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A More Effective Post-Crash Safety Feature to Improve the Medical Outcome of Injured Occupants

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ABSTRACT

Automatic Crash Notification (ACN) technology provides an opportunity to rapidly transmit crash characteristics to emergency care providers in order to improve timeliness and quality of care provided to occupants in the post crash phase. This study evaluated the relative value of crash attributes in providing useful information to assist in the identification of crashes where occupants may be seriously injured. This identification includes an indication of whether a crash is likely to require a level of emergency response with higher priority than is needed for most crashes reported by ACN Systems. The ability to predict serious injury using groupings of variables has been determined. In this way, the consequence of not transmitting each variable can be estimated. In addition, the incremental benefit of voice communication is shown.

The crash variables evaluated using regression analysis were: deltaV, impact direction, presence of the right front passenger, knowledge of three point belt usage in front seats and the recognition of multiple impact crash events. The analysis showed that each added variable improved the ability to identify and capture crashes with serious and fatal injuries. However, the extent of over-triage remained fairly constant at around 20%. The use of voice communications to identify cases without injury in low severity crashes could substantially reduce the over-triage rate.

INTRODUCTION

The goal of this study was to quantify the frequency that today’s ACN systems would accurately distinguish occupants who need immediate medical attention from those who do not. Additional parameters were identified that could be transmitted by future ACN systems to refine the criteria used to distinguish occupants in need. The relative rate that occupants are correctly flagged as likely to be severely injured versus non-severely injured are presented with the inclusion of each of these additional variables. Rapid identification and treatment of injured occupants will improve injury outcomes and reduce deaths following a crash.

The FARS data set contains several data elements to illuminate the value of improved rescue and treatment. One such variable is whether or not the fatally injured occupant was transported to a hospital. Analysis of FARS shows that approximately 50% of those fatally injured were transported to a hospital. The fraction who die in the hospital has been decreasing with time. Twenty-five years ago, 75% of the fatally injured were transported to a hospital. This difference suggests that medical care has continued to improve and reduce the deaths to seriously injured occupants that are transported to a Trauma Center. Faster rescue and triage of injured occupants could assure more of the severely injured receive timely hospital care.

The FARS also has a variable that indicates the time of death relative to the time of crash. About 34% of fatally injured occupants survive from 10 to 90 minutes. Another 31% survive more than 90 minutes.

Consequently there is the opportunity to intervene in at least 65% of the fatalities with faster rescue response, better triage, and better identification and treatment of the injuries. The ability to influence the fatality outcome will depend on a number of factors. However, the technology associated with ACN systems offers great opportunity to achieve faster rescue response and improving the identification of occupants with life threatening injuries.

Currently, ACN systems send a signal to emergency responders if a crash is severe enough to deploy airbags. This severity varies based on crash direction. In the case of side crashes where head, thorax or curtain airbags are not installed or during rear impacts where airbags may not be available, the ACN systems simply determine crash severity regardless of an actual airbag deployment event. The technology used to transmit crash information and exchange verbal information may also be used for non-crash applications including distress signals initiated by occupants, information requests or other available telematics services.

In the event of a crash, information provided by today's ACN systems are used differently by each 911 system or Public Services Answering Point (PSAP) based on protocols in place. Voice communications with occupants can provide a wealth of information to characterize how severe a crash event may have been regardless of the number data elements transmitted. As systems become more advanced in the future, data elements may be used to characterize crash severity in the absence of verbal information from in-vehicle occupants.

This study addresses passenger vehicle occupants over the age of 12 who may have severe or time critical injuries following a crash. This category includes occupants who sustained at least one or more injury 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+ injured occupants.

METHODS

The National Automotive Sampling System/Crashworthiness Data System (NASS/CDS), years 1997-2003, was the principal basis for this evaluation. This database 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.

Crash Mode- 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, frontal crush zones, seatbelts and frontal airbag systems help to manage energy along the longitudinal axis of the vehicle. Similarly, these features like seatbelts and frontal airbags do not provide significant protection or benefit for nearside occupants in high severity lateral crashes.

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: (PDOF≥11 and PDOF≤1, Any Seating Position) 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≥ 5and PDOF≤7

These crash categories were published and applied by NHTSA during the Final Economic assessment of the FMVSS Advanced Airbag Final Rule (NHTSA, 2000).

