# PREDICTING OCCUPANT OUTCOMES WITH EDR DATA

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## ABSTRACT

Recommendations were made in 2008 regarding advanced automatic collision notification or AACN and the data that should be used in attempting to predict the need for trauma center care (CDC, 2008). Some have considered those recommendations and begun to produce injury predicting algorithms that can be used in part to communicate the severity of crashes to emergency medical services (EMS) and trauma personnel (Kononen et al., 2010). One possible shortcoming of many of the data sets being used and the resulting algorithms is their reliance on investigator estimated change in velocity (delta V).

Prior work has investigated the predictive ability of various occupant and crash variables as they related to occupant outcomes (Craig et al, 2009). The National Highway Traffic Safety Administration's (NHTSA) Crash Injury Research and Engineering Network (CIREN) database provided the detailed crash and injury data as well as hospital care-based outcomes to enable that study. The current study has continued that work, but with an emphasis on studying the significance of the association between individual event data recorder (EDR) or telematics variables and patient outcomes that most justify the need for the highest level of care.

The primary aim of this study was to document the association between potential EDR or telematics variables and occupant outcomes using three frontal crash data sets. Analysis was limited to data that could be collected via telematics or voice communication and involved logistic regression analysis to document variables that were significant associated with the occupant outcomes studied. Two CIREN (non-EDR and EDR) and one National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) (EDR) data sets were analyzed. The CIREN data sets were used to study the association between predictors and hospital care-based outcomes. The NASS-CDS EDR data set was used to evaluate the association between the same predictors used in CIREN data analysis and injury severity-based outcomes. Both EDR data sets were also analyzed to evaluate differences in the predictive ability of delta V obtained from an EDR versus delta V calculated as part of the crash reconstruction (using WinSMASH, e.g.).

The results of this study show that many of the recommended predictors (CDC, 2008) were significantly associated with the outcomes of interest. The study also found that EDR delta V can be a better predictor of outcomes than WinSMASH delta V. This finding may have implications for the development and application of injury predicting algorithms that could be used as part of an AACN system.

## INTRODUCTION

Triage of occupants involved in motor vehicle crashes is currently assessed at the scene of the crash using the American College of Surgeons (ACS) field triage decision scheme that was published in 2006 (ACS, 2006) and later supported with detailed rationale (Sasser et al., 2009). The field triage decision scheme consists of four sections or steps: 1. vital signs and level of consciousness, 2. anatomy of injury, 3. mechanism of injury and evidence of high-energy impact, and 4. special patient or system considerations.

Step 3 of the 2006 Field Triage Decision Scheme includes a placeholder for "vehicle telemetry data consistent with high risk of injury." Related to this, an expert panel was formed by the Centers for Disease Control (CDC) to developed recommendations for Advanced Automatic Collision Notification (AACN) systems (CDC, 2008). Recommendations by the panel included the use of a 20% probability of an injury severity score (ISS) greater than 15 (ISS 16+) to indicate the need for Level I trauma center care. The expert panel also recommended a set of vehicle data elements that should be transmitted via telemetry to AACN providers that could be used to estimate the probability of an ISS of 16+. The recommended elements included change in velocity (delta V), principal direction of force (PDOF), seat belt usage, multiple impacts (i.e., multiple crashes or impact events), and vehicle type. They also recommended elements that could be collected by the AACN provider or PSAP (public-safety answering point, 9-1-1) through voice communication with the vehicle occupant. Those items included age (> 55 years), injuries to vehicle occupants, number of patients, and the number of vehicles in the crash. Collection of this information through voice could be used to augment the calculation of the probability of a vehicle occupant meeting the ISS 16 threshold.

Earlier work initiated at NHTSA documented the development of predictive models using vehicle and occupant data in an attempt to predict the probability of a maximum Abbreviated Injury Scale (MAIS) (AAAM, 1998) of 3+ for a case occupant in a given crash scenario. The URGENCY Algorithm is one such model (Malliaris et al., 1997; Augenstein et al., 2001). More recent work using NHTSA's National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) database has involved the development of algorithms that are currently being employed by some auto manufactures and their affiliated telematics providers to estimate the probability of severe injury in the spirit of Step 3 of the 2006 ACS Field Triage Decision Scheme. Kononen et al. (2010) followed the recommendations of the CDC AACN expert panel and developed a predictive model using NASS-CDS data and the previously mentioned list of the CDC expert panel's recommended predictors to estimate the probability of ISS 16+. As with prior studies that have attempted to predict injury severity resulting from car crashes, delta V was found to be the most significant predictor. Of the CDC expert panel's recommend predictors, only vehicle type was not found to be a significant predictor ($p > 0.10$ for model inclusion in that study).

Craig et al. (2009) developed models to predict the probability of occupant outcomes in motor vehicle crashes. However, that study, instead of focusing on the use of NASS-CDS data and the estimation of ISS or MAIS probabilities used NHTSA's Crash Injury Research and Engineering Network (CIREN) database to study the relationships between vehicle, crash and occupant characteristics and hospital care-based outcomes such as time spent in the intensive care unit (ICU), invasive procedures within 12 or 24 hours of the time of the crash (operating room or OR < 12, OR < 24) and fatality. While NASS-CDS and CIREN are similar with regards to the collection of vehicle, occupant and crash data, only CIREN documents hospital care-based outcomes such as admission to the ICU and need for invasive surgeries. In an earlier study, Lerner et al. (2006) suggested the use of a composite of hospital care-based outcomes as a better indicant of a patient's need for trauma center resources. Different than an ISS based threshold, Lerner et al. recommended the use of a combination of ICU time > 24 hours, in-hospital fatality or non-orthopedic emergency surgery within 24 hours of admission as a better outcome to be used to represent need for high-level trauma center care.

The primary aim of this study was to document the association between potential EDR or telematics variables and occupant outcomes using three frontal crash data sets. Compared to the prior study by Craig et al. (2009), this study takes an alternative approach to look at the CDC expert panel's recommended predictors of the probability of ISS 16+ and investigates the use of alternative hospital care outcomes, in particular the combination suggested by Lerner et al. (2006). Simple logistic regression analysis was completed to study the association between individual variables or predictors and hospital care-based outcomes of interest for CIREN cases with EDR data and for all CIREN frontal crash cases. The hospital care-based outcomes included time spent in the ICU, need for invasive surgery, in-hospital fatality and composites of those outcomes. Similar analyses were completed using NASS-CDS EDR cases with MAIS 3+ and ISS 16+ as the dependent outcomes studied. Analysis in all cases was limited to data that could be collected via telematics or voice communication.

As part of the analysis of EDR cases, the predictive ability of WinSMASH calculated delta V (Sharma et al., 2007) was compared to EDR measured delta V. Prior studies have shown relatively low correlation ($R^2 \sim 0.5$) between WinSMASH and EDR delta V and have shown that WinSMASH delta Vs are lower on average than EDR delta Vs by 10-15% (Gabler et al., 2004; Niehoff and Gabler, 2006). This difference may influence the predictive ability of algorithms that were developed using WinSMASH and not EDR delta V data. To that end, the predictive ability of EDR delta V data collected in NASS-CDS cases is compared to that of WinSMASH delta V in the current study.

## METHODS

### CIREN Case Analysis

The current study uses CIREN frontal crash data given the following inclusion criteria:

- Most severe event and damage from frontal collision (GAD1 = frontal)
- 1998+ vehicle model year (2001+ for EDR data set)
- Known EDR delta V (EDR data set)
- Known WinSMASH delta V (non-EDR data set)
- Frontal airbag deployed
- Known hospital outcomes (ICU, OR, etc.)

Two CIREN frontal crash data sets were produced. The first included all CIREN cases meeting the criteria above for non-EDR cases. The second included those where the case vehicle was equipped with an EDR. EDR cases did not require the existence of WinSMASH delta V, but did require a complete velocity-time history data set as obtained from the EDR for the crash event of interest. Niehoff et al. (2005) noted that older models of General Motors (GM) vehicles collected between 100-150 ms of longitudinal delta V data for airbag deployment cases and in more recent model years 300 ms of longitudinal and lateral delta v data is recorded. Given the very limited number of cases with lateral delta V data, this study chose to focus on analyzing only the longitudinal delta V data in frontal crashes.

The primary aim of this study was to document the relationship between potential predictors and the following hospital care-based outcomes:

1) time spent in the ICU,
2) any invasive procedure within 12 hours (OR < 12 hrs) of the crash,
3) any invasive procedure within 24 hours (OR < 24 hrs) of the crash,
4) non-orthopedic emergency surgery within 24 hours of a crash,
5) fatality (all)
6) fatality (in-hospital),
7) ICU, fatality or OR < 12 hrs,
8) ICU, fatality or OR < 24 hrs, and
9) ICU, fatality or non-orthopedic emergency OR < 24 hrs.

Associations between the independent variables and dependent outcomes were analyzed individually through simple binary logistic regression using SAS 9.1 (SAS Institute Inc.). Independent variables were determined to be significant predictors if the p value associated with Wald $\chi^2$ values was less than 0.05. For discussion purposes, predictors were considered to be "marginally" significant for $0.05 < p < 0.10$. In the prior study by Craig et al. (2009), $p < 0.10$ was the threshold used for retaining predictors for us in multivariable predictive model development. Minus two times the Log Likelihood (-2 Log L) was recorded for use in comparing the model fit for the respective predictors and outcomes. A lower value of -2 Log L indicates better model fit for a given predictor versus other predictors of the same outcome.

