



Elderly Occupants – Clinical Outcomes

Presented To
CIREN

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University Of Miami School Of Medicine

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George Washington University

December 6, 2001

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Crash Dummy Belted With Air Bag





Trauma Criteria and the Older Occupant

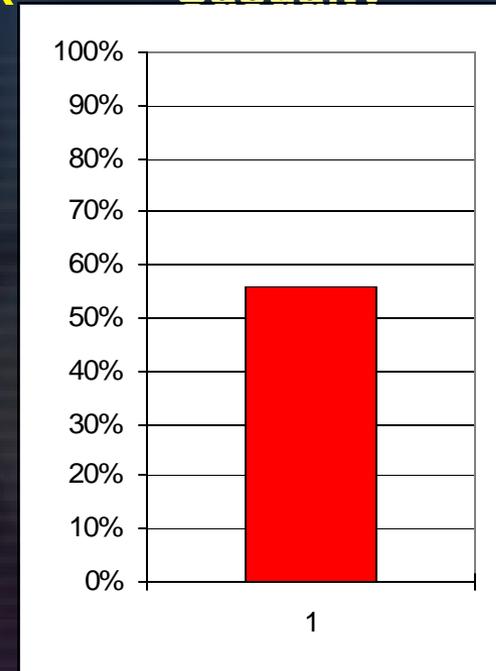
- Systolic BP \leq 90
- Respiratory rate $<$ 10 per minute or $>$ 29 per minute
- Glasgow Coma Scale \leq 12
- Penetrating injury to head, neck, chest, abdomen or groin
- Paralysis
- Second or third degree burns \geq 15% total body surface area
- Amputation proximal to wrist or ankle
- Ejection from motor vehicle
- Paramedic judgment --- high index of suspicion of injury
- In Florida $>$ 55 YOA Category 2 Criteria
Any (2) Category 2 Criteria Triggers Trauma Criteria



The URGENCY Algorithm

Vehicular Crash Site Data	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Side Damage, Passenger Compartment? (NO=0, YES=1)	0	TRUE
Rear Damage? (NO=0, YES=1)	0	TRUE
Car Curb Weight, in lbs.? (Default 3200 lbs.)	3200	
Safety Belt Use? (NO=0, YES=1)	1	TRUE
Car Occupant's Age, in years? (Default 30 yr.)	70	
Occupant's Gender? (FEMALE=1, MALE=0)	0	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE

Projection of the Probability of Casualty



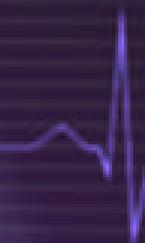
Probability of Severe Injury

56%

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Injury Rates and the Older Occupant



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Percent of Occupant Age Groups with MAIS 3+

	Population	Under 55	55 and Older	70 and Older
NASS CDS	2.34	2.00	4.16	6.33
WLIRC	59.34	56.93	66.67	76.19

*Belted occupants in frontal impact

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Severe Injuries Per 100 Occupants

	Population	Under 55	55 And Older
NASS CDS	5	4.6	7
WLIRC	17.7	15.5	24.4

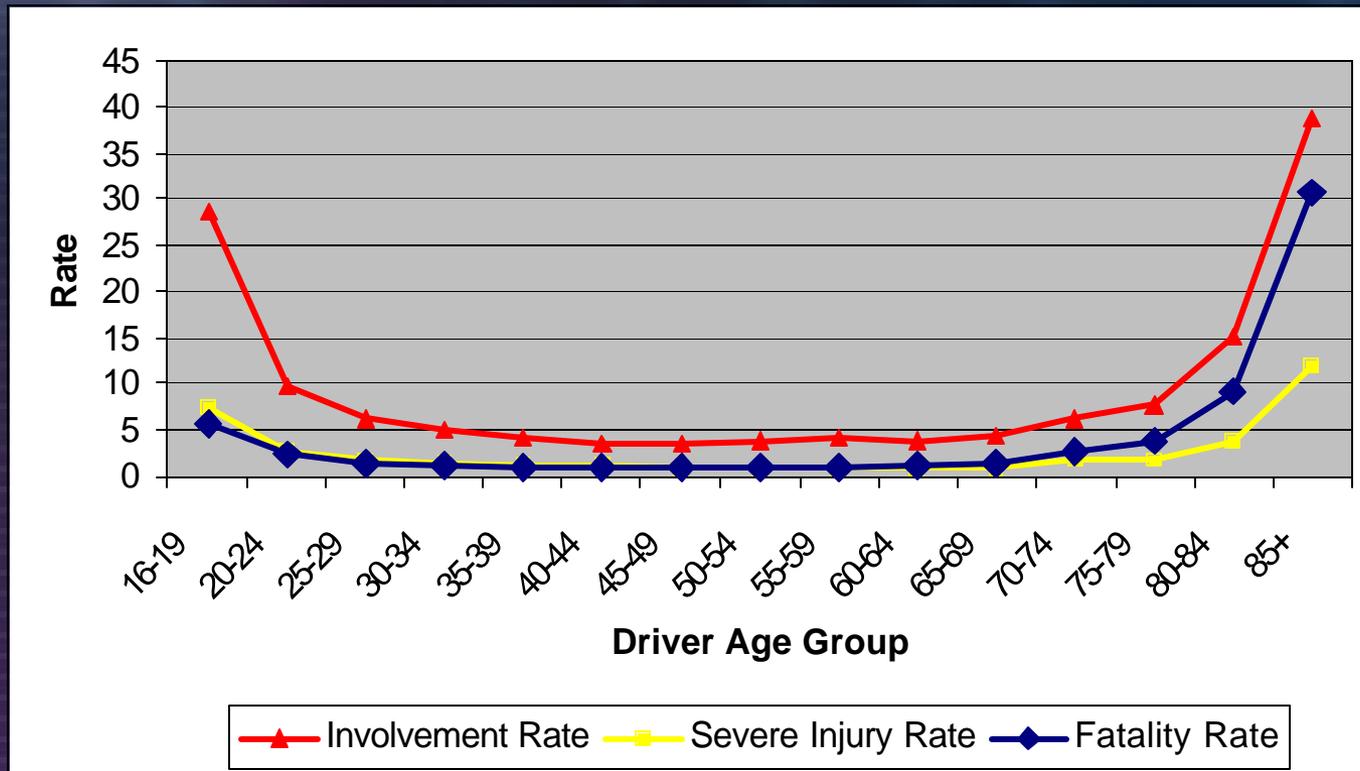
*Belted occupants in frontal impact

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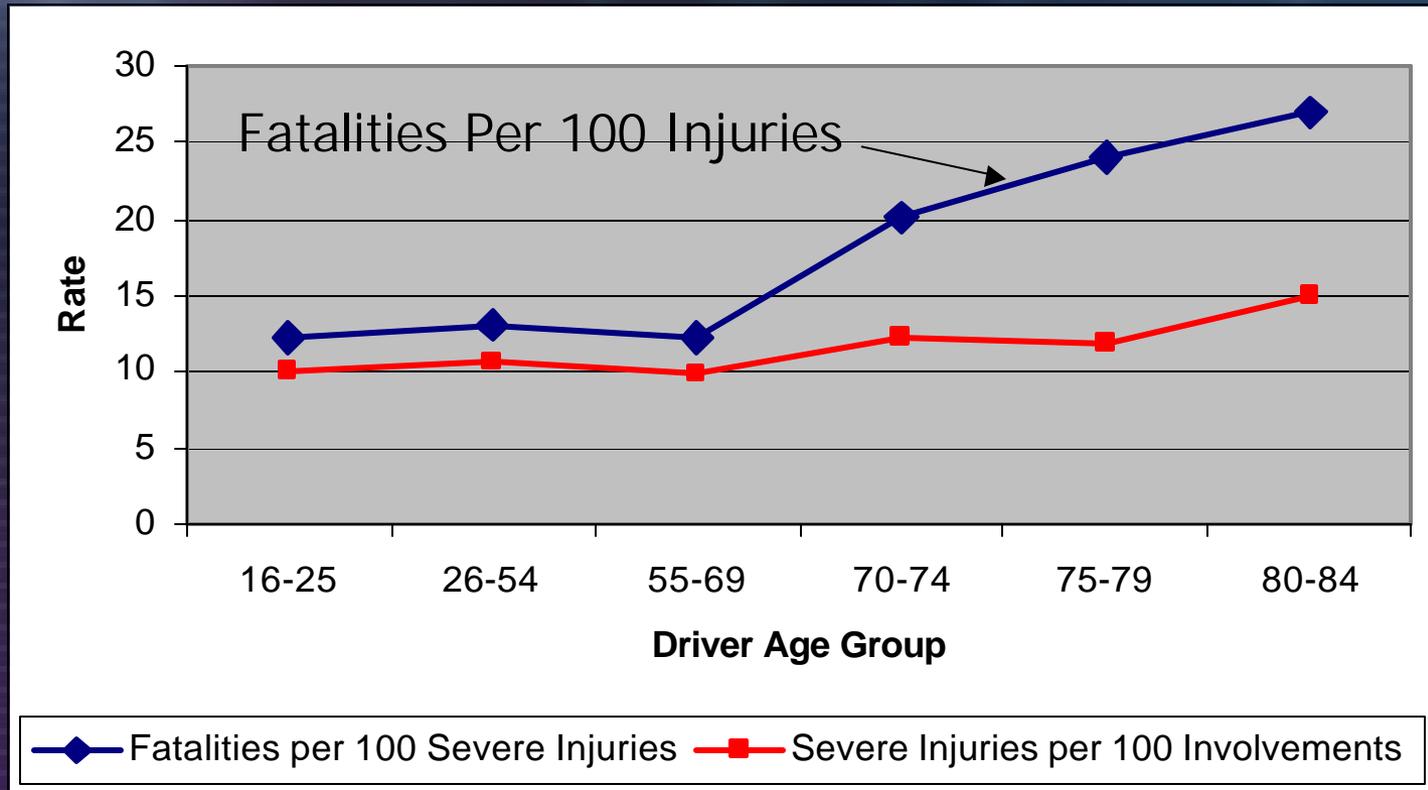
Involvement, Injury And Fatality Rates

(Rates per Vehicle Miles of Travel)



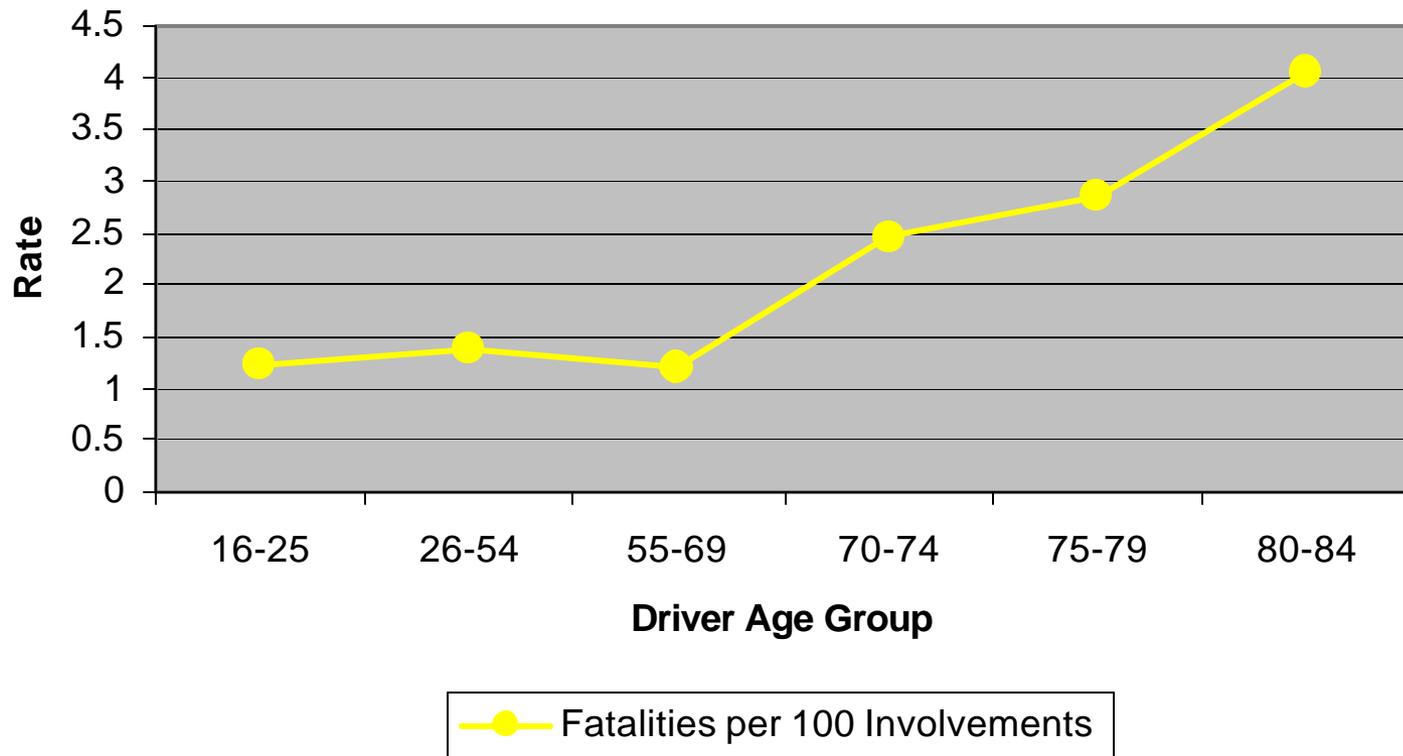


Driver Fatality And Injury Rates





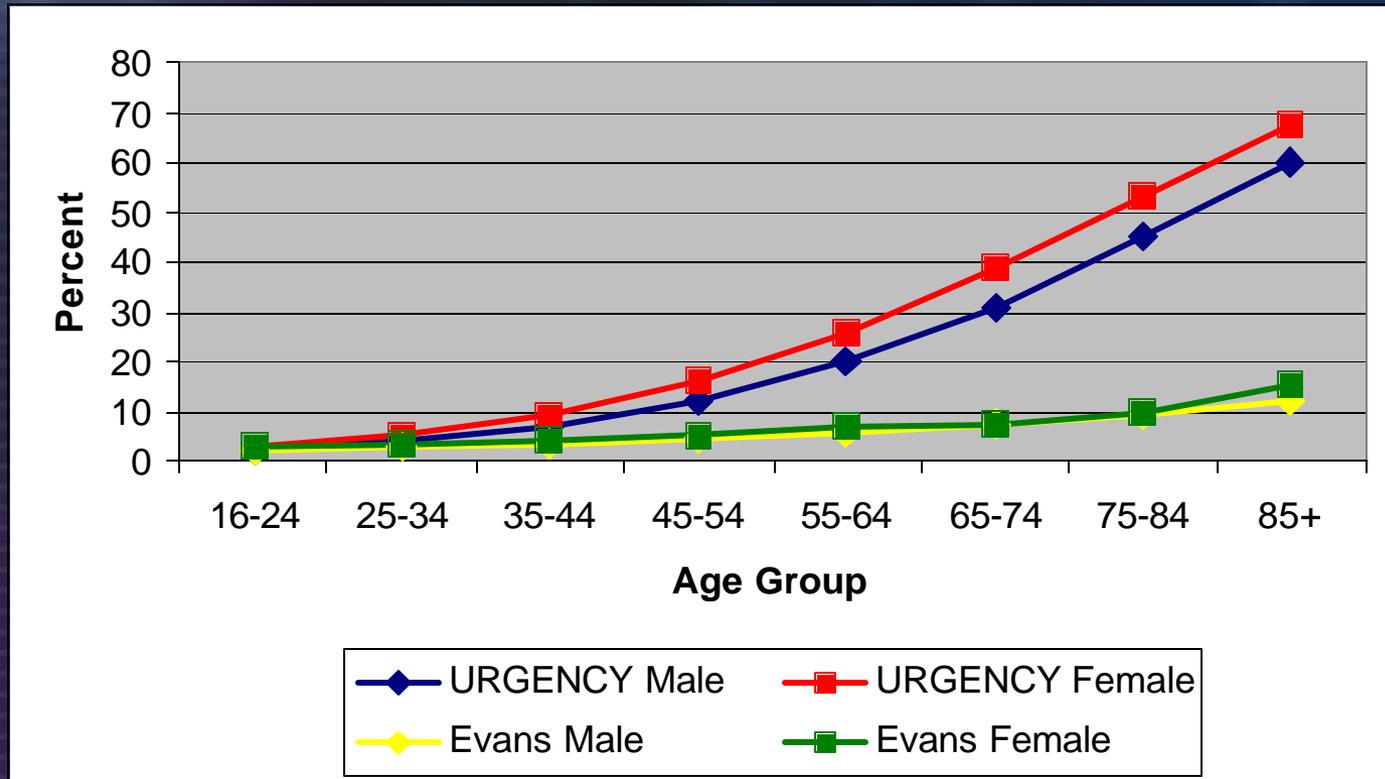
Driver Fatality Rates per 100 Involvements





Risk Of Fatality Due To Age

URGENCY Algorithm and Published Data



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URGENCY: Belted Occupants in Frontal Crashes, 35 mph Severity
Evans 2001: Belted Front Seat Occupants in Fatal Crashes, All Severities



URGENCY Algorithm Validation

All WLIRC Frontal Crashes

Population

Success Rate

All Less than 35

71%

All Older than 65

70%

High Suspicion Criteria - age 35- 67%

High Suspicion Criteria - age 65+ 53%



Observations

- NASS & WLIRC injury data shows:
 - High MAIS 3+ Rate Above 55 and Even Higher Above 70
 - High AIS 3+ Rate Above 55 and Even Higher Above 70
(More AIS 3 Injuries per Injured Occupant)
- NHTSA Analysis of on-the-road crashes shows:
 - Fatality Rate Has Large Increase from 55-69 to 70+
- URGENCY May Not Adequately Account for This Large Increase



Older Occupants and Restraint Systems



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NHTSA - Populations At-Risk From Air Bags

- Unrestrained Small Statured and/or Older People
- Infants In Rear-Facing Child Seats In Front Seat
- Children Unrestrained In Front Seat

Our Observation:

Restrained Older People Are Also At-Risk!