One issue related to NASS/CDS is the under prediction of fatalities. Fatalities are sufficiently rare that they are not adequately sampled by the limited number of NASS data collection sites. The total number of fatalities is known with good accuracy because each motor vehicle fatality in the US is recorded in another database known as the Fatality Analysis Reporting System (FARS). In estimating fatalities from NASS, it is generally necessary to apply a correction factor based on FARS.

Finally, there is an issue with the crash severity predictions in NASS. The crash severity is expressed in terms of deltaV. It 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. Less than half of the cases 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, however severe damage is often attributed as the reason for an uncalculated deltaV value.

The following paragraphs summarize the data from NASS/CDS 1997-2003. The data is for front seat occupants older than 12 years. The six years of data are averaged to provide annual estimates. The estimates are based on weighted data.

DATA ANALYSIS

The NASS/CDS data provides a basis for studying injured populations and determining which crash variables would be most beneficial in identifying crashes with severely injured occupants.

In NASS/CDS approximately 3.5 million front seat occupants are exposed to crashes each year. Of this population 101,000 are injured at with a Maximum AIS score of 3 or higher injuries (MAIS 3+), but survive these injuries. According to FARS, about 38,000 receive fatal injuries annually. These large differences in populations illustrate how difficult it may be to remotely recognize severely and fatally injured among crashes that are severe enough to have a vehicle towed from the scene.

For illustrative purposes, assume the fatalities and injuries are uniformly distributed. For each 1% change in occupants selected from the sample, about 33,000 would not be seriously injured, 1,000 would be seriously injured survivors, and 38 would be fatally injured. In fact, injuries and fatalities are not uniformly distributed. They vary depending on crash attributes including the severity of the crash or deltaV.

The application of crash variables to the population of occupants in crashes above the ACN threshold attempts to identify a subset of the sample so that a larger fraction is severely or 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 proportion of injured. If an injury risk threshold is established and all crashes above that risk value are designated as severe, the resulting population will contain both injured and uninjured people. Those that are not injured are called false positives. The population that is designated as in not severe crashes will also contain some injured people. These injured people that are missed are called false negatives. 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.

Figure 1 shows the relationship between the percentages of injured accurately identified vs. the percentage over-triaged for frontal crashes. Within the frontal crash population there are approximately 1.4 million occupants who do not sustain MAIS3 or higher injuries and there are approximately 40,000 who do sustain MAIS 3+ injuries. Note that a 1% increase in capture rate identifies 400 injured occupants while a 1% increase in over-triage increases the number incorrectly identified as being injured by about 14,000. Figure 1 shows how adding variables can improve the predictive relationship.

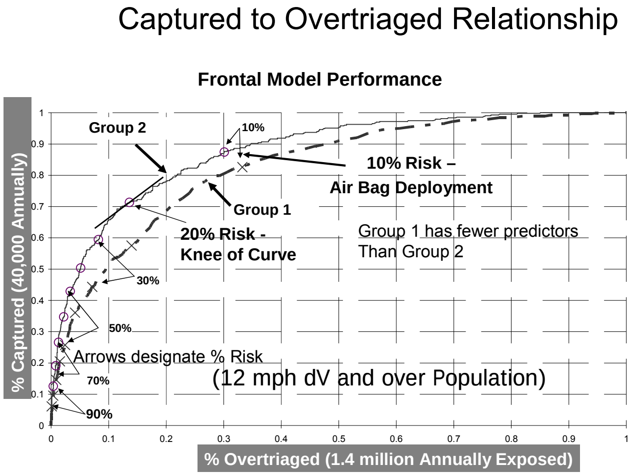


Figure 1- Relationship between threshold for risk and percent of the 40,000 injured during frontal crashes recognized and percent of 1.4 million non-MAIS 3+ injured who could be over-triaged.

Figure 1 shows the risk relationship between model sensitivity and specificity for 2 models where Group 1 contains fewer crash variables and Group 2 contains a larger set. This relationship is provided for a series of risk values at various points along the curve for both Group 1 and 2 variables. As the risk value decreases, the over-triage increases, but the number of injured that are captured also increases. The knee of the Group 2 curve is at a risk value of about 20%. Beyond 20% the percent over-triaged increases more rapidly than the percent of injured accurately captured. At this level for every injured person correctly identified, about 6 uninjured are incorrectly identified as injured. About 70% of the injured people are identified by using the 20% threshold.

