



Offset Frontal Collisions and the Effect on Opposite Side Occupants

Using Crash Data to Identify People with
Critical Injuries that are Difficult to Detect

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Outline

- Validation of URGENCY Algorithm to Detect Severe Injuries
- Corrections in Algorithms due to Offset Crashes
- Examples of injuries in Offset Crashes

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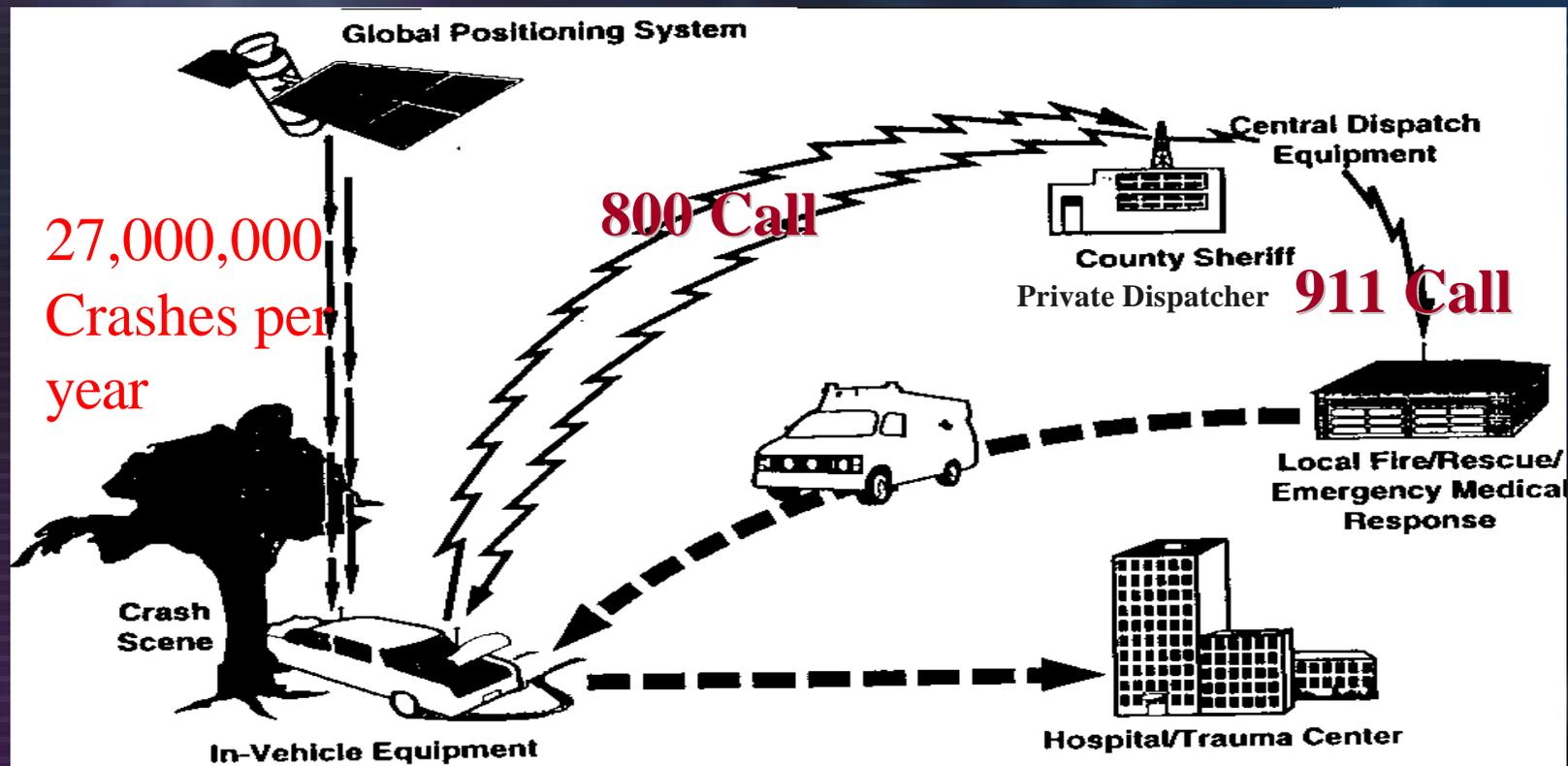


Definition of Automatic Crash Notification (1st Generation)

- Identifies that a Crash Has Occurred
- Identifies the Crash Location
- Automatically Transmits the Information to a Third Party Who Dispatches Assistance



Automatic Crash Notification



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Crash Signal Information

NHTSA/Calspan ACN System

- Delta-V
- Principal Direction of Force (PDOF)
- Rollover Indicator/Counter
- Travel Speed
- Vehicle Data (VIN Related)
- *2-Way Voice Communications*

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Crash Vehicle Location

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



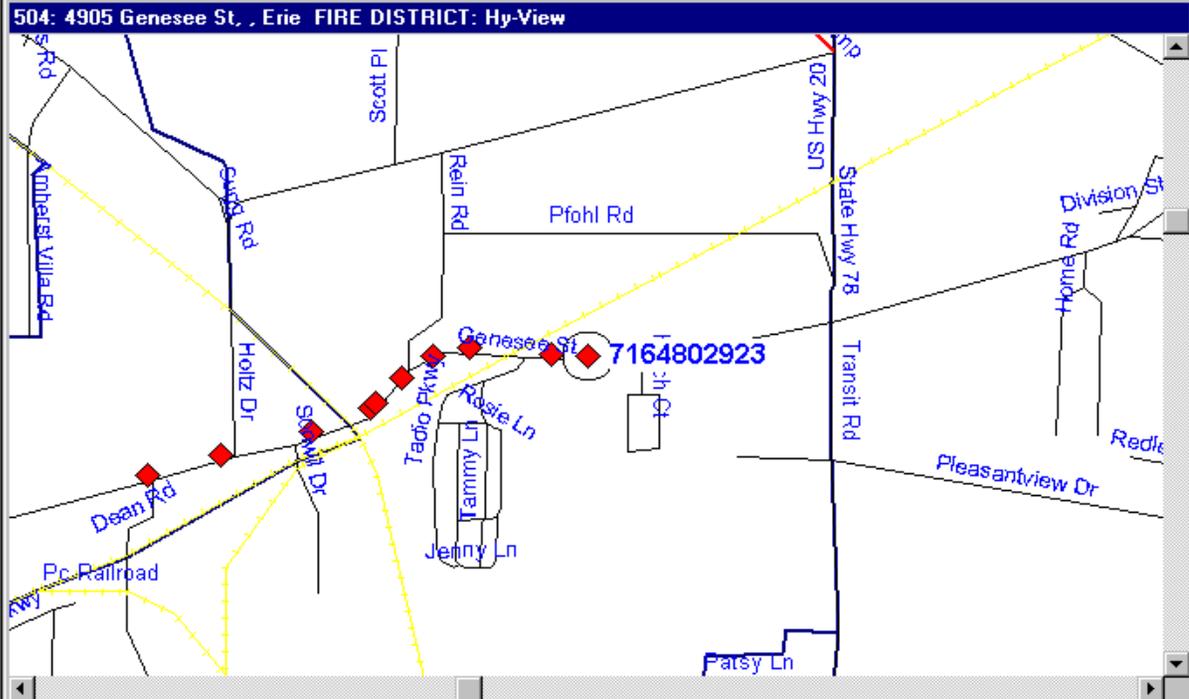
Final Resting Position:

