NHTSA is now implementing with carmakers and suppliers.

Much work remains to be done for frontal crashworthiness scenarios, beginning with merging the top-down data with the bottom-up data sets for head injury scenarios. Next, the approach could be extended into thoracic and other injuries in frontal crashes, then similarly into other crash types, especially rollover. For instance, a large number of head contacts with the roof can be found in frontal crashes in which the driver was belted (Figure 6). This phenomenon is also present when examining the rollover problem for belted drivers. Thus, an advanced restraint that keeps the belted driver’s pelvis in the seat could have a positive effect in both of these crash types. As these are preliminary results, the injury causation and occupant kinematics must be studied in greater detail before reaching any conclusions relative to frontal crashes and, subsequently, drawing any shared conclusions between frontal and rollover crashes. Nonetheless, it is precisely this type of insight that could lead to substantial benefits for advanced restraints.

Electronic case files may be accessed via the NHTSA website, Electronic Case Access Screen. The hyperlink is as follows:
http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa

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Table 1: Proposed Crashworthiness Scenario Taxonomy					
	Subcategory				
Crash Mode of Interest	Case Vehicle General Area of Damage	Other Vehicle General Area of Damage	Object Type	Taxonomy Index	Resultant Scenario
Frontal Impacts	Front	Front		1a	Front-vehicle front
	Front	Side		1b	Front-vehicle side
	Front	Rear		1c	Front-vehicle rear
	Front		Wide	2a	Front-wide object
	Front		Narrow	2b	Front-narrow object
Left Side Impacts	Left	Front		3	Left side-vehicle front
	Left		Any	4	Left side-object
Right Side Impacts	Right	Front		5	Right side-vehicle front
	Right		Any	6	Right side-object
Rear Impacts	Rear	Front		7	Rear-vehicle front
Rollover	Tripped			8	Tripped rollover
	Untripped			9	Untripped rollover

Note: Shaded areas denote regions inapplicable to the crash scenario.