The independent variables or predictors evaluated in the current study are summarized in Table 1. The predictors included those proposed by the CDC expert panel (CDC, 2008). The spirit of the expert panel's recommendation regarding principal direction of force (PDOF) was to distinguish between front, right, left, and rear impacts. Since all crashes were frontals in the current study, PDOF was separated into five categories; ten, eleven, twelve, one, and two o'clock. Vehicle type was separated into passenger cars, sport utility vehicles, pick-up trucks and vans. The CDC expert panel's proposed voice-collected data of injuries to vehicle occupants, number of patients and number of vehicles involved was not evaluated in the current study. Since the current analysis focused on the outcomes of individual CIREN case occupants, it was not possible to evaluate those additional recommended elements.

Other items considered to be possible elements to be communicated via telematics or voice that were evaluated include pre-impact braking, pre-impact vehicle speed, peak 50 ms slope of the EDR delta V time-history data, occupant height (50 ms peak acceleration), weight and the Glasgow Coma Scale or GCS. The change in velocity-time history data was used to calculate a peak slope over any 50 ms window. Given that weight and seat position (a surrogate for predicting occupant height) sensors exist in vehicles today, those predictors and body mass index (BMI) were also included as possible predictors. Regarding the GCS value, which evaluates motor, eye opening and vocal response, it is possible that GCS could be estimated via AACN provider or PSAP operator interaction with the crash occupant. For the purposes of the current study, GCS data was limited to "legitimate" GCS scores where the occupants were not sedated or intubated.

**Table 1**. Vehicle and occupant variables

| Vehicle/Crash Predictors | Occupant Predictors |
|---|---|
| WinSMASH - Longitudinal Delta V | Belt Use |
| EDR - Longitudinal Delta V | Age, Age > 55, Age > 65 |
| EDR - 50 ms Peak Acceleration | Gender |
| EDR - Pre-impact Vehicle Speed | BMI, BMI > 35 |
| EDR - Pre-impact Braking | Height |
| PDOF | Weight |
| Multiple Impacts | GCS, GCS < 14 |
| Vehicle Curb Weight | |
| Vehicle Type | |

**NASS-CDS EDR Case Analysis**

The NASS-CDS EDR data set was used to study the association between the variables listed in Table 1 and ISS 16+ and MAIS 3+. ISS 16+ was chosen given the CDC expert panel's recommendation (CDC, 2008). MAIS 3+ was chosen given its use as the dependent outcome in earlier development of predictive algorithms such as the URGENCY algorithm (Malliaris et al., 1997; Augenstein et al., 2001). As with the analysis of the CIREN data sets, this analysis involved measuring the association between individual predictors and outcomes (ISS 16+ and MAIS 3+) using simple logistic regression analysis to investigate and establish which predictors should be considered when developing multivariable models for predicting occupant outcomes or injury severity using telematics data. The study did not look at multiple variable regression model development or the potential interactions that may exist between predictors.

The NASS-CDS EDR data set was limited to NASS-CDS case years 2000 through 2009. As with the

CIREN EDR cases, vehicle model years of 2001+ were included in the analysis and cases were limited to frontal impacts with airbag deployments. Regression analysis was done using both unweighted and weighted case data from the EDR data set. The case weights were trimmed at three levels (ratwgt < 5000, < 2500 and < 500) to study the influence on regression results.

## RESULTS

Three data sets were created; two from CIREN and one from NASS-CDS. The first data set was the CIREN non-EDR data set (n=925). The second data set produced was the CIREN EDR data set (n=80). The third data set was the NASS-CDS EDR data set (n=811, unweighted). Of the 80 cases in CIREN EDR data set, 59 had available WinSMASH delta V. For the NASS-CDS EDR data set, 624 of 811 cases had known WinSMASH delta V. Unless otherwise noted, the results presented for the NASS-CDS EDR data set are for the unweighted data set. The usable set of cases in the NASS-CDS EDR data set is small. Thus, analyses would be subject to a large relative increase in variance with the inclusion of case weight. Also, since analyses were only concerned with studying the absolute relationships between variables and not the counts, case weights were not necessary.

The distribution of class variables for the three data sets can be seen in Figures 1 – 3. The distributions are similar between the CIREN data sets with few exceptions. For instance, there is a difference in multiple impacts that is likely due to the differences in definition between EDR and non-EDR cases. Multiple impacts in EDR cases is when the EDR recorded multiple events. Multiple impacts in non-EDR cases was defined when there was at least one additional frontal event with a delta V greater than 25 kph. In comparing the NASS-CDS and CIREN data sets, it can be seen that the NASS-CDS data set tends to have more male occupants and younger occupants than the CIREN data sets.

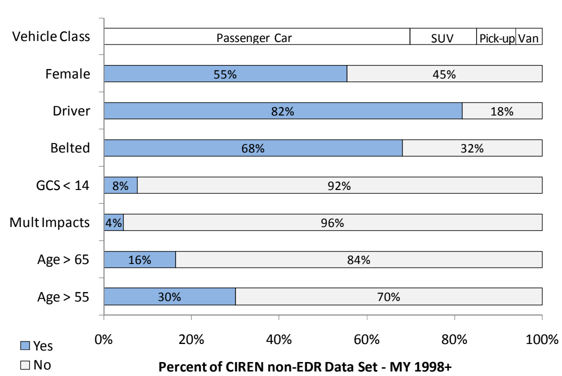


**Figure 1**. Distribution of class variables – CIREN non-EDR data set (n=925)

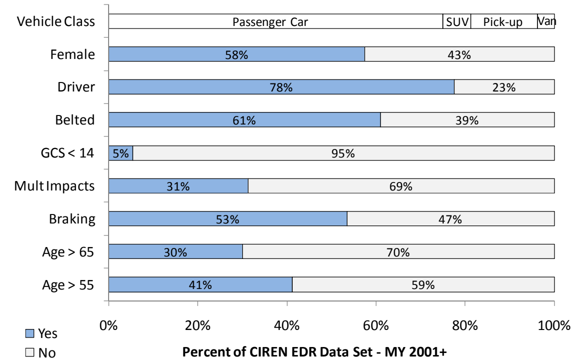


**Figure 2**. Distribution of class variables – CIREN EDR data set (n=80)

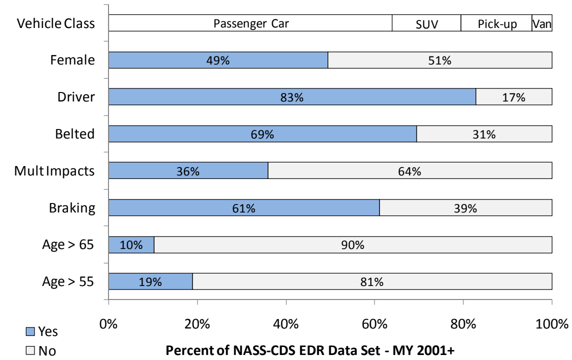


**Figure 3**. Distribution of class variables – NASS-CDS EDR data set (n=811)

Table A1 (Appendix) shows the mean and standard deviation values for the occupant-based continuous measures that were evaluated in the current study, grouped by all cases and by individual outcomes. Table A1 also includes information on outcomes such as MAIS, ISS and total hospital charges for reference. Table A2 (Appendix) shows data for the crash and vehicle-based variables that were studied for the CIREN data sets. Table A3 (Appendix) shows similar vehicle and occupant data for the NASS-CDS EDR data set. WinSMASH delta V can be compared across the three data sets. For the two CIREN data sets there is not a significant difference between WinSMASH delta V averages ($p > 0.05$). However, it is notable that the average delta V and associated average ISS and MAIS values for the NASS-CDS EDR data set is significantly lower than the CIREN data sets. For example, for the full CIREN data set the average WinSMASH delta V is 45.0±19.5 kph versus 25.2±13.3 kph in the NASS-CDS EDR data set. Similarly, average ISS is 19.2±12.4 in the CIREN frontal data set versus 3.7±8.3 in the NASS-CDS data set. This difference is expected based on the differences in inclusion criteria between CIREN (admission to Level I trauma center) and NASS-CDS (tow-away crash, in this case with airbag deployment required as part of the current study's inclusion criteria).

**Assessing Independent Variable Significance**

Tables 2 - 4 show the Wald $\chi^2$ values for significant ($p < 0.05$) and marginally significant ($0.05 < p < 0.10$, shaded in tables) predictors and the associated model fit (-2 Log Likelihood) values for CIREN non-EDR frontal cases, CIREN EDR frontal cases and NASS-CDS EDR cases, respectively. Empty cells in the tables signify variables with $p > 0.10$. The exception is for cells in Table 3 comparing the significance of the association of EDR and WinSMASH delta V, respectively, with the outcomes studied.

