Influence of Injury Risk Thresholds on the Performance of an Algorithm to Predict Crashes with Serious Injuries

George Bahouth  
Impact Research, Inc.

Kennerly Digges  
Carl Schulman  
The William Lehman Injury Research Center

ABSTRACT – This paper presents methods to estimate crash injury risk based on crash characteristics captured by some passenger vehicles equipped with Advanced Automatic Crash Notification technology. The resulting injury risk estimates could be used within an algorithm to optimize rescue care. Regression analysis was applied to the National Automotive Sampling System / Crashworthiness Data System (NASS/CDS) to determine how variations in a specific injury risk threshold would influence the accuracy of predicting crashes with serious injuries. The recommended thresholds for classifying crashes with severe injuries are 0.10 for frontal crashes and 0.05 for side crashes. The regression analysis of NASS/CDS indicates that these thresholds will provide sensitivity above 0.67 while maintaining a positive predictive value in the range of 0.20.

INTRODUCTION
Automatic Crash Notification Systems are now capable of transmitting vehicle data, in addition to geographic coordinates, after a crash with air bag deployment. In 2008, an expert panel sponsored by CDC recommended the transmission of the following crash variables: delta V, crash direction, belt use, multiple impact and rollover crashes [CDC 2008]. This data would be used as input to an algorithm that could predict those crashes most likely to require urgent response. The panel recommended that the algorithm prediction should not cause an over-triage (false positive) greater than 4 out of 5. This false positive ratio was expressed in the CDC report as a 20% risk of serious injury. The 20% requirement would limit the positive predictive value (PPV) of the algorithm to a value greater than 0.20.

The use of algorithms that use crash data to predict injury risk was the subject of research sponsored by the National Highway Safety Administration in 1996. One of the resulting papers showed the influence of as many as 23 crash variables on injury risk [Malliaris, 1997]. In the final presentation to NHTSA on March 27, 1997, the most influential variables from this analysis were programmed to provide a graphic depiction of the injury risk for any combination of values for the crash variables. This algorithm was named URGENCY and was then applied by NHTSA in their field trial of Automatic Crash Notification Systems [Kanianthra, 2000]. The application and benefits of the system to predict crash injuries were articulated in a paper written by the participants in the NHTSA study [Champion, 1999]. A more focused study separated the crash modes and evaluated the improved accuracy for each added variable [Bahouth, 2003].

Earlier papers [Malliaris, 1997, Augenstein, 2006] summarized the methodology for predicting injury risk from crash data that could be transmitted by an automatic crash notification system. The crash data for the algorithm was based on variables in the NASS/CDS database for the years 1997 to 2003. More recently, the Center for Disease Control (CDC) published a report [CDC 2008] that summarized recommendations from an expert panel for the crash data to be transmitted by ACN systems. The CDC report did not address the interpretation of the transmitted data. A goal of this study is to further develop and evaluate predictive algorithms from the data elements recommended in the CDC report, applying the methodology employed in earlier research [Malliaris, 1997, Bahouth, 2003, Augenstein, 2006]. Additional years of NASS/CDS data are now available to enrich the database over that used in the earlier papers.
A significant knowledge gap exists in determining the injury risk threshold required to capture a large percentage of vehicle occupants with serious injuries without overloading the response system with those who do not need urgent medical attention. There is no previously published research to address this problem. A principal objective of this paper is to determine the risk thresholds of a NASS based algorithm that will correctly identify a large fraction of the seriously injured while providing a positive predictive value (PPV) greater than 0.20.

METHODS

The National Automotive Sampling System/Crashworthiness (NASS/CDS) used in this study is the only available database that provides detailed information on injuries and crash factors and is representative of the crashes in a geographic area – in this case the US. The requirement for entry into NASS/CDS is that one of the vehicles involved in the crash must have been damaged sufficiently to be towed away from the scene. The NASS/CDS is a stratified sample, with the more severe crashes being sampled more frequently than the less severe crashes. Each case is assigned a weighting factor so that each case can be extrapolated to estimate the frequency of various crashes and injuries in the United States. Within NASS/CDS, specific injuries sustained, including their severities, are recorded allowing for the direct association of crash conditions with crash outcomes as used in this study.

