The Urgency Algorithm - A Thermometer for Trauma

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ABSTRACT

The URGENCY algorithm uses data from on board crash recorders to assist in identifying crashes that are most likely to have time critical injuries. The algorithm calculates the risk of an AIS 3+ injury being present in the crashed vehicle. The algorithm was based on a multiple regression analysis using data from the National Accident Sampling System/Crashworthiness Data System, years 1988-97. The algorithm has been successfully used by a NHTSA demonstration project in New York to assess the feasibility of Automatic Crash Notification Systems. The algorithm assists in identifying the small fraction of crashes with time critical injuries.

INTRODUCTION

The emergence of Automatic Crash Notification (ACN) Systems has provided the ability to rapidly determine the location of crashes that are severe enough to deploy the vehicle's air bags. This capability can greatly reduce the time required to rescue injured occupants and initiate medical treatment. In the United States, there are approximately 27,000,000 crashes per year. Of these, approximately 250,000 have MAIS 2+ injuries, and 110,000 have MAIS 3+ injuries. A challenge is to identify those crashes and deploy the appropriate rescue and treatment capabilities. Of particular importance is to identify those with injuries that are time critical and urgently need medical treatment.

In 1996, NHTSA initiated efforts to improve the criteria for recognizing time critical injuries at the crash scene, based on data from the crashed vehicles. Some of the results were published by Champion (1999). Another result of the study was published by Malliaris (1997). In the Mallairis study, relationships between crash attributes and crash injuries were postulated. The probability relationships for AIS 3+ injuries and selected crash attributes were subsequently incorporated into a user-friendly software program called the URGENCY algorithm. This algorithm projects the injury probability, based on crash attributes such as deltaV, restraint use, and occupant age and gender.

In the United States, there are 42,000 deaths annually in motor vehicle crashes. Of these 20,000 die at the scene. More rapid identification of the time critical crashes might reduce the number that die at the scene as well as those that die in hospital.

The Automatic Crash Notification System will provide the possibility of identifying the location of severe crashes. The challenge that remains is to identify that small percent (1% to 2%) that have time critical injuries and rapidly dispatch the appropriate rescue resources. The challenge for the URGENCY algorithm is to help identify those crashes.

DATA SOURCES FOR THE URGENCY ALGORITHM

The basis for the URGENCY algorithm is contained in the paper published by Malliaris, Digges and DeBlois (1997). The data was based on NASS/CDS 1988-1995. The NASS weights, necessary for national projections were used as weighing factors in the processing.

A maximum likelihood procedure, specifically a logistic regression with weighing factors, was used to fit various algorithms of raw data. In this procedure, the probability of casualty was projected as:

$$P = 1/[1 + \exp(-w)] \quad (1)$$

$$w = A0 + A1*PRED1 + A2*PRED2 + \ \ldots\ldots\ldots \quad (2)$$

where PRED1, PRED 2 etc. are the selected predictors and A0, A1, and A2 are coefficients estimated by logistic regression.

The NASS data concerning car occupants involved in tow away crashes was used for the derivation of algorithms that estimate the probability of a crash involved occupant with at least one injury of maximum severity MAIS 3+. For frontal crashes with occupants protected by belts plus air bags, the equation 2 coefficients for MAIS 3+ casualties are listed in Table 1.

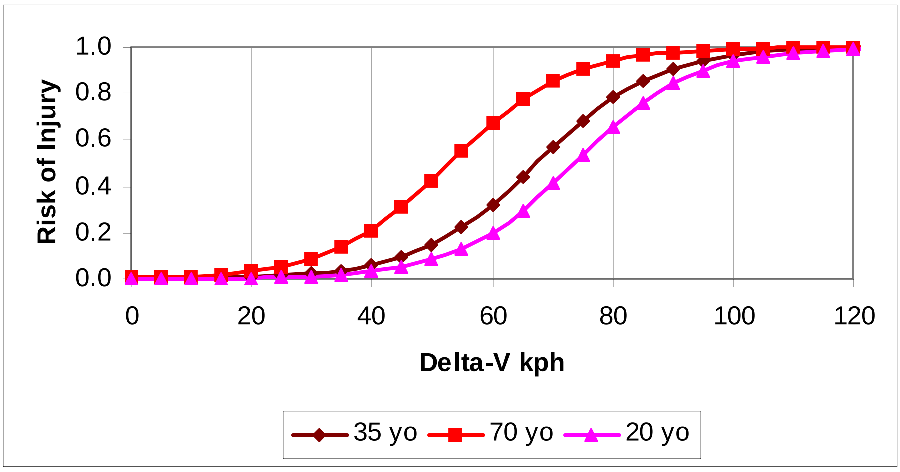
The predictors in Equation 2 are both continuous and binary. The variables Single Vehicle Crash, Occupant Gender, and Occupant Entrapment are binary variables. For a single vehicle crash, a female occupant, and an entrapped occupant the coefficients are assigned values of 1. Otherwise, the values of these variables are zero. The continuous variable coefficients assume values with units shown in Table 1. Positive values of coefficients increase the injury risk.