**Table 2**. Single variable logistic regression results for the CIREN non-EDR data set

| | | Outcome | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ICU[1] N=925 291 Cases | | | Fatal - All N=925 54 Cases | | | In-hospital Fatal N=925 25 Cases | | | OR LT12[1] N=925 348 Cases | | | OR LT24[1] N=925 520 Cases | | | Non-Ortho OR LT24[1] N=925 104 Cases | | | ICU, Fatal or OR LT12 N=925 526 Cases | | | ICU, Fatal or OR LT24 N=925 645 Cases | | | ICU, Fatal, Non-Ortho OR LT24 N=925 359 Cases | | |
| Predictor | Data Set | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] | $\chi^2$ | p | Fit[2] |
| WinSMASH Delta V | MY 98+ | 17.1 | <.001 | 1080.0 | 13.5 | <.001 | 399.1 | 4.5 | 0.034 | 225.8 | 4.6 | 0.032 | 1086.3 | 7.4 | 0.007 | 1122.2 | 10.6 | 0.001 | 626.4 | 12.0 | <.001 | 1175.4 | 15.0 | <.001 | 1007.8 | 22.6 | <.001 | 1167.6 |
| PDOF | MY 98+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | - | - | |
| Multiple Impacts | MY 98+ | - | - | - | 3.0 | 0.084 | 409.1 | 6.8 | <.001 | 224.8 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | - | - | |
| Veh Curb Weight | MY 98+ | - | - | - | 2.7 | 0.097 | 408.6 | - | - | - | 3.9 | 0.048 | 1086.9 | - | - | - | - | - | - | 2.9 | 0.091 | 1185.1 | - | - | | - | - | |
| Vehicle Type | MY 98+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | - | - | |
| Belted | MY 98+ | - | - | - | 22.5 | <.001 | 387.1 | 15.2 | <.001 | 212.0 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | | - | - | |
| Age | MY 98+ | 10.8 | 0.001 | 1086.5 | 8.1 | 0.044 | 403.5 | - | - | - | 12.1 | <.001 | 1078.5 | 15.6 | <.001 | 1114.0 | - | - | - | - | - | - | 5.9 | 0.016 | 1018.1 | 7.7 | 0.006 | 1183.2 |
| Age > 55 | MY 98+ | 9.4 | 0.002 | 1088.1 | 10.3 | <.001 | 401.6 | - | - | - | 7.7 | 0.006 | 1083.1 | 7.5 | 0.006 | 1122.4 | - | - | - | - | - | - | - | - | - | 7.3 | 0.007 | 1183.7 |
| Age > 65 | MY 98+ | 13.7 | <.001 | 1083.9 | 13.5 | <.001 | 399.6 | 6.5 | 0.011 | 224.1 | 9.0 | 0.003 | 1081.5 | 15.5 | <.001 | 1114.3 | - | - | - | - | - | - | - | - | - | 10.0 | 0.002 | 1180.9 |
| Gender | MY 98+ | - | - | - | - | - | - | 3.7 | 0.053 | 225.9 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| BMI | MY 98+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 10.5 | 0.001 | 622.8 | - | - | - | - | - | - | - | - | |
| BMI > 35 | MY 98+ | - | - | - | - | - | - | - | - | - | - | - | - | 3.6 | 0.056 | 1116.5 | 7.9 | 0.005 | 624.4 | - | - | - | 3.9 | 0.049 | 1007.4 | - | - | |
| Height | MY 98+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Weight | MY 98+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 10.5 | 0.001 | 623.2 | - | - | - | - | - | - | - | - | |
| GCS | MY 98+ | 25.9 | <.001 | 929.8 | 66.6 | <.001 | 161.8 | 37.5 | <.001 | 146.3 | - | - | - | - | - | - | 14.7 | <.001 | 538.8 | 12.5 | <.001 | 1084.2 | 5.6 | 0.018 | 960.1 | 26.0 | <.001 | 1012.7 |
| GCS < 14 | MY 98+ | 40.0 | <.001 | 928.3 | 53.2 | <.001 | 175.9 | 28.9 | <.001 | 149.7 | - | - | - | - | - | - | 9.8 | 0.002 | 543.5 | 17.7 | <.001 | 1082.5 | 6.8 | 0.009 | 960.0 | 39.3 | <.001 | 1016.7 |

1. Fatal cases not included in ICU and OR analysis
2. -2 Log Likelihood

**Table 3**. Single variable logistic regression results for CIREN EDR data set

| | | Outcome | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ICU N=80 40 (29)[2] cases | | | OR LT12 N=80 29 (22)[2] cases | | | OR LT24 N=80 46 (36)[2] cases | | | Non-Ortho OR LT24 N=80 10 (9)[2] cases | | | ICU, Fatal or OR LT12 N=80 54 (40)[2] cases | | | ICU, Fatal or OR LT24 N=80 62 (46)[2] cases | | | ICU, Fatal, Non-Ortho OR LT24 N=80 40 (33)[2] cases | | |
| Predictor | Data Set | $\chi^2$ | p | Fit[3] | $\chi^2$ | p | Fit[3] | $\chi^2$ | p | Fit[3] | $\chi^2$ | p | Fit[3] | $\chi^2$ | p | Fit[3] | $\chi^2$ | p | Fit[3] | $\chi^2$ | p | Fit[3] |
| WinSMASH Delta V | MY 2001+[1] | 0.01 | 0.907 | NA | 2.26 | 0.132 | NA | 3.65 | 0.056 | 69.0 | 0.00 | 0.957 | NA | 0.23 | 0.635 | NA | 0.38 | 0.539 | NA | 0.06 | 0.813 | NA |
| EDR Delta V | MY 2001+[1] | 4.90 | 0.027 | 76.2 | 4.79 | 0.029 | 71.7 | 3.51 | 0.061 | 69.1 | 2.40 | 0.122 | NA | 5.54 | 0.019 | 67.2 | 3.71 | 0.054 | 57.8 | 4.16 | 0.041 | 76.3 |
| EDR Delta V | MY 2001+ | 2.85 | 0.092 | 107.9 | 8.84 | 0.003 | 93.7 | 7.58 | 0.006 | 95.0 | 3.60 | 0.058 | 56.4 | 4.47 | 0.035 | 96.0 | 3.85 | 0.050 | 81.0 | - | - | - |
| 50 ms Peak Accel | MY 2001+ | - | - | - | 6.17 | 0.013 | 97.1 | 5.86 | 0.016 | 97.3 | - | - | - | 3.10 | 0.078 | 97.6 | 3.53 | 0.060 | 81.4 | - | - | - |
| Pre-impact Speed | MY 2001+ | 2.79 | 0.095 | 96.6 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.86 | 0.091 | 96.5 |
| Pre-impact Braking | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| PDOF | MY 2001+ | - | - | - | - | - | - | - | - | - | 4.48 | 0.034 | 55.3 | - | - | - | - | - | - | - | - | - |
| Multiple Impacts | MY 2001+ | 3.19 | 0.074 | 107.6 | - | - | - | - | - | - | - | - | - | 3.08 | 0.080 | 97.7 | - | - | - | - | - | - |
| Veh Curb Weight | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Vehicle Type | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Belted | MY 2001+ | - | - | - | 4.87 | 0.027 | 80.1 | 4.02 | 0.045 | 75.6 | - | - | - | - | - | - | - | - | - | - | - | - |
| Age | MY 2001+ | - | - | - | - | - | - | 4.77 | 0.029 | 98.7 | - | - | - | - | - | - | - | - | - | - | - | - |
| Age > 55 | MY 2001+ | - | - | - | - | - | - | 4.78 | 0.029 | 98.9 | - | - | - | - | - | - | - | - | - | - | - | - |
| Age > 65 | MY 2001+ | - | - | - | - | - | - | 6.81 | 0.009 | 96.7 | - | - | - | - | - | - | 4.21 | 0.040 | 81.1 | - | - | - |
| Gender | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| BMI | MY 2001+ | 3.82 | 0.051 | 104.0 | - | - | - | - | - | - | - | - | - | - | - | - | 7.57 | 0.006 | 69.6 | 3.27 | 0.071 | 103.7 |
| BMI > 35 | MY 2001+ | 4.07 | 0.044 | 103.4 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 2.78 | 0.095 | 104.1 |
| Height | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Weight | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 4.85 | 0.028 | 78.8 | - | - | - |
| GCS | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| GCS < 14 | MY 2001+ | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

1. This data set and comparison between EDR and WinSMASH delta V is limited to 59 of 80 cases with known WinSMASH delta V
2. Value in parenthesis represents number of cases in n=59 (known WinSMASH) data set
3. -2 Log Likelihood

There were a number of independent variables found to be significantly associated with the outcomes evaluated in analyses of the CIREN non-EDR data set (Table 2). First, WinSMASH delta V, is a significant predictor ($p<0.05$) of all outcomes studied. Looking at the other telematics variables recommended by the CDC expert panel, multiple impacts and belt use were only significant for fatalities. Vehicle type and PDOF, which again was limited to clock directions between ten and two o'clock, were not significant predictors of any outcome. Information that could be collected by PSAP or telematics provider such as age and GCS < 14 were significant predictors for a number of the individual outcomes such as ICU, fatality and composite outcomes. With the exception of OR < 12 hours and OR < 24 hours, GCS as a continuous or class variable predictor was one of the strongest predictors as evidenced by higher $\chi^2$ and lower -2 Log L values. Weight and/or BMI were at least marginally significant predictors of non-orthopedic emergency OR < 24 hours, OR < 24 hours and ICU, Fatal or OR < 24 hours. Gender was not a significant predictor for any outcome studied in the non-EDR CIREN data set. Age > 65 years was a better predictor than age > 55 as evidenced by higher $\chi^2$ and lower -2 Log L values.