Left Side

Rollover



Change in Velocity = 38 mph



Communications

Vehicle	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

URGENCY Estimate of Serious Injury Probability

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

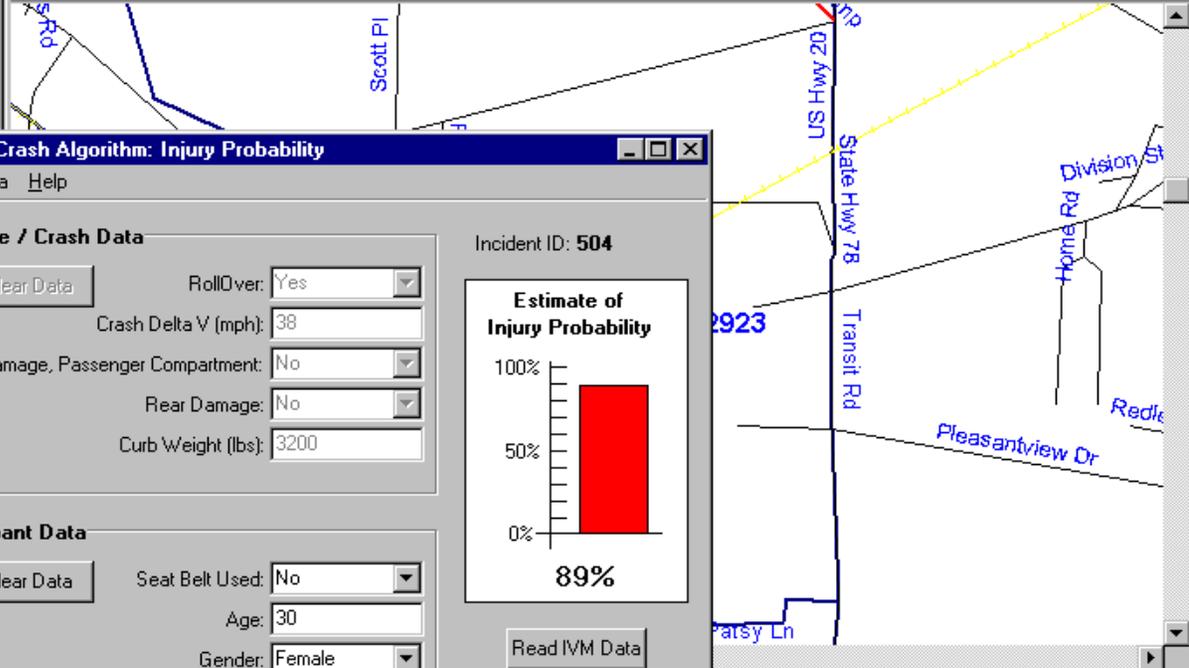


Final Resting Position:
 Left Side
Rollover



Change in Velocity = 38

504: 4905 Genesee St., Erie FIRE DISTRICT: Hy-View



Post Crash Algorithm: Injury Probability

File Data Help

Incident ID: 504

Vehicle / Crash Data

Clear Data RollOver: Yes

Crash Delta V (mph): 38

Side Damage, Passenger Compartment: No

Rear Damage: No

Curb Weight (lbs): 3200

Estimate of Injury Probability

89%

Occupant Data

Clear Data

Seat Belt Used: No

Age: 30

Gender: Female

Entrapment: No

Complete Ejection: No

Read IVM Data

Override IVM

Exit

Communications

Vehicle	Fax	Voice C
Dispatcher		
Cheektowaga Police		
Cheektowaga Fire		
ECMC		
Manual Dial:		
Manual Dial:		

Year: 1994
 Plate: 123456

Incident:504

Thursday November 19 1998, 2:01:03 PM



URGENCY Predictors of Injury

- Delta V & PDOF
- Rollover
- Belt Use
- Single Vs. Multi-vehicle Crash
- Extent of Damage
- Ejection & Entrapment
- Age & Gender
- Vehicle Weight

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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 = Intercept

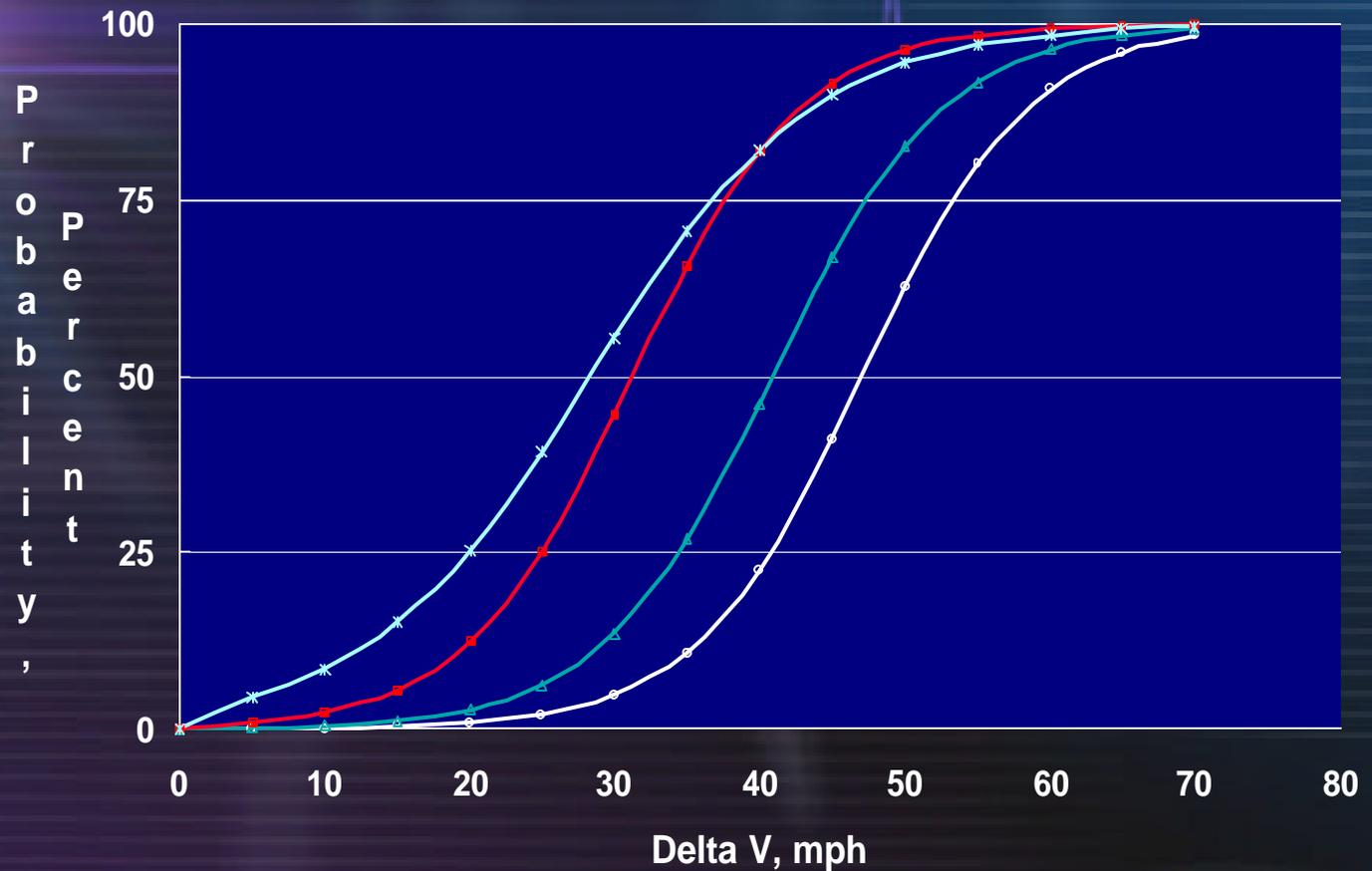
A_n = Coefficient

Pred n = Value of Predictor

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Principle of Maximum Likelihood

Probability of Shown Outcome Using Car Crash Severity



Probability of
Casualty Levels
Using
DeltaV only

—○— Occupant Fatality —△— Compelling Injury —■— Max AIS 3+ —*— Max AIS 2+

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A_n for MAIS 3+ Injury Risk Binary Factors

Predictor	A
SINGLE	0.322
ROLL	1.157
GADSP	0.219
GADB	-1.793
OCCRE	-0.65
FEMALE	0.464
ENT	2.378
EJC	1.859

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Source: Malliaris. SAE 970393, 1997



