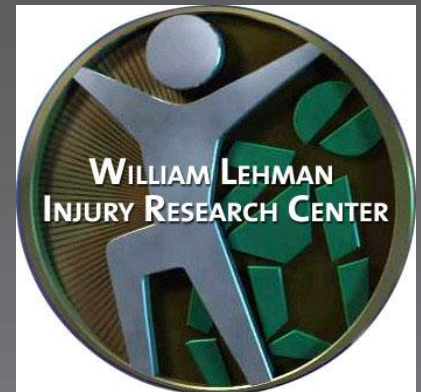
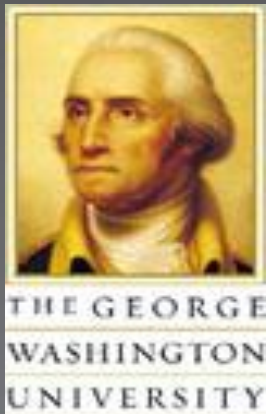


Research in Support of Enhanced Automatic Crash Notification

Prof. Kennerly Digges
VDI Symposium

8/3/11

IMPACT RESEARCH, INC.



enhanced Automatic Crash Notification

We think there is a better way --- eACN



Definition of Terms

- ACN Automatic Crash Notification –
 - Transmits geometric coordinates of crash
 - May also have voice communication with crashed vehicle occupants
- eACN enhanced Automatic Crash Notification
 - Transmits geometric coordinates
 - Provides for voice communication with occupants
 - Transmits vehicle crash data
- AACN Advanced Automatic Crash Notification
 - Similar to eACN

Definition of Terms

- URGENCY – a mathematical algorithm for estimating the risk of serious injury in crashes
 - Uses primarily on data measured by vehicle crash sensors
 - May also use occupant data such as age
- NHTSA – National Highway Traffic Administration (Federal Safety Regulations)
- CDC – Center for Disease Control (Federal Agency to reduce Disease and Trauma)
- WLIRC – William Lehman Injury Research Center of U of Miami (Augenstein, Digges & Bahouth)

Presentation Overview

- History of URGENCY
- URGENCY Crash Data Elements
- URGENCY Calculations and Accuracy

eACN Benefits to Injured Occupants

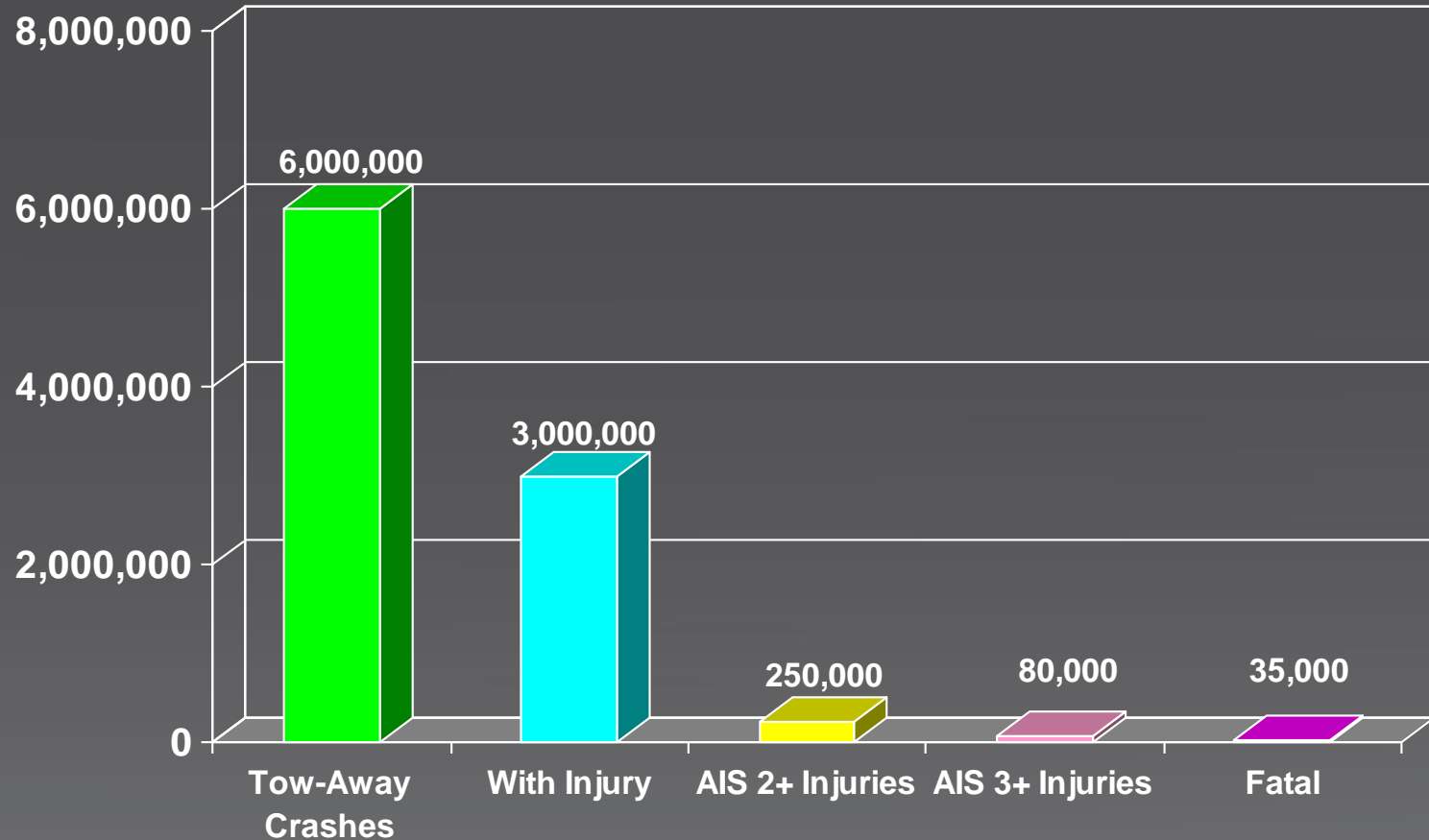
ACN BENEFITS

- Rapid and Accurate Location Would Help:
 - people with time critical injuries but are treated too late

eACN BENEFITS

- Improved Triage Would Reduce the Number of:
 - People who are mis-diagnosed and poorly triaged to the wrong care facility
 - People who are improperly treated in the right hospital due to missed injuries

US Annual Crash Distribution



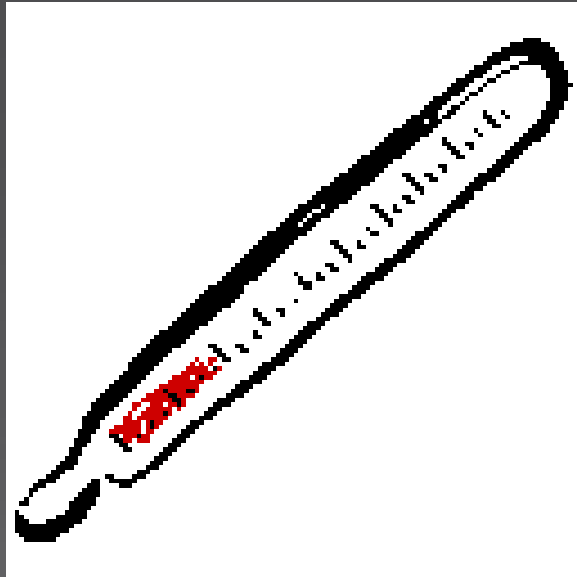
* Based on NASS/CDS 1997-2005 Annual Averages

Recognizing Crash Injured Occupants

- How do we distinguish these 80,000 MAIS 3+ from the 6,000,000 rapidly and remotely?
- What information will help rescue provide care to potentially injured occupants?