**Table 4**. Single variable logistic regression results for NASS-CDS EDR data set

| | | Outcome | | | | | |
|---|---|---|---|---|---|---|---|
| | | ISS 16+ N=811 43 (24)[2] Cases | | | MAIS 3+ N=811 119 (77)[2] Cases | | |
| Predictor | Data Set | $\chi2$ | p | Fit[3] | $\chi2$ | p | Fit[3] |
| WinSMASH Delta V | MY 2001+[1] | 39.44 | < .0001 | 159.1 | 55.88 | < .0001 | 393.1 |
| EDR Delta V | MY 2001+[1] | 44.63 | < .0001 | 154.0 | 51.88 | < .0001 | 408.7 |
| EDR Delta V | MY 2001+ | 68.37 | < .0001 | 261.2 | 84.38 | < .0001 | 576.3 |
| 50 ms Peak Accel | MY 2001+ | 67.67 | < .0001 | 262.2 | 85.05 | < .0001 | 575.1 |
| Pre-impact Speed | MY 2001+ | 37.48 | < .0001 | 263.3 | 32.53 | < .0001 | 569.4 |
| Pre-impact Braking | MY 2001+ | 3.92 | 0.0477 | 332.3 | 3.81 | 0.0508 | 672.6 |
| PDOF | MY 2001+ | 3.20 | 0.07 | 324.5 | 5.69 | 0.0171 | 659.7 |
| Multiple Impacts | MY 2001+ | - | - | - | - | - | - |
| Veh Curb Weight | MY 2001+ | 3.15 | 0.0761 | 333.3 | - | - | - |
| Vehicle Type | MY 2001+ | 6.93 | 0.0742 | 329.9 | 11.99 | 0.0074 | 665.2 |
| Belted | MY 2001+ | 14.73 | 0.0001 | 321.2 | 25.49 | < .0001 | 647.1 |
| Age | MY 2001+ | - | - | - | 3.63 | 0.0567 | 672.8 |
| Age > 55 | MY 2001+ | - | - | - | 2.74 | 0.0978 | 673.8 |
| Age > 65 | MY 2001+ | - | - | - | - | - | - |
| Gender | MY 2001+ | - | - | - | - | - | - |
| BMI | MY 2001+ | 3.76 | 0.0525 | 289.9 | 12.15 | < .0001 | 569.7 |
| BMI > 35 | MY 2001+ | 3.95 | 0.0469 | 290.0 | 9.85 | 0.0017 | 572.5 |
| Height | MY 2001+ | - | - | - | - | - | - |
| Weight | MY 2001+ | 5.65 | 0.0174 | 300.2 | 9.50 | 0.0021 | 580.7 |

1. This data set and comparison between EDR and WinSMASH delta V is limited to the 624 of 811 cases with known WinSMASH delta V
2. Value in parenthesis represents number of cases in n=624 data set
3. -2 Log Likelihood

Analysis of the CIREN EDR data set found that fewer variables were significantly associated with the outcomes studied (Table 3), which was likely due to the limited sample size (n=80). However, for non-EDR variables, significance was established for items such as age, belt use and GCS in analyses of the non-EDR CIREN data set. Assessing just the EDR-related data, in most cases EDR delta V was a significant predictor of the individual and composite outcomes that were studied. Multiple impacts as indicated by multiple events recorded by the EDR, was marginally significant for ICU and ICU, fatal or OR < 12 hrs ($p < 0.1$). Similarly, pre-impact vehicle speed was marginally significant ($p < 0.1$) in predicting ICU and the composite of ICU, fatal or non-orthopedic OR < 24 hrs. Pre-impact braking was not a significant predictor for any outcome studied (p=0.207). Craig et al. (2009) had found that pre-impact braking was a marginally significant predictor of ICU (p=0.063). Additionally, since there were only three fatalities in the CIREN EDR data set, no analyses were performed to document the association between predictors and fatality.

Finally, it can be seen in Table 3 that when analyzing the subset of CIREN EDR cases with known WinSMASH delta V (n=59), EDR delta V was a better predictor of outcomes than WinSMASH delta V. For that data set, EDR delta V was a significant predictor ($p < 0.05$) of four out of seven outcomes studied and was marginally significant in two others (p=0.061 for OR < 24 hrs and p=0.054 for ICU, fatal or OR < 24 hrs), while WinSMASH delta V was not a significant predictor for any outcomes ($p > 0.05$) and was marginally significant (p=0.056 for OR < 24 hrs) for only one case. Figure 4 shows the correlation between EDR and WinSMASH delta V for these 59 cases. The correlation (Pearson correlation coefficient, r = 0.72) between EDR and WinSMASH delta V may in part explain why it would be reasonable to expect different $\chi^2$ values between the two estimates for delta V. Additionally, Figure 4 shows the delta V values for ICU and non-ICU cases. It can be observed that ICU cases tend to have higher EDR delta V than non-ICU cases (54.7±18 kph vs. 48.6±13 kph per Table A2) while the same is not true for WinSMASH delta V where average delta V was actually higher (difference not significant, p>0.05) for non-ICU cases at 48.0±19.1 kph versus 47.4±20.1 kph for ICU cases (Table A2).

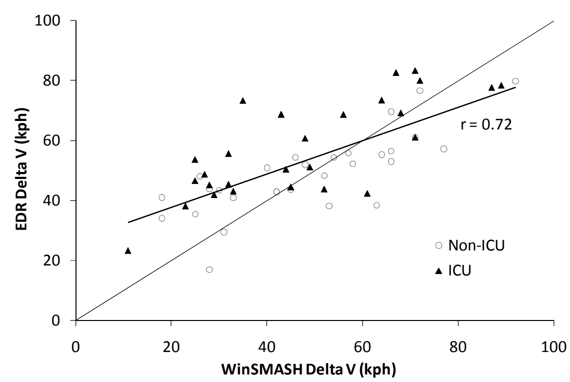


**Figure 4**. EDR vs. WinSMASH delta V for MY 2001+ CIREN EDR cases (n=59)

Table 4 shows the regression results for the unweighted NASS-CDS EDR data set. Though the dependent outcomes that the independent variables were evaluated against are limited to ISS 16+ and MAIS 3+, it is reasonable to believe that these injury severity-based outcomes would correlate well with the outcomes studied in the CIREN data sets. For example, simple logistic regression analysis of the CIREN non-EDR data set found that ISS was a significant predictor of ICU ($p < 0.0001$). Regression results for the NASS-CDS EDR data set shows that EDR delta V, 50 ms peak acceleration derived from EDR delta V, pre-impact vehicle speed, pre-impact braking, vehicle type, belt use, BMI and weight were all at least marginally significant predictors ($p < 0.10$) for both ISS 16+ and MAIS 3+.

While age was significantly associated with many of the hospital care-based outcomes studied in the CIREN non-EDR data set, it was only a marginally significant predictor for MAIS 3+ in the NASS-CDS EDR data set. The existence of multiple impacts, gender and occupant height were not significant predictors for either outcome.

Table A4 (Appendix) compares the single variable logistic regression results of the weighted NASS-CDS EDR data sets versus the unweighted data set. It can be seen that some variables that were at least marginally significant ($p<0.1$) predictors of the dependent outcomes with the unweighted data set were no longer significant ($p < 0.05$) or marginally significant ($p < 0.1$) predictors in many cases with the weighted data sets. These included pre-impact braking, BMI, weight, and age.

Different than the CIREN EDR data set, WinSMASH delta V was generally equivalent to EDR delta V with respect to the significance of its association (as evidenced by similar $\chi^2$ values) with ISS 16+ and MAIS 3+ in analyses of the NASS-CDS EDR data set. Model fit (-2 Log L) was also comparable for EDR and WinSMASH delta V. However, as previously documented (Gabler et al., 2004; Niehoff and Gabler, 2006), WinSMASH delta V tends to underestimate actual delta V based on EDR data. Similar to Figure 4, Figure 5 plots EDR vs. WinSMASH delta V for the NASS-CDS 2001+ model year unweighted data. The correlation was similar to that seen with the CIREN EDR cases (r=0.73). Additionally, it was found that the average WinSMASH delta V was 12.1% lower than EDR delta V (Table 5) and that the difference was significant ($p < 0.001$). In addition to comparing means and evaluating the correlation of EDR and WinSMASH delta V, the maximum likelihood estimates for the WinSMASH delta V and EDR delta V from logistic regression analysis of the unweighted sample were used to plot the predicted risk of MAIS 3+ against delta V (Figure 6). It can be seen that the logistic curve for WinSMASH delta V predicts a higher probability of MAIS 3+ for a given delta V value as compared to EDR delta V.

Table 5 compares the rates of ISS 16+ and MAIS 3+ and the associated differences in delta V when looking at NASS-CDS EDR cases where WinSMASH delta V was available versus cases where it was missing. The shaded boxes are for comparisons in which the difference in means (ISS, MAIS, delta V) was significant ($p < 0.05$). It can be seen that the average ISS and MAIS values were significantly higher for cases with missing WinSMASH delta V versus cases with known WinSMASH delta V.