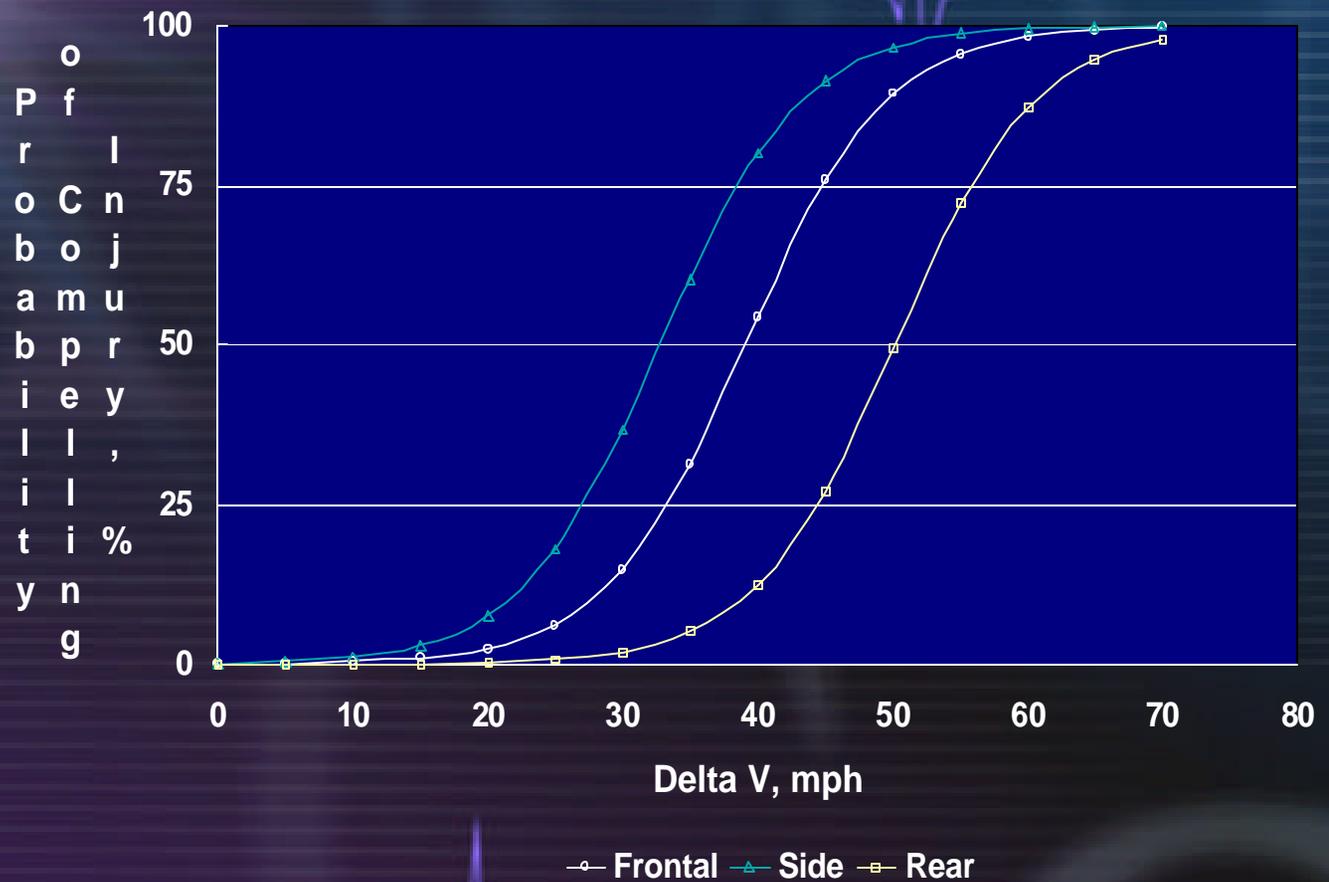
A_n for MAIS 3+ Injury Risk Continuous Variables

Predictor	A
TOTALDV	0.164
AGE	0.042
MAX CRUSH	0.037
CURBWT	-0.027

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Source: Malliaris. SAE 970393, 1997

Sensitivity of Severe Injury to the Direction of Force, as a Function of Car Crash Severity



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Application to Field Cases

- Frontal Crash
- Restrained Occupant
- 30 YO Male Driver
- 30 mph vehicle-to-vehicle crash
- 3200 Lb Car
- What is the probability of an AIS 3 Injury?

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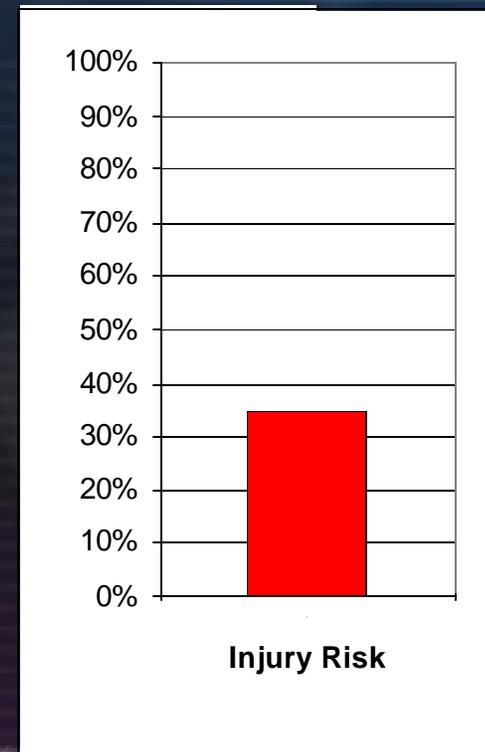


Baseline MAIS 3+ Injury Risk 3200 lb Car

Vehicular Crash Data Frontal Crashes

	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	0	TRUE
Max Crush (in.)	22	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	3200	
Air Bag + 3Pt Belt? (NO=0, YES=1)	0	TRUE
3 Pt Belt Only? (NO=0, YES=1)	1	TRUE
Car Occupant's Age, in years? (Default 30 yr.)	30	
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	TRUE

Probability of MAIS 3+ Injury



Probability of Severe Injury

35%

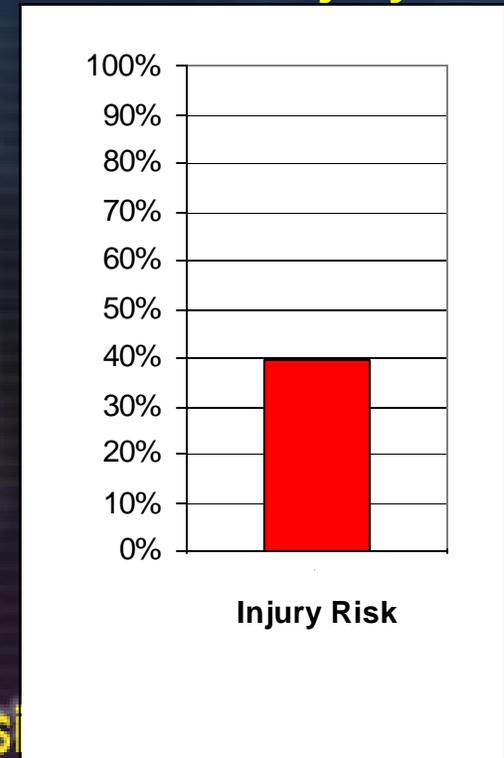


MAIS 3+ Injury Risk 2400 lb Car

Vehicular Crash Data Frontal Crashes

	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	0	TRUE
Max Crush (in.)	22	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	2400	
Air Bag + 3Pt Belt? (NO=0, YES=1)	0	TRUE
3 Pt Belt Only? (NO=0, YES=1)	1	TRUE
Car Occupant's Age, in years? (Default 30 yr.)	30	
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	TRUE