Based on injury populations in NASS/CDS, a 12 MPH (estimated) frontal air bag deployment threshold corresponds to a 10% risk of serious injury. At this risk level, 88% of the injured would be captured, but the over-triage rate would be 30%. This would result in an over-triage ratio of about 12 to 1. Even if the threshold is set at a low value, the value of the risk associated with each case is important. For example, if the risk value is

60% there will be 4 injured people for each uninjured person identified.

For the emergency response decision, a lower threshold may be appropriate. The 10% threshold corresponds to the approximate crash severity at which the air bag deploys and the ACN notification is initiated. This estimate is based on the relationship between frontal crash injury risk, deltaV and approximate crash speeds where airbags typically deploy. This level would capture 90% of the MAIS 3+ injuries but would increase the number of false positives to about 30%. Further evaluation of field performance may be required to establish the best threshold for identifying a severe crash.

In summary, Figure 1 illustrates several significant points. First, it shows that in a given set of predictors, increases in the capture rate of the injured results in increases in the over-triage rate. Second, it shows how adding predictors can increase the number of injured captured without increasing the over-triage rate. Third, it shows how different risk thresholds affect the relationship between the capture rate for the injured and the over-triage rate.

To better understand how MAIS 3+ injuries are distributed among crash modes, a detailed analysis of NASS was undertaken. Two parameters were developed to assist in understanding these distributions. The first was the risk of serious injury expressed as number of people with MAIS 3+ or fatal injuries per 100 occupants exposed to a particular crash condition. This parameter is designated as: MAIS 3+F/100. The second is the risk of a fatality, given an MAIS 3+F injury. This parameter is an indicator of the fatality content of the population with serious injuries. The higher the fatality content, the more severe the injuries in the seriously injured population are likely to be. This parameter is designated: Fatals/MAIS 3+F.

Table 1 provides insight into how serious injuries and fatalities are distributed by crash mode. In the figure, multiple impacts are designated according to the most severe planar impact. All rollovers that involve planar impacts are categorized according to the most severe planar impact. The figure shows the distribution of MAIS 3+ and Fatal injuries by crash direction. The figure also shows the distribution of MAIS 3+F/100 and Fatals/MAIS 3+F. Several significant observations emerge. Frontals have a relatively low injury risk and fatality content. Rollovers have three times the risk of serious injuries as compared to frontals. Rollovers also have higher fatality content. Nearside crashes have a higher injury risk and fatality content than frontals. This suggests that other things being equal, over-triage would be higher for frontal crashes compared to nearside or rollover.

Table 1. Injuries and Fatalities by Crash Mode.

Crash Mode	MAIS 3+	Fatals	MAIS 3+F/100	Fatal/MAIS 3+F
Frontal	54%	43%	3.03	0.23
Nearside	14%	15%	7.10	0.29
Farside	7%	8%	3.90	0.30
Rear	2%	3%	1.06	0.32
Rollover	23%	31%	10.25	0.34
Average			4.13	0.27

Table 2. Injuries and Fatalities in Frontal Crashes by Crash Severity.

Delta V, mph	MAIS 3+	Fatals	MAIS 3+F/100	Fatal/MAIS 3+F
0-10	5%	2%	0.4	0.10
11-20	42%	16%	2.3	0.10
21-30	30%	35%	11.6	0.26
31-40	13%	19%	27.3	0.30
41+	9%	29%	85.9	0.48
All	100%	100.0%	3.0	0.23

Table 2 examines the distributions of occupants in frontal crashes by deltaV. The figure shows how the injury risk and fatality content increase dramatically with deltaV. It also shows that, on average, about 23% of those with serious injuries die. However, the rate increases from about 10% in low severity crashes to about 50% in high severity crashes (with deltaV's over 35 MPH). Several significant observations follow. The higher severity events are not only more likely to have serious injuries, but also are likely to have higher severity injuries that need rapid response. These higher severity injuries make it more likely that the occupant may not be able to respond to voice communications. These cases are most likely to carry high risk values that could be used to dispatch appropriate emergency response. ACN would be particularly valuable in identifying these cases.