URGENCY Algorithm Offers Help



- Uses crash data
- Estimates the risk of serious injury

**URGENCY –
A Thermometer
for Trauma**

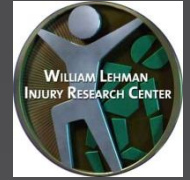
Precursors to the URGENCY Algorithm

Jones and Champion; Journal of Trauma; 1989 – *Damage Greater than 20" is indicator of severe injury - (1 Variable)*



Precursors to the URGENCY Algorithm

Lombardo and Ryan; *NHTSA Research Note* 1993 “Detection of Internal Injuries in Drivers Protected by Air Bags”, *Steering wheel deformation (1 Variable)*



1993 Scene SCALE

- Proposed by WLIRC
- Triggered by Unexpected Injuries at **Low Delta-V**
 - **S**evere Loading of the Chest - A Bent Steering Wheel – “Lift & Look”
 - **C**lose-in Occupants
 - **E**xcessive Energy in the Crash
 - **N**on-Use of Lap Belts (2-point belts)
 - **E**ye-witness Observations On-scene

Look Beyond The Obvious

While air bags, seat belts, side-impact and rollover-overhead protection belts and child safety seats are saving thousands of lives and preventing hundreds of thousands of injuries each year, they can't do it all. For more information, National Highway Traffic Safety Administration research indicates that some people are using in the United States as the use of of in-vehicle air bags that are not being detected and used. The following checklist is a rough NHTSA should increase the rates of application for a fatal injury may have occurred.

Shifting wheel information? Did air bags work? A bent steering wheel could indicate a frontal impact.

Close proximity of driver to the crossing wheel? (Close proximity of driver to the crossing wheel could be the cause of a fatal injury.)

Energy of the crash? Heavy intrusion into vehicle metal indicates a crash forces.

Non use of seat belts? A vehicle occupant should be wearing a seat belt and a proper use of seat belts.

Eye-witness reports of crash scene? Initial reports from and subsequent images of the crash scene are critical to the investigation.

William Lehman Injury Research Center

NHTSA
www.nhtsa.gov

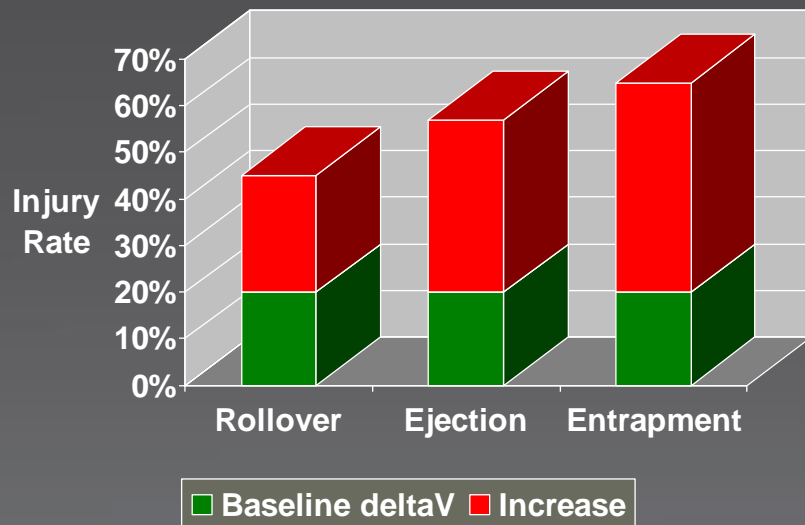
Precursors to the URGENCY Algorithm

Malliaris, Digges & DeBlois;
SAE 970393 “Relationships
Between Crash Casualties and
Crash Attributes” Regression
Analysis of NASS/CDS-
(21 Variables) -Basis for
URGENCY



NHTSA Post-Crash Injury Control Study- 1997

Produced the basis for the
URGENCY Algorithm
21 crash variables include
Influences other than DeltaV



Baseline – 25 mph Frontal

SAE TECHNICAL
PAPER SERIES

970393

Relationships Between Crash Casualties and Crash Attributes



A. C. Malliaris
DeBlois Associates

K. H. Digges
George Washington Univ.

J. H. DeBlois
DeBlois Associates

Reprinted from: Occupant Protection and Injury
Assessment in the Automotive Crash Environment
(SP-1231)

SAE The Engineering Society
For Advancing Mobility
Land Sea Air and Space
INTERNATIONAL

International Congress & Exposition
Detroit, Michigan
February 24-27, 1997

400 Commonwealth Drive, Warrendale, PA 15096-0001 U.S.A. Tel: (412)776-4841 Fax: (412)776-5760

NHTSA ACN Field Operational Test

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

Communications

Vehicle	Fax	Voice	Call status	Hold	Prerec
Cheektowaga Police					
Cheektowaga Fire					
ECMC					

Manual Dial: [Dropdown]
Manual Dial: [Dropdown]

Vehicle Information - 7164802923

Vehicle	Owner	Likely Occupants
Make: Ford		
Model: Taurus		
Color: Blue		
Year: 1994		
Plate: 123456		

Crash Location Display

Incident:504 Thursday November 19 1998, 1:56:52 PM

850 Vehicles in New York State with ACN – 1997-2000



NHTSA ACN Field Operational Test

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 00:06:03

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

Vehicle / Crash Data

RollOver: Yes
Crash Delta V (mph): 38
Side Damage, Passenger Compartment: No
Rear Damage: No
Curb Weight (lbs): 3200

Occupant 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

Year: 1994
Plate: 123456

Communications

Vehicle
Dispatcher
Cheektowaga Police
Cheektowaga Fire
ECMC

Manual Dial: [Dropdown]
Manual Dial: [Dropdown]

Fax: [Input]
Voice: [Input]