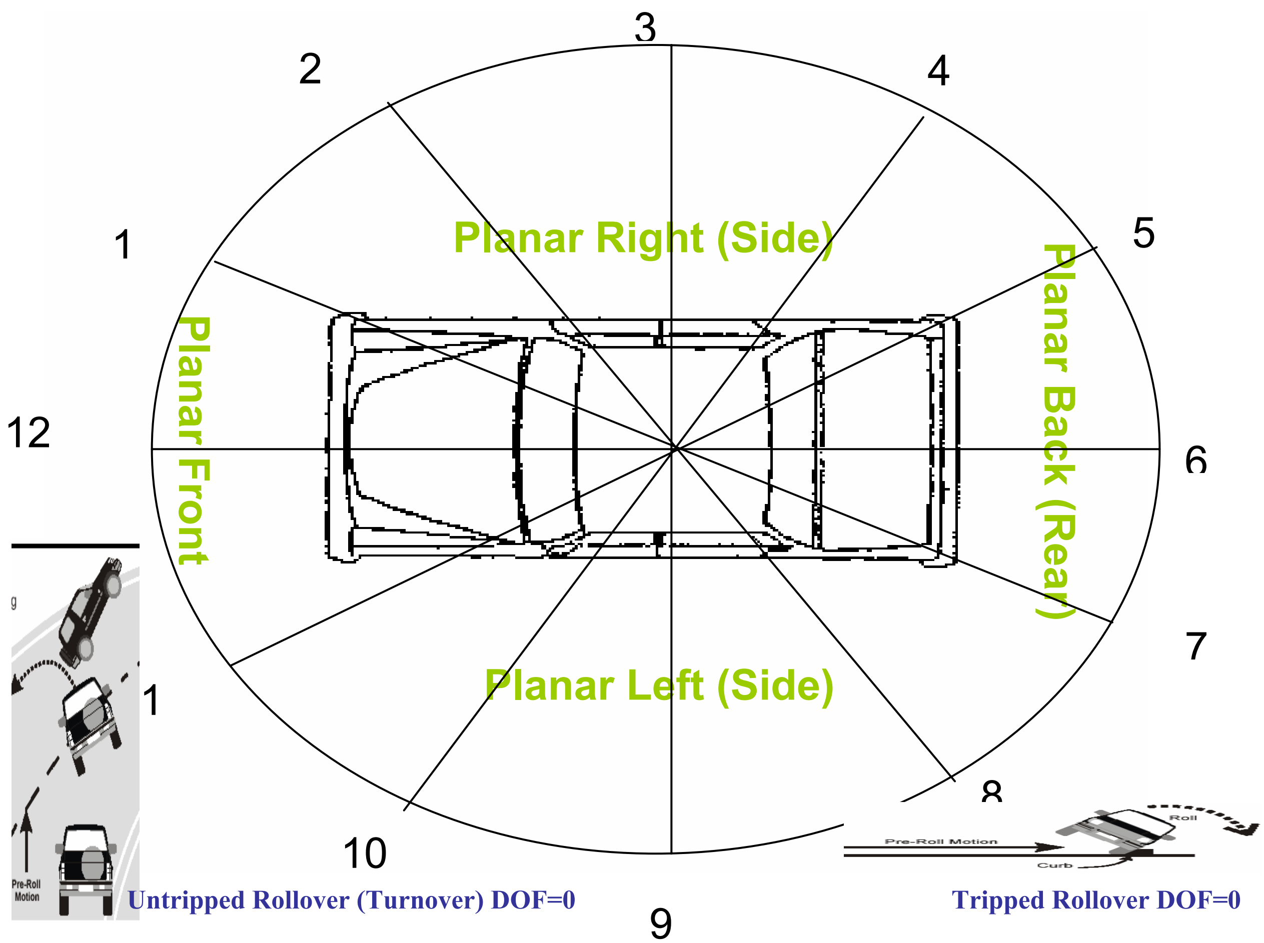

Figure 1. Zones of Interaction

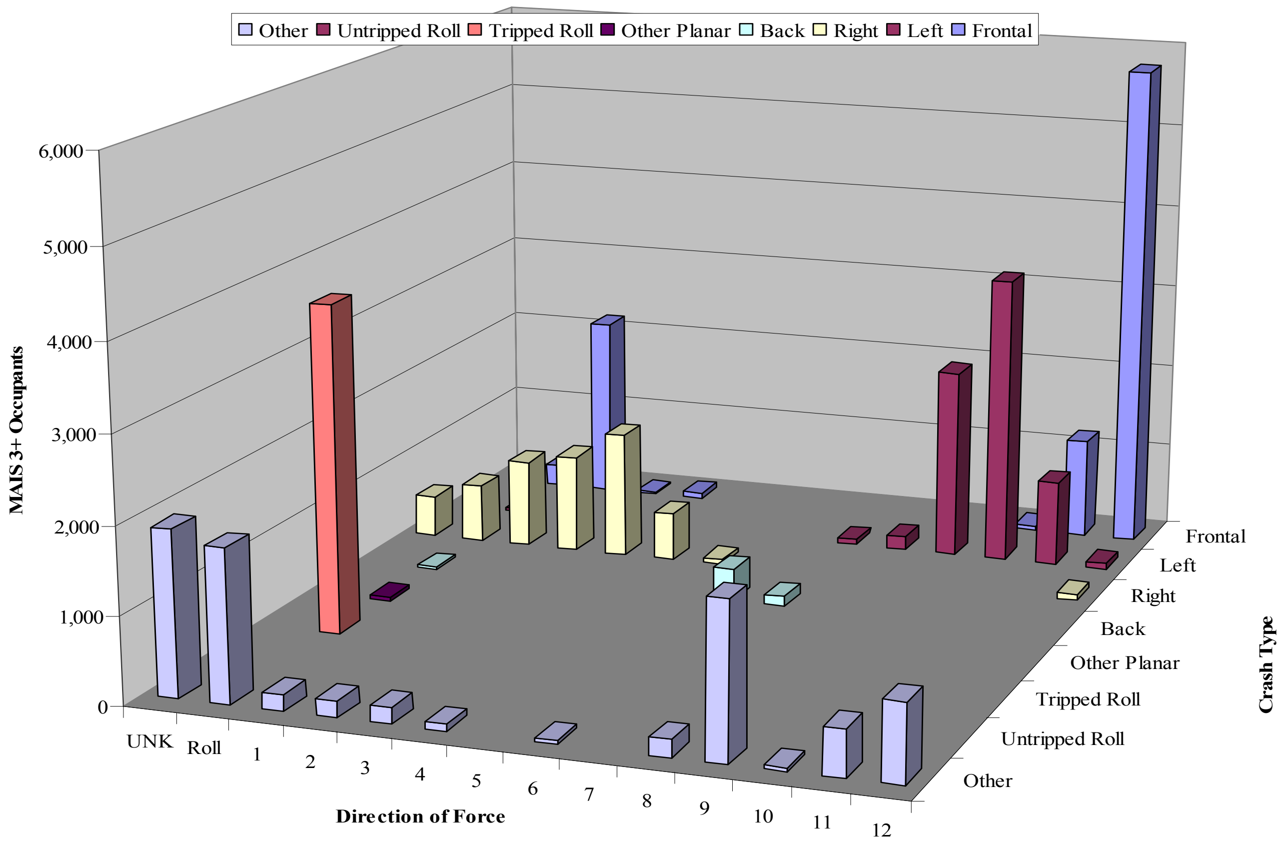

Figure 2. Occupants with MAIS 3+ Head Injury, traveling in Model Year 1998+ Vehicles, involved in Tow-Away Crashes, by Planar Direction of Force or Rollover and Crash Type, Weighted Data