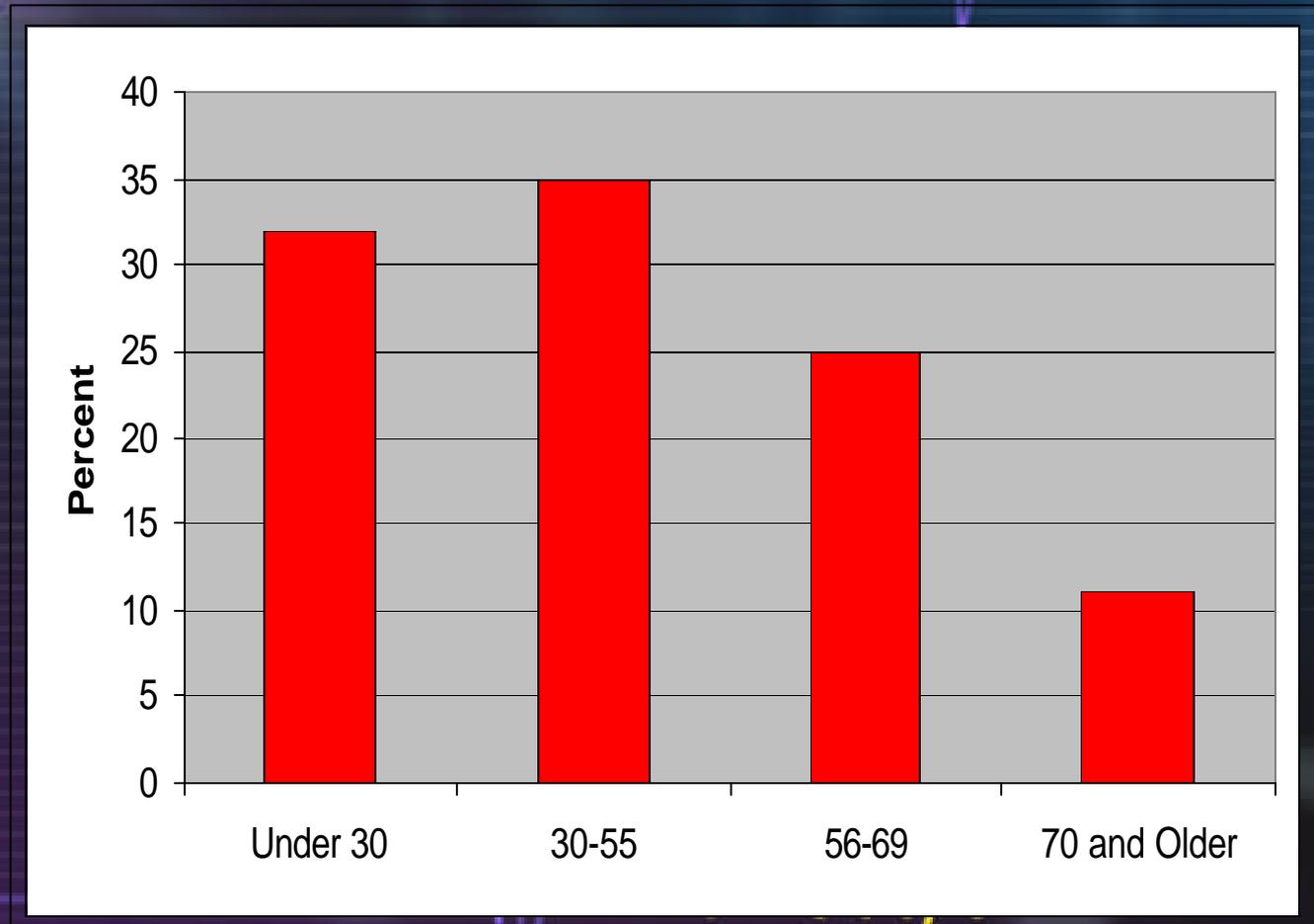
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Effectiveness Of Occupant Protection Systems

	Drivers Age 15-49	Drivers Age 50+
Air Bag Plus Lap & Shoulder Belt	62%	57%
Manual Lap & Shoulder Belt	46%	54%

Fatality Reduction Due To Air Bags In Pure Frontal Crashes

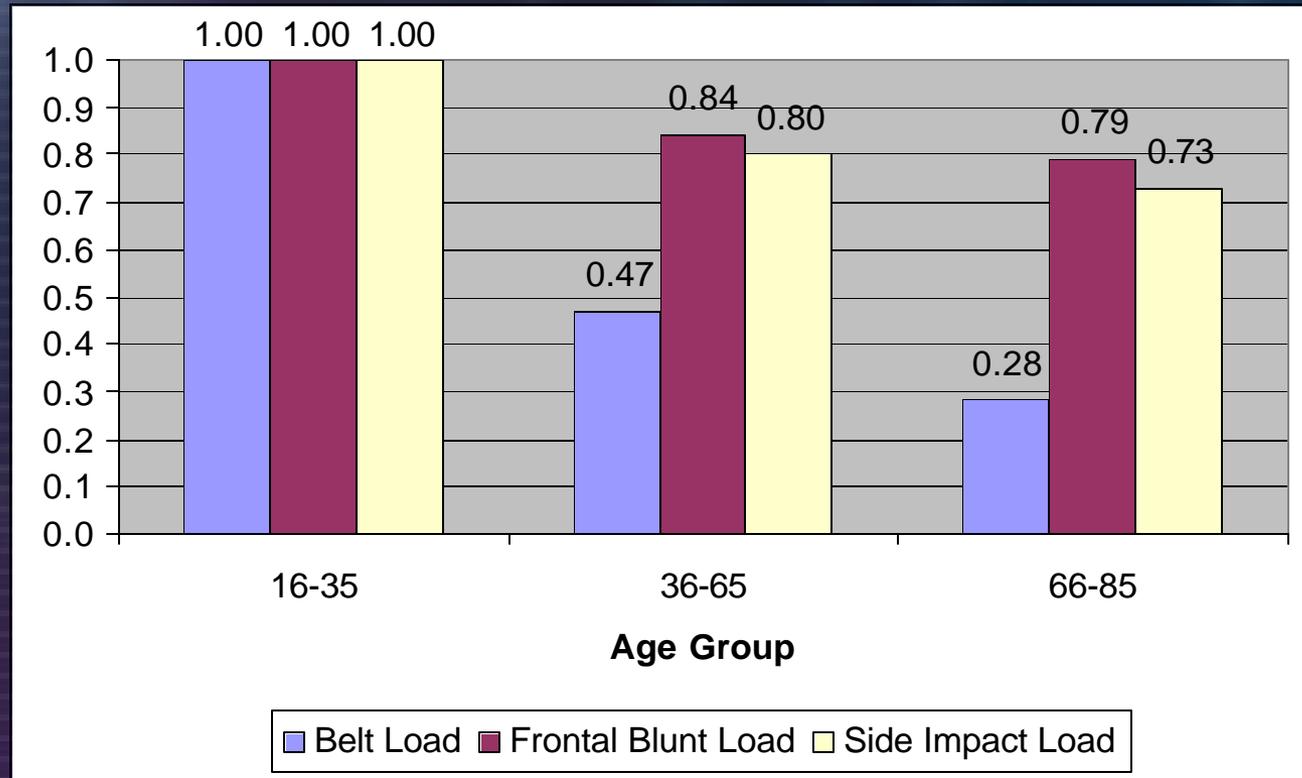


Effectiveness of Occupant Protection Systems
and Their Use, NHTSA 1996



Injury Tolerance

Recommended Reduction Ratios



Age Effects in Thoracic Injury Tolerance
Zhou et al. 1996

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Observations

- Air Bags + Belts Have Low Effectiveness for Older Drivers.
- Chest injury tolerance for air bag loading reduces with age.
- Chest injury tolerance for belt loading reduces even more drastically with age.



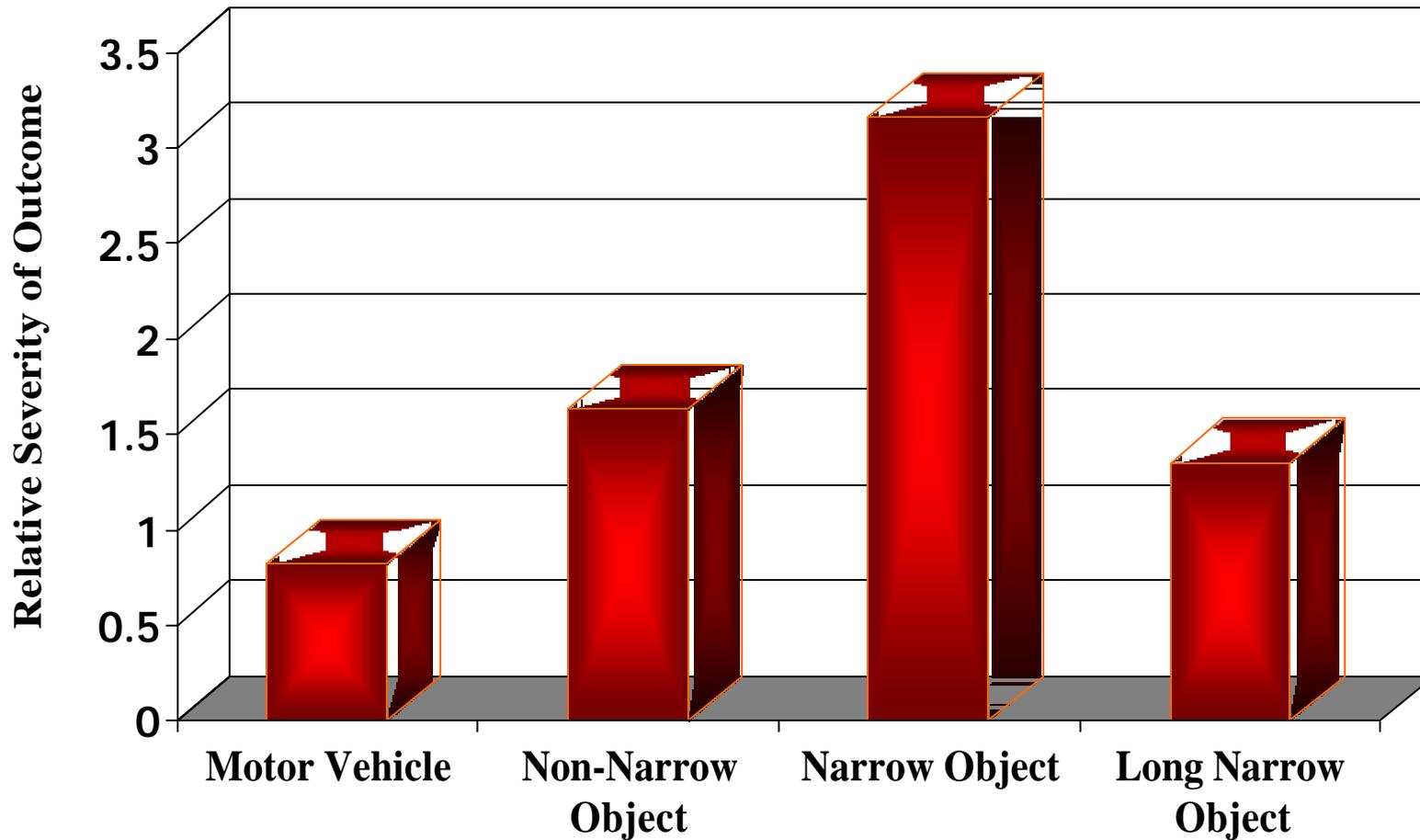
Narrow Object Impacts

These Crashes May Produce High Belt Loading
and High Air Bag Loading

Conditions That are Harmful to Older
Occupants

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Relative Harm By Crash Type



Narrow Object Statistics



Crashes	Harm	WLIRC Cases	FARS Cases	WLIRC Fatafs
3.2%	10%	22%	16.1%	24.3%

3.8 Times As Harmful As Vehicle-to-Vehicle Crashes

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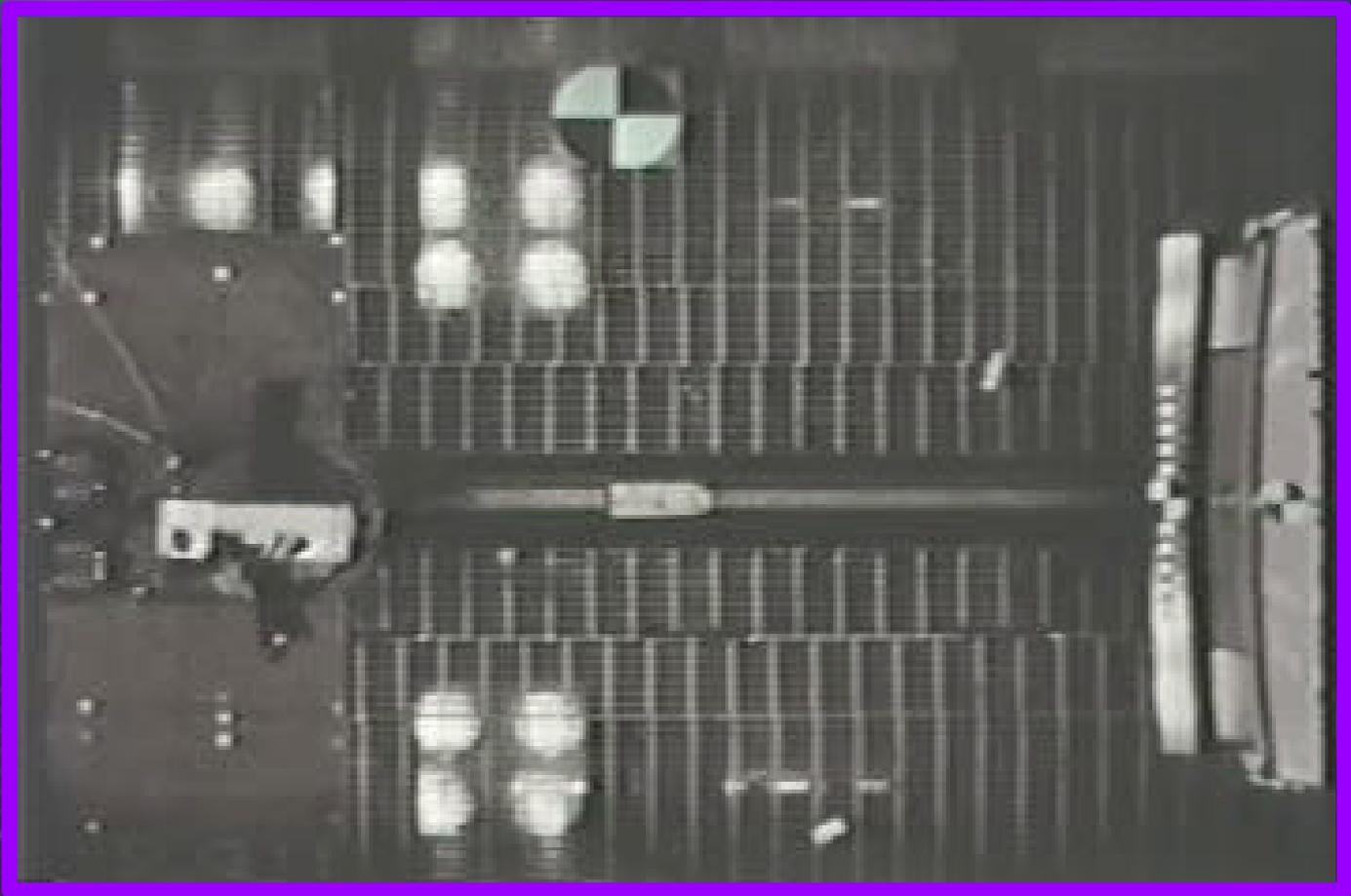
Observations From Crash Statistics