This study addresses passenger vehicle occupants over the age of 16 who may have severe or time critical injuries following a crash. This category includes occupants who sustained at least one or more injuries with an Abbreviated Injury Severity (AIS) Score of 3 or those who were fatally injured during a crash due to trauma. AIS 3 or higher injuries are serious (AIS3), severe (AIS4), critical (AIS5) and maximum (AIS6) injuries. Throughout this text, these occupants will be referred to as MAIS 3+F injured occupants. In NASS/CDS weighted data, approximately 3.5 million front seat occupants are exposed to crashes each year (1998-2007). Of this population, 101,000 are injured with a Maximum AIS score of 3 or higher injuries (MAIS 3+F).

The injury predictive algorithm was developed using multiple regression analysis of the crash variables recommended by the CDC panel. Separate algorithms were developed for different crash directions. The algorithms were trained using NASS 1998-2007. NASS 2008 and 2009 were used to test its predictive accuracy of the algorithms. The predictive accuracies were found to vary with the risk threshold applied to the algorithm. The risk thresholds were varied and the resulting predictions were evaluated to determine the threshold that corresponded to a PPV of 0.20.

Findings from available literature confirm the use of change of velocity (deltaV) as a measurement of crash energy and crash severity. (Malliaris 1997, Jones 1989, Siegel 1993, Augenstein 2003). There is, however, an issue with the crash severity predictions in NASS. The deltaV is based on a calculation of the energy absorbed by the vehicle structure. It relies on measurements of the vehicle damage and estimates of the masses of the vehicles, their stiffness and the direction of the crash. Slightly more than half of the cases of the approximate severity to deploy the airbag have a deltaV recorded. For the purpose of this study, it is assumed that the crashes without deltaV recorded have the same crash severity as those with recorded deltaV and their exclusion will not likely bias estimates presented here.

The ability to manage the kinetic energy of a vehicle and occupant depends largely on the primary direction that decelerating forces are applied. For example, in frontal crashes the frontal crush zones, seatbelts and frontal airbag systems help to manage energy along the longitudinal axis of the vehicle. These features are less effective in reducing injury to nearside occupants in lateral crashes of equivalent severity as measured by deltaV.

For this study, crash mode has been categorized using Collision Deformation Classification (CDC) data collected by NASS/CDS investigators. Each mode is categorized as follows:

Frontal: Any Seating Position, (PDOF≥11 and PDOF≤1), or (PDOF=10 or 2 where General Area of Damage is Front)

Nearside: (PDOF≥2 and PDOF≤4, Right Seating Position, General Area of Damage is Right) or (PDOF≥8 and PDOF≤10 and, Left Seating Position, General Area of Damage is Left)

Farside: (PDOF≥2 and PDOF≤4, Left or Middle Seating Position, General Area of Damage is Right) or (PDOF≥8 and PDOF≤10 and, Right or Middle Seating Position, General Area of Damage is Left)

Rear: PDOF≥5 and PDOF≤7
These same crash categories for frontal and side impacts were published and applied by NHTSA during the Final Economic assessment of the FMVSS Advanced Airbag Final Rule (NHTSA, 2000). In the regression analysis to follow, these definitions will be applied to occupants seated at the driver and right front passenger positions.

**Regression Analysis**

The application of crash variables to the population of occupants in crashes above the ACN threshold attempts to identify front seat occupants who may be seriously to fatally injured. A model which estimates injury risk based on crash characteristics can be applied. This model or approach to processing crash information to improve rescue care is known as the URGENCY algorithm [Malliaris, 1997]. The higher the injury risk, the larger the expected proportion of seriously injured. If an injury risk threshold is established and all crashes above that risk value are designated as serious, the resulting population will contain both seriously injured and non-seriously injured people. Within that population, those that are not seriously injured are called false positives. The proportion of seriously injured occupants who are correctly identified as injured by the model is known as sensitivity. The population that is designated as not serious crashes will also contain some seriously injured people. These seriously injured people that are missed are called false negatives. The proportion of non-seriously injured occupants who are correctly identified as non-seriously injured is known as specificity. The ratio of the correctly identified MAIS 3+ to the false positives plus the true positives is known as the positive predictive value (PPV). The challenge is to select a risk threshold that does not contain excessive false positives, yet does not allow an excessive number of false negatives. The CDC has proposed that a PPV of .20 is acceptable for triage decisions for transporting injured people to a trauma center [CDC 2008].

An objective of the regression analysis was to determine appropriate injury risk thresholds for the different crash directions. A principal constraint on the analysis was the requirement that the PPV value not be less than .20.