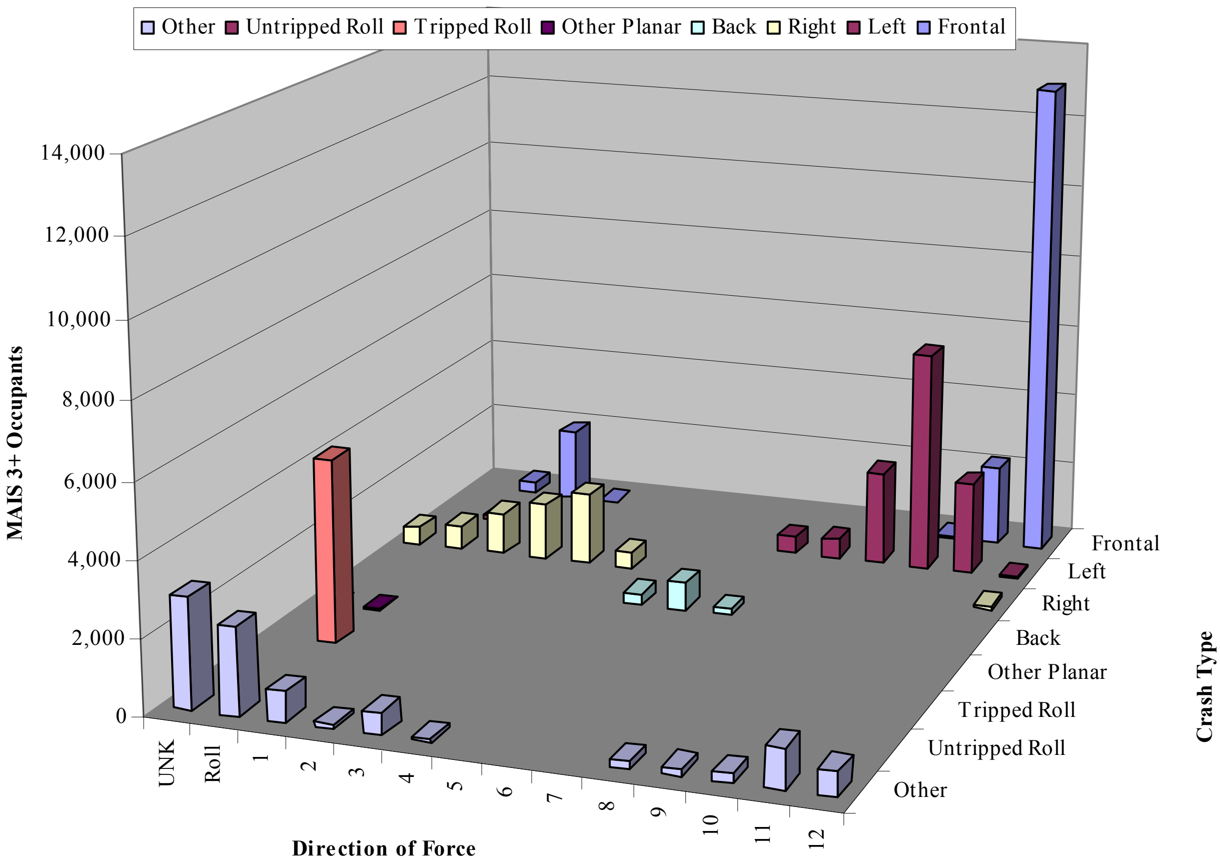

Figure 3. Occupants with MAIS 3+ Thorax Injury, traveling in Model Year 1998+ Vehicles, involved in Tow-Away Crashes, by Planar Direction of Force or Rollover and Crash Type, Weighted Data

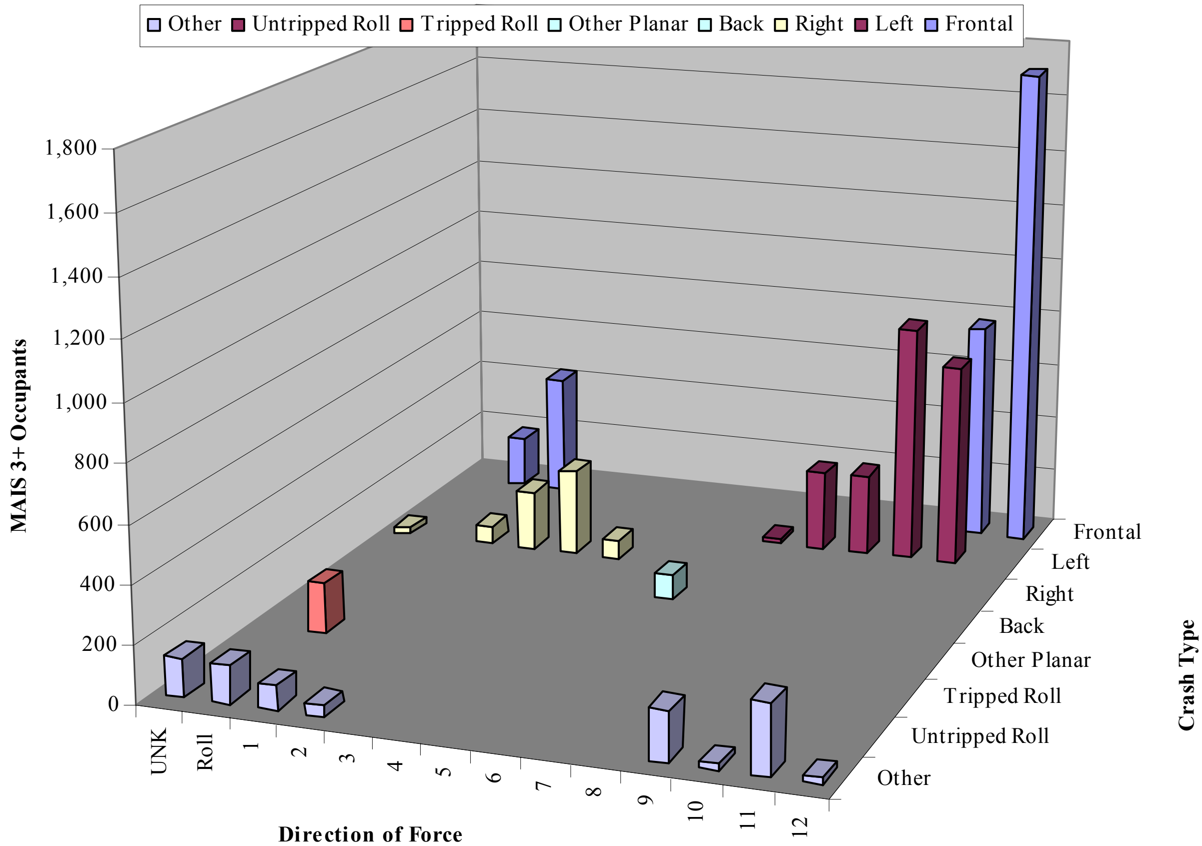

Figure 4. Occupants with MAIS 3+ Abdominal Injury, traveling in Model Year 1998+ Vehicles, involved in Tow-Away Crashes, by Planar Direction of Force or Rollover and Crash Type, Weighted Data