URGENCY Display

Incident: 504 Thursday November 19 1998, 2:01:03 PM

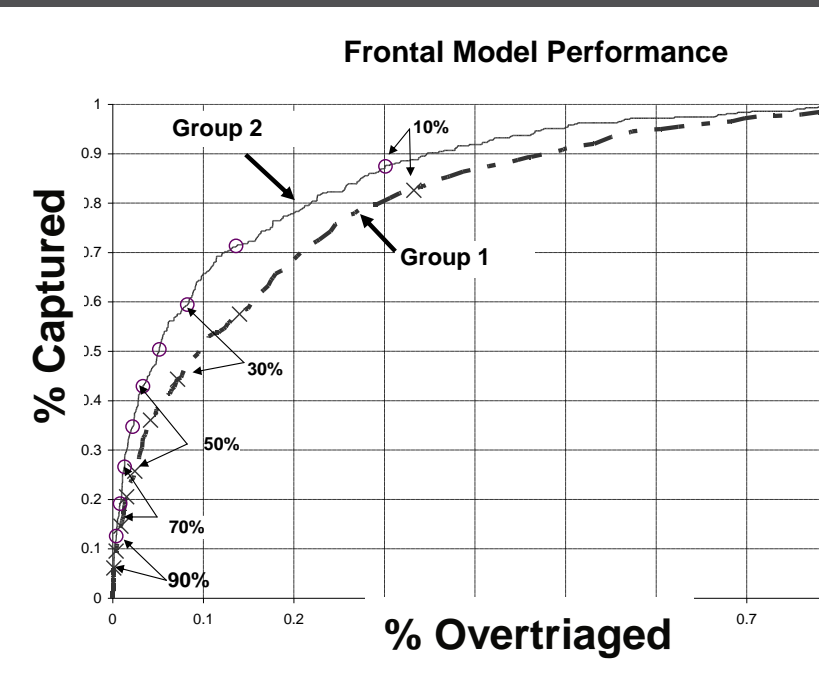
First Application of URGENCY

Dissertation by Bahouth- 2002

Refined and Validated URGENCY
Determined the accuracy for

- groups of risk predictors
- threshold risk for prediction

Published AAAM 2002, ESV 2003



DEVELOPMENT AND VALIDATION OF INJURY PREDICTING ALGORITHMS FOR AUTOMOTIVE CRASH APPLICATIONS

By
George T. Bahouth

SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF SCIENCE
AT
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, D.C.
JANUARY 2003



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THE GEORGE
WASHINGTON
UNIVERSITY
WASHINGTON DC

BMW eACN Support Research- 2002 - on

- National Survey of First Responders
 - What rescue data is most useful?
- Further URGENCY development
 - What vehicle crash data is most useful?
 - What are the benefits for each data element?
 - What should be the threshold for the ACN call?
 - What should be the criteria for “Severe Crash”?
- Research to improve the eACN performance
- Research to remove impediments to the use of the eACN technology by 1st responders



BMW eACN Support Research- 2002 - on

BMW Supported Publications

- Augenstein, J, Perdeck, E., Stratton, J., Digges, K., and Bahouth, G., “Characteristics of Crashes that Increase the Risk of Injury”, *47th Annual Proceedings of the Association for the Advancement of Automotive Medicine*, p. 561-576, September, 2003.
- Augenstein, J, Bahouth, G, and Perdeck, E, Digges, K., “Injury Identification: Priorities For Data Transmitted”, Paper 05-0355, 19th ESV Conference, June 2005.
- Augenstein, J, Perdeck, E., Digges, K., Bahouth, G., Baur, P., and Borchner, N., “A More Effective Post-Crash Safety Feature to Improve the Medical Outcome of Injured Occupants”, SAE 2006-01-0675, April 2006.
- Augenstein, J., Digges, K. Perdeck, E., Stratton, J., and Bahouth G., “Application of ACN Data to Improve Vehicle Safety and Occupant Care” Paper, 07-0512, *20th ESV Conference*, June 2007.
- Rauscher, S., Messner, G., Baur, P., Augenstein, J., Digges, K., Perdeck, E., Bahouth, G., Pieske, O., “Enhanced Automatic Collision Notification System – Improved Rescue Care Due To Injury Prediction – First Field Experience”, Paper Number: 09-0049, *Proceedings of the 21st ESV Conference*, June 2009.



Early eACN Vehicles

- GM OnStar - 2004 Chevrolet Malibu “Safe and Sound” Package – Capability to send crash data
- BMW 2008 All Models – “Assist Package” Capability to send crash data.
 - Database of eACN calls maintained by WLIRC (University of Miami)
 - Incorporated the URGENCY risk prediction

BMW eACN Report

Vehicle Accident Information - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address

Vehicle Accident Information

BMW Assist™ Safety and Convenience Services
bmwassist.com

The Ultimate Driving Machine™

Date of Incident - 11-23-2008
Incident # - 99999999

Time of Incident - 03:03:35
Central Time Zone - [Time Zone Chart](#)

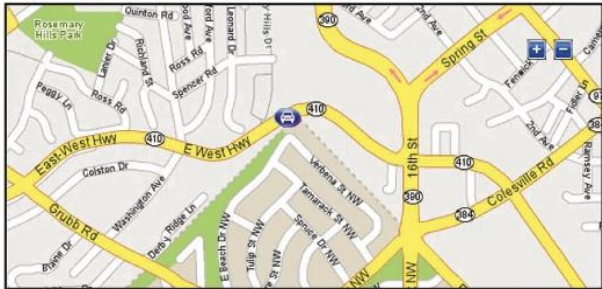
Logout

Verbal Information from Occupant

Number of Injured People in the car - 1
Number of People Seriously Bleeding - IIA
Number of People Unconscious - 1
Respective Ages - IIA
Gender - 1 Male IIA Female
Number of other individuals involved in the accident - 0

Additional Details of Accident - IIA

Vehicle Location



Vehicle Travelling -
Latitude, Longitude - 38.995888, -77.041306
Address - 1867 EAST-WEST HWY E WEST HWY MD-410 MD 20910

Vehicle Information

Make - BMW
Model - 335i Coupe
Year - 2009
VIN - WBAWC99999999999

Color - Black Sapphire Metal
License Number -
State/Province -

Information Transmitted by Vehicle

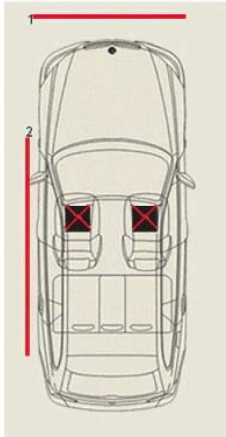
CRASH DATA INDICATES **RISK OF SEVERE INJURY**

Number of Occupants - 2
(Only Front Seats Known)

Number of Impacts - 2

Type of Crash - **Multiple Crash**

Deployed Airbag(s) - YES



Red bar indicates detected crash type (front, rear, left, right). Numbering in order of impact detection (max 3)

NEITHER BMW, NOR ITS TELEMATICS SERVICE PROVIDER, ATX, WARRANTS OR MAKES ANY REPRESENTATIONS REGARDING THE USE, VALIDITY, ACCURACY OR REUSABILITY OF, OR THE RESULTS OR THE USE OF, OR OTHERWISE RESPECTING, THE