The variables identified by the CDC Committee for transmission with the ACN data were as follows:

- Delta V
- Principal direction of force (PDOF)
- Seatbelt usage/or without
- Crash with multiple impacts
- Vehicle type

In addition, the Committee recommended that the voice communication with crash involved occupants determine if any were 55 years old or older. For the purposes of this analysis, rollover after a front or side crash was added as a class of multiple impacts.

In order to take into account multiple factors influencing crash severity and the likelihood of injury, multiple regression techniques were used. Since the outcome of interest could fall into one of two categories (MAIS 3+ injured or non-MAIS 3+ injured), binary logistic regression is ideally suited for the analysis. In addition, certain high severity crash attributes like the occurrence of complete occupant ejection were assumed to indicate high probability of severe injury even in the absence of other crash factors.

Binary logistic regression relates the contribution of independent predictor variables (crash conditions) with dependant outcomes (injury). Using the Principle of Maximum Likelihood, an estimate of the likelihood of the outcome (injury) is derived on a scale from 0 to 100% probability. The method is described in detail in earlier publications [Malliaris 1997, Augenstein 2003, Bahouth 2003].

Equations 1-2 show the mathematical relationship between crash characteristics and injury outcome probability following logistic regression model creation. The regression parameters including the Intercept, $\beta_1, \beta_2...$ shown below are based on a least squares fit of existing historical crash data from NASS/CDS.

Eq. 1: \[ w = \text{Intercept} + \beta_1 \ast \text{deltaV} + \beta_2 \ast \text{factor}_2 \]

\[ P(MAIS3+) = \frac{1}{1 + \exp(-w)} \]

Eq. 2:

Each logistic regression model was trained using NASS/CDS 1998-2007 data. 2008 and 2009 datasets were used to evaluate the accuracy of the resulting models. Initial sensitivity evaluations were conducted using a risk prediction threshold of 0.1 for frontal and rollover crashes and 0.05 for the other crash modes. Ultimately, assessments of varying thresholds were conducted to determine best risk value to produce a PPV greater than 0.2.

Before the creation of each logistic regression model, all relevant crash attributes were reviewed for consistency and reconditioned when appropriate using SAS version 9.2. Analysis of the
NASS/CDS data was performed using procedures appropriate for the analysis of survey data and the correct interpretation of sample variances for multi-stage, clustered samples.

As previously mentioned, the binary outcome variable MAIS 3+F was used in the analysis to distinguish injured from non-injured. For this study MAIS 7 were considered unknown unless a fatality occurred. These occupants were discarded from the analysis. Cases with missing values for any model variable are unusable for model training and testing and were therefore discarded, as well.

Each vehicle front seat occupant was analyzed separately. Multiple front seat occupant vehicles would be represented twice and, in the case of lateral collisions, would be classified as nearside and farside crash involved.

A separate regression analysis was performed for each crash mode. In each of these analyses, the dependent variable was binary with MAIS 3+F injured as 1 and all others as 0.

For frontal, near-side and far-side crash modes, the variables used for regression were as follows:

- DeltaV – continuous in MPH
- Impact – binary – multi-impact yes or no
- Rollover - binary – rollover occurrence yes or no
- Belt Use – binary – belts used yes or no
- Age – 16-45 reference; 55-74 and 75+ groupings

For the binary variables 1 is yes and 0 is no.

The injury reduction benefits of air bags are well established. In virtually all front and side crashes that result in an ACN signal, the air bags will have deployed. It is not necessary to include air bag deployment as an injury predictor.

RESULTS

Table 1 summarizes the data from NASS/CDS 1998-2009. The data is for front seat occupants older than 16 years. The 11 years of data are averaged to provide annual estimates. The vehicles are limited to model year 1998 and later. The estimates are based on weighted data. In Table 1, the NASS/CDS data is separated by crash mode. The rollover category is based on the NASS rollover category. However, rollovers with damage areas associated with front, side or rear impacts prior to the rollover were excluded. For these pure rollovers, there is no basis for coding the deltaV. Consequently, these crashes were excluded from the algorithm analysis, but were included in Table 1. The annual numbers of occupants with and without MAIS 3+F injured occupants are displayed by crash direction in Table 1.

Table 1 shows that the population of seriously injured in a rear crash is small. It comprises only 2% of the seriously injured population. The rear crash mode data is insufficient to generate suitable algorithms. Consequently, this crash mode was excluded from the regression analysis results reported in the tables to follow.