Table 1: Logistic Regression Coefficients

Predictor	Coefficient, Ai
Intercept	-8.056
Vehicle Delta V, mph	0.164
Max. Vehicle Crush, in.	0.037
Single Vehicle Crash	0.322
Vehicle Curb Weight, lbs.	-0.027
Occupant Age, years	0.042
Occupant Gender	0.464

A plot of delta-V and predicted injury risk is shown in Figure 1. In this Figure the binary variables were zero, the crush and delta-V were assumed to have similar values, and the vehicle weight was 3200 lbs. Plots for ages of 35, 70, and 20 years old are shown. The relationship depicted in Figure 1 will vary depending on the values of the predictor variables in Equation 2.

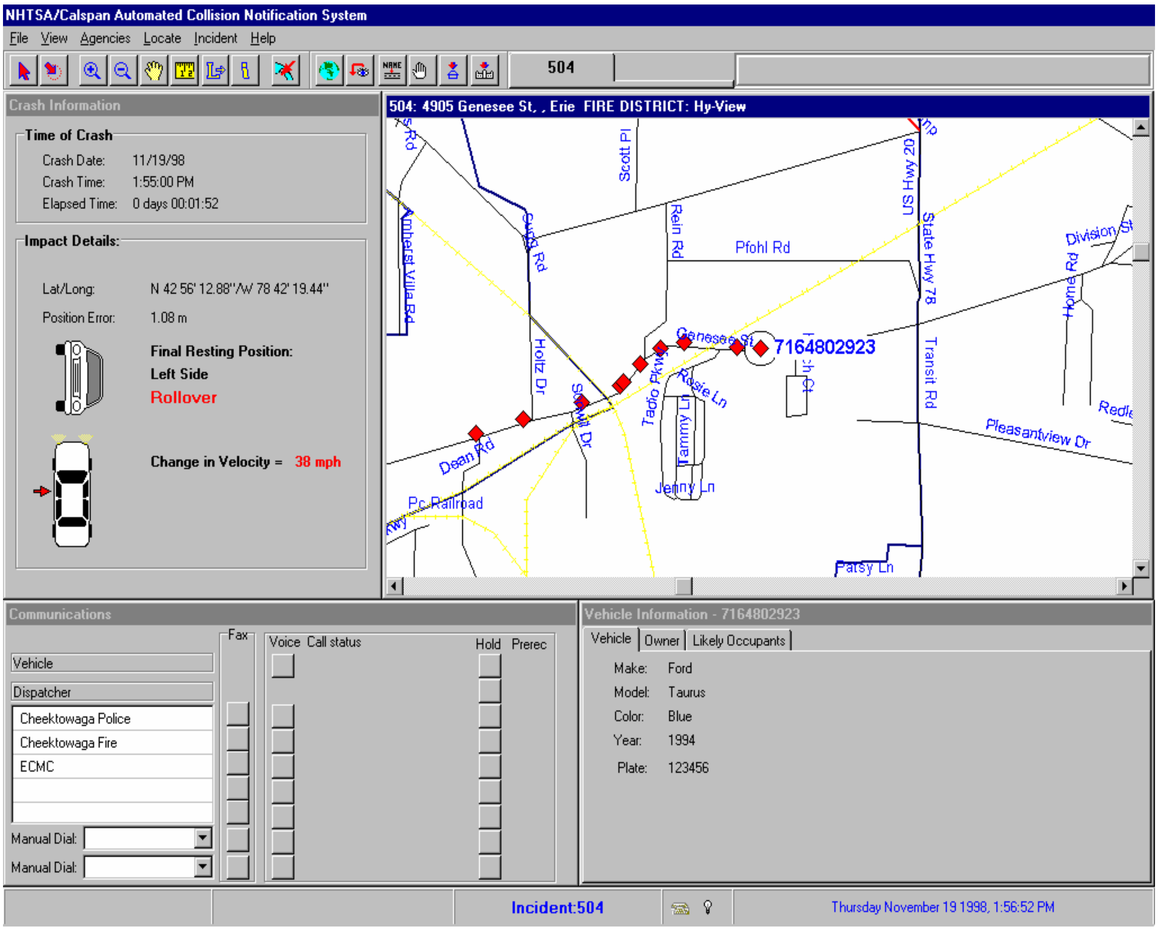
Figure 1: Probability of MAIS 3+ Outcome as a Function of Crash Severity