Don



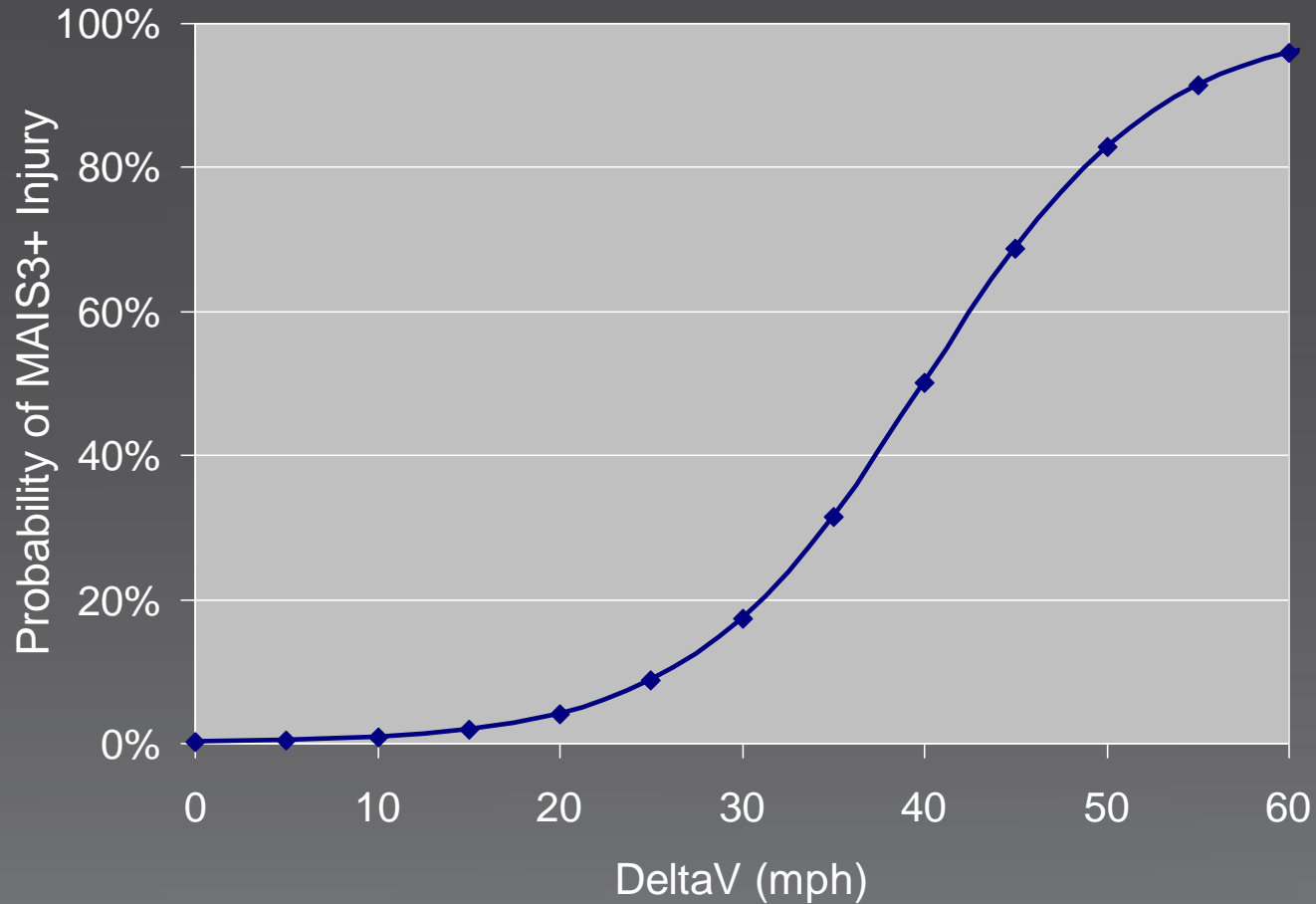
Available on-line to EMS & Trauma Centers

Presentation Overview

- History of URGENCY
- **URGENCY Crash Data Elements**
- URGENCY Calculations and Accuracy

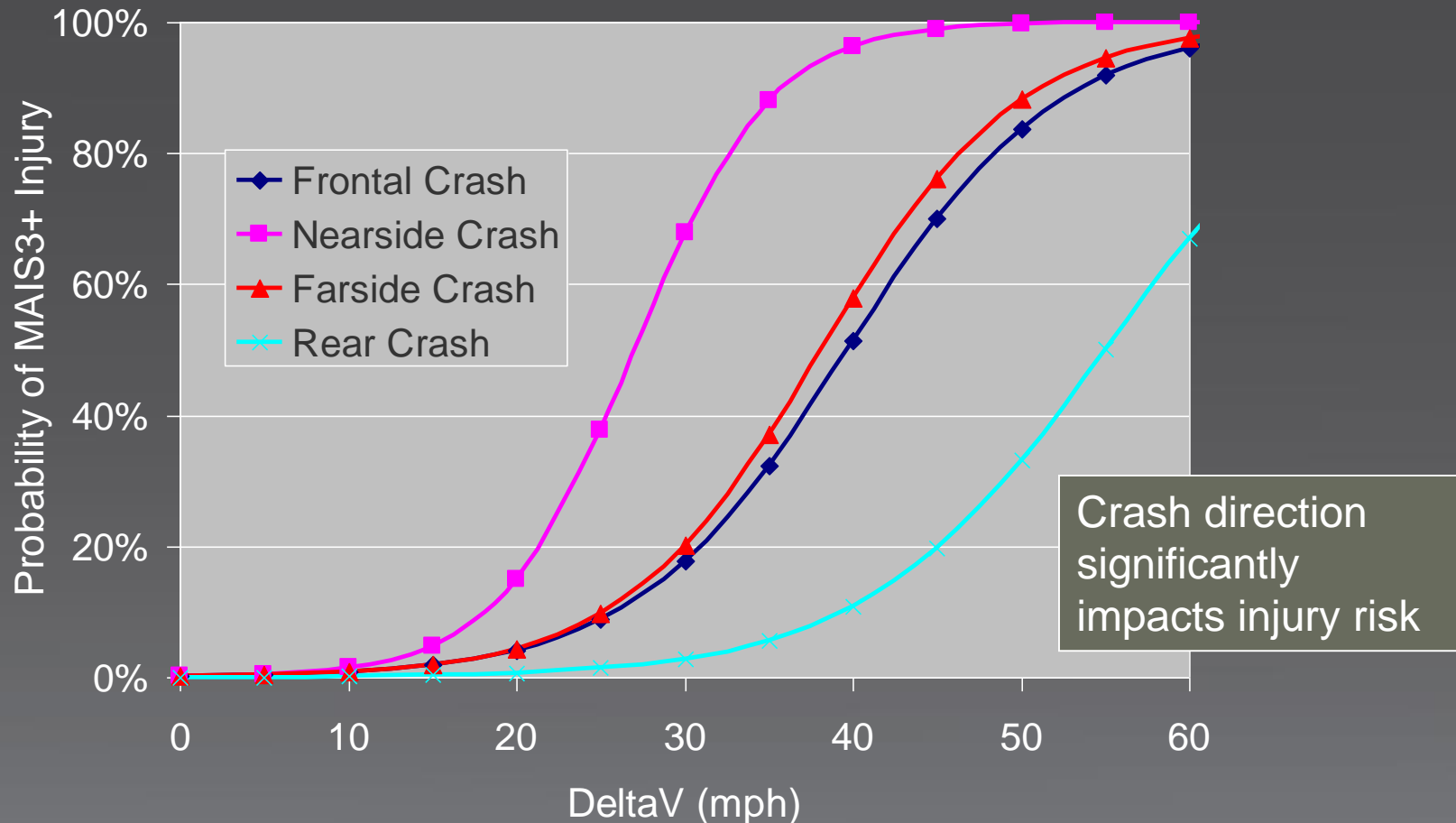
Probability of Injury Versus Crash DeltaV