Narrow Object Impacts

Frequency Is Low

Higher Risk Of Severe Injury

30 MPH Pole Crash





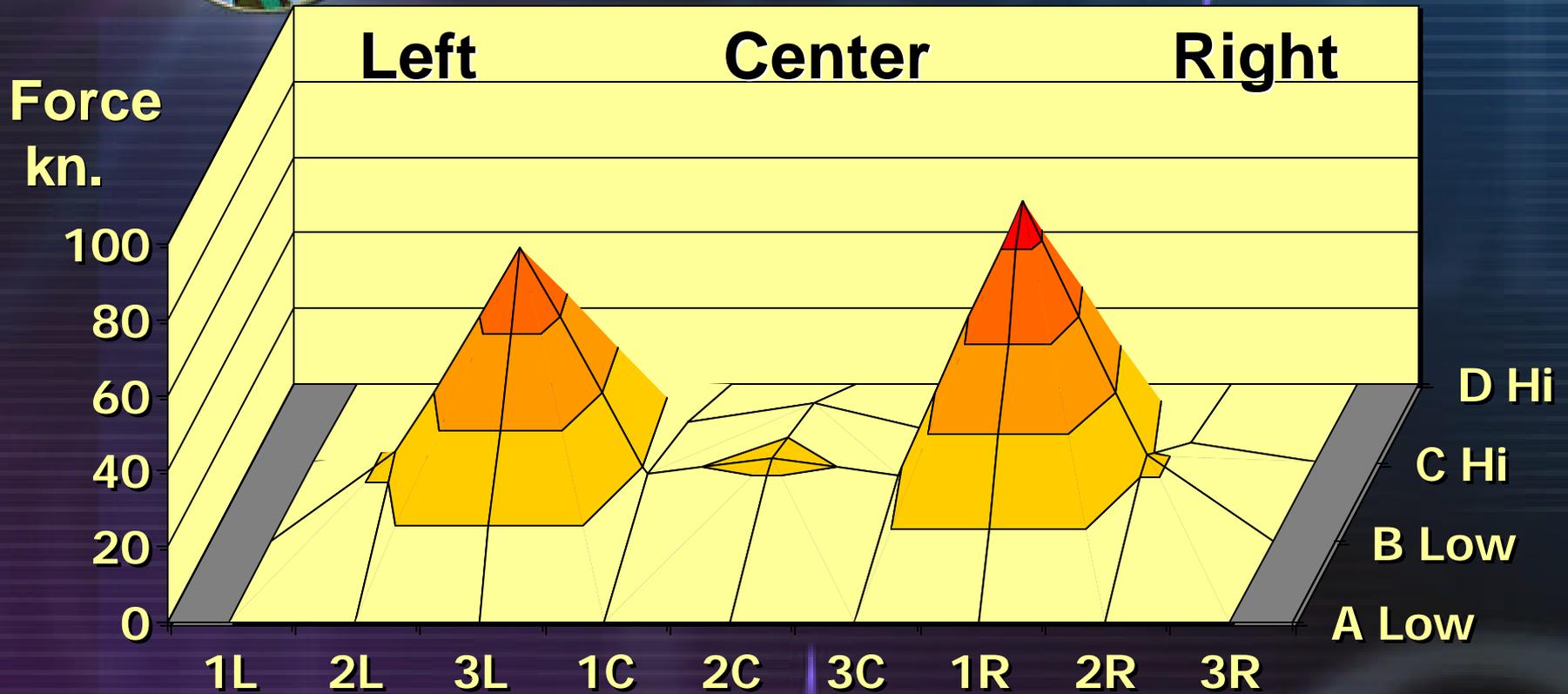
Crash into Load Cell Barrier



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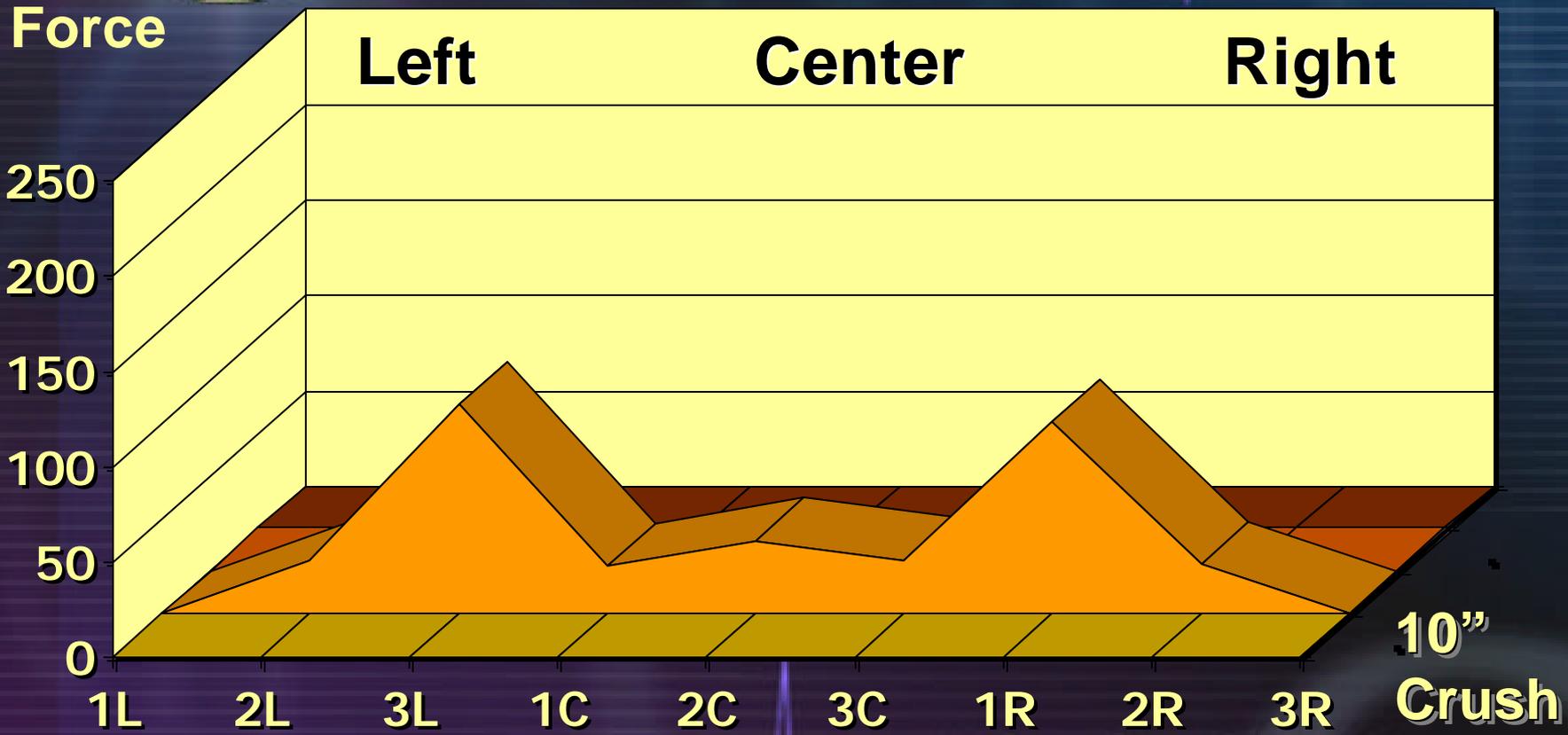
Contour Plot Of Barrier Force

Vehicle Crush = 10 Inches



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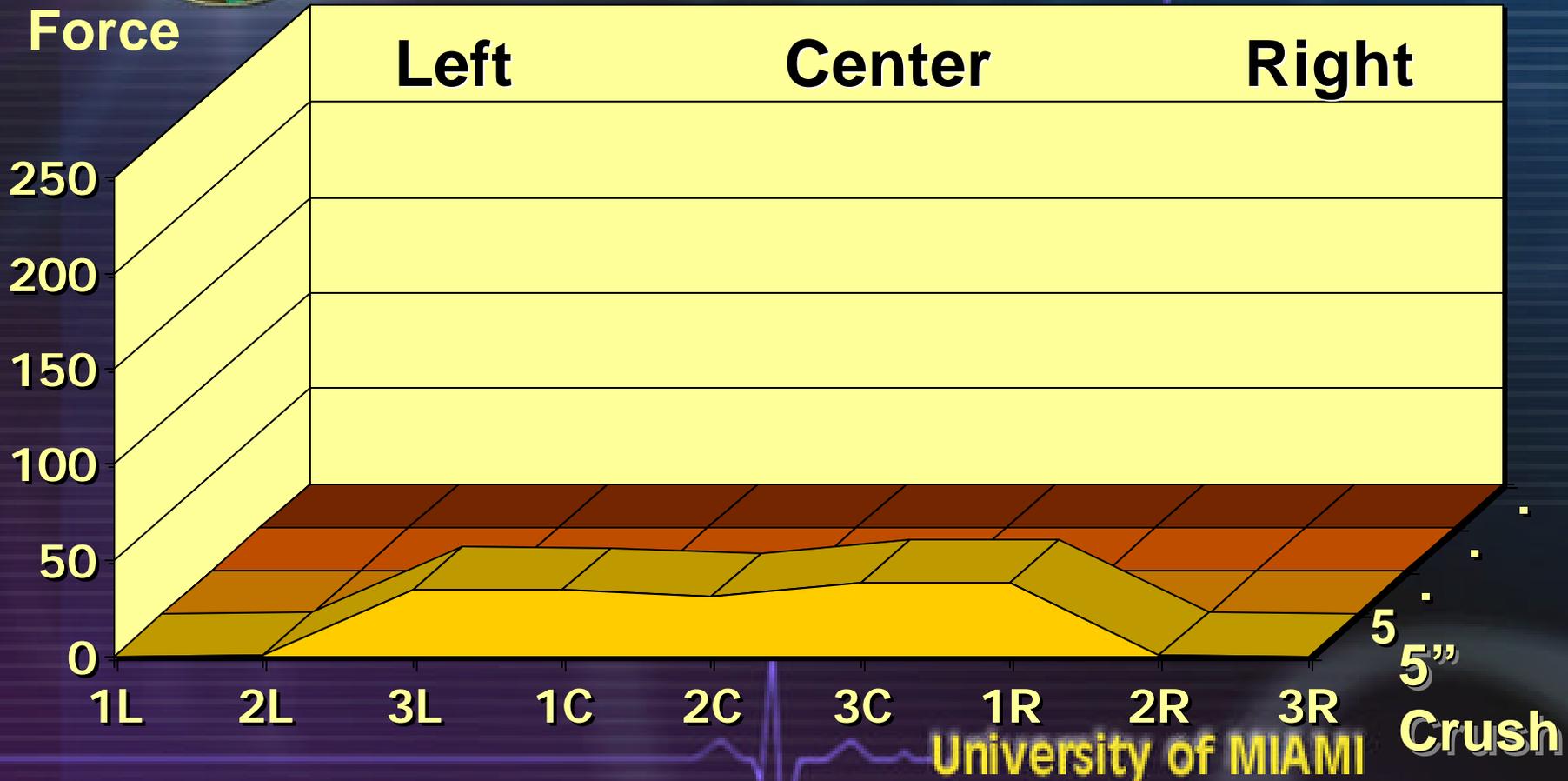
Barrier Force Across Vehicle Width



10"
Crush

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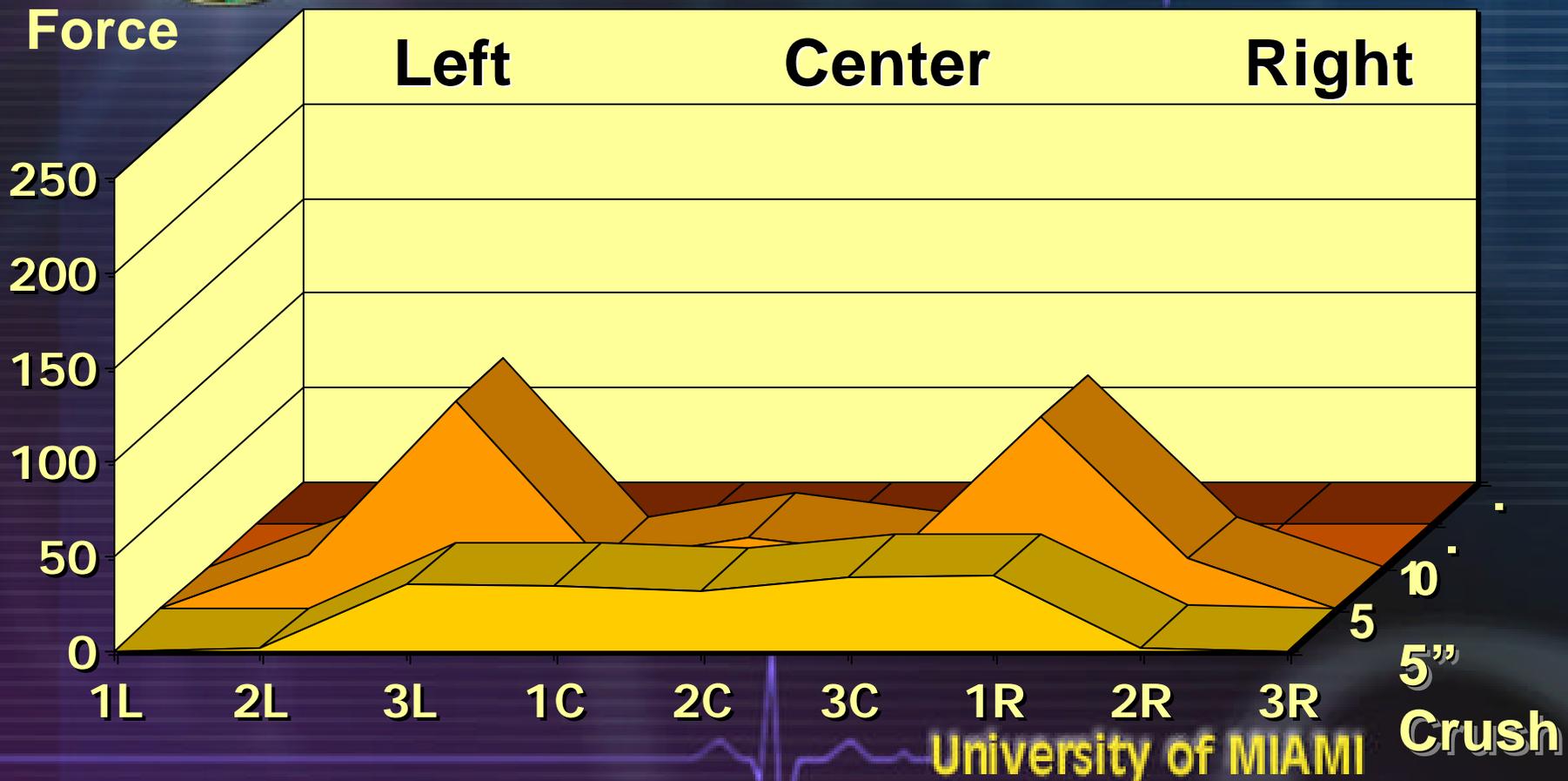
Barrier Force – Vehicle Width