<table>
<thead>
<tr>
<th>Crash Mode</th>
<th>Not MAIS 3+F</th>
<th>MAIS 3+F</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>4,659,399</td>
<td>100,404</td>
<td>4,759,803</td>
</tr>
<tr>
<td>Near Side</td>
<td>1,123,509</td>
<td>45,027</td>
<td>1,168,536</td>
</tr>
<tr>
<td>Far Side</td>
<td>1,127,373</td>
<td>21,543</td>
<td>1,148,916</td>
</tr>
<tr>
<td>Rear</td>
<td>797,255</td>
<td>3,572</td>
<td>800,827</td>
</tr>
<tr>
<td>Rollover</td>
<td>322,693</td>
<td>24,777</td>
<td>347,470</td>
</tr>
</tbody>
</table>

The pure rollovers constitute about 13% of the seriously injured occupants. For these cases there are no recorded deltaV and insufficient vehicle information in NASS to generate risk factors that are currently measured in vehicles. Development of risk factors for pure rollovers may need to wait for the information from rollover sensors to be collected in real world crashes. However, another 13% of the MAIS 3+F injured are in rollovers with a pre-roll crash and an associated deltaV. These rollovers are included as multiple impacts within crashes with front or side damage.

For the exposed population in NASS 1998-2009, the average belt use rate was 90%. For the seriously injured it was 61%. The vehicles in NASS 1998-2009 population were 62% cars, 19% SUV’s, 7% vans and 13% pickups.

The baselinemodel used all the variables listed above except age in the initial regression analysis. The model coefficients are shown in Table 2.
The consequences of varying probability cut points for the frontal, near side and far side algorithms are shown in Tables 3, 4 and 5. The prevalence of the injuries for each crash mode are listed in Table 1.

### Table 2. Coefficients for URGENCY Algorithm

<table>
<thead>
<tr>
<th>Variable</th>
<th>Frontal</th>
<th>Near Side</th>
<th>Far Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-5.2321 (p=&lt;.001)</td>
<td>-5.9529 (p=&lt;.001)</td>
<td>-5.0963 (p=&lt;.001)</td>
</tr>
<tr>
<td>(\Delta_v)</td>
<td>0.1335 (p=&lt;.001)</td>
<td>0.2092 (p=&lt;.001)</td>
<td>0.1641 (p=&lt;.001)</td>
</tr>
<tr>
<td>Impact</td>
<td>0.2743 (P=0.02)</td>
<td>1.0401 (p=&lt;.001)</td>
<td>0.6528 (p=.11)</td>
</tr>
<tr>
<td>Roll</td>
<td>1.526 (p=.001)</td>
<td>-0.4525 (p=&lt;.001)</td>
<td>0.8247 (p=.74)</td>
</tr>
<tr>
<td>Belt_Use</td>
<td>-1.1045 (p=&lt;.001)</td>
<td>-0.5558 (P=&lt;.01)</td>
<td>-1.9522 (P=&lt;.001)</td>
</tr>
</tbody>
</table>

In order to achieve a PPV of 0.20 or greater, the data from the above tables suggests a cut point for frontal crashes at 0.10 and for side crashes at 0.05. When these cut points are applied and the age of the occupant is included, the resulting sensitivity is displayed in Table 6.

In a multi-vehicle collision the algorithm may be useful in predicting injuries in other vehicles. To investigate this possibility, the regression analysis was applied at the accident level rather than the occupant level. The results are displayed in Table 7.

### Table 3. Sensitivity, Specificity and PPV of Frontal Algorithm Prediction to Probability Cut Point

<table>
<thead>
<tr>
<th>Frontal probability cut point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.595</td>
<td>0.938</td>
<td>0.183</td>
</tr>
<tr>
<td>0.10</td>
<td>0.509</td>
<td>0.971</td>
<td>0.288</td>
</tr>
<tr>
<td>0.15</td>
<td>0.321</td>
<td>0.982</td>
<td>0.293</td>
</tr>
<tr>
<td>0.20</td>
<td>0.294</td>
<td>0.986</td>
<td>0.325</td>
</tr>
</tbody>
</table>

### Table 5. Sensitivity, Specificity and PPV of Far Side Algorithm Prediction to Probability Cut Point

<table>
<thead>
<tr>
<th>Far Side probability cut point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.725</td>
<td>0.951</td>
<td>0.235</td>
</tr>
<tr>
<td>0.10</td>
<td>0.421</td>
<td>0.975</td>
<td>0.259</td>
</tr>
<tr>
<td>0.15</td>
<td>0.349</td>
<td>0.984</td>
<td>0.311</td>
</tr>
<tr>
<td>0.20</td>
<td>0.337</td>
<td>0.987</td>
<td>0.341</td>
</tr>
</tbody>
</table>