MAIS3+ Injury Risk vs. DeltaV- All Crashes
(NASS/CDS 2005)

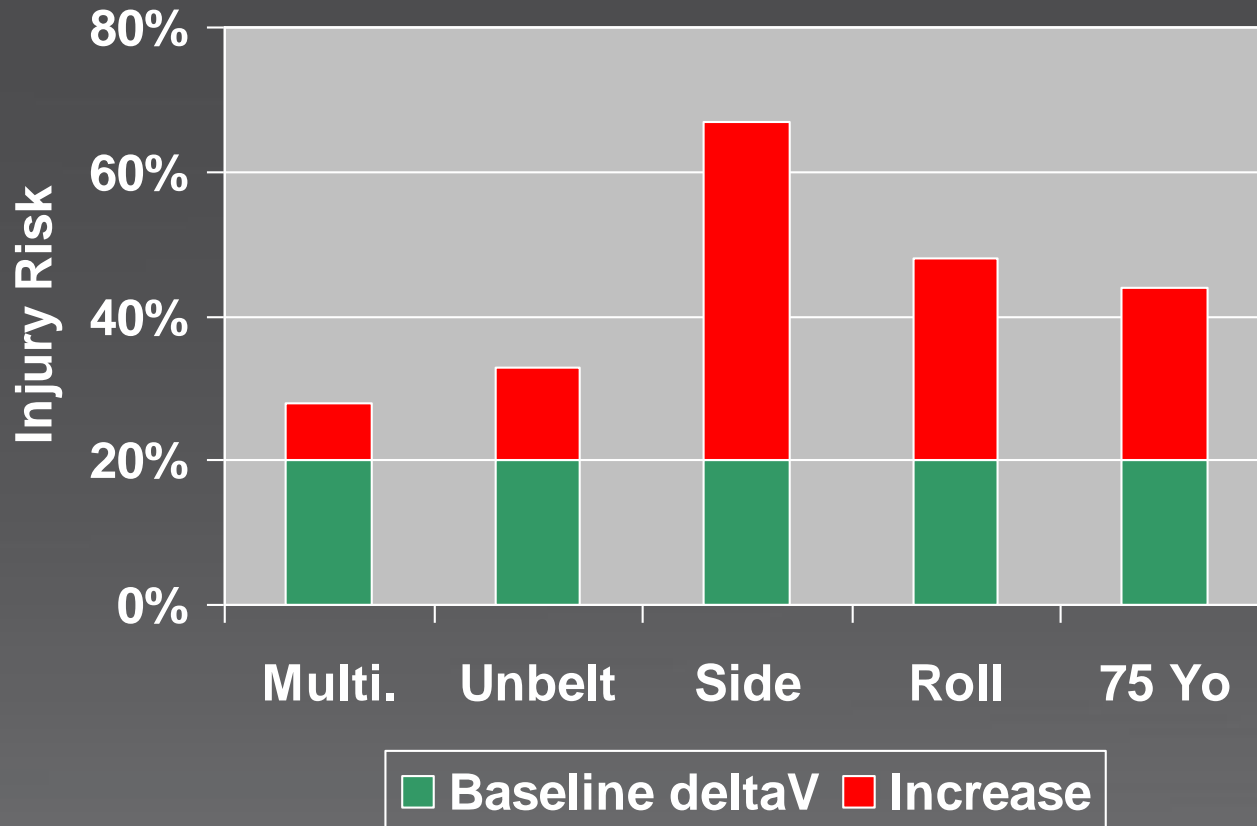


Risk of Injury Versus Impact Direction

MAIS3+ Injury Risk By Mode
(NASS/CDS 1997-2005)



Benefit of Factors Added to DeltaV



Baseline Risk – Frontal 27 mph deltaV (Belted)

Example of Injury Risk Calculation

Crash	
Delta V, Mph	27
Safety Belt	Yes
Multiple Impact	No
Rollover	No
Frontal Crash	Yes

Injury Risk Prediction

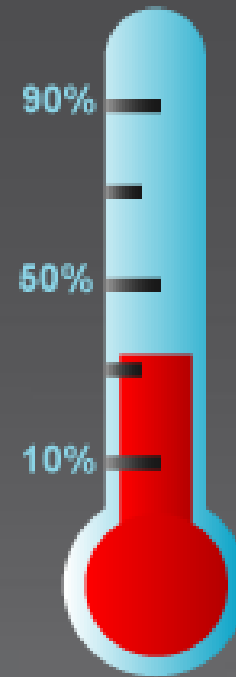


Belted Occupant

Added Variables

Crash	
Delta V, Mph	27
Safety Belt	No
Multiple Impact	No
Rollover	No
Frontal Crash	Yes

Injury Risk Prediction

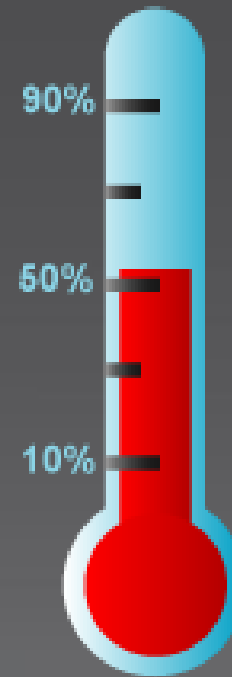


Risk - 38%

Added Variables

Crash	
Delta V, Mph	27
Safety Belt	No
Multiple Impact	Yes
Rollover	No
Frontal Crash	Yes