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5
5"
Crush

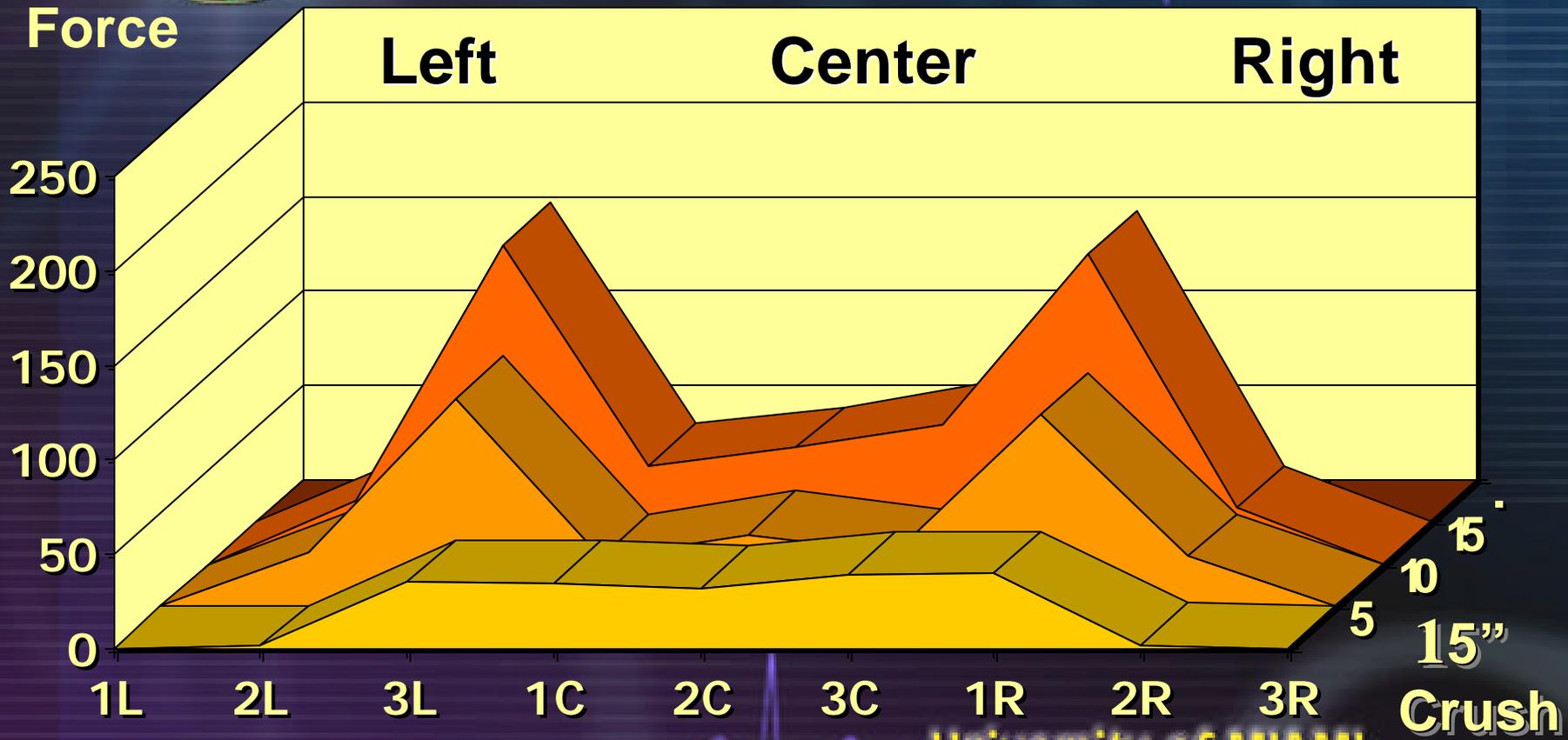
Barrier Force – Vehicle Width



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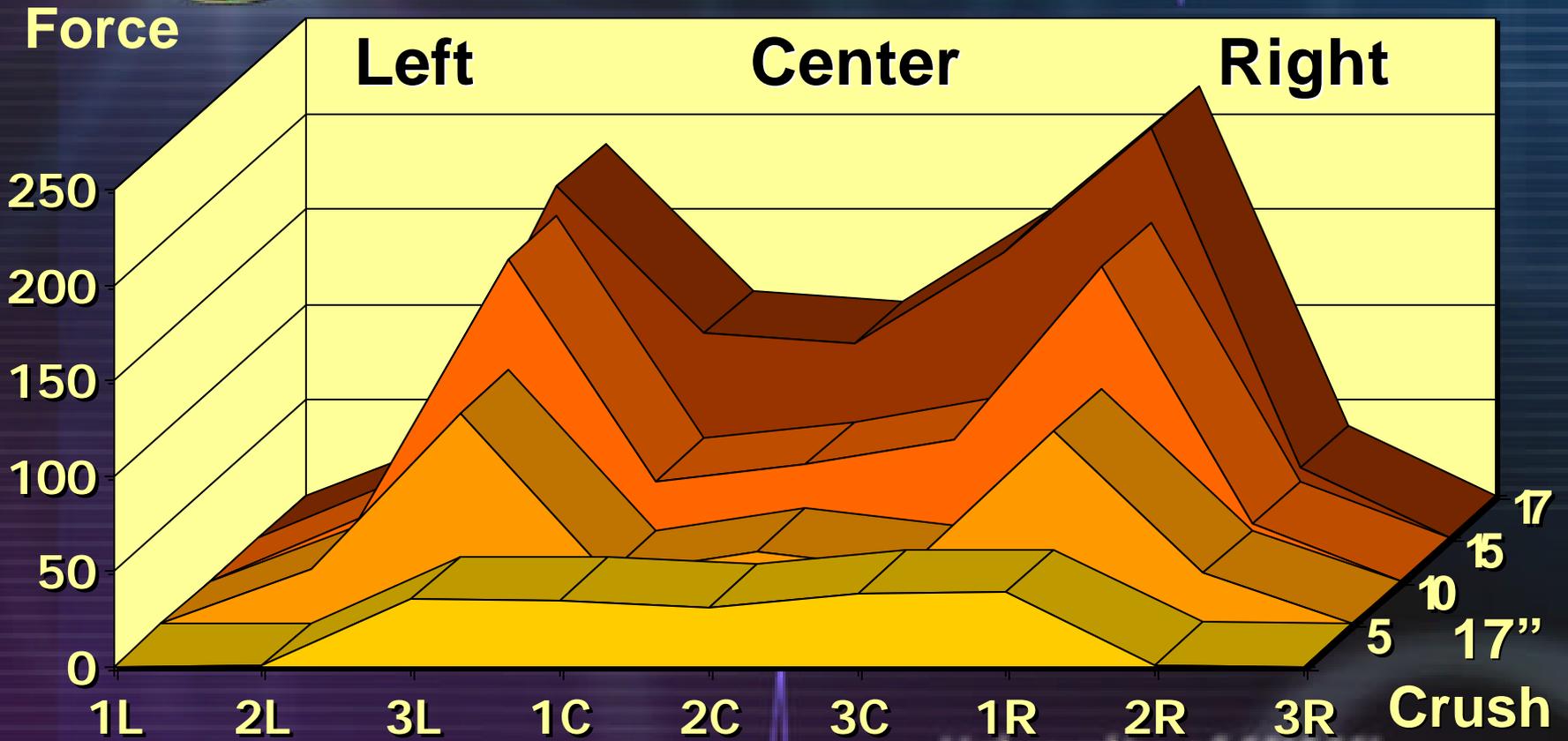
10
5
Crush

Barrier Force – Vehicle Width



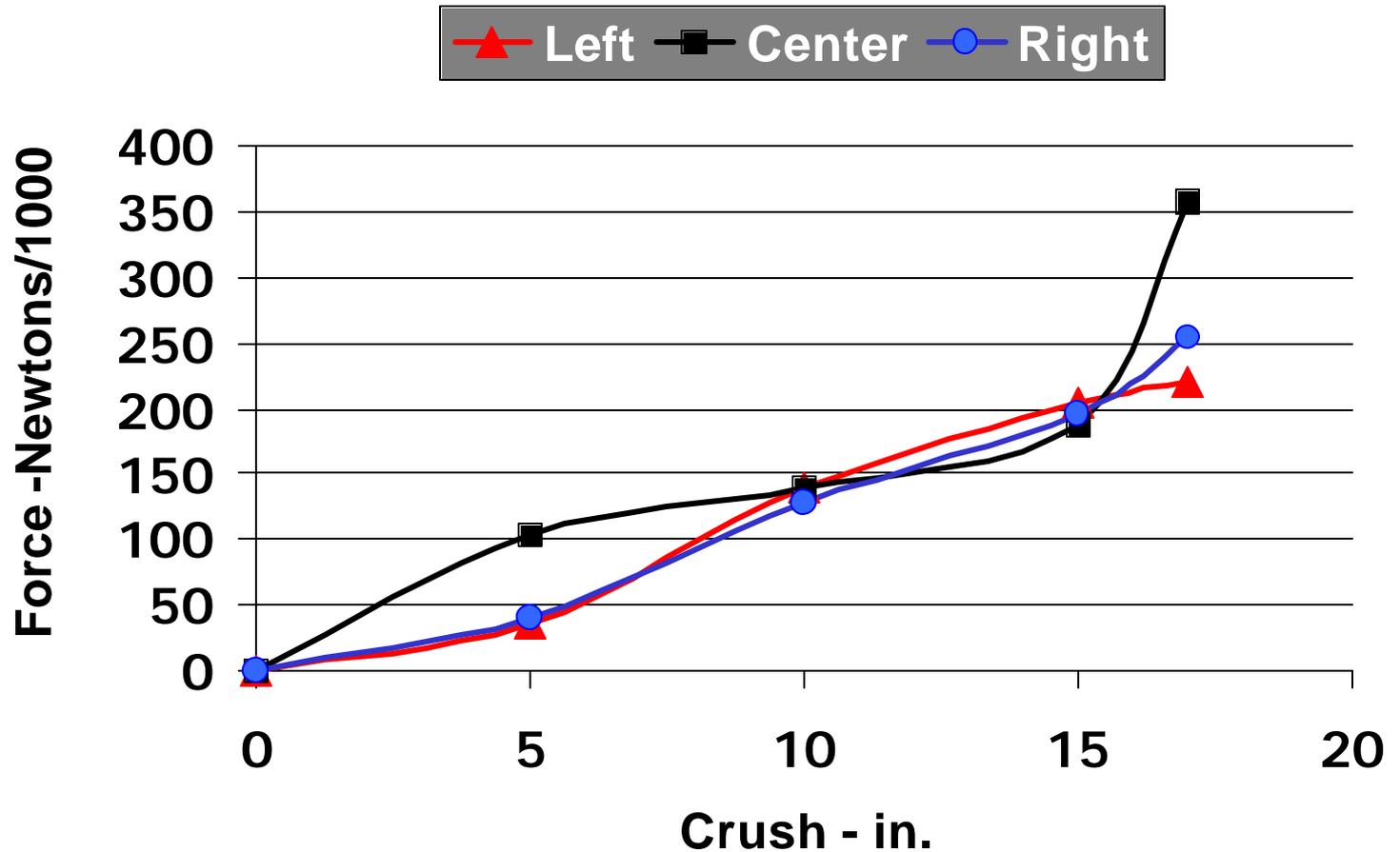
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Barrier Force – Vehicle Width