Based on NASS/CDS data, 21% of the MAIS 3+F and 9% of the fatals occur below 15 mph. Individual NASS cases were examined to determine the reason for these unexpected results. The three largest factors that contributed were injuries from 2-point shoulder belts (probably without a lap belt fastened), injuries from multiple impacts and injuries to very elderly occupants (i.e. 80 years and older). Other factors were: aggressive air bags and vehicles involved in narrow overlap crashes. In the latter cases, the main vehicle structure was generally not involved and extensive intrusion along the side of the vehicle could result.

The accuracy of the fatality distribution shown in Table 2 may be questionable. It was mentioned earlier that NASS undercounts fatalities. This undercount is further exacerbated by large number of cases with unknown deltaV. These cases had to be excluded from Table 2, and the distributions are based on cases with known deltaV. It is probable that these cases have a bias toward low severity crashes. If the injuries and fatalities with unknown deltaV are distributed according to the percentages with known deltaV, the fatalities (and to a lesser degree the MAIS 3+ survivors) may be overrepresented in lower severity crashes.

Occupant age is another important factor regarding the outcome of a MAIS 3+ injury. Overall the fatality content of MAIS 3+F injuries is 27%. Broken down according to age, the fatality contents are: 15 to 35 – 25%; 36 to 65 – 28%; 66+ - 35%.

Table 3 examines the distributions of occupants in nearside crashes by deltaV. The table shows the injury risk and fatality content increase dramatically above deltaV of 20 mph.

Table 3. Injuries and Fatalities in Nearside Crashes by Crash Severity

Delta V, mph	MAIS 3+	Fatals	MAIS 3+F/100	Fatal/MAIS 3+F
0-10	8%	0.2%	0.9	0.01
11-20	36%	18%	5.4	0.16
21-30	42%	47%	34.7	0.30
31-40	11%	26%	55.3	0.48
41+	3%	8%	65.3	0.51
All	100%	100%	7.10	0.28

Tables 2 and 3 show that the injury risk increase with deltaV is much more dramatic in nearside crashes compared to frontals. The tables also show that a large fraction of the serious injuries occur at crash severities below 20 mph. However, the fatality content of the injured population in lower severity crashes is much lower that the fatality content at crash severities above 20 mph. Because of the higher fatality content of these higher severity crashes the overall injury severity of the population is expected to be higher and the time criticality of rescue more urgent.

REGRESSION ANALYSIS

The method used during this analysis to quantify the opportunities or rescue enhancements of future ACN technology included a series of steps as listed below. A more detailed description of methods and findings is presented below for each of these analysis steps.

1. Assumed a 20% URGENCY risk factor as threshold for identifying a severe crash.
2. Evaluated the rate that URGENCY captured injured occupants for each added variable in Group 1 and 2, and for the combination of variables.
3. Compared the percentage of captured populations of MAIS 3+ injured for each added variable
4. Reported the percentage increase in captured injured and in captured events without MAIS 3+ injuries.

The evaluation assumed that a subset of crash information would be available to Telematics Service Porviders (TSPs) and dispatch personnel immediately after or soon after a crash occurred through automatic or verbal transmission. Second, it assumes that this information would be processed to estimate crash severity so that rescue personnel could utilize this information to make dispatch, on-scene triage and in-hospital care decisions.

A review of crash characteristics as well as occupant characteristics available within the NASS/CDS dataset was conducted to identify the most influential variables for crash severity assessment. These characteristics were compiled based on findings from available literature as well as the real life experience of the University of Miami CIREN team during crash case collection since 1991 (Malliaris 1997, Jones 1989, Siegel 1993, Augenstein 2003).

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*, β_1, β_2… shown below are based on a least squares fit of existing historical crash data from NASS/CDS.

Eq. 1: $$w = (Intercept) + \beta_1 * deltaV + \beta_2 * factor_2$$

Eq. 2: $$P(MAIS3+) = \frac{1}{(1+\exp(-w))}$$

Each logistic regression model was trained using NASS/CDS 1997-2001 data. 2002 and 2003 datasets were used to evaluate the accuracy of the resulting models. As an example, Table 4 below lists parameter estimates for a model relating the continuous variable deltaV to the likelihood of MAIS 3+ injury. This model assumes average values for all other crash factors which may influence the risk of injury that are not explicitly included within the model.