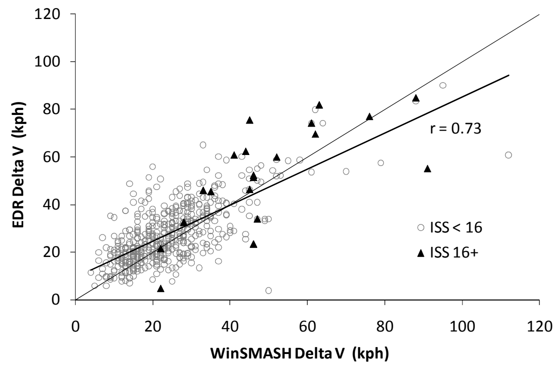


**Figure 5.** EDR vs. WinSMASH delta V for MY 2001+ NASS-CDS EDR cases

**Table 5**. Comparison of MAIS and ISS for cases with known vs. missing WinSMASH delta V

| Data Set[1] | N[2] | ISS 16+ Count | ISS 16+ % of Tot | ISS 16+ Avg | MAIS 3+ Count | MAIS 3+ % of Tot | MAIS 3+ Avg | Avg EDR Delta V (kph) | Avg WinSMASH Delta V (kph) |
|---|---|---|---|---|---|---|---|---|---|
| MY 2001+ | 811 | 43 | 5.3% | 3.7 | 119 | 14.7% | 1.4 | 29.0 | **25.2** |
| Known WinSMASH DV MY 2001+ | 624 | 24 | 3.8% | 3.2 | 77 | 12.3% | 1.3 | 28.5 | **25.2** |
| Missing WinSMASH DV MY 2001+ | 187 | 19 | 10.2% | **5.4** | 42 | 22.5% | **1.6** | 30.8 | NA |

1. GAD1 frontals with known injury data, good EDR delta V, and NASS case years of 2000-08
2. Number of cases represents number of occupant cases; same inclusion criteria as CIREN case study

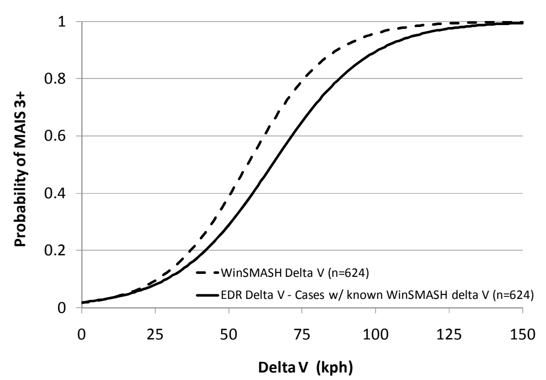


**Figure 6**. Probability of MAIS 3+ vs. EDR and WinSMASH delta V; NASS-CDS EDR data set

## DISCUSSION

As has been previously shown (Craig et al., 2009), telematics/EDR variables can be significant predictors of hospital care-based outcomes. This study has looked again at CIREN case data to reassess the current significance of those EDR variables and has expanded to include alternative dependent outcomes for evaluation including a composite outcome recommended by Lerner, 2006. In the case of delta V, which was a significant predictor for all outcomes in the CIREN non-EDR data set (MY 1998+, n=925, Table 2), the significance of the association between delta V and outcome (based on $\chi^2$

values) was strongest for the composite outcome recommended by Lerner, which was ICU within 24 hours, non-orthopedic emergency procedure within 24 hours or in-hospital fatality.

Many studies have discussed the need to combine telematics data with crash reconstruction-based algorithms such as the URGENCY Algorithm for the purpose of improving emergency response for seriously injured motor vehicle crash victims (Augenstein et al., 2001; Augenstein et al., 2003; Augenstein et al., 2005; Augenstein et al., 2006; Augenstein et al., 2007; Champion et al., 2003; Champion et al., 2005). More recent work (Bahouth et al., 2008; Kononen et al., 2010) has followed those recommendations and the recommendations from the CDC expert panel (CDC, 2008) in developing algorithms for use in production AACN systems.

The study by Craig et al. (2009) took advantage of the strengths of both CIREN and NASS-CDS to develop combined outcome models. The current study took an alternative approach to look at the predictors and outcomes that should be considered in the development of future predictive models that could be used as part of an AACN system and has highlighted a few deficiencies in the current data sets. Analyses included the addition of alternative composite outcomes and the evaluation of association between the predictors studied (Table 1) and ISS 16+ and MAIS 3+ using the NASS-CDS EDR data set. As noted, ISS was found to be a strong predictor of ICU ($p < 0.0001$). So, it is reasonable to believe that potential telematics or voice communicated variables that were significant predictors of ISS 16+ in the NASS-CDS EDR data set, such as pre-impact braking, could also be significant predictors of hospital care-based outcomes, such as ICU, in an expanded data set of CIREN EDR cases.

In completing logistic regression analysis of independent variables and dependent outcomes, the current study re-affirms that many typical factors generally thought to be positively associated with severity of injury such as delta V and occupant age were found to be significant predictors of many of the outcomes studied for the CIREN non-EDR data set. GCS, which is currently a measure used in Step 1 of the 2006 ACS Field Triage Decision Scheme was also a strong predictor of outcomes in the non-EDR CIREN data set. In the case of both NASS–CDS and CIREN EDR data sets, EDR delta V was the independent variable most frequently found to be significantly associated with the outcomes studied and in most cases had the highest $\chi^2$ values and the lowest -2 Log L values. In the case of the CIREN EDR data set, EDR delta V was a better predictor of outcomes than WinSMASH delta V. To further study the predictive abilities of delta V and other EDR/telematics variables, especially in the case of the hospital care-based outcomes found in CIREN, a much larger data set of EDR cases may be needed.

As noted, there were other variables that were found to be at least marginally significant predictors for many of the outcomes studied. These included items recommended by the CDC expert panel such as age > 55 years old, vehicle type, seat belt use, and multiple impacts. Though, vehicle type, and for the most part, seat belt use were not found to be significantly associated with the outcomes studied in the CIREN data sets, they were significant predictors of ISS 16+ and MAIS 3+ in the NASS-CDS EDR data set. Conversely, while the independent variable multiple impacts was a significant predictor for a few of the hospital care-based outcomes, at least at the $p < 0.1$ level, it was not a significant predictor of ISS 16+ or MAIS 3+ in analysis of the NASS-CDS EDR data set.

There are additional items beyond those recommended by the CDC expert panel that were shown to be significantly associated with the hospital care-based and/or injury severity-based (ISS, MAIS) outcomes that could also be communicated via telematics or be variables that could be considered in future multivariate predictive model development. Those included pre-impact braking, pre-impact vehicle speed, occupant weight/BMI, and GCS.

EDR delta V was found to be significantly associated with many hospital care-based outcomes in analyses of the CIREN EDR data set. The 50 ms peak acceleration variable was also a significant predictor of outcomes, but was not better than EDR delta V. The 50 ms window is associated with the acceleration severity index (CEN, 1998). Gabauer and Gabler (2007) also found that the acceleration severity index was not a better predictor of injury than delta V.

Similar to the prior study by Craig et al. (2009), in single variable logistic regression analysis of CIREN EDR cases, EDR delta V was a better predictor of the outcomes studied than WinSMASH delta V. However, when analyzing larger data sets such as the CIREN non-EDR (WinSMASH delta V, only) or the NASS-CDS EDR data sets (WinSMASH and EDR delta V) both WinSMASH- and EDR-based delta V were shown to be significant predictors of motor vehicle crash occupant outcomes. Future study with a larger data set of EDR cases should be done to further assess the predictive performance of all EDR-based variables including delta V, pre-impact braking and pre-impact vehicle speed for both hospital care-based outcomes and injury severity measures such as ISS 16+ and MAIS 3+.

Missing WinSMASH delta V data may affect the severity of cases included in modeling and thus may change the significance found and/or model coefficients. In the CIREN and NASS-CDS EDR data sets, WinSMASH delta V was missing 26% and 23% of the time, respectively. For the unweighted NASS-CDS data set, Table 5 highlighted the significant increase in injury severity (ISS and MAIS) in cases with unknown WinSMASH delta V versus cases with known WinSMASH delta V. Additionally, as found in prior studies (Gabler et al., 2004; Niehoff and Gabler, 2006), the current study noted that WinSMASH delta V was on average significantly less than EDR delta V. As shown in Figure 6, a given WinSMASH delta V value will predict a higher probability of MAIS 3+ than for the same value of EDR delta V given WinSMASH delta V being significantly lower on average than EDR delta V (12.1% in the current study for MY 2001+).

In summary, though WinSMASH delta V can be a significant predictor of outcomes, predictive models that are developed with it may be limited due to the following issues: 1) cases with missing WinSMASH delta V, which have more severe outcomes on average (MAIS and ISS), may not be used to develop the respective predictive models and 2) over-prediction of the probability for a given outcome since WinSMASH delta V is on average significantly lower than EDR delta V.

**Study Limitations**

As with the prior study (Craig et al., 2009), the current study was limited by the number of CIREN EDR frontal cases available (n=80). To do a more thorough study of the association between potential telematics/EDR and voice communicated variables and the individual or composite hospital care-based outcomes, a much larger data set of EDR cases would need to be developed. Even in the NASS-CDS EDR data set, there were relatively few cases (raw count of n=43 ISS 16+ cases out of 811 total).

Another limitation of this study is that only frontal crash cases were analyzed as part of the three data sets. CDC expert panel recommended elements such as PDOF (front, right, left, or rear impact) were not evaluated in the current study as recommended by the Expert Panel. Additionally, it is expected that variables such as delta V and belt use may have different relationships with hospital care- and injury severity-based outcomes in side impact than they do in frontal impacts. As additional EDR data becomes available in side impact cases, there will be an opportunity to employ the current methods of this study and the prior study by Craig et al. (2009) to study the association between telematics/EDR and voice communicated variables and occupant outcomes in side impact crashes.

This study only looked at the significance of association and model fit for a set of independent variables (Table 1) through simple univariate logistic regression. This study did not attempt to study the interactions that may exist between variables. The study also did not attempt to develop multivariable predictive models as was done by Craig et al., (2009). While some variables may not have been shown to be even marginally ($p< 0.10$) associated with any or all of the hospital care-based outcomes, ISS 16+ or MAIS 3+, it is still possible that those variables could improve the predictive power of a multi-variable model.

**Future Study**

Though, not evaluated in the current study, other considerations such as vehicle compliance status and performance in consumer metric tests may want to be considered for future study when testing the association of independent variables and outcomes of interest. The assumption is that newer model year vehicles with more advanced restraint systems and vehicle structures will perform differently (higher delta V for a given probability of ICU or ISS 16+, e.g.) than an older model vehicle. For example, Ryb et al., (2009) found that later model year vehicles experienced a decreased likelihood of severe thoracic and spinal injuries and death. The average age by model year of vehicles in this study were 2001.9±2.9, 2003.3±2.0 and 2002.9±1.6 for the CIREN non-EDR, CIREN EDR and NASS-CDS EDR data sets, respectively. Thus it is possible that the relationship between predictors and outcomes could be different when applied to newer vehicles. Future studies looking at the significance and magnitude of the association between predictors and outcomes of interest may benefit from having a greater concentration of newer vehicles.