Probability of MAIS 3+ Injury



Probability of Severe Injury **40%** University

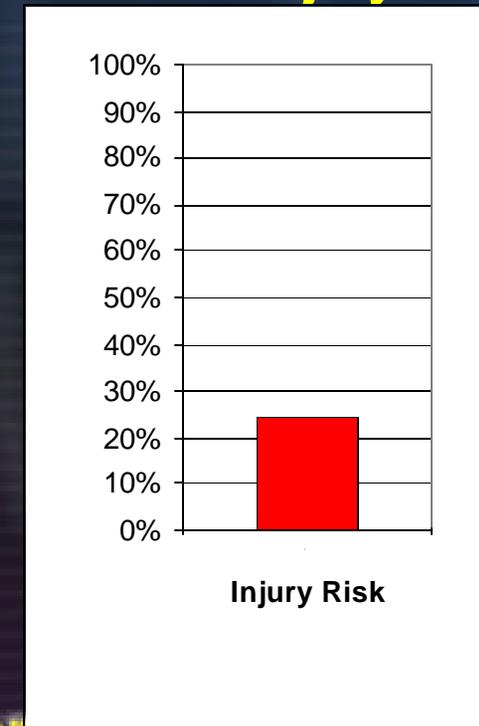


MAIS 3+ Injury Risk 2400 lb Car (Belt+ Bag)

Vehicular Crash Data Frontal Crashes

	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0, YES=1)	0	TRUE
Max Crush (in.)	22	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	2400	
Air Bag + 3Pt Belt? (NO=0, YES=1)	1	TRUE
3 Pt Belt Only? (NO=0, YES=1)	0	TRUE
Car Occupant's Age, in years? (Default 30 yr.)	30	
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	TRUE

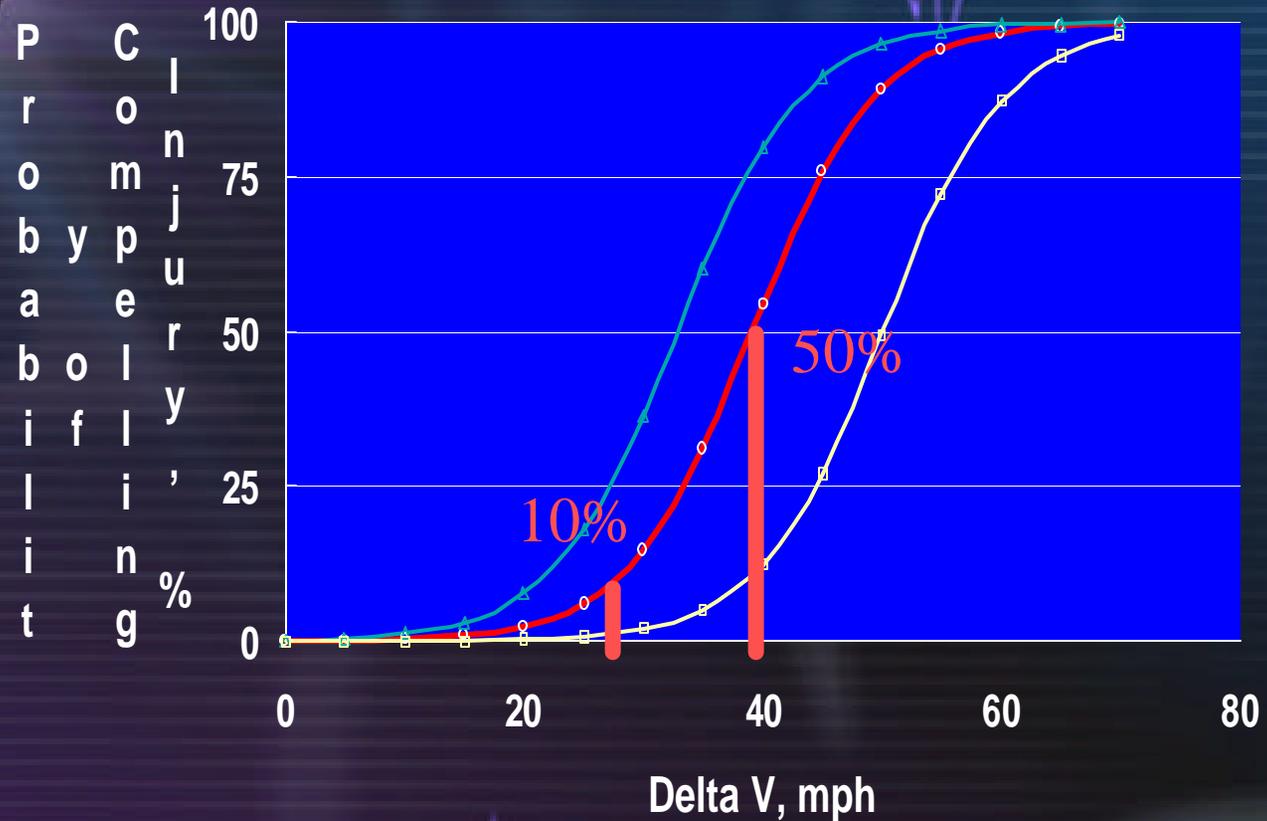
Probability of MAIS 3+ Injury



Probability of Severe Injury

24%

Sensitivity of Severe Injury to the Direction of Force, as a Function of Car Crash Severity



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Validation of URGENCY Algorithm

Apply to WLIRC Cases with the Following Criteria:

- Frontal Crashes
- Belt + Air Bag

Cases that met Criteria

- 7 DOS
- 20 Met Physiological Triage (16 with MAIS 3+)(4 No)
- 30 Hi Suspicion of Injury (18 with MAIS 3+)(12 No)

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URGENCY Validation - Baseline Prediction

	Low Risk	Med Risk	Hi Risk
Baseline	0-10	11-49	50+
DOS	0/	0/	7/
TRAUMA	8/	4/	8/
HISUS	8/	11/	11/

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URGENCY Validation - Baseline Accuracy

	Low Risk	Med Risk	Hi Risk
Baseline	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	4/4	8/8
HI SUS	8/2	11/6	11/10

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URGENCY Validation - Pole +



	Low Risk	Med Risk	Hi Risk
Baseline	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	4/4	8/8
HI SUS	8/2	11/6	11/10
Pole +	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	8/2	9/4	13/12

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URGENCY Validation - Multiple Impacts

Pole +	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	8/2	9/4	13/12
Multiple	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	6/0	6/1	18/17

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Frail Individual missed



URGENCY Validation - Close-in

Multiple	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	6/0	6/1	18/17

Close-in	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	4/0	1/1	15/15
HI SUS	6/0	6/1	18/17

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Better Predictors - Frontals

- Pole Crashes at 20+ mph
- Multiple-impacts
- Close-in Occupants; Late deployments
- Other Factors
 - Frail Individuals
 - Complex Directions
 - Off-side Frontals

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Off-side Frontals

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Off-side Frontal (Driver)