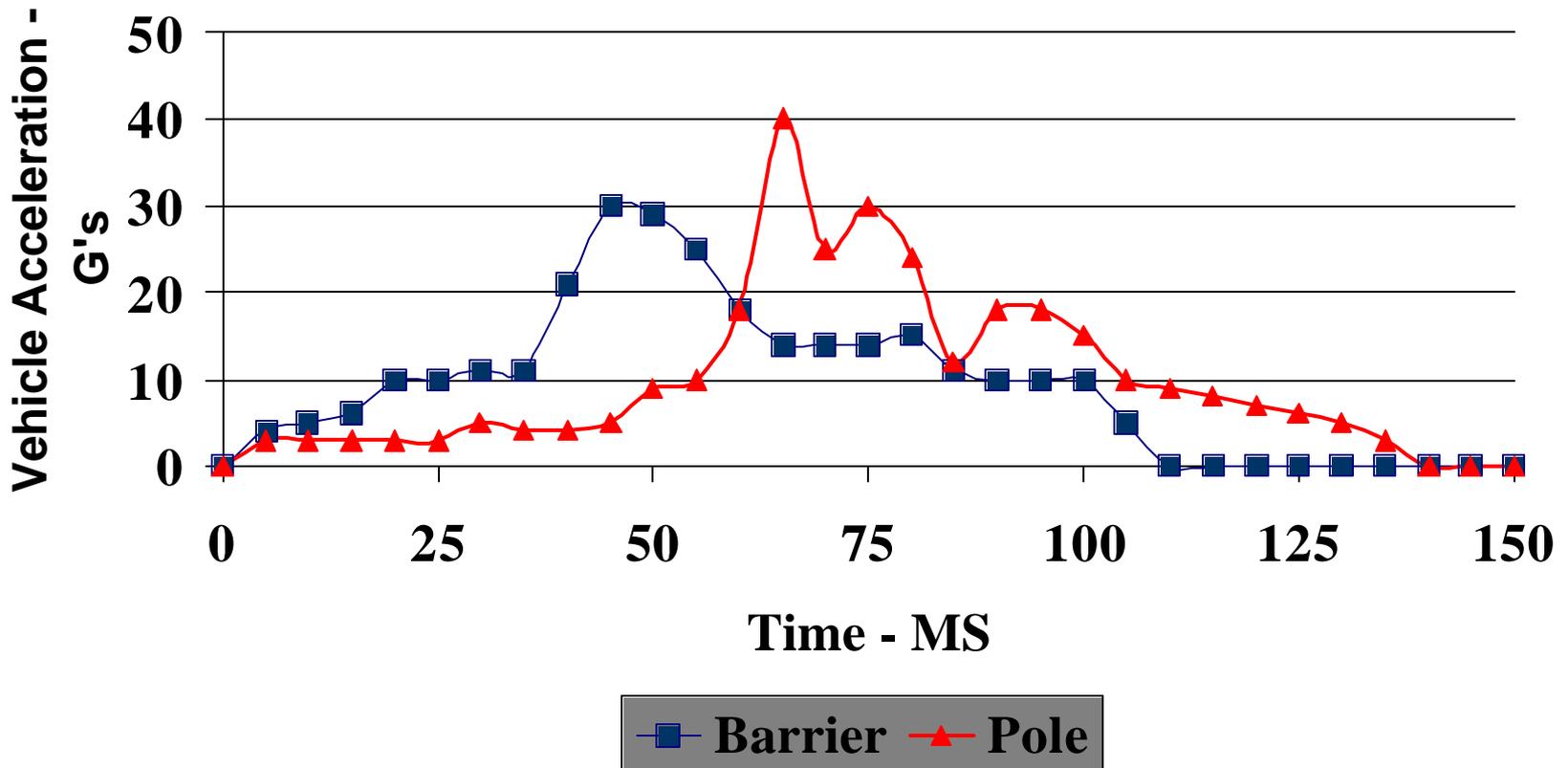


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Force vs. Crush

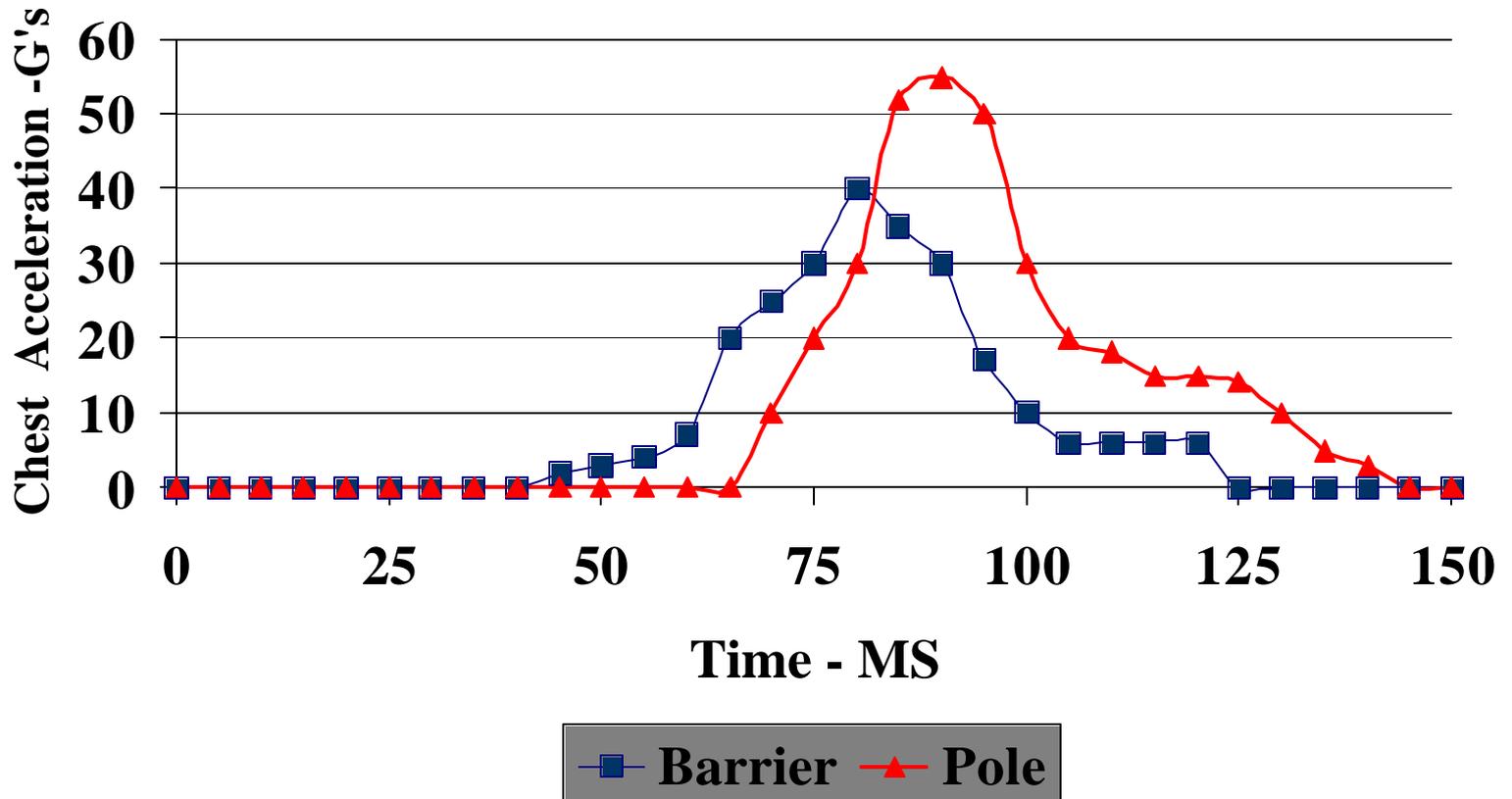


Vehicle Acceleration - Pole vs. Barrier Crashes with Equal Delta-V (30 MPH)



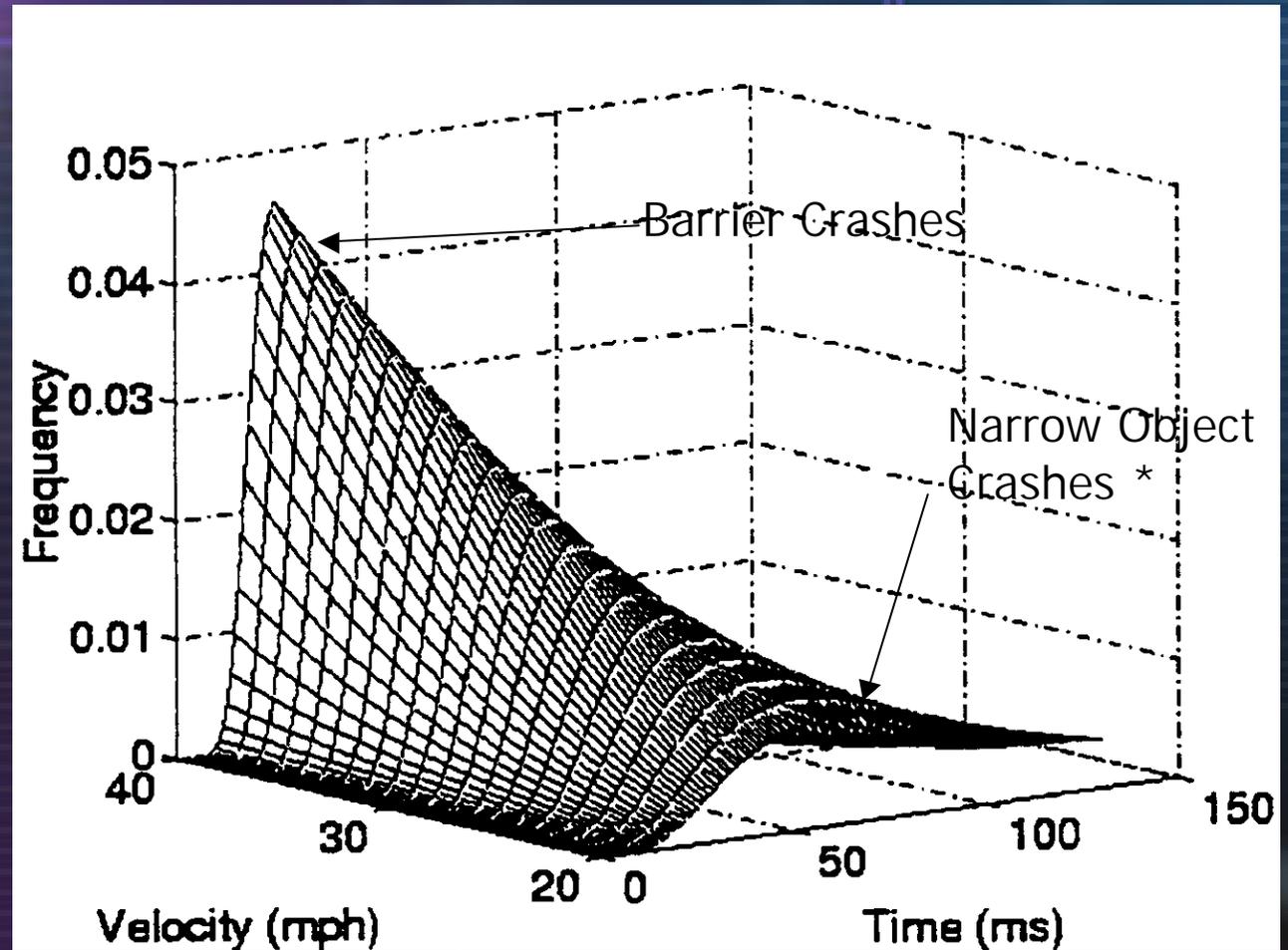


Chest G's In 30 MPH Crash Pulses Belted Driver Dummy





Air Bag Fire-time Probability



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* First Generation Air Bags



Summary

Injury Tolerance Reduction With Advanced Age Is Nonlinear.

Close-in Air Bags and Narrow Object Impacts Are Particularly Harmful.

Triage Criteria May Not Adequately Address Frailty at 70+.

Reduced Stiffness of Restraint Systems Required.

URGENCY Does Not Predict Close-in Air Bag Injuries.



Selected Cases



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Multiple Impacts With Narrow Frontal Component

Survivor

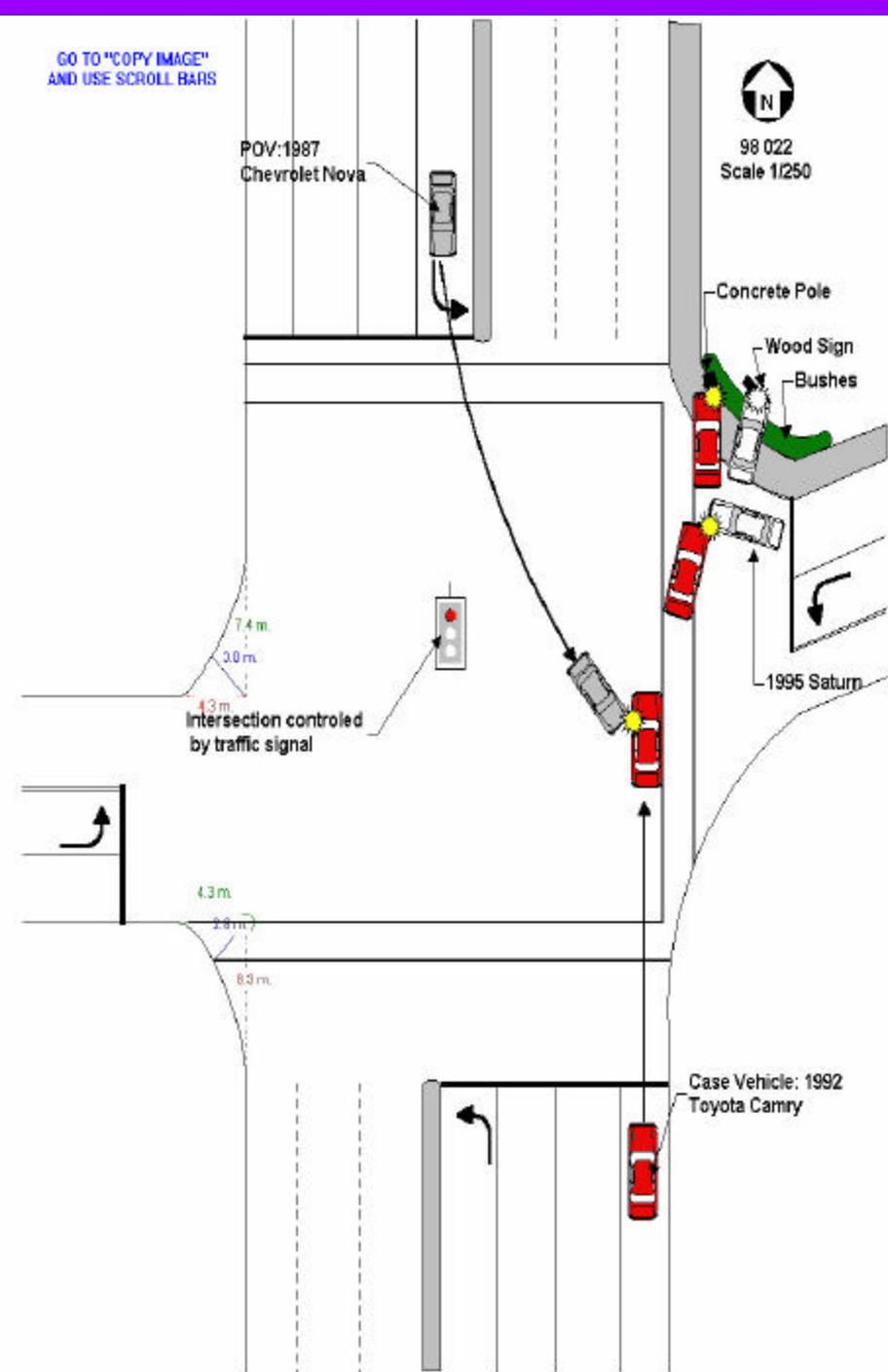
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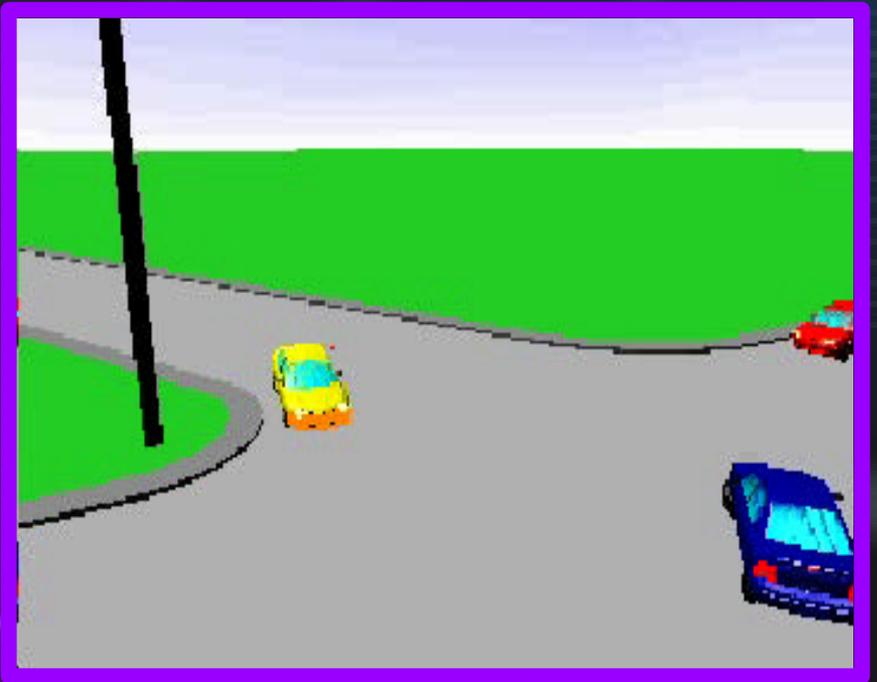
Scene



GO TO "COPY IMAGE"
AND USE SCROLL BARS



PC Crash Animation



Vehicle Damage



Case Vehicle: 1992 Toyota Camry

PDOF: 12 O'clock

DeltaV: 15mph / 24km/h

Max. Crush: 21in / 53cm

Type: Multiple Impact

With Narrow Frontal



Occupant Information



- Case Subject: 76-Year-Old Male
- 67in / 170cm
- 170lbs / 77kg
- Position: Driver
- Restraint: Lap & Shoulder
- Frontal Air Bag Deployed
- Length of Stay: 9 Days



Injuries



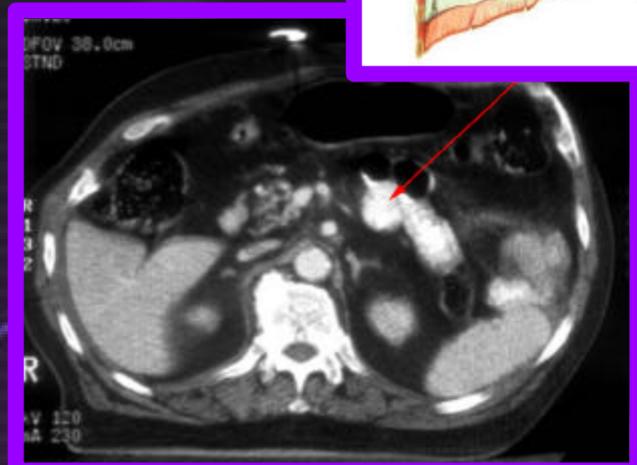
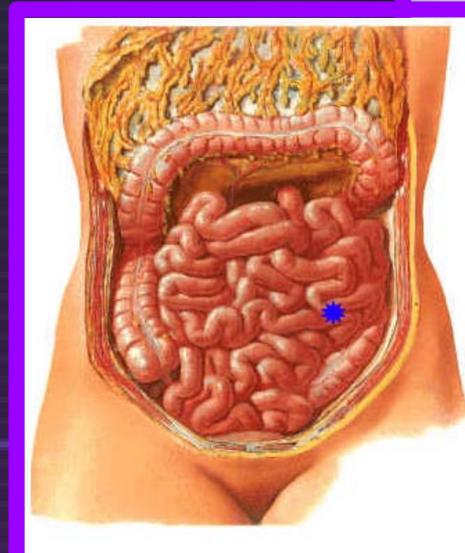
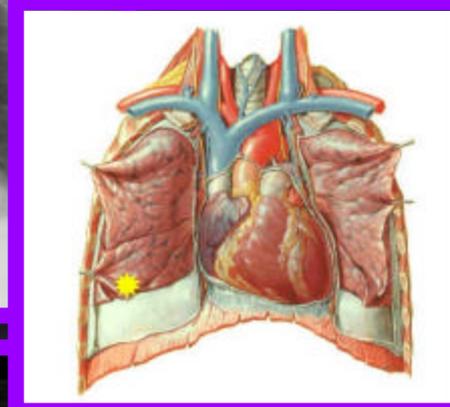
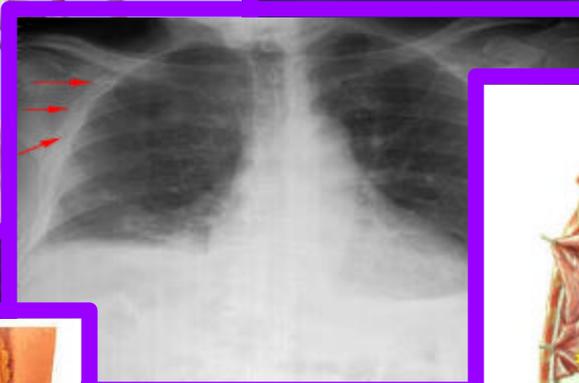
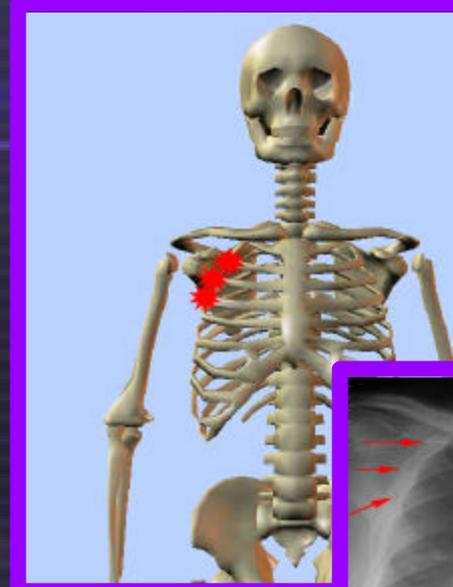
Front Air Bag