The CDC's expert panel recommended ISS 16+ as the threshold for someone needing trauma center care. It is debatable whether ISS 16+ is the best measure for trauma center need. The composite measure proposed by Lerner (2006) or a similar composite measure may be a better or more reliable outcome to model with respect to need for someone getting Level I or highest available trauma center care. Unfortunately, it is not possible to compare models of ISS and hospital care-based outcomes using CIREN data. There is no reason to believe that CIREN data would be biased in a way that would alter the measures of association observed between the independent variables and the hospital care-based dependent outcomes of interest in this study. However, with respect to ISS and MAIS, CIREN may have a different distribution of vehicle and occupant variables than NASS-CDS or the real-world since all CIREN occupants were treated at a Level I trauma center. Thus, it is not possible or appropriate to compare prediction strength between the hospital-based outcomes and the CDC expert panel's ISS 16+ recommendation using CIREN data alone. Unfortunately, hospital care-based outcomes, such as ICU and need for invasive surgery, are not available for study in NASS-CDS. Future studies may need to consider the use of alternative databases and/or the collection of new data within existing databases to enable a comparison of models that predict injury severity (MAIS 3+, ISS 16+) versus hospital care-based outcomes.

## CONCLUSIONS

This study looked at three sets of frontal crash data to assess the significance of the association between independent variables that can be part of what is communicated via telematics or direct communication with a PSAP or telematics provider and hospital care-based (ICU, OR, etc.) and injury severity (MAIS, ISS) outcomes. The following conclusions can be made:

- Of the CDC expert panel recommended telematics elements (delta V, belt use, PDOF, multiple impacts, vehicle type) only delta V was found to consistently be a significant predictor of hospital-care-based outcomes in analysis of the two CIREN data sets. Belt use was only significant for fatality (non-EDR data set) and OR < 12 and 24 hours (EDR data set), multiple impacts was only significant for fatality (non-EDR data set) and vehicle type was not significant for any outcome in studies using CIREN data.
- Of the five expert panel recommended telematics variables, only multiple impacts was not a significant predictor of ISS 16+ or MAIS 3+ in the NASS-CDS EDR data set.
- Additional variables beyond those recommended by the CDC Expert Panel (CDC, 2008) that could be communicated via telematics were also found to be significantly associated with hospital care-based outcomes, ISS 16+, and/or MAIS 3+. Those included pre-impact braking, pre-impact vehicle speed, occupant weight, and BMI.
- Items that could be collected through vehicle occupant communication with the telematics provider or PSAP, including age and GCS, were found to be significantly associated with many of the outcomes studied. In the CIREN non-EDR data set in particular, GCS, either as a continuous variable or as GCS < 14, was one of the most significant predictors of outcome.
- The composite measure of ICU, in-hospital fatality or non-orthopedic emergency surgery within 24 hours proposed by Lerner et al. (2006) had a strong relationship between delta V, age and GCS and could be considered as an alternative to ISS and MAIS-based models.
- WinSMASH Delta V was the only variable that was significantly associated with all outcomes studied in the CIREN non-EDR data set.
- EDR delta V was a better predictor of hospital care-based outcomes than WinSMASH delta V based on analysis of the CIREN EDR data set.
- Cases with missing WinSMASH delta V have significantly higher average MAIS and ISS. All else equal, this could result in differences in the probability function developed for the respective outcome or outcomes.
- An algorithm developed using WinSMASH delta V may over-predict the probability of a given outcome when applied as part of an AACN system given WinSMASH delta V being significantly lower than EDR delta V on average.