Before the creation of each logistic regression model, all relevant crash attributes were reviewed for consistency and reconditioned when appropriate using

SAS version 8.2. All regression models were created using SAS callable SUDAAN. SUDAAN is a statistical package which allows for the analysis of complex sample data like NASS/CDS. It allows for the correct interpretation of sample variances for multi-stage, clustered samples.

As previously mentioned, the binary outcome variable MAIS 3+ 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 where missing values exist for any model variable are unusable for model training as well as testing and were therefore discarded as well.

Table 4. Logistic Regression model parameters including deltaV only by crash direction

Crash Mode	Parameter	Estimate
Frontal	Intercept	-4.2052
	DeltaV	0.1157
Nearside	Intercept	-4.0652
	DeltaV	0.181
Farside	Intercept	-4.5426
	DeltaV	0.1384
Rear	Intercept	-5.5143
	DeltaV	0.1303

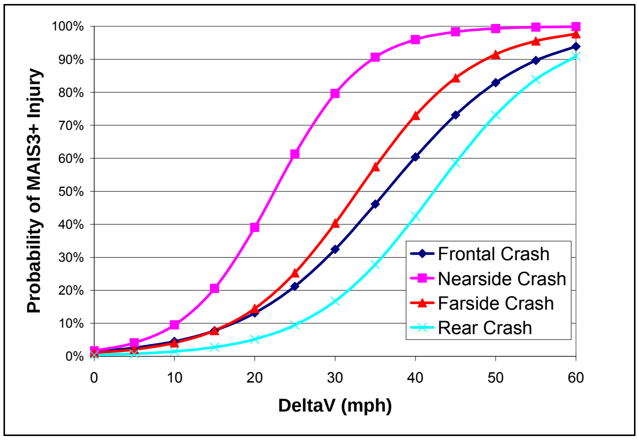


Figure 2. MAIS 3+ injury risk by delta-V and crash direction

Figure 2 shows the resulting risk of MAIS 3+ injury which may be calculated using Equations 1-2 for crashes by deltaV and parameter estimates shown in Table 4. For these curves, only the intercept and DeltaV parameter estimates are used. If other parameters were included within this model factor 2, factor 3 and others would be added.

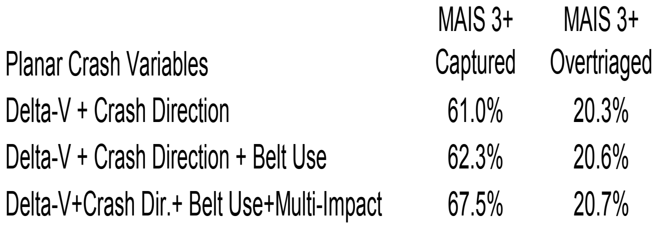
DeltaV estimates the difference between pre-impact and post-impact velocity as a function of the damage of a vehicle involved in a crash. Figure 2 shows that as deltaV increases, the risk of injury increases from 0 to 100% risk. Crash direction influences these relative values considerably due to differences in available occupant protection, crush space and human tolerance to injury.

Figure 2 illustrates the importance of adding the crash direction variable to deltaV. Assuming the use of a 20% threshold, the DeltaV values the various crash modes are: frontal – 24 mph; nearside – 15 mph; farside – 23 mph; rear - 32 mph. If crash direction is not used as an injury predictor, most nearside injuries will be missed, and rear impacts will be over-triaged. It should be noted that to determine if a side crash is near-side or far-side, the presence of the right front passenger is needed.

The injury reduction benefits of safety belts and 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. The regression analysis to follow assumes that the air bags have deployed. Knowledge of the presence or absence of belt use can further improve percentage of injured that are captured by an ACN system. The incremental changes in % of injured captured and % over-triaged are shown in Table 5.

Earlier studies have found that multiple impact crashes increase injury risk [Digges 2003, Bahouth 2005]. A substantial improvement in the injury capture rate is achieved by including the multiple impact variable, as shown in Table 5.