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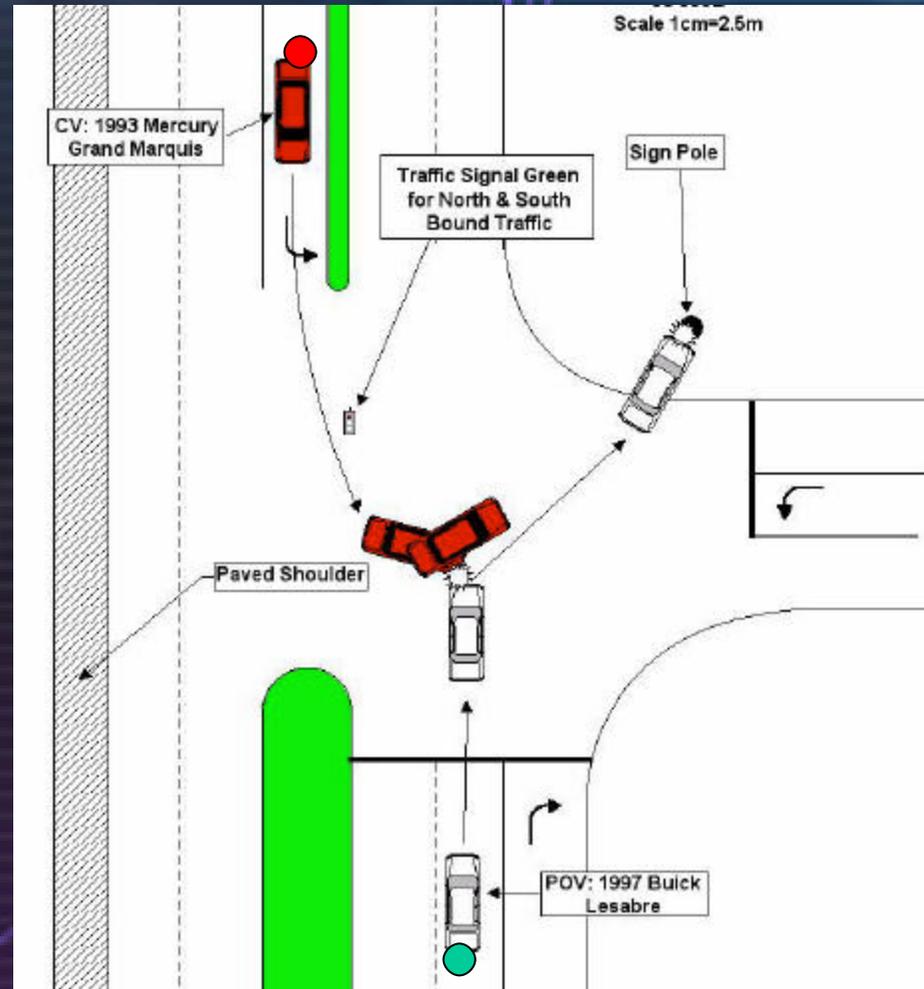
Off-side Case

- Case 98-006BL
- 2-o'clock
- 9 mph Delta-V
- Fatal



9 mph Crash - Fatality

- 2 o'clock, 9 mph
- Restraints:
Lap & Shoulder Belt
Driver & Passenger
Air Bags Deployed

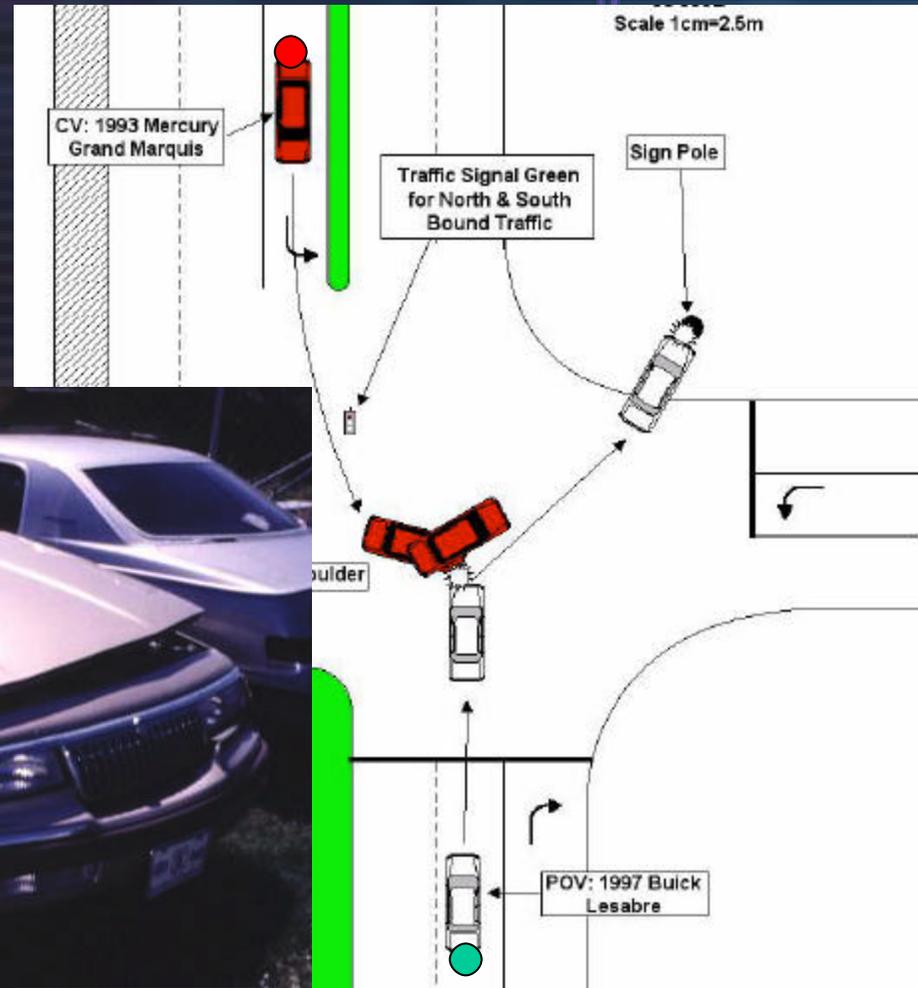


Case 98-006BL



9 mph Crash - Fatality

- 2 o'clock, 9 mph
- '93 Mercury Marquis



Case 98-006BL



9 mph Crash - Fatality

- Male Driver; 77 YO; 68" Tall; 272 Lbs
- Veh. - '93 Mercury Marquis
- POV- '97 Buick LeSabre
- 2 o'clock, 9 mph
- 10" Max Crush
- No Intrusion



Case 98-006BL



9 mph Crash - Fatality

Upper Body
Markings



Case 98-006BL



9 mph Crash - Fatality



Case 98-006BL



9 mph Crash - Fatality

- Trauma Criteria - Expired at Scene
- Restraints-
Lap & Shoulder
Belt
Air Bags Deployed



Case 98-006BL



9 mph Crash - Fatality

AIS-5 Brain Injury
Passenger Air Bag
Contact

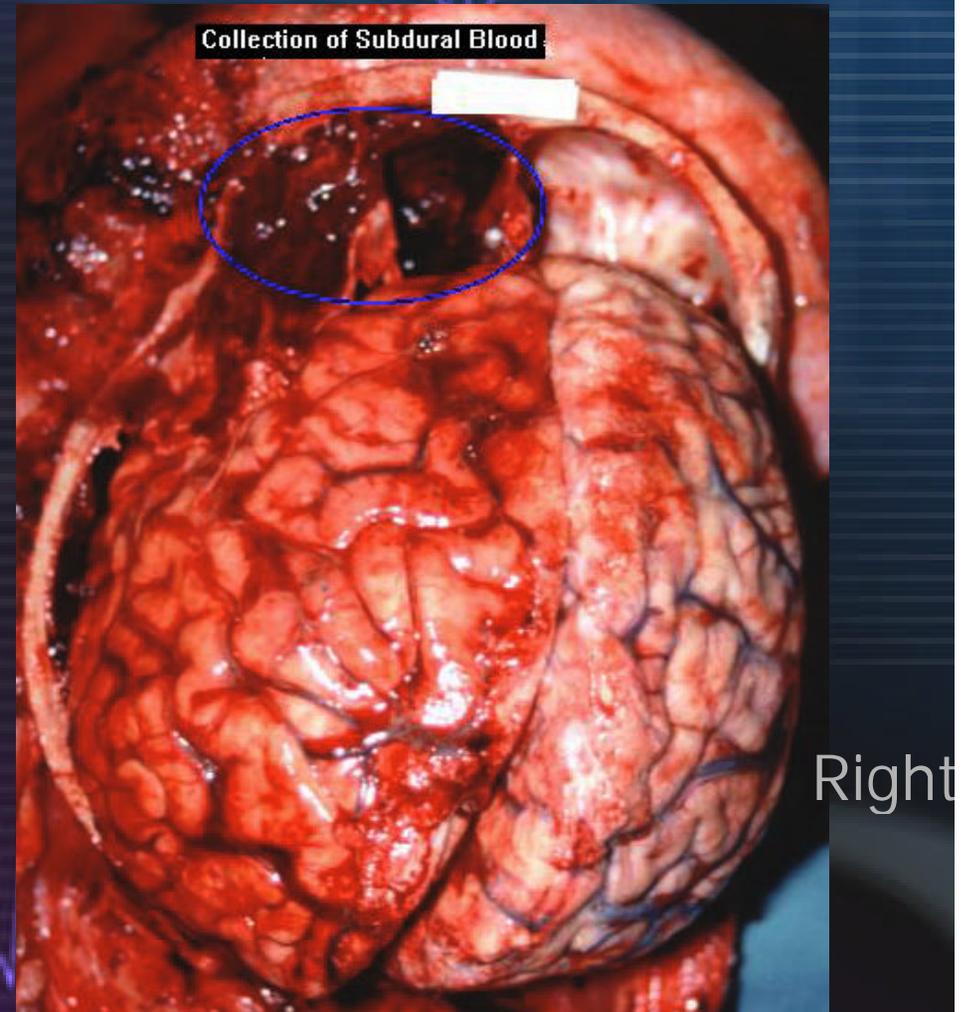


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Case 98-006BL



9 mph Crash - Fatality

- **Belt Induced Injuries:**
None
- **Other Injuries:**
AIS 5 - Brain
Passenger Air Bag