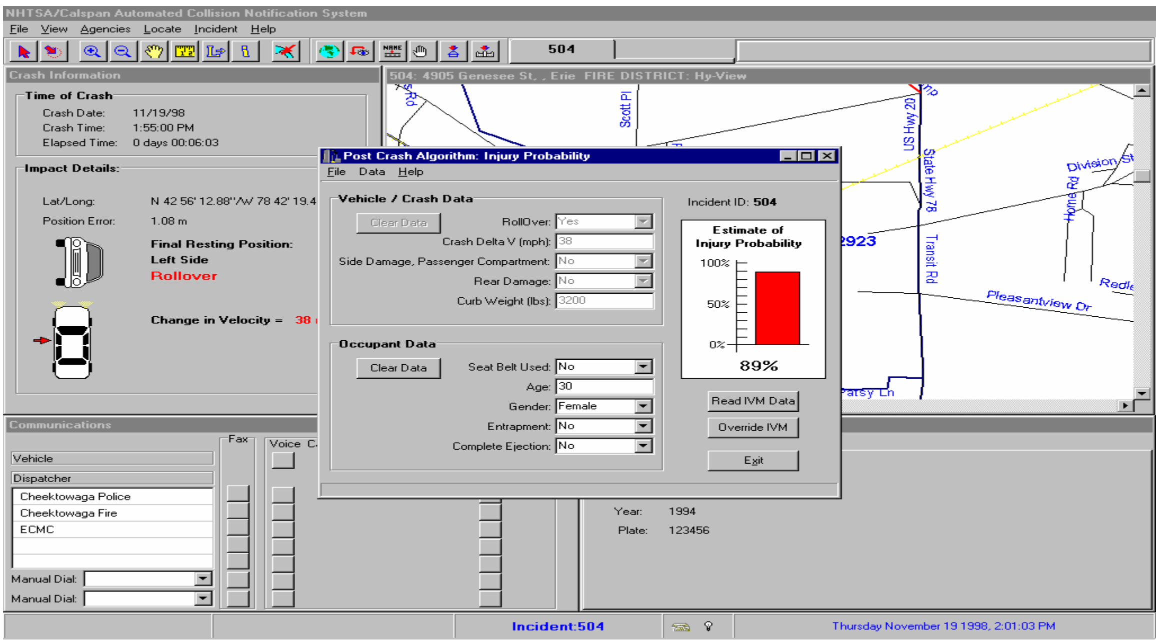


APPLICATION OF THE URGENCY ALGORITHM

The algorithm has been used by NHTSA research activities involved in evaluating ACN technology. In a study involving 1000 ACN equipped cars, NHTSA evaluated the efficicy of ACN. The dispatcher received not only the location and direction of travel, as shown in Fig 2, but also the output of the URGENCY Algorithm as shown in Figure 3.

Figure 2: Crash Location and URGENCY Score


NHTSA/Calspan Automated Collision Notification System
File View Agencies Locate Incident Help
504
Crash Information
Time of Crash
Crash Date: 11/19/98
Crash Time: 1:55:00 PM
Elapsed Time: 0 days 00:01:52
Impact Details:
Lat/Long: N 42 56' 12.88"/W 78 42' 19.44"
Position Error: 1.08 m
Final Resting Position:
Left Side
Rollover
Change in Velocity = 38 mph
504: 4905 Genesee St, , Erie FIRE DISTRICT: Hy-View
7164802923
Pfohl Rd
Scott Pl
Rein Rd
US Hwy 20
State Hwy 78
Transit Rd
Division St
Holtz Dr
Genesee St
Rosie Ln
Tammy Ln
Jenny Ln
Dean Rd
Pc Railroad
Pleasantview Dr
Patsy Ln
Communications
Fax
Voice Call status
Hold Prerec
Vehicle
Dispatcher
Cheektowaga Police
Cheektowaga Fire
ECMC
Manual Dial:
Manual Dial:
Vehicle Information - 7164802923
Vehicle Owner Likely Occupants
Make: Ford
Model: Taurus
Color: Blue
Year: 1994
Plate: 123456
Incident:504
Thursday November 19 1998, 1:56:52 PM


NHTSA/Calspan Automated Collision Notification System
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Crash Information
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Elapsed Time: 0 days 00:06:03
Impact Details:
Lat/Long: N 42 56' 12.88"/W 78 42' 19.4
Position Error: 1.08 m
Final Resting Position:
Left Side
Rollover
Change in Velocity = 38
504: 4905 Genesee St, , Erie FIRE DISTRICT: Hy-View
Post Crash Algorithm: Injury Probability
File Data Help
Vehicle / Crash Data
Clear Data
RollOver: Yes
Crash Delta V (mph): 38
Side Damage, Passenger Compartment: No
Rear Damage: No
Curb Weight (lbs): 3200
Occupant Data
Clear Data
Seat Belt Used: No
Age: 30
Gender: Female
Entrapment: No
Complete Ejection: No
Incident ID: 504
Estimate of Injury Probability
100%
50%
0%
89%
Read IVM Data
Override IVM
Exit
Communications
Fax
Voice
Vehicle
Dispatcher
Cheektowaga Police
Cheektowaga Fire
ECMC
Manual Dial:
Manual Dial:
Year: 1994
Plate: 123456
Incident:504
Thursday November 19 1998, 2:01:03 PM