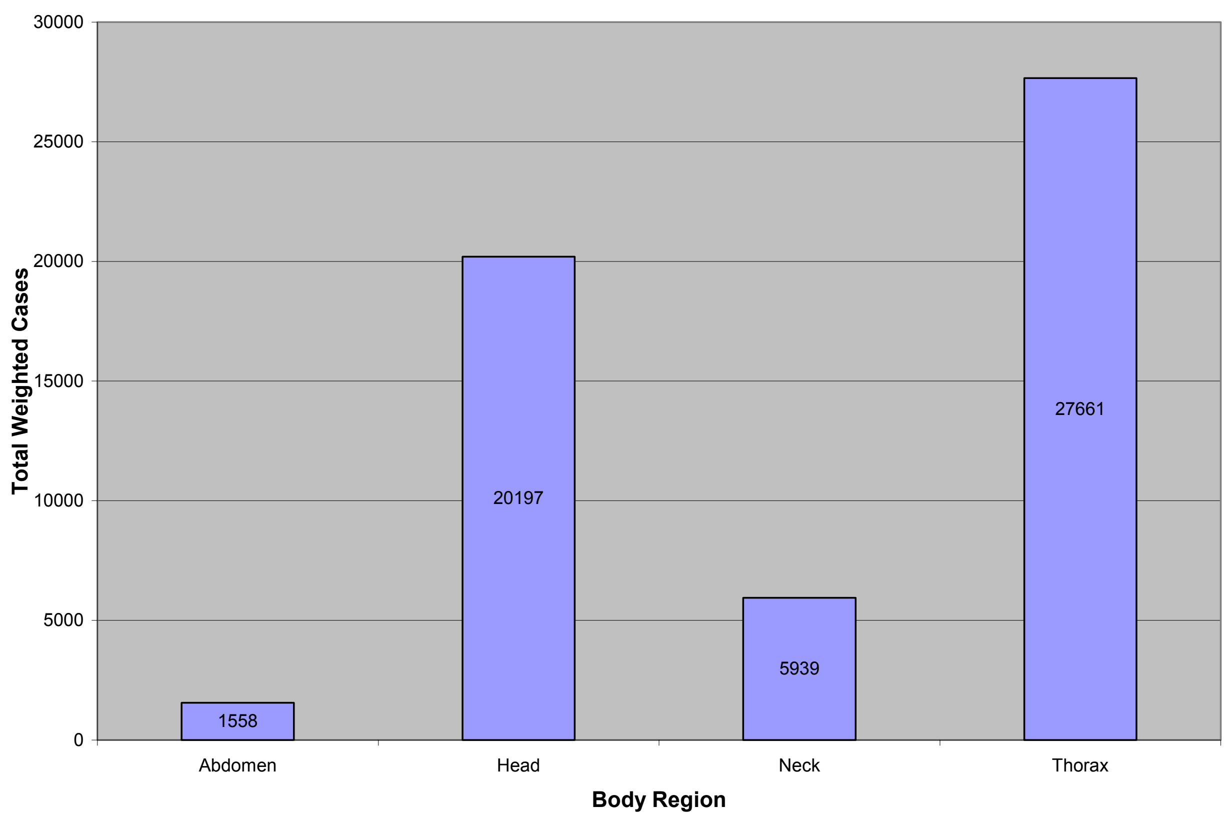

Figure 5. Total weighted cases by body region for drivers with MAIS 3+ injuries sustained in frontal crashes