Injury Risk Prediction

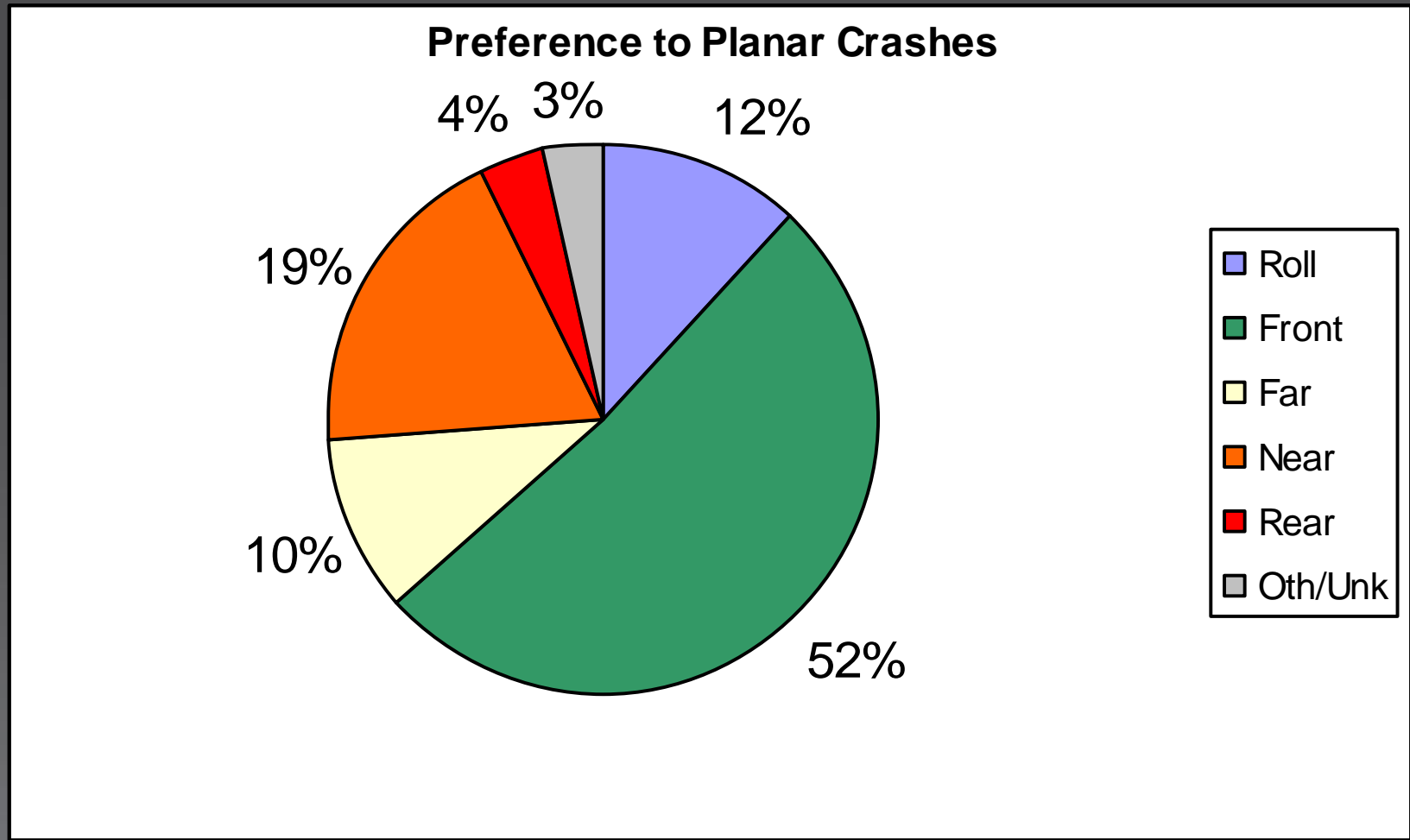


Unbelted +
Multiple Impact

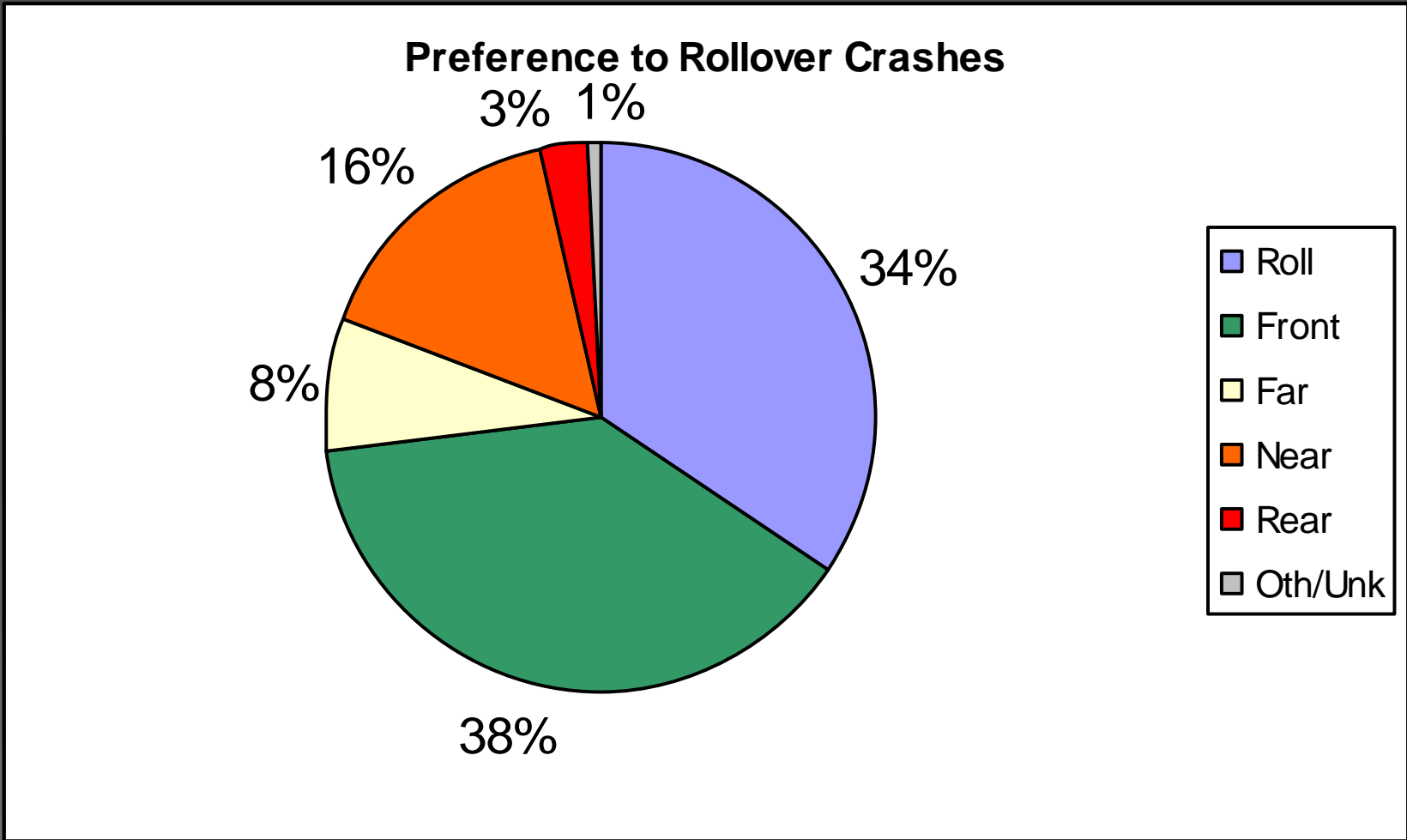
Most Important Variables for URGENCY

- Crash Speed – DeltaV
- Crash Direction
- Belt Use
- Multi-impact
- Rollover
- Age of Occupant