DISCUSSION

Table 3 summarizes the results of the study. The three columns group the injury probabilities predicted by the URGENCY algorithm. The injury probabilities are: 0 to 10% (low); 11% to 49% (moderate); and 50+% (high). The three rows are group th occupants based on the triage criteria that caused them to be in the study. The criteria are: occupants dead at the scene (DOS); occupants that met physiological trauma criteria; and occupants transported to the Trauma Center because of high suspicion of injury. Each cell in the Table shows in the numerator, the number of cases predicted by the URGENCY algorithm. The actual number of AIS 3+ cases is shown in the denominator. For low values of injury risk, the denominator should approach zero. For high values of risk, the fraction should approach one.

The URGENCY algorithm predicted a probability of injury greater than 50% for all seven of the occupants that were dead at the scene.

For the occupants that met physiological triage criteria, the prediction was not as good. For the 50% probability of injury group the algorithm predicted all 8 occupants with AIS 3+ injuries. For the low probability group, the algorithm predicted the six occupants without AIS3+ injuries. However, there were seven occupants with AIS 3+ injuries that were predicted with injury risks less than 50%. Algorithm improvements to assist in predicting the missed AIS 3+ injuries are highly desirable.

Table 3: Number Of Cases And AIS 3+ Injuries At Each Injury Risk Grouping.

Baseline	0-10%	11-49%	50+%
DOS	0/0	0/0	7/7
Trauma	9/3	4/4	8/8
Hi Sus	9/3	11/6	11/10

For the occupants that were transported due to high suspicion of injury, the algorithm predicted 11 with 50+ probability of injury. Ten of these had AIS3+ injuries. The algorithm predicted 9 with low injury probability, and six of these did not have AIS 3+ injuries. In the 11% to 49% range, there were 6 of 11 with AIS 3+ injuries.

Table 4: Number Of Cases And AIS 3+ Injuries At Each Injury Risk Grouping With Revised Pole Impact Weighting

Pole +	0-10	11-49	50+
DOS	0/0	0/0	7/7
Trauma	7/1	2/2	12/12
Hi Sus	9/3	11/6	11/10

In examining the cases with AIS 3+ injuries and low injury probabilities, several patterns emerged. The first was that occupants exposed to crashes with fixed narrow objects had more serious injuries than predicted. By adjusting the algorithm to increase the weighting for narrow object impacts, the improvements shown in Table 4 resulted. The improvements were among the group that met physiological triage criteria.

A second improvement would be better prediction of injuries to close-in occupants from air bag deployment. If these injuries could be better predicted, the results would be as shown in Table 5. Again, the improvement is in the group that met physioligical triage criteria.

Table 5: Number Of Cases And AIS 3+ Injuries At Each Injury Risk Grouping With Revised Close-in Occupant Weighting

Close-in	0-10	11-49	50+
DOS	0/0	0/0	7/7
Trauma	6/0	1/1	14/14
Hi Sus	9/3	9/5	13/12

The largest improvement in the group that met High Suspicion of Injury criteria would result from a better algorithm to predict femur and AIS 3+ extremity injuries. If an accurate prediction could be developed, Table 3 predictions could be further improved as shown in Table 6.

Table 6: Number Of Cases And AIS 3+ Injuries At Each Injury Risk Grouping With Revised Extremity Weighting

Extrem +	0-10	11-49	50+
DOS	0/0	0/0	7/7
Trauma	6/0	1/1	14/14
Hi Sus	7/1	7/3	17/16

The cases of AIS 3 injury that remain undetected in Table 6 involve the following: frail individual, multiple impact; penetration of occupant compartment by foreign object and offside frontal impact.

One AIS 3+ case with low probability of injury involved an offside frontal crash. Increased injury risk from two-point belts in this type of crash has been reported earlier (Augenstein 2000). Additional investigation of this crash mode regarding three point belts is now underway.

CONCLUSIONS

The use of a injury probability of greater than 50% gives reasonable predictions of AIS 3+ injuries.

Improvements in the algorithm are necessary to predict air bag deployment related injuries associated with close-in occupants. In addition, pole crashes appear to carry a higher level of risk than predicted.

Overall, the predictive capability of the URGENCY algorithm was considered to be satisfactory for use as an aid in identifying occult injuries among occupants that do not meet physiological triage criteria at the crash scene. Additional, refinements identified by this study are being incorporated.

Validation using crash based data is desirable to refine the risk criteria for anticipating time critical injuries.

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