Multiple R. Rib Fx AIS-3

Belt Restraint

R. Lung Contusion AIS-3

Small Intestine Tear AIS-2

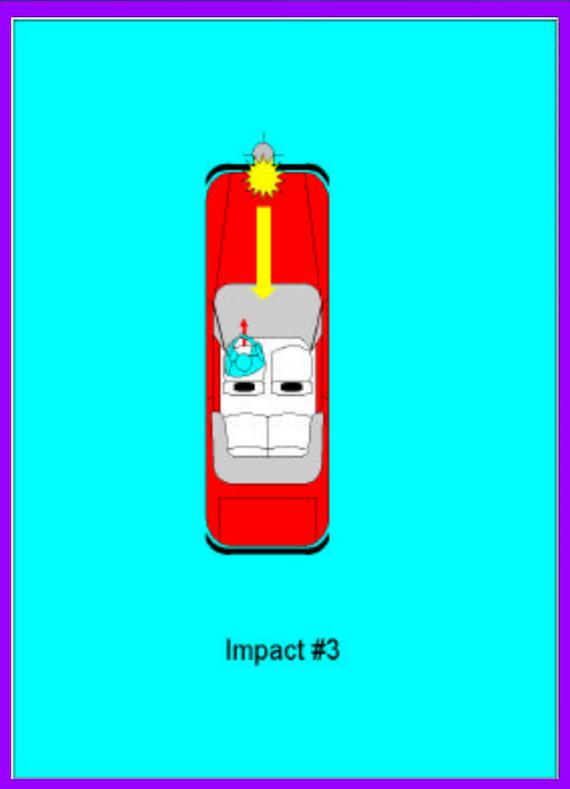
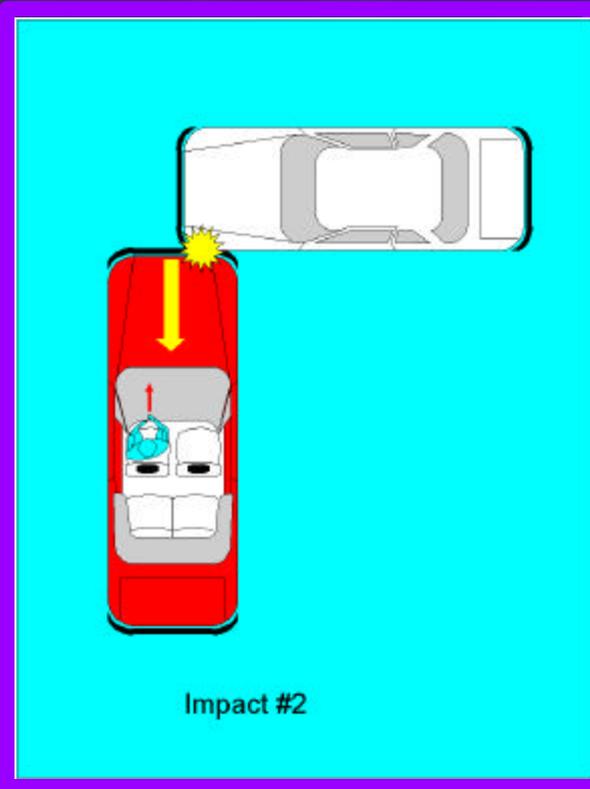
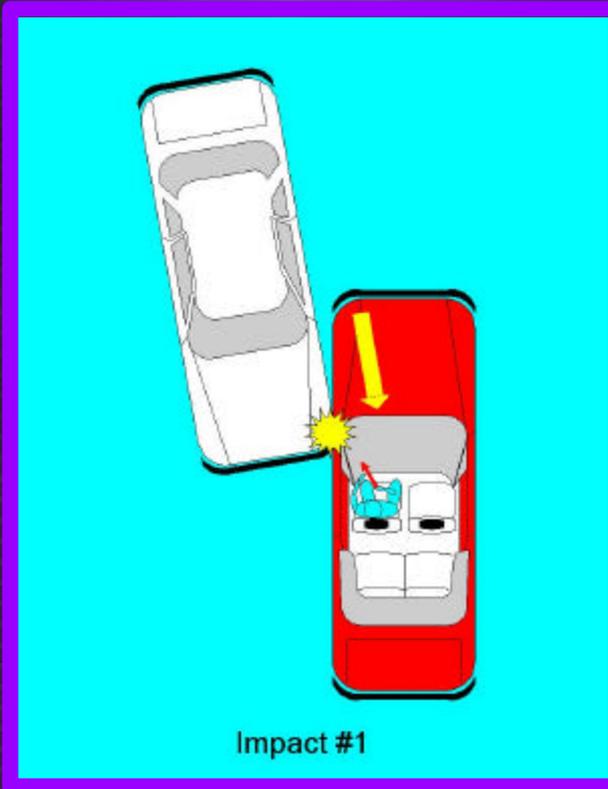


Case Information



- Married / Retired
- Excellent Family Support
Daughter Living In Area To Help In Rehab

Occupant Movement



URGENCY Algorithm



Vehicular Crash Data Frontal Crashes

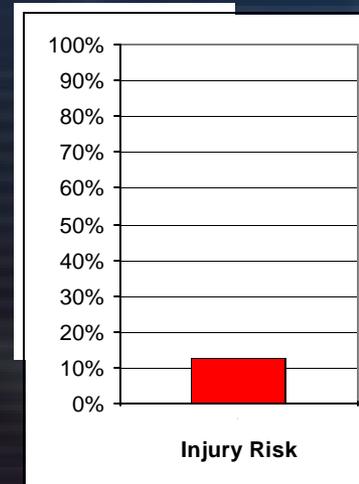
	Value	Data Check
DELTAV, in MPH?	15	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	0	TRUE
Max Crush (in.)	21	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	3272	TRUE
Air Bag + 3Pt Belt? (NO=0, YES=1)	1	TRUE
3 Pt Belt Only? (NO=0, YES=1)	0	
Car Occupant's Age, in years? (Default 30 yr.)	76	TRUE
Occupant's Gender? (FEMALE=1, MALE=0)	0	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	

Probability of Severe Injury

13%

Data Check

Probability of MAIS 3+ Injury



Complications



- Driver's Advanced Age- 76 Years With Multiple Rib Fxs
- Air Bag Deployed With Narrow Frontal Component Of Crash (Third Impact)
- Driver Out Of Position At Air Bag Deployment

Case Significance

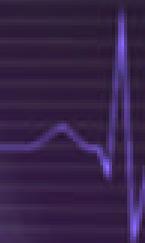


- Elderly Driver Failed to Notice Red Light And Entered Intersection
- Elderly Occupant Sustained Chest Injuries In A Moderate Crash
- First Generation Air Bag Deployment Forces Too Extreme For Out Of Position Elderly Occupants
- URGENCY Does Not Predict Injuries From Close-In Air Bag Deployments



Multiple Impact With Narrow Frontal Component

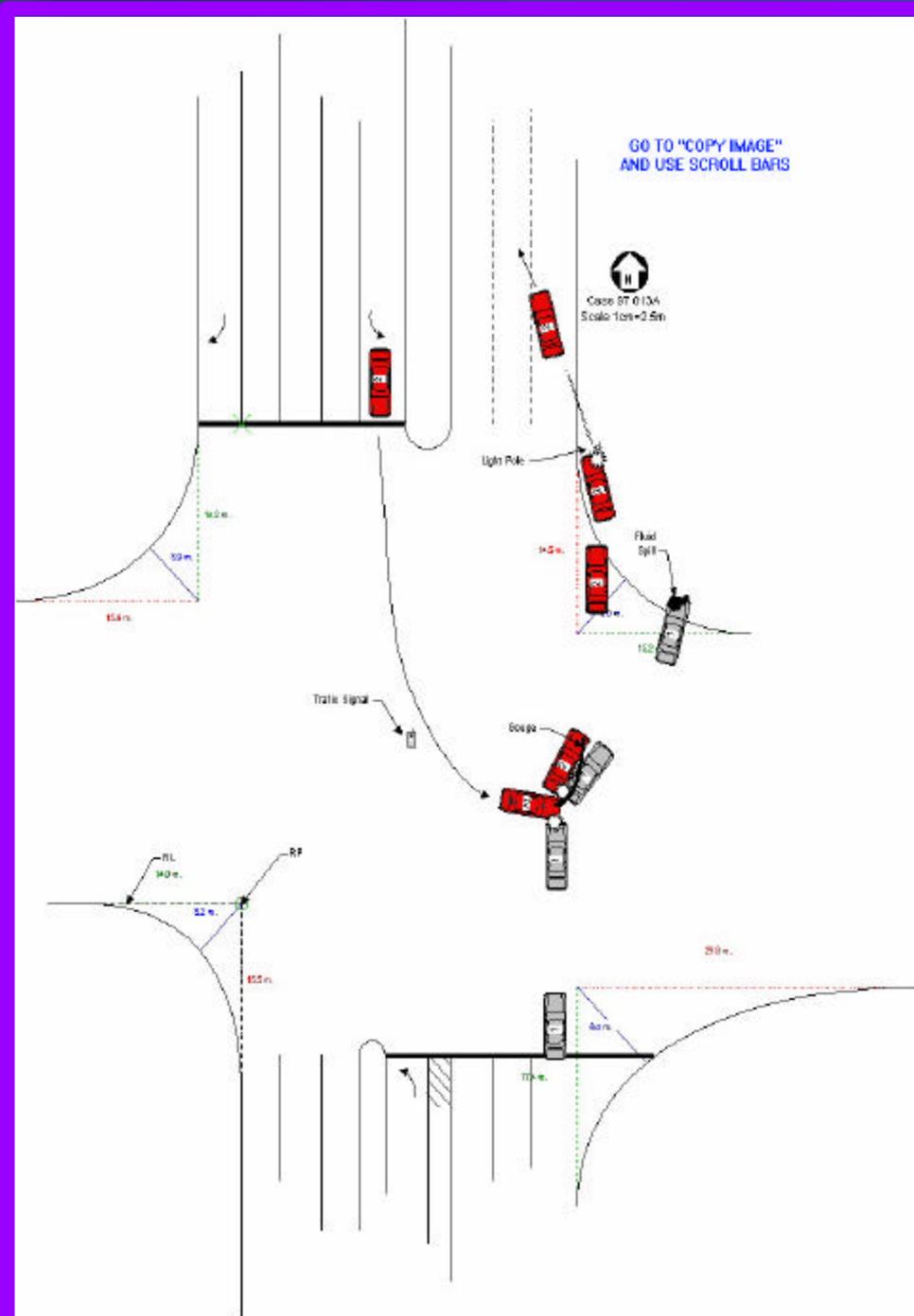
Fatality



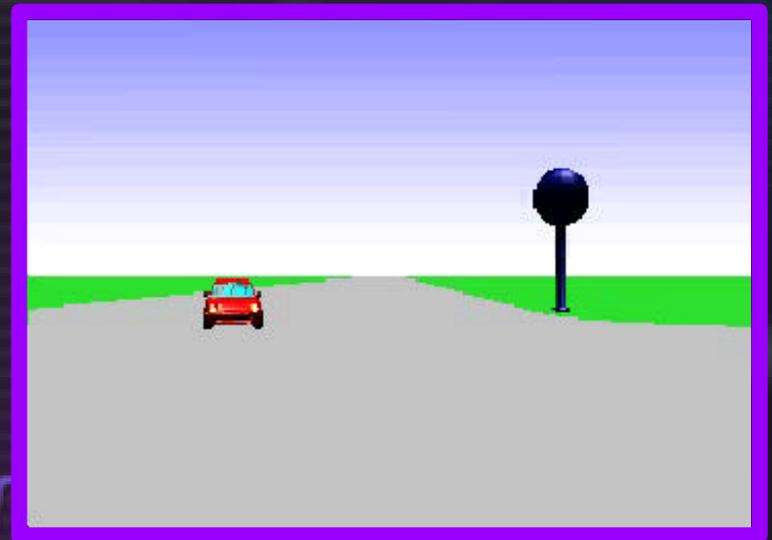
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Scene



PC Crash Animation



Vehicle Damage



Case Vehicle: 1995 Honda Civic

PDOF: 12 O'clock

(Narrow Frontal Component)

DeltaV: 17 mph / 27km/h

Max Crush: 10in / 25cm

Type: Multiple Impact

With Narrow Frontal Impact





Occupant Information

- Case Subject: 78-Year-Old Male
- 68in / 173cm
- 149lbs / 68kg
- Position: Driver
- Restraint: Lap and Shoulder
- Front Air Bag Deployed
Dead On Arrival



Injuries

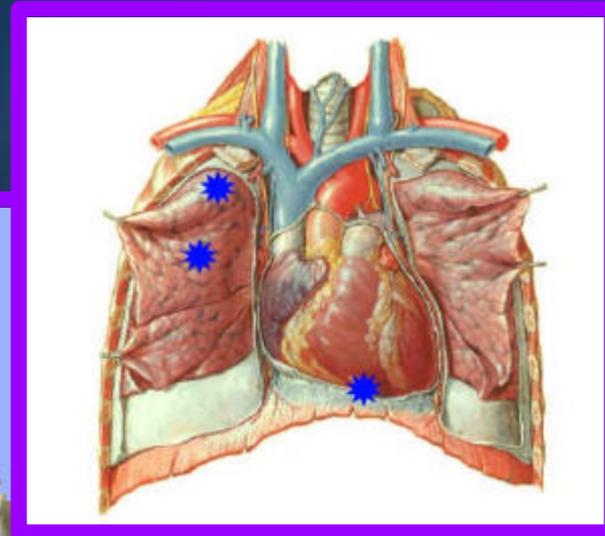
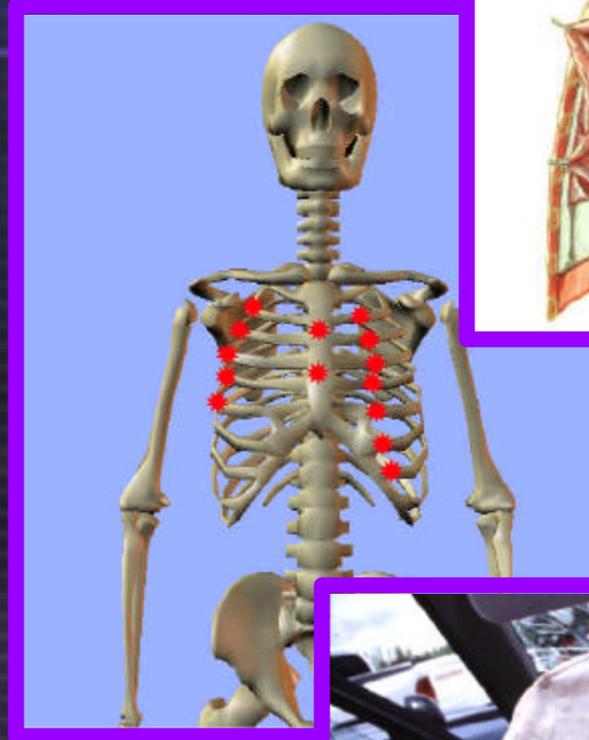