Case 98-006BL



Observations

- Shoulder Belt has Limited Effectiveness in Off-side Crashes
- Adjustments in URGENCY Algorithm May be Necessary



Past Studies Have Shown that
2-point Belts
Require Triage Criteria
Adjustment
in Far Side
Offset Frontal Crashes

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Injury Risk- 3-Point Belts

Vehicular Crash Site Data	Value	Data	Serious Injury Risk
Damage to Left Front? (Left Front=1)	1	L. Front	
Damage to Center Front? (Center Front=1)	1	C Front	
Damage to Right Front? (Right Front=1)	0	NO	
Damage Greater Than 15"?(G.T. 15"=1)	1	G.T. 15	
Damage Greater Than 25"?(G.T. 25"=1)	1	G.T. 25	
Damage Greater Than 35"?(G.T. 35"=1)	0	L.T. 35	
Single Vehicle Crash? (Single Vehicle=1)	0	MULTI.	
Rollover? (Rollover=1)	0	NO ROLL	
Entrapped or Ejected? (NO=0, YES=1)	0	NO	
Driver? (DRIVER=1, PASSENGER=0)	1	DRIVER	
Occupant's Gender? (FEMALE=1, MALE=0)	0	MALE	
Car Occupant's Age, in years? (Default 30 yr.)	30	TRUE	
Safety Belt Use? (NO BELT=0, YES, BELT=1)	1	YES	
Shoulder Belt Without Lap Belt? (NO LAP=1)	0	W LAP	
Probability of Severe Injury	19%		



Injury Risk 2-Point Belts

Vehicular Crash Site Data	Value	Data	Serious Injury Risk
Damage to Left Front? (Left Front=1)	1	L. Front	<p>A bar chart with a vertical axis from 0% to 100% in 10% increments. A single red bar is shown at the 68% mark, labeled 'Risk' at the bottom.</p>
Damage to Center Front? (Center Front=1)	1	C Front	
Damage to Right Front? (Right Front=1)	0	NO	
Damage Greater Than 15"?(G.T. 15"=1)	1	G.T.15	
Damage Greater Than 25"?(G.T. 25"=1)	1	G.T. 25	
Damage Greater Than 35"?(G.T. 35"=1)	0	L.T. 35	
Single Vehicle Crash? (Single Vehicle=1)	0	MULTI.	
Rollover? (Rollover=1)	0	NO ROLL	
Entrapped or Ejected? (NO=0, YES=1)	0	NO	
Driver? (DRIVER=1, PASSENGER=0)	1	DRIVER	
Occupant's Gender? (FEMALE=1, MALE=0)	0	MALE	
Car Occupant's Age, in years? (Default 30 yr.)	30	TRUE	
Safety Belt Use? (NO BELT=0, YES, BELT=1)	0	NO	
Shoulder Belt Without Lap Belt? (NO LAP=1)	1	NO LAP	
Probability of Severe Injury	68%		
			SUSPECT LIVER INJURY

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Basis for Change in URGENCY

AAAM 2000 Paper by Augenstein,
et. al.



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Population of Occupants

Restraint	NASS Belted (Exposed)	Lehman Belted (Injured)	Ratio
2- point	13%	32%	2.4
3-point	87%	68%	0.8



WLRIC- 48 Cases of Drivers with 2-Point Belts

Liver Injuries - 50%

From the Population with Liver Injuries:

Occult Liver Injuries - 78%

Mal-triaged Liver Injuries - 25%

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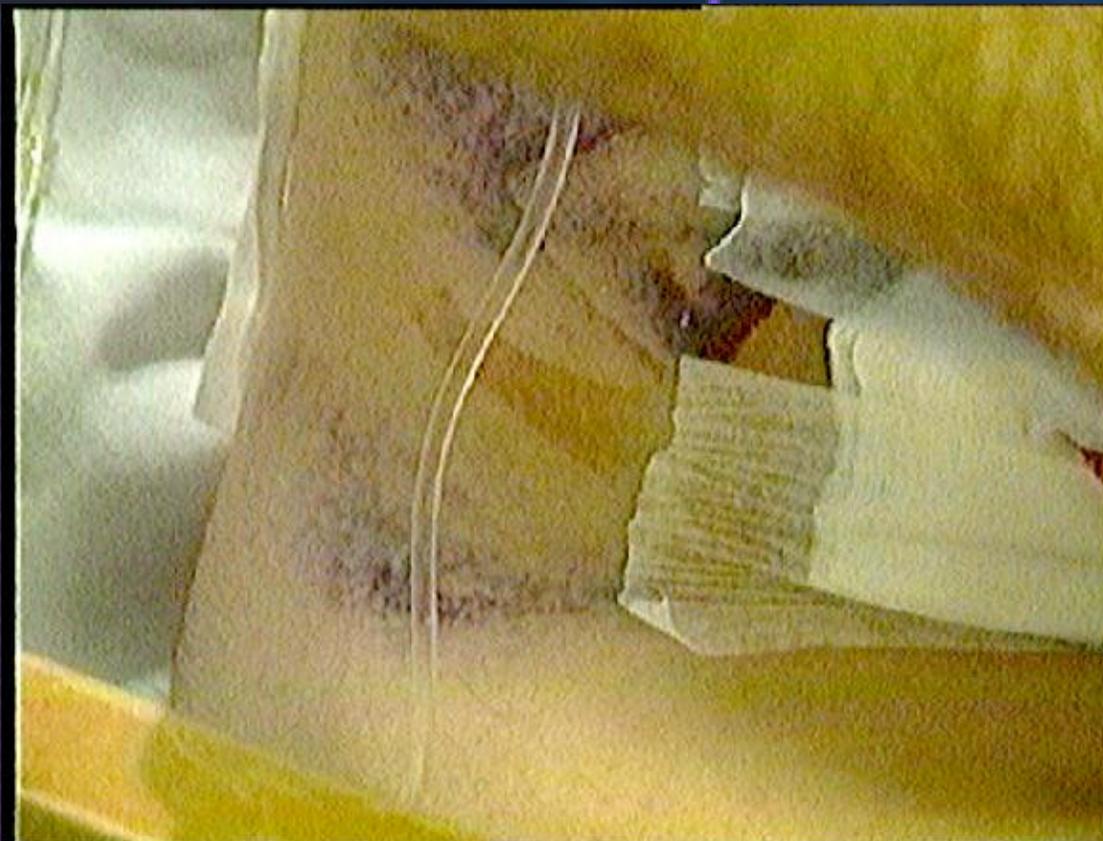
Case 94-003 Shoulder Belt Only Right Flank Bruises