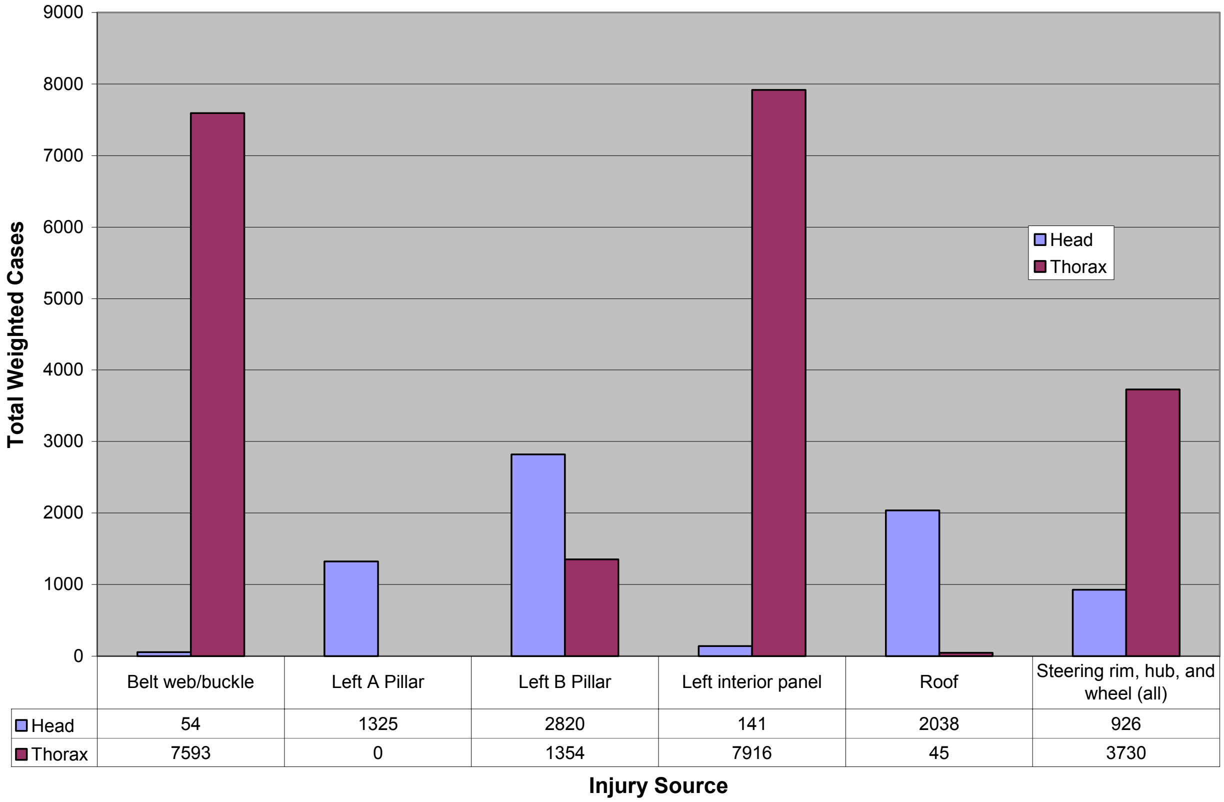

Figure 6. Sample of Several Injury Sources for the Head and Thorax Body Regions in Frontal Crashes, Weighted Data

Table 2: Top ten head injuries for drivers with MAIS 3+ injuries sustained in frontal crashes	Total Weighted Cases
Cerebrum hematoma/hemorrhage NFS - extra axial*	1902
Cerebrum hematoma/hemorrhage intracerebral small	1817
Cerebrum subarachnoid hemorrhage	1673
Orbit fracture open/displaced/comminuted	1212
Cerebrum hematoma/hemorrhage subdural small	1048
Cerebrum diffuse axonal injury (white matter shearing)	929
Vault skull fracture comminuted	806
Cerebrum contusion single small	720
Brain stem laceration	704
Cerebellum hematoma/hemorrhage subdural NFS*	694
*Note: NFS = Not Further Specified.	

Table 3: NASS CDS parameters that will aid in the transition from the occupant to the vehicle level (injury to CDC)
All other injured body regions (regardless of injury severity) and its corresponding injury source (if multiple injuries were sustained)
All severe events resulting from the crash and its corresponding CDC, where applicable
All vehicle intrusions
Avoidance maneuver performed
Critical pre-crash event that resulted in the crash
Gender, Age, Height, and Weight
Heading angle and Other angle to describe vehicle configuration and location of the damage to the vehicle with respect to the North direction, where applicable. These two angles provide a geometric configuration of two vehicles at the point of impact. This information is used to supplement the PDOF.
Injury source
Pre-event movement which initiated the crash
Presence of alcohol or drugs
Seat back position
Seat track position
Seat belt anchorage position