Front Air Bag

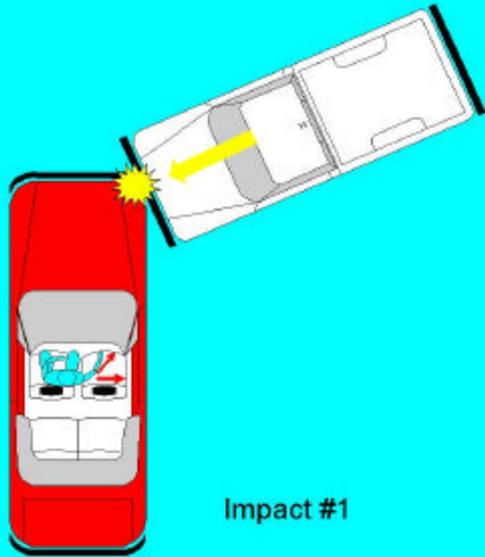
- R. Ventricle Rupture AIS-6
- Multiple Bilateral Rib Fx AIS-5
- R. Lung Contusion AIS-3
- Sternum Fx AIS-2
- Pericardium Lac. AIS-2
- R. Visceral Pleura Tear AIS-2

Non-Contact Source

- 5th Thoracic Vertebra Fx AIS-2



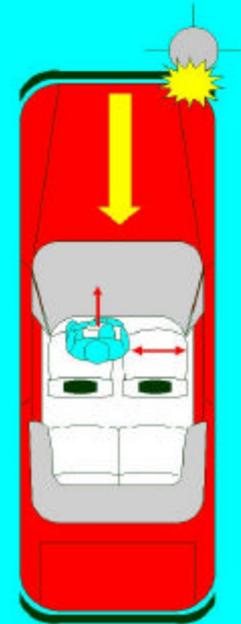
Occupant Movement



Impact #1



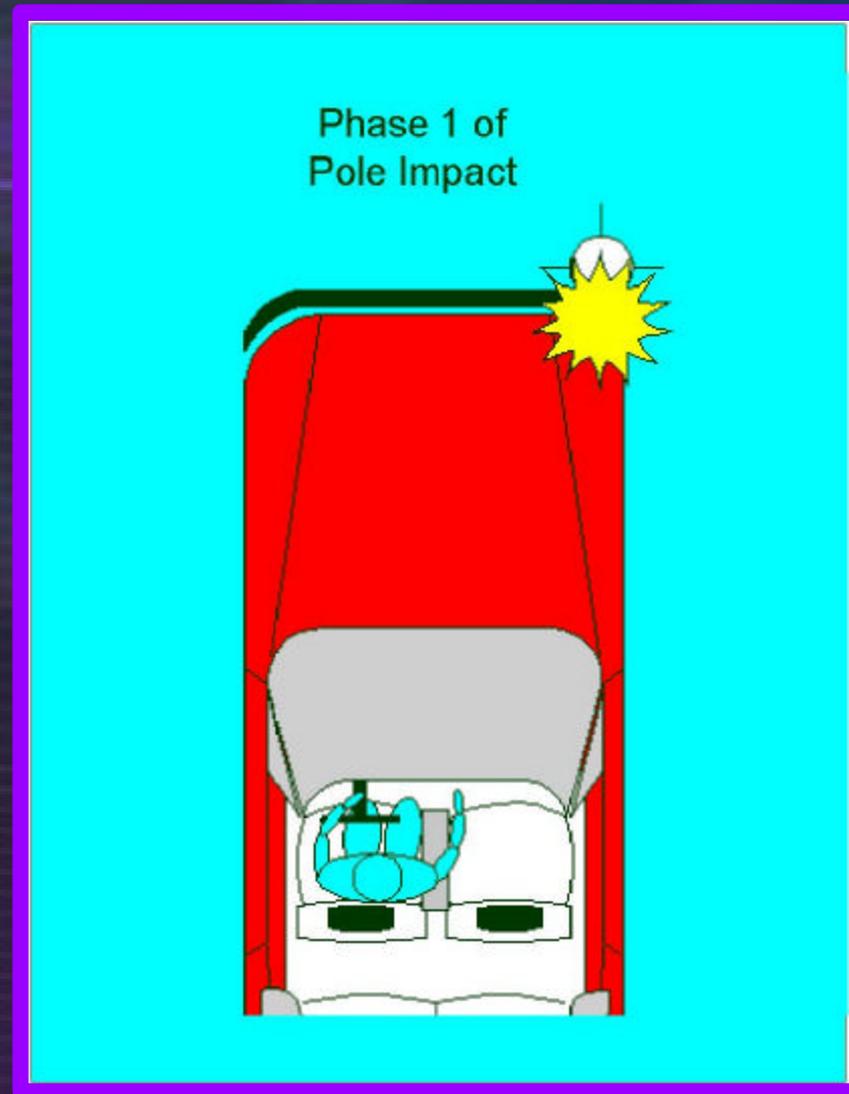
Impact #2



Impact #3

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Occupant Movement

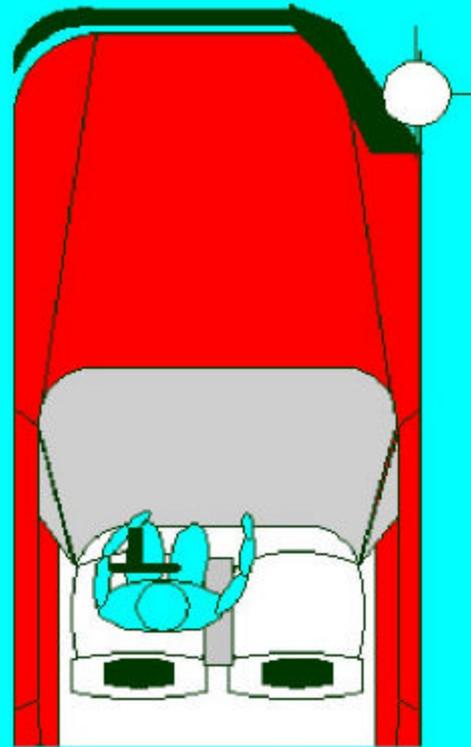


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Occupant Movement

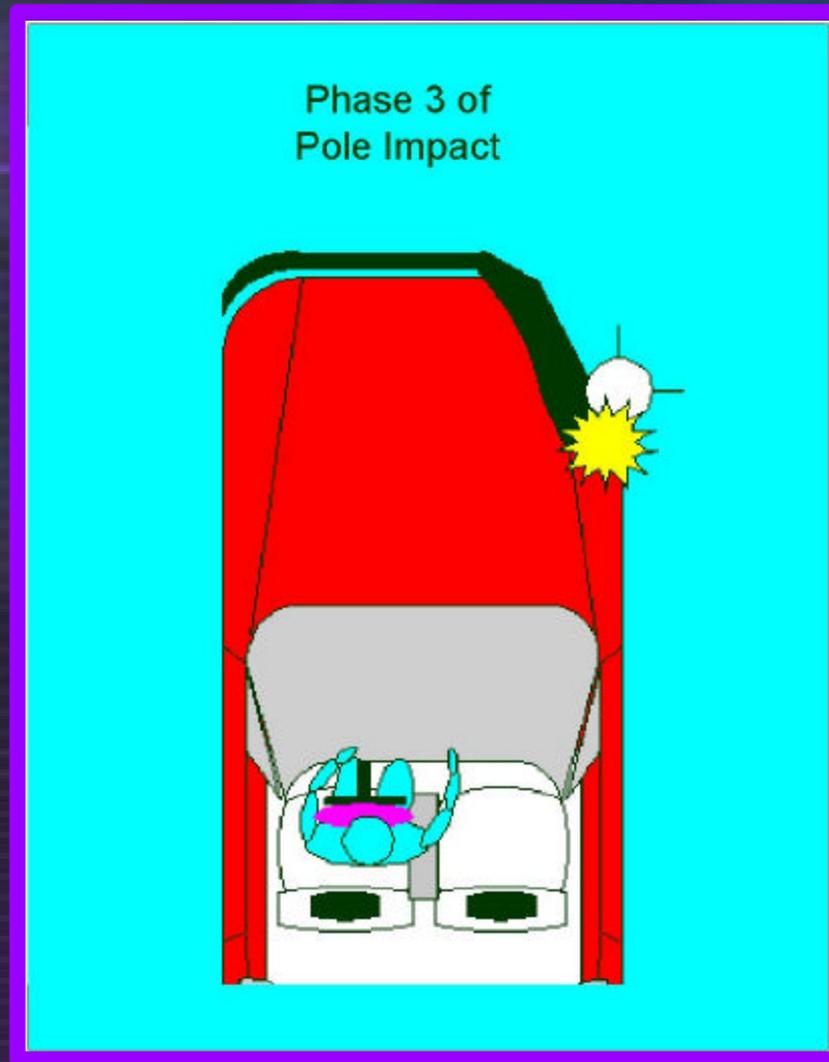


Phase 2 of
Pole Impact



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Occupant Movement



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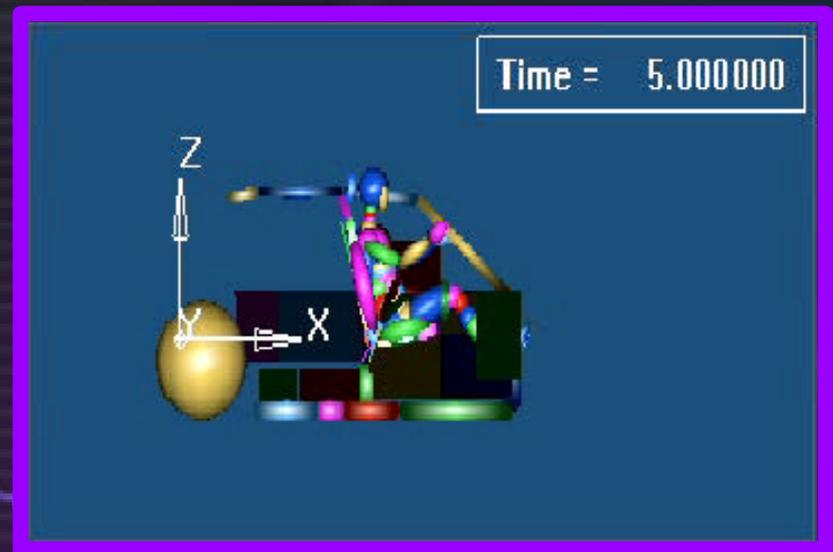
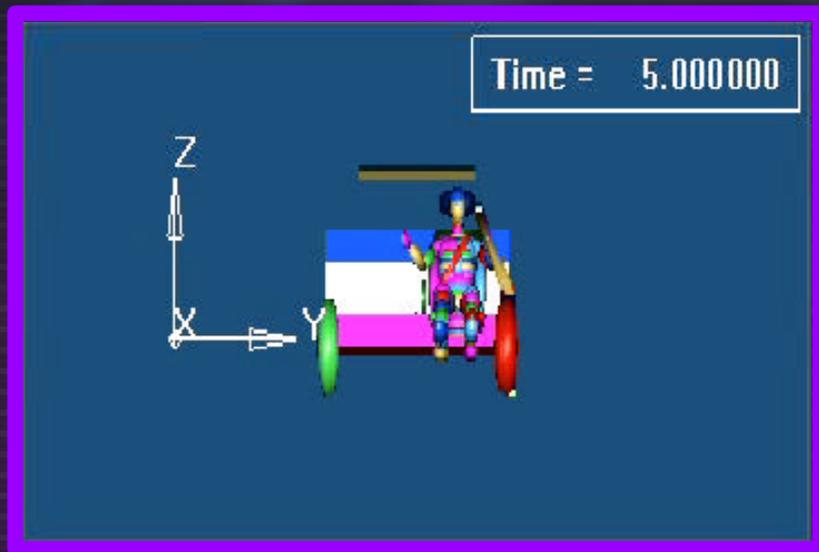
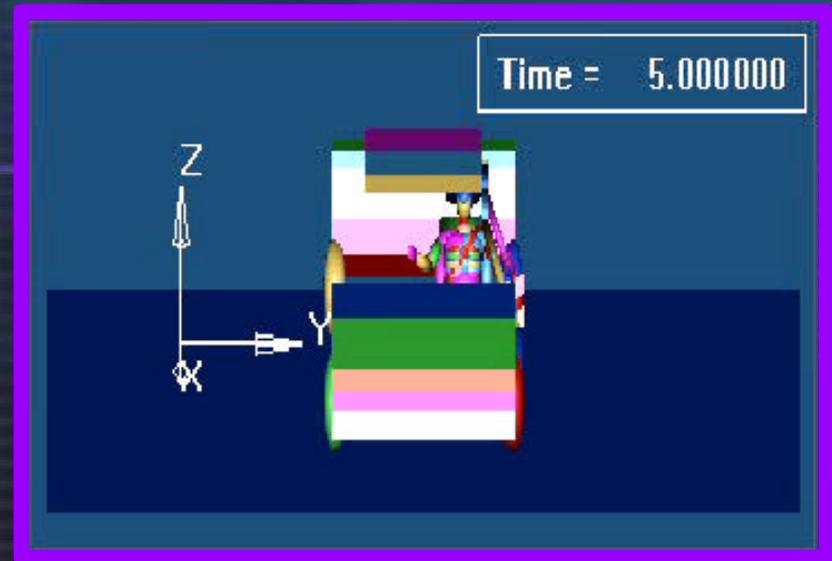
Occupant Movement



Occupant Movement



Occupant Movement



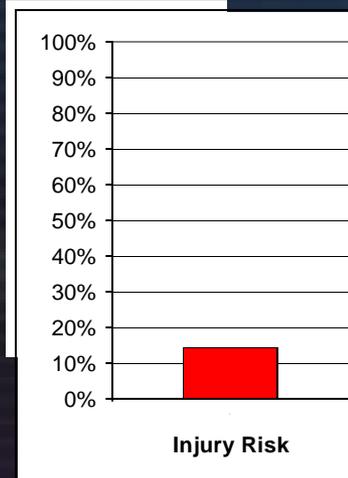
URGENCY Algorithm



Vehicular Crash Data Frontal Crashes

	Value	Data Check
DELTAV, in MPH?	17	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	0	TRUE
Max Crush (in.)	6	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	2213	TRUE
Air Bag + 3Pt Belt? (NO=0, YES=1)	1	TRUE
3 Pt Belt Only? (NO=0, YES=1)	0	
Car Occupant's Age, in years? (Default 30 yr.)	78	TRUE
Occupant's Gender? (FEMALE=1, MALE=0)	0	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	

Probability of MAIS 3+ Injury



Probability of Severe Injury

14%

Complications



- Driver's Advanced Age- 78 Years
 - Multiple Chest Injuries
- Multiple Impacts - 3 Total
- Lateral Impact, With Rotation Caused Driver To Be Out Of Position At Air Bag Deployment-(Third Impact)

Case Significance



- Elderly Driver Violated POV Right Of Way Making A Left Hand Turn
- Elderly Occupant Sustained Fatal Injuries In A Moderate Crash
- Air Bag Deployment Forces Too Extreme For Out Of Position Elderly Occupants
- 3-Point Restraint Failed To Keep Occupant In Proper Position For Air Bag Deployment
- Urgency Does Not Predict Injuries From Close-In Air Bag Deployments