Table 5. Summary of Results for Planar Crash Variables DeltaV, Crash Direction, Belt Use and Multi-Impact



Planar Crash Variables	MAIS 3+ Captured	MAIS 3+ Overtriaged
Delta-V + Crash Direction	61.0%	20.3%
Delta-V + Crash Direction + Belt Use	62.3%	20.6%
Delta-V+Crash Dir.+ Belt Use+Multi-Impact	67.5%	20.7%

The deltaV, crash direction and belt use are variables that are used by the air bag system logic to decide on air bag deployment. Multiple-impacts are also included in the logic of some systems. These variables should be easily available for transmission by the ACN system at the same time the geographic coordinates of the crash are transmitted.

In many of the ACN calls, voice communication will be established with the crashed vehicle occupants. This communication can provide valuable information on the safety and condition of the occupants. This information may further improve the triage accuracy particularly in the low severity crashes. An added data element that would be very valuable would be the age of the occupants exposed to the crash. The age, alone, may be a sufficient factor to increase the injury risk to the severe level. Consequently, the determination of the age of the occupant becomes an important variable to obtain either through voice communication or through ownership records.

DISCUSSION

The automatic crash notification system offers the possibility of providing three types of data to aid in the rescue. First the geographic coordinates of the crash are provided. Second, the voice communication with the crashed vehicle occupants provides valuable information. Third, the vehicle data that was used by the air bag logic to make the deployment decision could be provided.

The vast majority of crashes with air bag deployment do not result in significant injury to the vehicle occupants. Voice communications with the occupants can further verify rescue urgency. Much of the over triage that is most prevalent in low severity crashes may be reduced by voice communications. However, in a fraction of the cases there may be no voice response. In these cases, the added data from the vehicle would be particularly valuable. When used in conjunction with voice communication, the accuracy of capturing injuries is more important than the errors in over-triage.

The difficulty in recognizing seriously injured occupants in low severity crashes is illustrated by examining Tables 3 and 4. In frontal crashes, 42% of the MAIS 3+F injuries occur at crash severities of 11-20 mph. The frequency of these injuries is only 2.3 per 100 exposed to crashes in this range. For near-side impacts 36% of the MAIS 3+F injuries occur in the 10-20 mph range. The frequency is 5.4 per 100 exposed to crashes in the 10-20 mph range. The vast majority of the MAIS 3+F injuries in this crash severity range are MAIS 3 injuries. Voice communication is more likely for these cases than at the higher speeds where the injury content is more severe. Consequently, it is anticipated that voice communications can assist in improving the accuracy of the triage.

CONCLUSIONS

The distribution of serious and fatal injuries (MAIS 3+F) by crash severity was examined for frontal and near-side crashes. When examining MAIS 3+F injuries, 42% in frontal crashes and 36% in side crashes occur in the 10-20 mph deltaV range. The fatality content for crashes in this lower severity range was much lower than at higher crash severities.

For all frontal crashes with MAIS 3+F injuries, the average fatality content was 23%. For side crashes with MAIS 3+F injuries, the average fatality content was 28%. The fatality content in frontal crashes varied from 10% at 10-20 mph to 48% at 41+ mph. For side crashes, the fatality content was 16% at 10-20 mph and 48% at 31-40 mph. These results suggest that regression analysis based on MAIS 3+F injuries may not adequately account for the higher content of severe and fatal injuries that are present at the higher crash severity and the added need for urgent rescue response.

Regression analysis of NASS/CDS shows that crash severity (DeltaV) and crash direction are two variables that are readily available to be transmitted with the ACN call and are most useful in predicting the risk of a serious injury in the crash. Other important variables are belt use, multiple impact and age of the occupants exposed. The addition of each of these variables improves the capture rate of the MAIS 3+F injuries, but does not reduce the over-triage.

The voice communication between the TSP and the crashed car occupants can be used in conjunction with the vehicle data to reduce the over-triage, particularly in lower severity crashes. These lower severity crashes are much less likely to have severe injuries that would prevent a voice response from the vehicle occupants.

A continuing challenge is to utilize the combination of voice communication and vehicle crash data in a way to increase the identification of crashes with serious injuries while reducing the over-triage rate.

Based on FARS time of death data, there is the opportunity to intervene in at least 65% of the fatalities with faster rescue response, better triage, and better identification and treatment of the injuries. The use of ACN technology to provide vehicle location, voice communication, and vehicle crash severity data offers the possibility of further reduction of the injuries and deaths from motor vehicle crashes.

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