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## APPENDIX

**Table A1**. Average occupant measures for CIREN data sets by outcome

| Data Set | Outcome | Group | N | MAIS | | ISS | | Occupant Age (years) | | Occupant Height (cm) | | Occupant Weight (kg) | | BMI | | # of AIS 3+ Injuries | | # of AIS 2+ Injuries | | Total Injuries | | Total Charges | | GCS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| CIREN - EDR Data Set | All | NA | 80 | 3.3 | 0.7 | 18.9 | 9.8 | 49.9 | 20.7 | 170.1 | 11.0 | 82.7 | 22.1 | 28.4 | 6.8 | 2.6 | 1.9 | 5.7 | 3.5 | 10.6 | 5.2 | $73,938 | $82,288 | 14.6 | 1.7 |
| | ICU | No | 40 | 3.1 | 0.5 | 15.6 | 6.8 | 47.8 | 20.7 | 170.5 | 10.6 | 79.2 | 20.9 | 26.8 | 5.6 | 2.1 | 1.2 | 4.5 | 2.8 | 8.6 | 4.4 | $49,475 | $35,751 | 14.9 | 0.4 |
| | | Yes | 40 | 3.5 | 0.8 | 22.2 | 11.2 | 52.0 | 20.9 | 169.8 | 11.6 | 86.3 | 23.0 | 29.9 | 7.5 | 3.1 | 2.3 | 7.0 | 3.7 | 12.6 | 5.2 | $97,178 | $104,973 | 14.3 | 2.3 |
| | Fatal | No | 77 | 3.2 | 0.6 | 18.3 | 9.3 | 49.5 | 20.2 | 170.3 | 11.2 | 83.1 | 22.5 | 28.4 | 6.9 | 2.5 | 1.7 | 5.5 | 3.3 | 10.3 | 5.1 | $72,424 | $82,854 | 14.9 | 0.4 |
| | | Yes | 3 | 4.7 | 0.6 | 35.7 | 8.7 | 60.4 | 35.3 | 165.3 | 4.0 | 73.3 | 4.7 | 26.8 | 1.9 | 5.7 | 3.8 | 10.7 | 4.2 | 18.3 | 2.9 | $111,801 | $66,787 | 8.3 | 5.9 |
| | ICU, Fatal or OR < 12 hrs | No | 26 | 3.0 | 0.5 | 14.7 | 6.5 | 51.9 | 20.9 | 171.0 | 11.0 | 79.4 | 22.9 | 26.6 | 6.2 | 2.0 | 1.0 | 3.8 | 1.8 | 7.6 | 3.6 | $47,534 | $35,131 | 14.9 | 0.5 |
| | | Yes | 54 | 3.4 | 0.7 | 21.0 | 10.5 | 48.9 | 20.8 | 169.7 | 11.1 | 84.3 | 21.8 | 29.2 | 6.9 | 2.9 | 2.1 | 6.7 | 3.7 | 12.0 | 5.3 | $85,674 | $94,053 | 14.5 | 2.0 |
| | ICU, Fatal or OR < 24 hrs | No | 18 | 2.8 | 0.5 | 13.1 | 5.5 | 57.0 | 21.9 | 170.1 | 10.5 | 72.2 | 19.3 | 24.0 | 3.4 | 1.9 | 1.0 | 3.2 | 1.7 | 7.3 | 4.1 | $48,303 | $30,410 | 14.9 | 0.2 |
| | | Yes | 62 | 3.4 | 0.7 | 20.6 | 10.1 | 47.8 | 20.1 | 170.2 | 11.3 | 85.8 | 22.1 | 29.6 | 7.0 | 2.8 | 2.0 | 6.5 | 3.5 | 11.6 | 5.1 | $81,082 | $90,583 | 14.5 | 1.9 |
| | ICU, Fatal or Non-Ortho OR < 24 hrs | No | 36 | 3.0 | 0.5 | 14.6 | 6.2 | 48.2 | 20.6 | 170.3 | 10.2 | 79.1 | 21.6 | 26.8 | 5.8 | 2.1 | 1.2 | 4.5 | 2.9 | 8.7 | 4.7 | $52,063 | $36,510 | 14.9 | 0.4 |
| | | Yes | 44 | 3.5 | 0.8 | 22.5 | 10.7 | 51.2 | 21.0 | 170.0 | 11.8 | 85.7 | 22.4 | 29.6 | 7.3 | 3.0 | 2.2 | 6.8 | 3.6 | 12.1 | 5.2 | $90,842 | $102,136 | 14.3 | 2.3 |
| | OR < 12 hrs | No | 50 | 3.2 | 0.7 | 18.8 | 10.0 | 52.4 | 21.8 | 170.2 | 11.4 | 84.7 | 23.5 | 29.0 | 7.4 | 2.5 | 1.9 | 4.9 | 3.1 | 9.2 | 4.5 | $69,478 | $81,886 | 14.5 | 2.0 |
| | | Yes | 29 | 3.3 | 0.6 | 19.7 | 9.4 | 46.0 | 18.8 | 169.8 | 10.6 | 79.5 | 20.1 | 27.4 | 5.7 | 2.8 | 1.9 | 7.1 | 3.9 | 12.6 | 5.6 | $81,973 | $85,159 | 14.8 | 0.5 |
| | OR < 24 hrs | No | 31 | 3.2 | 0.8 | 18.7 | 10.7 | 57.1 | 21.4 | 170.0 | 11.5 | 81.0 | 23.5 | 27.5 | 6.5 | 2.6 | 2.1 | 4.4 | 3.2 | 8.4 | 4.6 | $68,104 | $93,033 | 14.3 | 2.6 |
| | | Yes | 46 | 3.3 | 0.6 | 19.7 | 9.1 | 46.4 | 19.3 | 170.4 | 10.9 | 83.9 | 21.7 | 28.8 | 6.7 | 2.7 | 1.8 | 6.7 | 3.5 | 11.9 | 5.1 | $80,817 | $76,824 | 14.8 | 0.5 |
| | Non-Ortho OR < 24 | No | 70 | 3.2 | 0.7 | 18.5 | 10.2 | 50.1 | 20.9 | 170.1 | 10.9 | 84.0 | 22.7 | 28.8 | 7.0 | 2.6 | 1.8 | 5.5 | 3.3 | 10.5 | 5.3 | $76,240 | $85,481 | 14.6 | 1.7 |
| | | Yes | 10 | 3.5 | 0.5 | 21.7 | 6.0 | 48.3 | 20.9 | 170.4 | 12.3 | 73.9 | 15.8 | 25.3 | 3.6 | 2.8 | 2.3 | 7.5 | 4.3 | 11.1 | 4.4 | $58,288 | $56,782 | 14.5 | 0.8 |
| CIREN - Non-EDR Data Set | All | NA | 591 | 3.3 | 0.8 | 19.2 | 12.4 | 45.5 | 19.1 | 170.1 | 10.1 | 82.3 | 23.0 | 28.5 | 7.3 | 2.7 | 2.4 | 5.6 | 4.5 | 10.4 | 6.4 | $88,017 | $113,383 | 14.5 | 1.8 |
| | ICU | No | 371 | 3.0 | 0.7 | 15.4 | 10.3 | 43.9 | 18.3 | 170.5 | 9.8 | 82.1 | 21.3 | 28.3 | 6.9 | 2.0 | 1.4 | 4.2 | 2.8 | 8.5 | 4.8 | $53,993 | $56,368 | 14.8 | 1.3 |
| | | Yes | 212 | 3.7 | 0.8 | 26.1 | 13.1 | 48.7 | 20.2 | 169.5 | 10.5 | 82.4 | 25.4 | 28.8 | 7.9 | 4.0 | 3.0 | 8.1 | 5.8 | 13.8 | 7.4 | $147,210 | $156,851 | 14.0 | 2.5 |
| | Fatal | No | 578 | 3.2 | 0.8 | 18.9 | 12.2 | 45.3 | 19.0 | 170.1 | 10.1 | 82.1 | 22.8 | 28.4 | 7.3 | 2.6 | 2.2 | 5.5 | 4.5 | 10.3 | 6.4 | $88,855 | $114,228 | 14.6 | 1.6 |
| | | Yes | 13 | 4.2 | 1.0 | 34.3 | 14.1 | 54.8 | 24.1 | 172.9 | 9.3 | 92.1 | 29.1 | 32.5 | 9.9 | 6.8 | 4.5 | 10.3 | 4.8 | 17.1 | 4.5 | $51,693 | $58,649 | 10.6 | 5.2 |
| | ICU, Fatal or OR < 12 hrs | No | 239 | 2.9 | 0.6 | 14.2 | 6.9 | 45.5 | 18.2 | 171.0 | 9.5 | 80.8 | 21.3 | 27.7 | 6.4 | 1.8 | 1.1 | 3.9 | 2.5 | 8.1 | 4.3 | $50,896 | $52,992 | 14.9 | 0.8 |
| | | Yes | 330 | 3.4 | 0.8 | 21.5 | 12.0 | 45.3 | 19.4 | 169.7 | 10.5 | 83.0 | 24.0 | 28.9 | 7.8 | 3.2 | 2.7 | 6.7 | 5.3 | 11.8 | 7.0 | $117,857 | $136,603 | 14.4 | 2.0 |
| | ICU, Fatal or OR < 24 hrs | No | 151 | 2.9 | 0.6 | 14.0 | 6.4 | 49.0 | 18.7 | 171.0 | 9.6 | 79.9 | 19.7 | 27.5 | 5.9 | 1.7 | 1.1 | 3.8 | 2.7 | 8.1 | 4.5 | $46,381 | $52,784 | 14.8 | 1.0 |
| | | Yes | 418 | 3.3 | 0.8 | 20.0 | 11.6 | 44.1 | 18.8 | 170.0 | 10.2 | 82.9 | 24.0 | 28.8 | 7.7 | 3.0 | 2.5 | 6.2 | 4.9 | 11.0 | 6.7 | $105,411 | $126,055 | 14.5 | 1.8 |
| | ICU, Fatal or Non-Ortho OR < 24 hrs | No | 335 | 2.9 | 0.6 | 13.7 | 6.5 | 43.5 | 18.0 | 170.6 | 9.9 | 82.4 | 21.4 | 28.4 | 6.9 | 1.8 | 1.1 | 3.9 | 2.5 | 8.0 | 4.3 | $53,186 | $53,923 | 14.9 | 0.7 |
| | | Yes | 234 | 3.6 | 0.8 | 25.2 | 12.0 | 48.1 | 19.8 | 169.7 | 10.4 | 81.6 | 25.0 | 28.5 | 7.8 | 3.8 | 2.9 | 7.9 | 5.7 | 13.5 | 7.2 | $142,063 | $151,821 | 14.1 | 2.4 |
| | OR < 12 hrs | No | 307 | 3.1 | 0.7 | 16.9 | 9.7 | 46.8 | 19.2 | 170.2 | 9.7 | 81.3 | 23.3 | 28.0 | 7.0 | 2.2 | 1.7 | 4.6 | 3.5 | 9.1 | 5.1 | $74,359 | $105,595 | 14.7 | 1.4 |
| | | Yes | 227 | 3.4 | 0.7 | 20.1 | 11.7 | 43.3 | 18.4 | 170.2 | 10.4 | 83.7 | 22.6 | 29.1 | 7.9 | 3.1 | 2.8 | 6.7 | 5.5 | 11.6 | 7.1 | $109,026 | $121,470 | 14.5 | 1.9 |
| | OR < 24 hrs | No | 215 | 3.1 | 0.8 | 17.2 | 9.4 | 48.3 | 19.6 | 169.8 | 9.7 | 79.4 | 20.8 | 27.5 | 6.3 | 2.2 | 1.8 | 4.5 | 3.6 | 9.2 | 5.3 | $70,743 | $113,276 | 14.6 | 1.6 |
| | | Yes | 351 | 3.3 | 0.7 | 19.0 | 11.4 | 43.3 | 18.1 | 170.3 | 10.3 | 83.7 | 24.1 | 28.9 | 7.8 | 2.9 | 2.5 | 6.1 | 4.9 | 10.8 | 6.7 | $100,052 | $110,950 | 14.6 | 1.6 |
| | Non-Ortho OR < 24 | No | 500 | 3.1 | 0.7 | 16.7 | 9.4 | 45.4 | 19.0 | 170.2 | 10.0 | 83.3 | 23.6 | 28.8 | 7.5 | 2.4 | 1.9 | 4.9 | 3.7 | 9.6 | 5.6 | $81,562 | $102,348 | 14.6 | 1.5 |
| | | Yes | 77 | 3.8 | 0.8 | 28.8 | 12.7 | 44.3 | 18.4 | 170.3 | 10.4 | 75.1 | 16.9 | 26.3 | 5.7 | 4.3 | 3.6 | 9.3 | 7.1 | 14.1 | 8.6 | $143,741 | $162,032 | 14.2 | 2.2 |