### Table 4. Sensitivity, Specificity and PPV of Near Side Algorithm Prediction to Probability Cut Point

<table>
<thead>
<tr>
<th>Near Side probability cut point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.674</td>
<td>0.900</td>
<td>0.175</td>
</tr>
<tr>
<td>0.10</td>
<td>0.511</td>
<td>0.954</td>
<td>0.257</td>
</tr>
<tr>
<td>0.15</td>
<td>0.436</td>
<td>0.975</td>
<td>0.351</td>
</tr>
<tr>
<td>0.20</td>
<td>0.373</td>
<td>0.984</td>
<td>0.427</td>
</tr>
</tbody>
</table>

### Table 6. Sensitivity, Specificity and PPV of Algorithm Prediction when Occupant Age is Included

<table>
<thead>
<tr>
<th>Age Inclusion prob. cut point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal (0.1)</td>
<td>0.594</td>
<td>0.882</td>
<td>0.269</td>
</tr>
<tr>
<td>Nearside (0.05)</td>
<td>0.839</td>
<td>0.741</td>
<td>0.192</td>
</tr>
<tr>
<td>Farside (0.05)</td>
<td>0.738</td>
<td>0.905</td>
<td>0.208</td>
</tr>
</tbody>
</table>

### Table 7. Sensitivity, Specificity and PPV of Algorithm Prediction when Accident Level is Included

<table>
<thead>
<tr>
<th>Accident Level prob. cut point</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal (0.1)</td>
<td>0.679</td>
<td>0.524</td>
<td>0.202</td>
</tr>
<tr>
<td>Nearside (0.05)</td>
<td>0.716</td>
<td>0.739</td>
<td>0.237</td>
</tr>
<tr>
<td>Farside (0.05)</td>
<td>0.520</td>
<td>0.895</td>
<td>0.283</td>
</tr>
</tbody>
</table>
DISCUSSION

According to a recent CDC expert panel, rapid identification and treatment of injured occupants will improve injury outcomes and reduce deaths following a crash [CDC 2008]. A goal of this study was to quantify the frequency that an URGENCY algorithm would accurately distinguish occupants who need immediate medical attention from those who do not. A number of previous studies have applied the methodology developed by Malliaris and expanded by Bahouth [Malliaris, 1997; Bahouth, 2003]. However, there have been no published values for the coefficients used in the predictive algorithm since the study by Bahouth in 2003. This paper presents the URGENCY coefficients, based on the most recent years of NASS data.

A critical impediment to the use of vehicle crash data to improve triage decisions is the lack of an agreed upon threshold to be used with the predictive algorithm to trigger a rapid emergency response. If the threshold is too low, the rescue system may be overwhelmed by responding to crashes with minor or no injuries. If the threshold is too high, too many of the seriously injured may be missed. It is essential that a threshold be agreed upon that will capture most of the seriously injured without misidentifying an excessive number of crashes that do not require immediate response. The goal established by CDC was a PPV greater than 0.2. The discussion to follow examines the threshold and the specificity achieved when PPV goal is achieved.

An excessive number of false positives predicted by the injury risk algorithm could result in wasted resources and ultimately in ignoring its prediction by the services that are adversely affected. Several features can act to reduce the consequence of false positives predicted by the algorithm. The most useful feature is the voice communication with the occupants of the crashed vehicle that can be used to reinforce or revoke the severe injury prediction.

The study defines serious injuries as MAIS 3+ and fatalities. This MAIS 3+ definition is frequently used in safety regulatory analyses [NHTSA, 2000]. An alternative definition is the ISS scale that is more appealing to CDC [CDC 2008]. This scale recognizes multiple injuries by summing the square of the three highest AIS injuries. Both scales lack precision in identifying the entire population of time critical injuries. The URGENCY algorithm predictive value for the MAIS scale is a percentage risk, while the value for the ISS is a scalar number. Since NASS is better suited to the analysis of MAIS 3+F injuries and the prediction of risk is more intuitively appealing, that definition of serious injury was chosen over the ISS scale.