dV=19 mph

PDOF- 1 O'clock

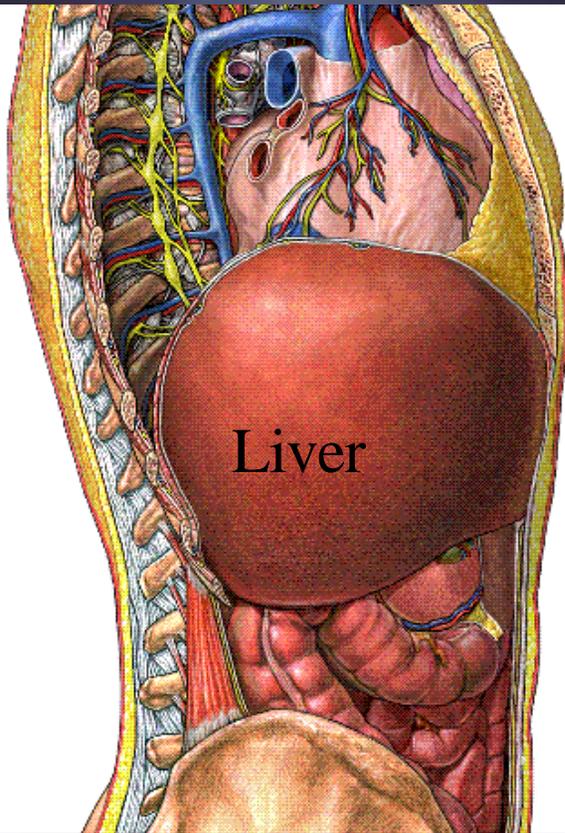
Liver Injury-
AIS-4



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Location of Liver and of Belt Marks



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Undamaged Human Liver

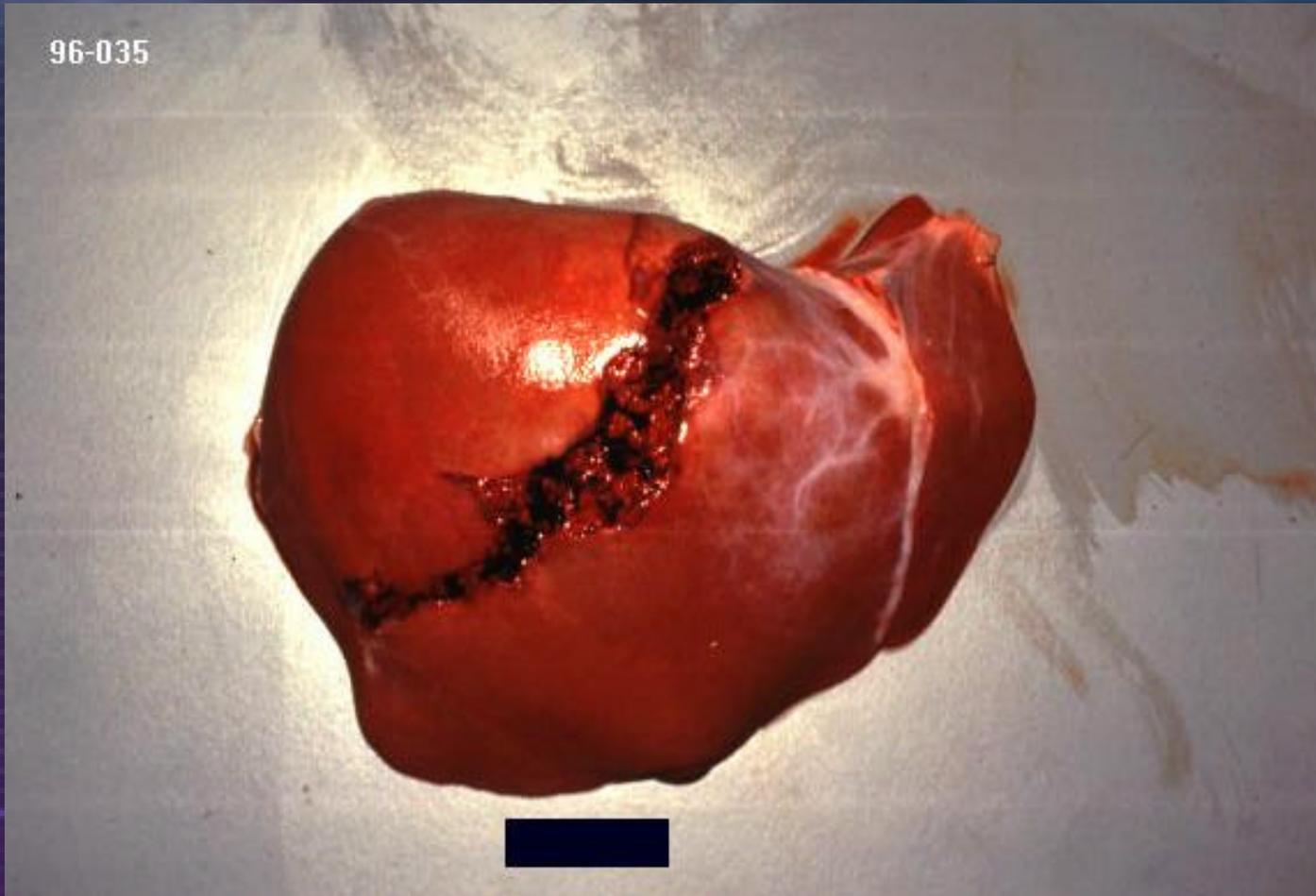




Liver Laceration Caused by Belt Loading



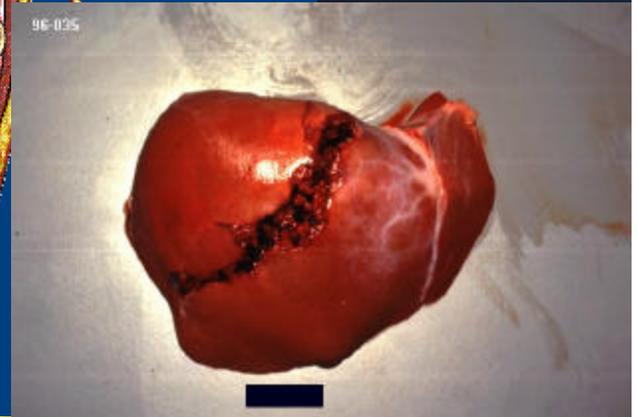
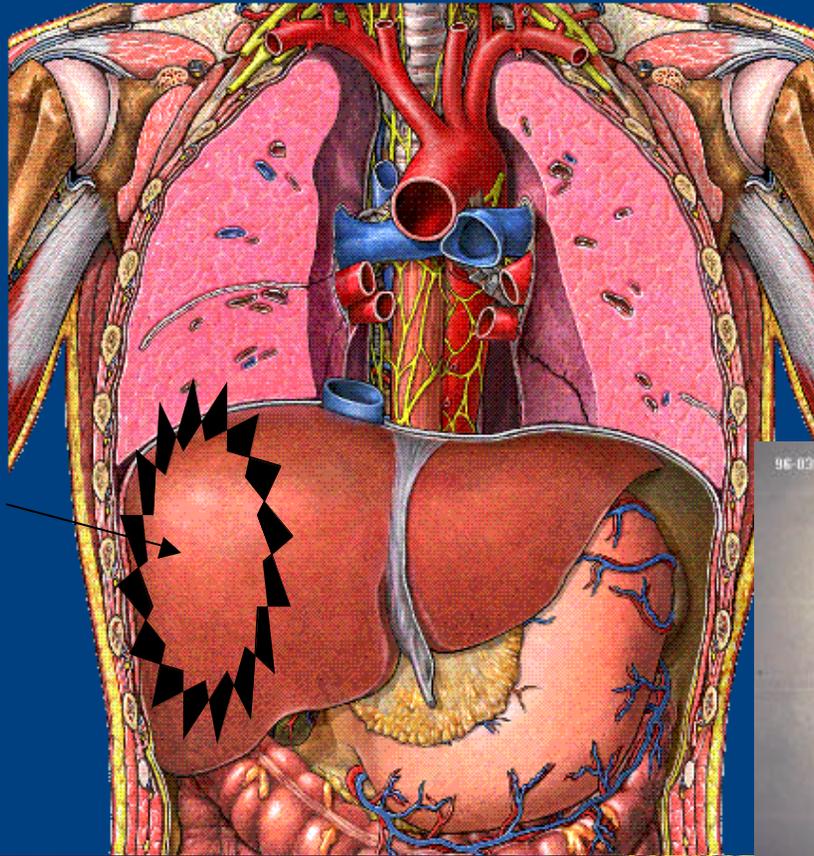
96-035