**Table A2**. Average vehicle measures for CIREN data sets by outcome

| Data Set | Outcome | Group | N | EDR Longitudinal DV (kph) | | WinSMASH Longitudinal DV (kph) | | 50 ms Peak Accel (g) | | Pre-impact Vehicle Speed (kph) | | Vehicle Curb Wt (kg) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| CIREN - EDR Data Set | All | NA | 80 | 51.7 | 16.0 | 47.7 | 19.5 | 19.8 | 6.6 | 65.4 | 25.2 | 1547 | 360 |
| | ICU | No | 40 | 48.6 | 13.2 | 48.0 | 19.1 | 18.8 | 5.5 | 60.7 | 27.2 | 1561 | 391 |
| | | Yes | 40 | 54.7 | 18.0 | 47.4 | 20.1 | 20.8 | 7.4 | 70.7 | 21.9 | 1534 | 331 |
| | Fatal | No | 77 | 51.6 | 15.9 | 48.1 | 19.4 | 19.7 | 6.5 | 65.7 | 25.3 | 1552 | 365 |
| | | Yes | 3 | 54.7 | 21.2 | 25.0 | - | 21.7 | 8.5 | 57.2 | 23.9 | 1440 | 223 |
| | ICU, Fatal or OR < 12 hrs | No | 26 | 46.1 | 13.0 | 46.0 | 17.9 | 17.9 | 5.3 | 60.0 | 27.8 | 1592 | 428 |
| | | Yes | 54 | 54.4 | 16.7 | 48.5 | 20.3 | 20.7 | 7.0 | 68.3 | 23.4 | 1526 | 325 |
| | ICU, Fatal or OR < 24 hrs | No | 18 | 45.0 | 14.3 | 44.8 | 18.0 | 17.2 | 5.7 | 60.8 | 28.0 | 1535 | 422 |
| | | Yes | 62 | 53.6 | 16.0 | 48.5 | 20.0 | 20.6 | 6.7 | 66.9 | 24.3 | 1551 | 344 |
| | ICU, Fatal or Non-Ortho OR < 24 hrs | No | 36 | 48.5 | 13.8 | 48.4 | 19.2 | 18.8 | 5.7 | 60.0 | 28.5 | 1562 | 399 |
| | | Yes | 44 | 54.3 | 17.3 | 47.2 | 19.9 | 20.6 | 7.1 | 70.2 | 21.0 | 1536 | 330 |
| | OR < 12 hrs | No | 50 | 47.4 | 14.5 | 44.4 | 16.4 | 18.3 | 5.9 | 63.9 | 25.6 | 1521 | 339 |
| | | Yes | 29 | 59.0 | 16.3 | 52.4 | 23.3 | 22.2 | 7.1 | 66.3 | 23.5 | 1555 | 345 |
| | OR < 24 hrs | No | 31 | 45.4 | 14.8 | 40.8 | 17.0 | 17.6 | 6.1 | 62.8 | 24.9 | 1514 | 341 |
| | | Yes | 46 | 56.2 | 15.8 | 51.5 | 20.3 | 21.4 | 6.6 | 66.8 | 24.8 | 1556 | 344 |
| | Non-Ortho OR < 24 | No | 70 | 50.4 | 15.9 | 47.6 | 19.7 | 19.4 | 6.4 | 64.7 | 26.5 | 1526 | 349 |
| | | Yes | 10 | 60.9 | 14.4 | 48.0 | 19.0 | 22.6 | 7.6 | 70.5 | 12.4 | 1695 | 422 |
| CIREN - Non-EDR Data Set | All | NA | 591 | - | - | 45.0 | 19.5 | - | - | - | - | 1515 | 315 |
| | ICU | No | 371 | - | - | 42.7 | 18.1 | - | - | - | - | 1525 | 327 |
| | | Yes | 212 | - | - | 49.0 | 21.4 | - | - | - | - | 1504 | 293 |
| | Fatal | No | 578 | - | - | 44.7 | 19.3 | - | - | - | - | 1514 | 314 |
| | | Yes | 13 | - | - | 56.2 | 25.9 | - | - | - | - | 1580 | 364 |
| | ICU, Fatal or OR < 12 hrs | No | 239 | - | - | 41.8 | 18.2 | - | - | - | - | 1543 | 340 |
| | | Yes | 330 | - | - | 47.1 | 20.3 | - | - | - | - | 1503 | 298 |
| | ICU, Fatal or OR < 24 hrs | No | 151 | - | - | 39.8 | 17.4 | - | - | - | - | 1541 | 314 |
| | | Yes | 418 | - | - | 46.7 | 20.1 | - | - | - | - | 1512 | 318 |
| | ICU, Fatal or Non-Ortho OR < 24 hrs | No | 335 | - | - | 42.3 | 18.3 | - | - | - | - | 1534 | 331 |
| | | Yes | 234 | - | - | 48.5 | 21.0 | - | - | - | - | 1499 | 295 |
| | OR < 12 hrs | No | 307 | - | - | 43.4 | 19.2 | - | - | - | - | 1529 | 325 |
| | | Yes | 227 | - | - | 47.0 | 19.8 | - | - | - | - | 1503 | 308 |
| | OR < 24 hrs | No | 215 | - | - | 42.3 | 19.6 | - | - | - | - | 1532 | 307 |
| | | Yes | 351 | - | - | 46.3 | 19.4 | - | - | - | - | 1510 | 324 |
| | Non-Ortho OR < 24 | No | 500 | - | - | 43.7 | 19.1 | - | - | - | - | 1522 | 319 |
| | | Yes | 77 | - | - | 52.2 | 21.3 | - | - | - | - | 1486 | 302 |

**Table A3**. Average occupant and vehicle measures for NASS-CDS EDR data set by outcome

| | | | EDR Longitudinal DV (kph) | | WinSMASH Longitudinal DV (kph) | | 50 ms Peak Accel (g) | | Pre-impact Vehicle Speed (kph) | | Vehicle Curb Wt (kg) | | MAIS | | ISS | | Occupant Age (years) | | Occupant Height (cm) | | Occupant Weight (kg) | | BMI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Outcome | Group | N | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| All | NA | 811 | 29.0 | 15.9 | 25.2 | 13.3 | 10.8 | 6.5 | 34.6 | 17.7 | 1652 | 420 | 1.4 | 1.5 | 3.7 | 8.3 | 39.0 | 18.2 | 171.3 | 10.2 | 80.0 | 20.0 | 27.2 | 6.0 |
| ISS 16+ | No | 768 | 27.7 | 13.8 | 24.2 | 12.2 | 10.2 | 5.6 | 33.6 | 17.3 | 1646 | 418 | 1.3 | 1.4 | 2.1 | 3.0 | 38.9 | 18.2 | 171.2 | 10.3 | 79.6 | 19.6 | 27.1 | 5.8 |
| | Yes | 43 | 53.5 | 27.3 | 48.5 | 18.6 | 21.1 | 11.2 | 52.7 | 15.8 | 1764 | 447 | 3.9 | 1.0 | 31.6 | 17.9 | 40.8 | 18.0 | 173.9 | 8.4 | 87.4 | 24.5 | 29.0 | 8.3 |
| MAIS 3+ | No | 692 | 26.5 | 12.4 | 23.2 | 10.4 | 9.8 | 5.0 | 33.0 | 16.7 | 1644 | 422 | 0.9 | 0.7 | 1.7 | 2.0 | 38.5 | 18.0 | 171.3 | 10.4 | 79.1 | 19.2 | 26.9 | 5.7 |
| | Yes | 119 | 43.7 | 24.1 | 38.8 | 21.5 | 17.0 | 10.1 | 44.0 | 20.7 | 1700 | 405 | 4.4 | 1.7 | 15.5 | 16.8 | 41.9 | 18.9 | 171.6 | 9.2 | 85.7 | 23.5 | 29.1 | 7.5 |

**Table A4**. Regression results for unweighted vs. weighted data from NASS-CDS EDR data set

| | Outcome | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ISS 16+ | | | | | | | | MAIS 3+ | | | | | | | |
| | Unweighted | | Ratwgt ≤ 5000 | | Ratwgt ≤ 2500 | | Ratwgt ≤ 500 | | Unweighted | | Ratwgt ≤ 5000 | | Ratwgt ≤ 2500 | | Ratwgt ≤ 500 | |
| | Unweighted Counts: N=811 Set - 43 Cases<br>Weighted Counts: N=244,545 - Cases 2549 | | | | | | | | Unweighted Counts: N=811 - 119 Cases<br>Weighted Counts: N=244,545 - 9734 Cases | | | | | | | |
| **Predictor** | $\chi^2$ | p | $\chi^2$ | p | $\chi^2$ | p | $\chi^2$ | p | $\chi^2$ | p | $\chi^2$ | p | $\chi^2$ | p | $\chi^2$ | p |
| WinSMASH Delta V[1] | 39.44 | < .0001 | 37.06 | < .0001 | 37.61 | < .0001 | 34.97 | < .0001 | 55.88 | < .0001 | 41.59 | < .0001 | 47.04 | < .0001 | 46.82 | < .0001 |
| EDR Delta V | 68.37 | < .0001 | 75.03 | < .0001 | 79.99 | < .0001 | 66.56 | < .0001 | 84.38 | < .0001 | 39.77 | < .0001 | 47.49 | < .0001 | 58.28 | < .0001 |
| 50 ms Peak Accel | 67.67 | < .0001 | 56.40 | < .0001 | 58.61 | < .0001 | 57.43 | < .0001 | 85.05 | < .0001 | 42.09 | < .0001 | 48.69 | < .0001 | 52.75 | < .0001 |
| Pre-impact Speed | 37.48 | < .0001 | 28.94 | < .0001 | 27.08 | < .0001 | 21.86 | < .0001 | 32.53 | < .0001 | 20.86 | < .0001 | 19.59 | < .0001 | 13.66 | 0.0002 |
| Pre-impact Braking | 3.92 | 0.0477 | - | - | - | - | - | - | 3.81 | 0.0508 | - | - | - | - | - | - |
| PDOF | 3.20 | 0.0737 | - | - | - | - | - | - | 5.69 | 0.0171 | 3.29 | 0.0697 | 3.16 | 0.0756 | 3.96 | 0.0467 |
| Multiple Impacts | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Veh Curb Weight | 3.15 | 0.0761 | - | - | - | - | - | - | - | - | 2.84 | 0.0920 | - | - | - | - |
| Vehicle Type | 6.93 | 0.0742 | - | - | - | - | - | - | 11.99 | 0.0074 | 10.36 | 0.0157 | 10.95 | 0.0120 | 9.87 | 0.0197 |
| Belted | 14.73 | 0.0001 | 4.41 | 0.0336 | 5.46 | 0.0195 | 6.68 | 0.0098 | 25.49 | < .0001 | 6.07 | 0.0137 | 8.35 | 0.0039 | 10.53 | 0.0012 |
| Age | - | - | - | - | - | - | - | - | 3.63 | 0.0567 | - | - | - | - | - | - |
| Age > 55 | - | - | - | - | - | - | - | - | 2.74 | 0.0978 | - | - | - | - | - | - |
| Age > 65 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Gender | - | - | - | - | - | - | - | - | - | - | 7.57 | 0.0059 | 6.61 | 0.0102 | 4.63 | 0.03 |
| BMI | 3.76 | 0.0525 | - | - | - | - | - | - | 12.15 | < .0001 | - | - | - | - | 3.49 | 0.0619 |
| BMI > 35 | 3.95 | 0.0469 | - | - | - | - | - | - | 9.85 | 0.0017 | - | - | - | - | - | - |
| Height | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Weight | 5.65 | 0.0174 | - | - | - | - | - | - | 9.50 | 0.0021 | - | - | 3.30 | 0.0694 | 4.20 | 0.0403 |

1. 624 of 811 cases had WinSMASH delta V