US Fatalities by Crash Direction



US Fatalities by Crash Direction



Priorities for Accuracy of URGENCY

- Predictive accuracy most beneficial in frontal, near-side and rollover crashes
- Predictions for multiple impacts with rollover desirable
- Rear impact is direction with fewest fatalities

Presentation Overview

- History of URGENCY
- Priority for Crash Data Elements
- URGENCY Calculations and Accuracy

- **URGENCY interprets key crash information to estimate injury risk**
- **Multinomial regression models are used to estimate risk based on multiple crash factors at the same time**

URGENCY Injury Predictor Algorithm

- Probability of Injury (P) Using Logistic Regression Analysis with Weighting Factors

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

- $w = A_0 + A_1 * \text{Pred } 1 + A_2 * \text{Pred } 2 + \dots$
- $A_0 = \text{Intercept}$
- $A_n = \text{Coefficient}$
- $\text{Pred } n = \text{Value of Predictor}$

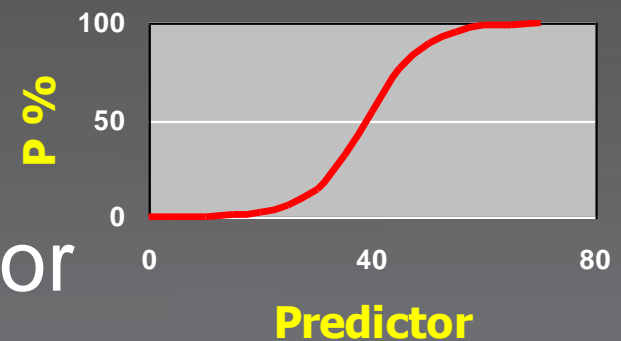
Principle of Maximum Likelihood

URGENCY Injury Predictor Algorithm

- Probability of Injury (P) Using Logistic Regression Analysis with Weighting Factors

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

- $w = A_0 + A_1 * \text{Pred 1} + A_2 * \text{Pred 2} + \dots$
- $A_0 = \text{Intercept}$
- $A_n = \text{Coefficient}$
- $\text{Pred } n = \text{Value of Predictor}$



Principle of Maximum Likelihood

Calculation of Injury Risk

- 2 Regression Predictors-Frontal Crash

Variable	Type	Value
A ₀ Intercept	Constant	-5.232
A ₁ (DeltaV)	Continuous	0.1482
A ₂ (Belt Use)	Binary	-1.143

- Principle of Maximum Likelihood
-
- (1) $P = 1/[1+\exp(-w)]$
- (2) $w = A_0 + A_1 * \text{Pred 1} + A_2 * \text{Pred 2}$
- For frontal crash
- (3) $w = -5.2319 + (0.1482) * \text{DeltaV} + (-1.143) * \text{Belt}$
- $A_0 = \text{Intercept}$
- $A_n = \text{Coefficient}$
- $\text{Pred } n = \text{Value of Predictor}$

Calculation of Injury Risk

- 2 Regression Predictors-Frontal Crash

Variable	Type	Value
Intercept	Constant	-5.232
A ₁ (DeltaV)	Continuous	0.1482
A ₂ (Belt Use)	Binary	-1.143

- Principle of Maximum Likelihood

-

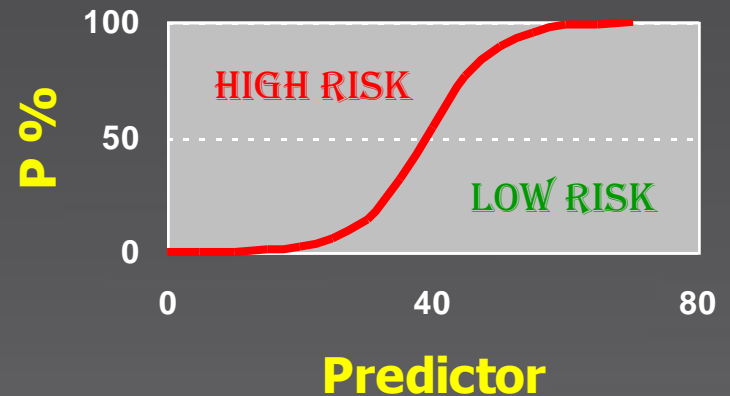
- (1) $P = 1/[1+\exp(-w)]$

- (2) $w = A_0 + A_1 * \text{Pred 1} + A_2 * \text{Pred 2}$

- For frontal crash

- (3) $w = -5.232 + (0.1482)*\text{DeltaV} + (-1.143)*\text{Belt}$

- $A_0 = \text{Intercept}$
- $A_n = \text{Coefficient}$
- $\text{Pred } n = \text{Value of Predictor}$



Calculation of Injury Risk

- 2 Regression Predictors-Frontal Crash

Variable	Type	Value
Intercept	Constant	-5.232
A ₁ (DeltaV)	Continuous	0.1482
A ₂ (Belt Use)	Binary	-1.143

- Principle of Maximum Likelihood

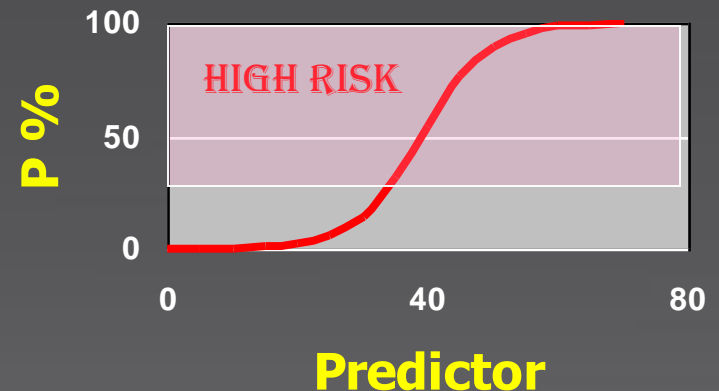
- (1) $P = 1/[1+\exp(-w)]$

- (2) $w = A_0 + A_1 * \text{Pred 1} + A_2 * \text{Pred 2}$

- For frontal crash

- (3) $w = -5.232 + (0.1482)*\text{DeltaV} + (-1.143)*\text{Belt}$

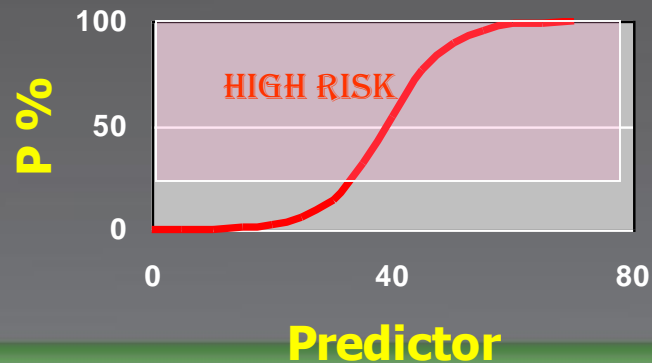
- $A_0 = \text{Intercept}$
- $A_n = \text{Coefficient}$
- $\text{Pred } n = \text{Value of Predictor}$