Occupant age was found to be an influential variable in determining injury risk in this study and in the previous studies already cited. At present, occupant age is not transmitted with the automatic crash notification data. However, voice communication with vehicle occupants can, in many cases, determine the age range of the occupants. Alternatively, occupant age range may be inferred from owner registration data. In future crash notification systems, occupant age and medical data may be transmitted along with the geographic coordinates and the crash data. For these reasons, occupant age was included as a variable in this study.

These results apply to front seat occupants only. Two important factors preclude the analysis of rear seat occupants in the same way that front seat occupants were analyzed. First, current vehicles do not automatically detect rear seat occupancy and therefore could not accurately trigger an injury risk calculation. Second, the number of seriously injured rear seat occupants within the NASS CDS was insufficient to train such models in order to produce reliable estimates. Therefore, rear seat occupants were excluded from this evaluation.

The best prediction was for far-side crashes. A risk threshold of 0.05 produced a specificity of 0.725 and a PPV of 0.235. For near-side crashes, the same threshold gave a specificity of 0.674 but a PPV of 0.175. For frontal crashes the best prediction was achieved by estimating the risk of injury at the accident level rather than the occupant level. For that prediction, a threshold of 0.10 produced a specificity of 0.679 and a PPV of .203.

The lowest sensitivity was for frontal crashes. However, it was observed that frontal crashes frequently involved crashes with the side of other vehicles. In these crashes the occupants involved in the side crashes were more likely to be seriously injured. When the algorithm for frontal crashes was applied to a dataset at the crash level rather than the vehicle level, improved sensitivity resulted. The interpretation of this result was that some occupants involved in the crash would prompt medical attention, even though that occupant was not in the vehicle involved in the frontal crash. The sensitivity for the frontal model applied at the accident level was 0.679. The PPV was 0.203.
The use of a risk threshold of 0.20 was considered by the CDC Committee as an appropriate level for classifying crashes with severe injuries. However, Tables 3, 4 and 5 show that for that threshold, the sensitivity ranges from 0.294 for frontal to 0.373 for near side. A higher sensitivity would be desirable. For the thresholds suggested in this paper, sensitivities above 0.67 appears to be possible while maintaining a PPV in a range acceptable to rescue and triage services. It should be noted that due to the overwhelming percentage of non-seriously injured occupants within the crash population, higher positive predictive values could be achieved by simply raising injury risk thresholds to the 20% level or beyond. However, while this would effectively improve model performance, it would render this potentially lifesaving technology less effective in identifying injured occupants in need of care. Such a tradeoff must be considered when policy decisions regarding injury risk threshold are put forth.

The prediction of serious injuries in rollover crashes remains a challenge. The present crash notification systems do not transmit crash severity measures for the rollover phase of a crash. The current injury prediction of rollovers is based primarily on the planar deltaV that may occur before the rollover takes place. The presence of a rollover in conjunction with a planar deltaV modifies the injury risk by a fixed percent, regardless of the severity of the rollover. It is interesting to note from Table 2 that a rollover reduces injury risk when it follows a near side crash. An explanation may be that less of the crash energy is absorbed by the occupant compartment.

Another concern is the degree to which the NASS database represents the current automatic crash notification fleet. A recent study of NASS has shown that injury risks are reducing in all crash modes for the most recent vehicle model years [Eigen, 2012]. This result suggests that an injury predictive algorithm using the NASS database of the current fleet would over predict serious injuries. This over prediction would be offset to some extent by the injuries that occur in the vehicle without automatic crash notification when impacted by a newer vehicle. In order to reduce the influence of vehicles with older safety technology, model years prior to 1998 were excluded from the analysis.

CONCLUSIONS

The recommended thresholds for classifying crashes with severe injuries are 0.10 for frontal crashes and 0.05 for side crashes. The regression analysis of NASS/CDS indicates that these thresholds will provide a sensitivity above 0.67 while maintaining a PPV in the range of 0.20.

ACKNOWLEDGEMENT

The authors would like to acknowledge the US Centers for Disease Control for sponsoring this research.

BIBLIOGRAPHY


Augenstein, J, Digges, K., Bahouth, G. and others, “Characteristics of Crashes that Increase the Risk of Injury”, 47th Annual Proceedings of the Association for the Advancement of Automotive Medicine, p. 561-576, September, 2003


Eigen, AM, Digges, KH, and Samaha, RR, “Safety Changes in the US Vehicle Fleet since Model Year 1990, Based on NASS Data”, Annual Proceedings of
the Association for the Advancement of Automotive Medicine, Vol. 56, 2012.