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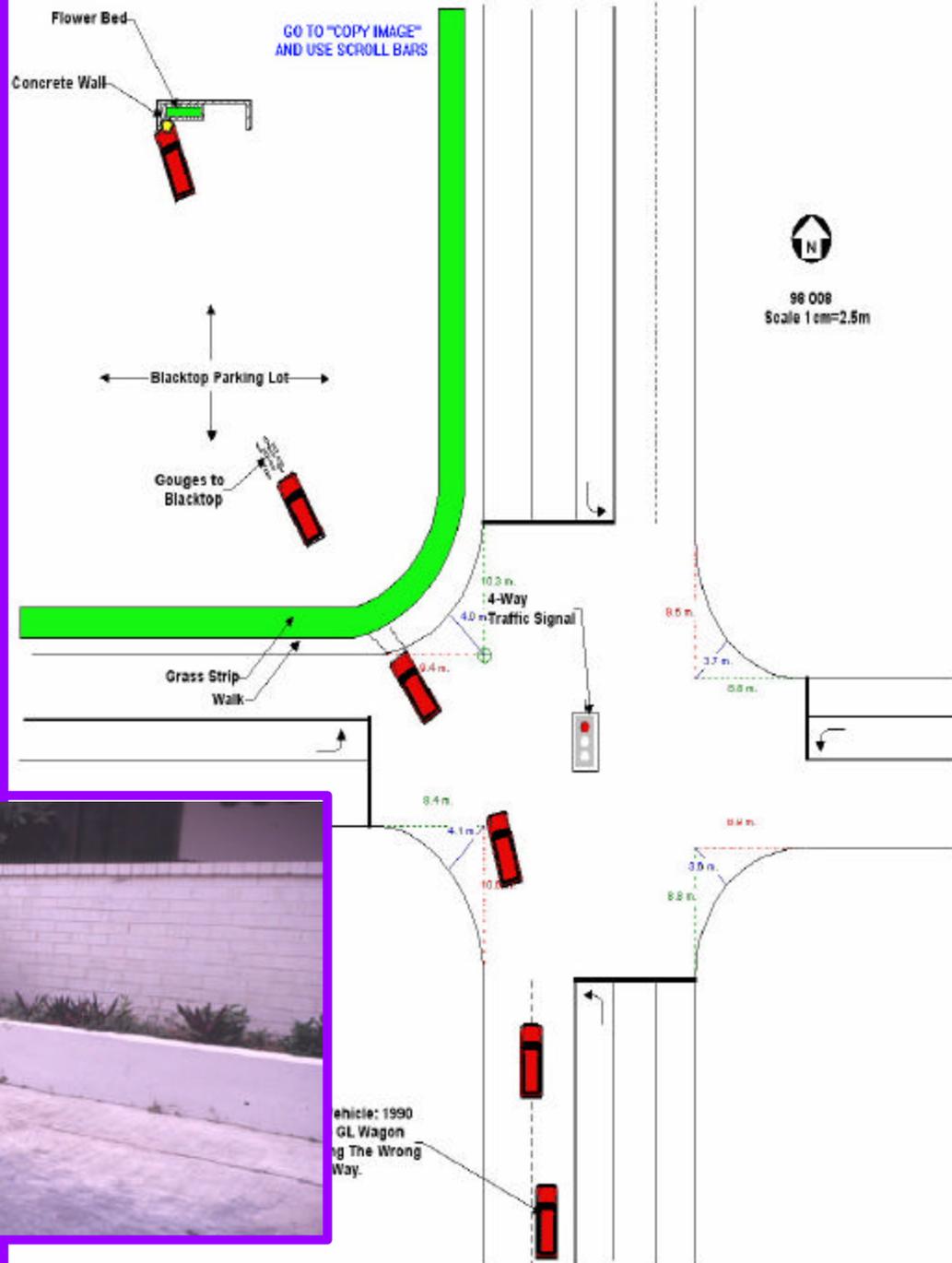
Barrier Impact

Survivor

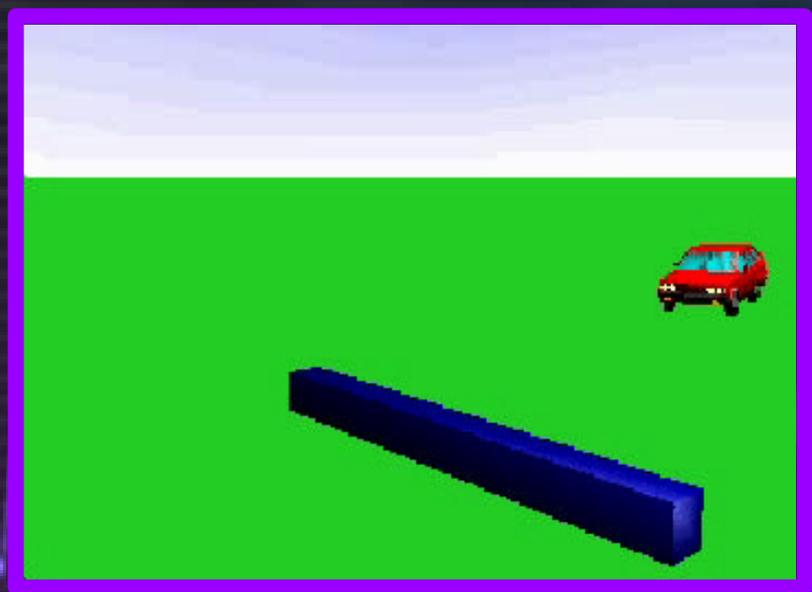


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Scene



PC Crash Animation



Vehicle Damage



Case Vehicle: 1990 Volvo 740 Station Wagon

PDOF: 11 O'clock

DeltaV: 29mph / 47km/h

Max Crush: 38in / 96cm

Type: Vehicle To Barrier



Occupant Information



- Case Subject: 55-Year-Old Female
- 66in / 168cm
- 245lbs / 111kg
- Position: Driver
- Restraint: Lap and Shoulder
- Front Air Bag Deployed
Length Of Stay: 10 days



Injuries



Belt Restraint

- R. Lobe Liver Lac AIS- 3

Steering Wheel Rim

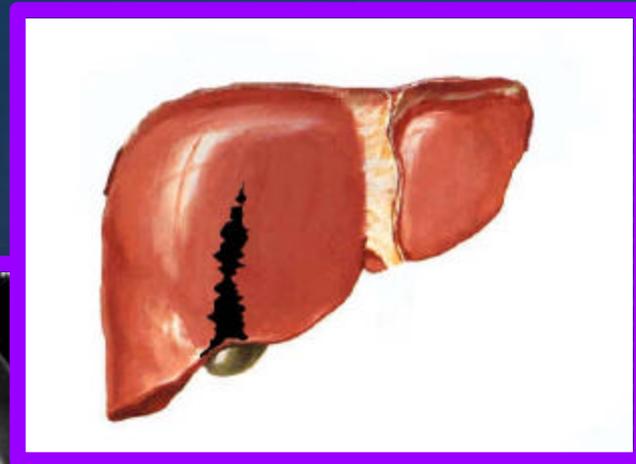
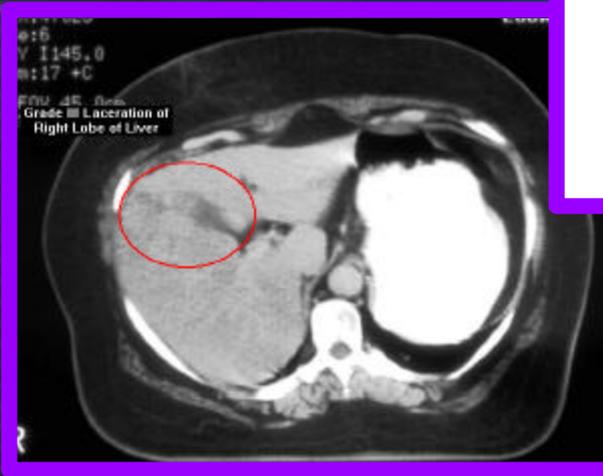
- L. Radius Comm. Fx AIS-3
- L. Ulnar Comm. Fx AIS-3

Knee Bolster

- L. Femur Comm. Fx AIS-3

Toe Pan

- R. Calcaneus Fx AIS-2

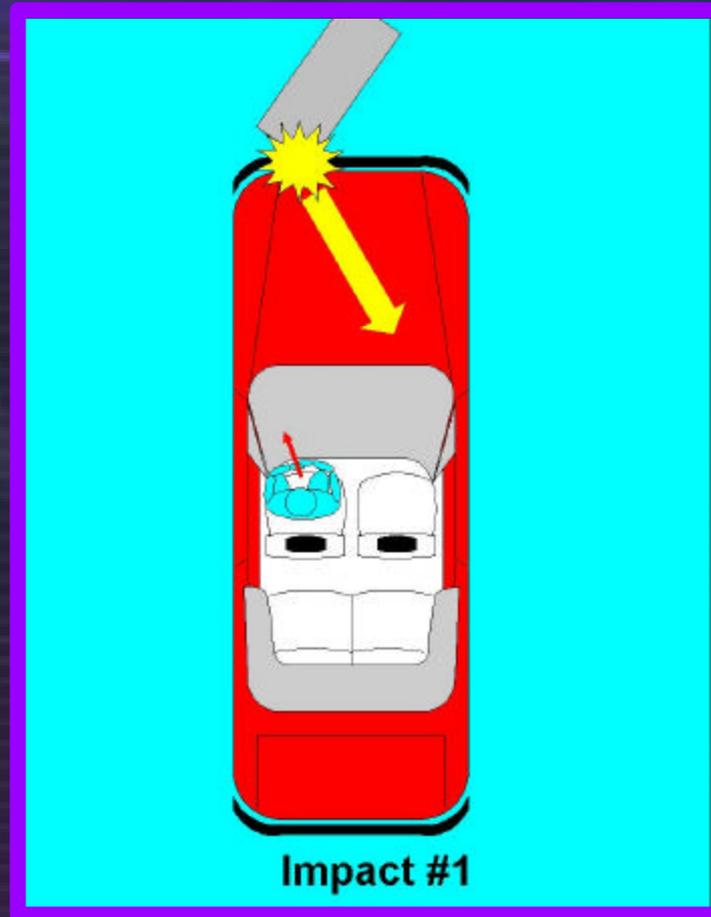




Case Information

- Moved To The United States In The 60's From Haiti
- Registered Nurse
- Strong Family Support During Rehab
- Maintains Her Pleasant Demeanor In Spite Of Circumstances

Occupant Movement



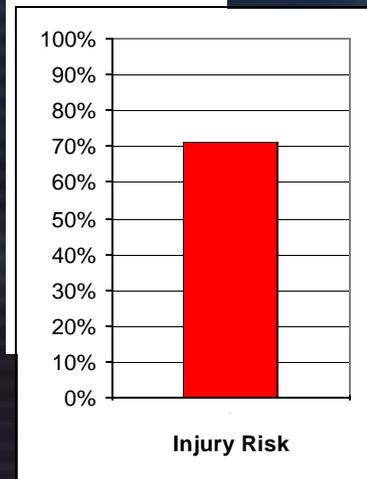
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URGENCY Algorithm



Vehicular Crash Data Frontal Crashes	Value	Data Check
DELTAV, in MPH?	29	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	1	TRUE
Max Crush (in.)	38	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	3200	TRUE
Air Bag + 3Pt Belt? (NO=0, YES=1)	1	TRUE
3 Pt Belt Only? (NO=0, YES=1)	0	
Car Occupant's Age, in years? (Default 30 yr.)	55	TRUE
Occupant's Gender? (FEMALE=1, MALE=0)	1	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	

Probability of MAIS 3+ Injury



Probability of Severe Injury **72%**

URGENCY Algorithm

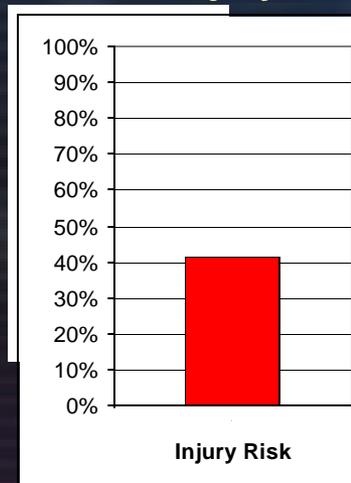
Same Crash, Younger Driver



Vehicular Crash Data Frontal Crashes

	Value	Data Check
DELTAV, in MPH?	29	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	1	TRUE
Max Crush (in.)	38	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	3200	TRUE
Air Bag + 3Pt Belt? (NO=0, YES=1)	1	TRUE
3 Pt Belt Only? (NO=0, YES=1)	0	
Car Occupant's Age, in years? (Default 30 yr.)	25	TRUE
Occupant's Gender? (FEMALE=1, MALE=0)	1	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	

Probability of MAIS 3+ Injury



Probability of Severe Injury

42%

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Complications



- Obese Driver Complicates Recovery And Rehab
- As A Registered Nurse, Required To Be On Feet, Prolonging Her Recovery And Rehabilitation

Case Significance



- Liver Laceration With No Rib Fracture
- Narrow Impact Condition Results In Maximum Loading Of Restraint System
- Bracing By Driver At Impact, Both Upper And Lower Extremities
- URGENCY Shows The Strong Influence Of Age



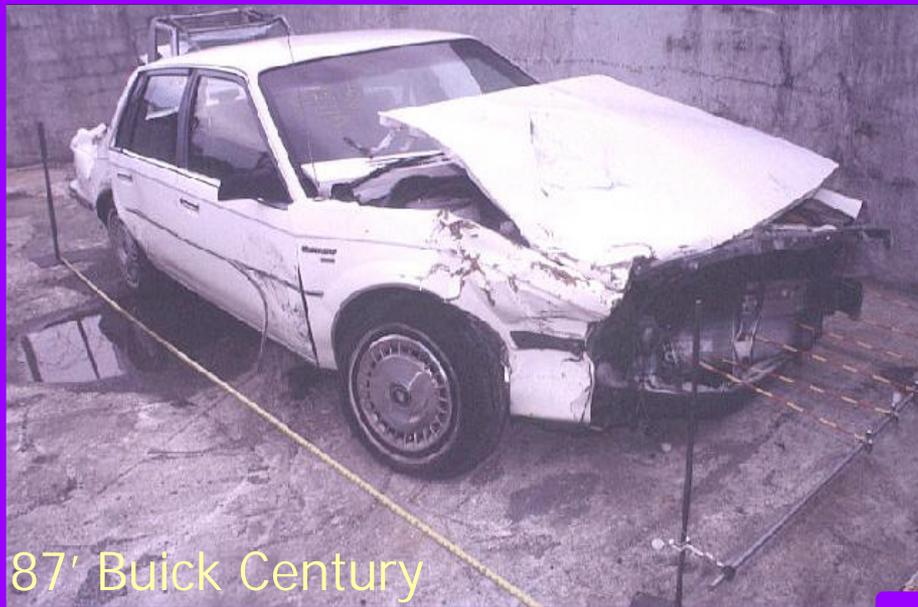


Similar Damage Different Outcome



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Similar Damage Different Results



87' Buick Century

- 68-Year-Old Female / Fatality
- DeltaV: 25mph / 40km/h
- Max Crush: 12in / 30cm
- MAIS-5: Liver Laceration



95' Mazda 626

- 23-Year-Old Female / 21 Days Hosp.
- DeltaV: 23mph / 37km/h
- Max Crush: 12in / 30cm
- MAIS-4: Liver Laceration

Moderate Crash Different Results

92' Chevrolet Corsica



- 71-Year- Old Female / Fatality
- DeltaV: 24mph / 39km/h
- Max Crush: 15in / 38cm
- MAIS- 4: Kidney Rupture

98' Honda Accord



- 18-Year- Old Female / 5 Days Hosp.
- DeltaV: 19mph / 31km/h
- Max Crush 18in / 29cm
- MAIS-5: Liver Laceration

Conclusions



- Need Better Predictors For Close-In Air Bag Injuries
- More Emphasis On Older Occupants In Urgency And Trauma Criteria
 - Success Rate For Older Occupants Not As High As For Younger Occupants
 - Real Data Shows Risk Is Non-Linear In Older Population
- Older Population Require More Benign Belts And Air Bags
- Narrow Object Impacts Are Particularly Challenging For Protecting Older People