Injury Prediction
requires a threshold

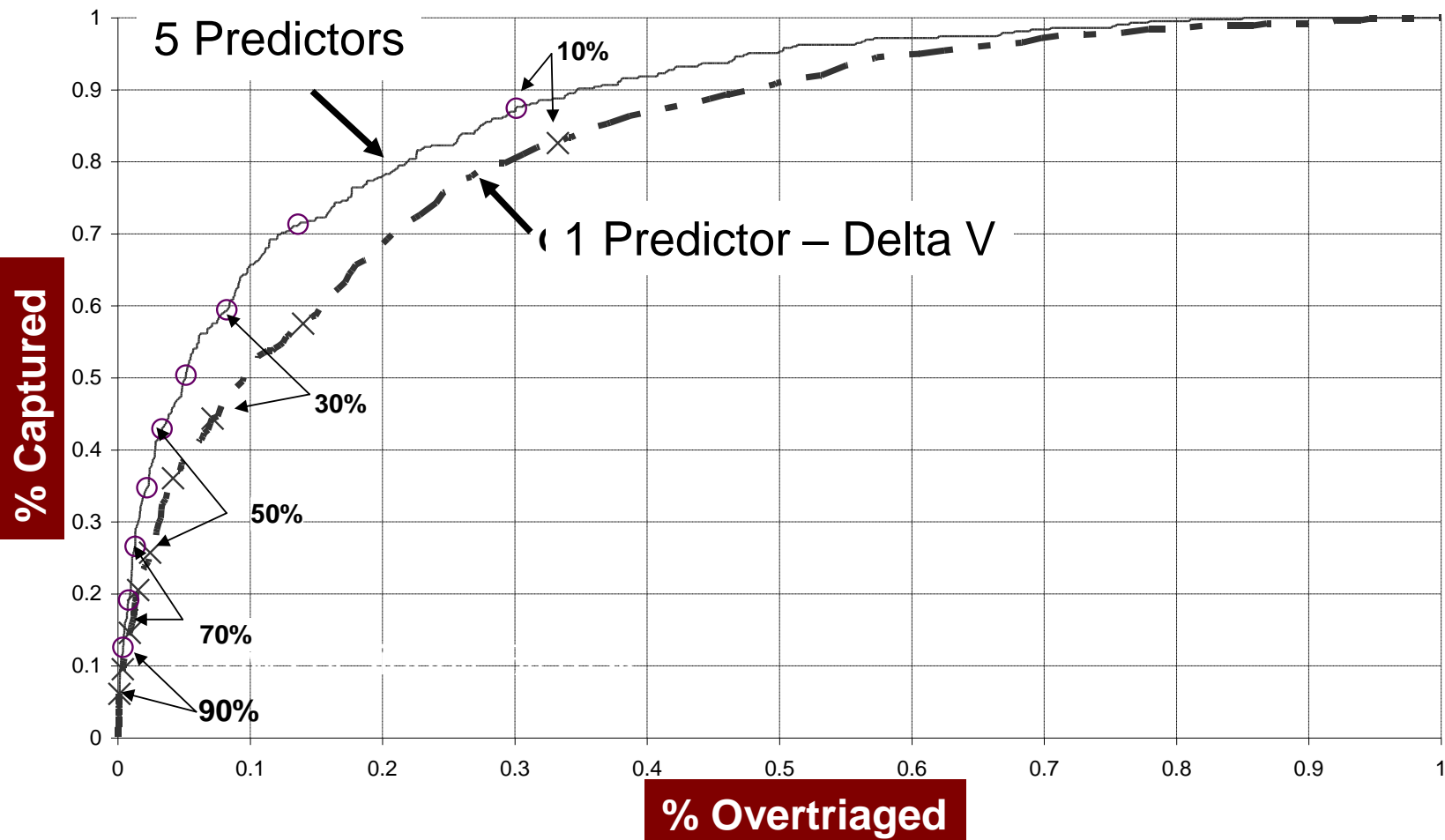
Injury Risk Threshold Issues

- High Threshold – Too many missed injuries
- Low Threshold - Too many uninjured
- Proper balance is an issue
- CDC suggests 1 in 5 accuracy for trauma centers
- Rescue units may permit less accuracy
- Voice communications can improve accuracy
- On-scene judgment can improve accuracy



Predictive Response for Added Variables

Frontal Model Performance



Summary of Capture Rates

Frontal Crash Direction – 20% Risk Threshold

	MAIS 3+ Captured	MAIS 3+ Overtriaged
Planar Crash Variables		
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%

Above Table from Paper SAE 2006-01-0675

More Recent Research uses Risk Thresholds lower than 20%

Examples of Crashes – Missed Injury



Narrow Offset Frontal – Fatal aortic injury
DeltaV reported does not address intrusion
NASS Case 2009 9 32 2

Examples of Crashes – Missed Injury



Pole Impact – AIS 5 Chest Injury
No Air Bag deployment when needed
NASS Case 2005 50 18 1

Examples of Crashes – Missed Injury



Low Severity Offset Crash – AIS 5 Chest Injury
Driver with severe coronary atherosclerosis
NASS Case 2004 73 42 1

Examples of Crashes – Missed **No** Injury



Frontal Crash + Rollover – 21 YO belted male – AIS 1 Injury
Extensive damage suggests serious injury
NASS Case 2002 74 42 1

Examples of Crashes – Missed **No** Injury



Tree Impact – 39 YO unbelted male – AIS 1 injury
Extensive damage suggests serious injury
NASS Case 2006 73 181 1

Continuing Research

- Compare URGENCY Score from BMW crashes with actual Triage Decisions
- Compare URGENCY Score from BMW crashes with actual injuries

Summary

- URGENCY uses crash data (and occupant data when available) to estimate injury risk in a crash
- The risk estimate is immediately available to assist rescue and triage decisions
- Predictors in addition to DeltaV are needed to improve the prediction accuracy
- A 14 year research base exists for URGENCY development
- The risk threshold for “High Risk” prediction is a critical number – Agreement on acceptable levels of over-triage required

Opportunities for improving medical care and impediments to deployment of eACN to be discussed by Dr. Augenstein

- <http://psap.atxg.com/aacn/welcome.do>