All Case to Follow Had Liver Injuries of Type Shown



Injury Location



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Belt Geometry Comparison



3-Pt Belt



2-Pt Belt
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Characteristics of Liver Injury Cases

- Driver in 2 - Point Belt
- Right Front Vehicle Damage (Low Delta-V)
- Liver Injury on Right Rear Lobe

16 Cases to Follow

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96-020



96-020 AIS-3 $dV=12$ mph

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97-049
Air Bag

AIS-5

$dV=12$ mph

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97-018

AIS-5

dV=15 mph

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96-041
Air Bag

AIS 3

$dV=16$ mph

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94-005
Air Bag

AIS-4

$dV=16$ mph

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93-013

AIS-4

$dV=17$ mph

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96-016

96-016

AIS-2

$dV=18$ mph

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94-003

AIS-4

$dV=19$ mph

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96-008

AIS-5 $dV=19$ mph

Fatal

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96-012

AIS -5 $dV=19$ mph

Fatal

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97-047

AIS-4

dV=19 mph

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92-029

AIS-2

$dV=20$ mph

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91-011

AIS-4

$dV=25$ mph

University of MIAMI



96-035

AIS-4

$dV=25$ mph

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94-008

AIS-4

$dV=26$ mph

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93-017

AIS-3

dV=27 mph

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Are 3-point Belts Vulnerable to Injury in Off-side Crashes?

Case Studies from WLRIC

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Driver and 3-Point Restraint

1 O'clock PDOF



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Vehicle Damage

- Case Vehicle: 1988 Chevrolet Corsica
- PDOF: 1 O'clock
- DeltaV: 20.6 mph
- Max Crush: 12.5"
- Type: Frontal Offset
Vehicle to Vehicle
- POV: 1989 International
School Bus

Case #95-012





Occupant Information

- Case Subject: 70 Year Old Female
64" 125 lbs.
- Position: Driver
- Restraint: Lap and Shoulder
No Air Bag
- Admitted
LOS: 11 Days

Case #95-012





Injuries

Belt Restraint

- Contusion, Heart AIS-3
- Contusion, Chest, Right AIS-1
- Abrasion, Neck, Anterior AIS-1

Toe Pan

- Fx Malleolus, Left Posterior AIS-3
- Fx Malleolus, Left Medial AIS-2
- Fx Fibula, Left AIS-2
- Fx Fibula, Right AIS-2
- Fx Malleolus, Right Medial AIS-2

Case #95-012





Complications

- Heart Contusion In 70 Year Old Female
- Multiple Lower Extremity Fractures
Compounds Rehabilitation For Elderly

Case #95-012

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Case Significance

- Restraint System Too Stiff For Elderly
Results In Heart Contusion
- Good Outcome For Elderly Driver
Length Of Stay 11 Days
- Off-side Frontal Crash

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Driver and 3-Point Restraint

1 O'clock PDOF



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Vehicle Damage

- Case Vehicle: 1990 Nissan Pathfinder
- PDOF: 1 O'clock
- DeltaV: 26 mph
- Max Crush: 23"
- Type: Frontal Offset
Vehicle to Vehicle
- POV:
1987 Toyota Camry

Case #98-017





Occupant Information

- Case Subject: 49 Year Old Female
64" 170 lbs.
- Position: Driver
- Restraint: Lap and Shoulder
No Air Bag
- Admitted
LOS: 8 Days

Case #98-017





Injuries



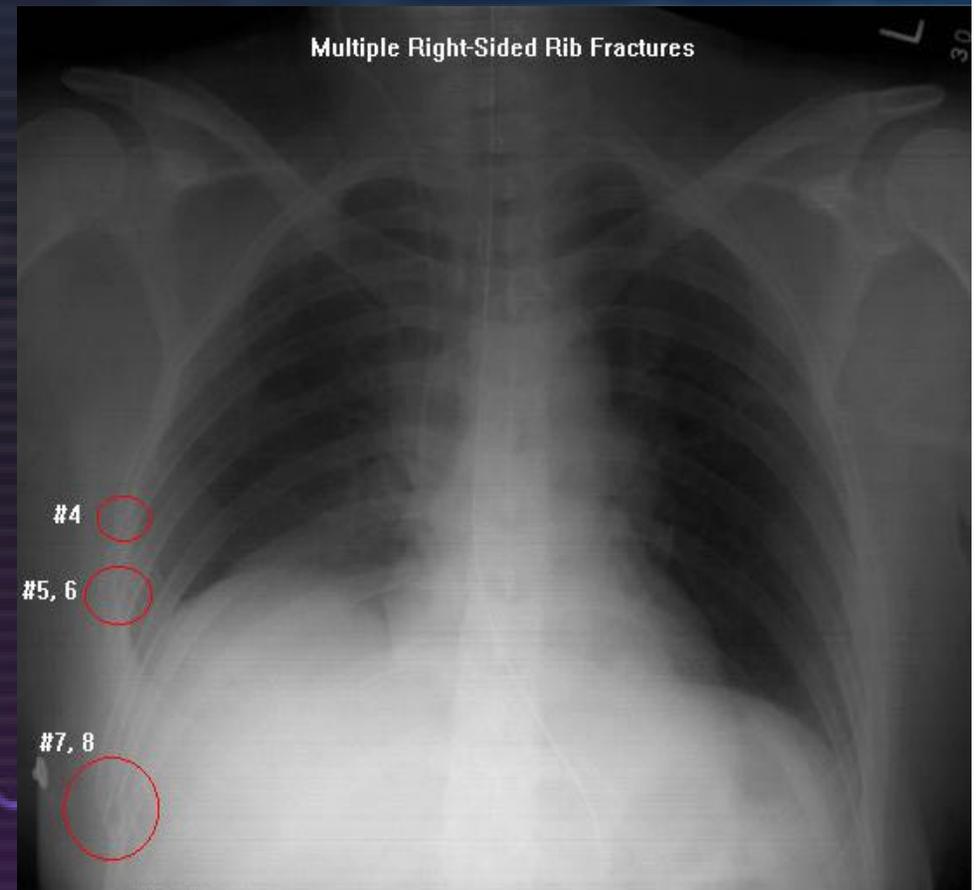
Belt Restraint

- Fx Ribs, Right AIS-3
- Avulsion, Omentum AIS-3
- Tear, Small Intestine AIS-2
- Abrasions, Multiple AIS-1
- Contusions, Multiple AIS-1

Steering Wheel Rim

- Contusions, Multiple AIS-1

Case #98-017





Complications

- Multiple Right Sided Rib Fractures
- Abdominal Injuries From Lap Belt Loading

Case #98-017

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Case Significance

- Incompatible Vehicle Impact
Case Vehicle Size Helped Driver In Severe Impact
- Restraint Geometry Unfavorable To Short, Obese Female
- Abdominal Injuries From Lap Belt Suggest It was Not Tight Over Iliac Crests
- Off-side Frontal Crash

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Driver and 3-Point Restraint

1 O'clock PDOF



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Vehicle Damage

- Case Vehicle: 1987 Buick Century
 - PDOF: 1 O'clock
 - DeltaV: 24 mph
 - Max Crush: 11"
 - Type: Frontal Offset
Vehicle To Vehicle
 - POV:
 - 1987 GMC Jimmy
- Case #98-046





Occupant Information

- Case Subject: 68 Year Old Female
59" 108 lbs.
- Position: Driver
- Restraint: Lap And Shoulder
No Air Bag
- Died In Resuscitation

Case #98-046





Injuries

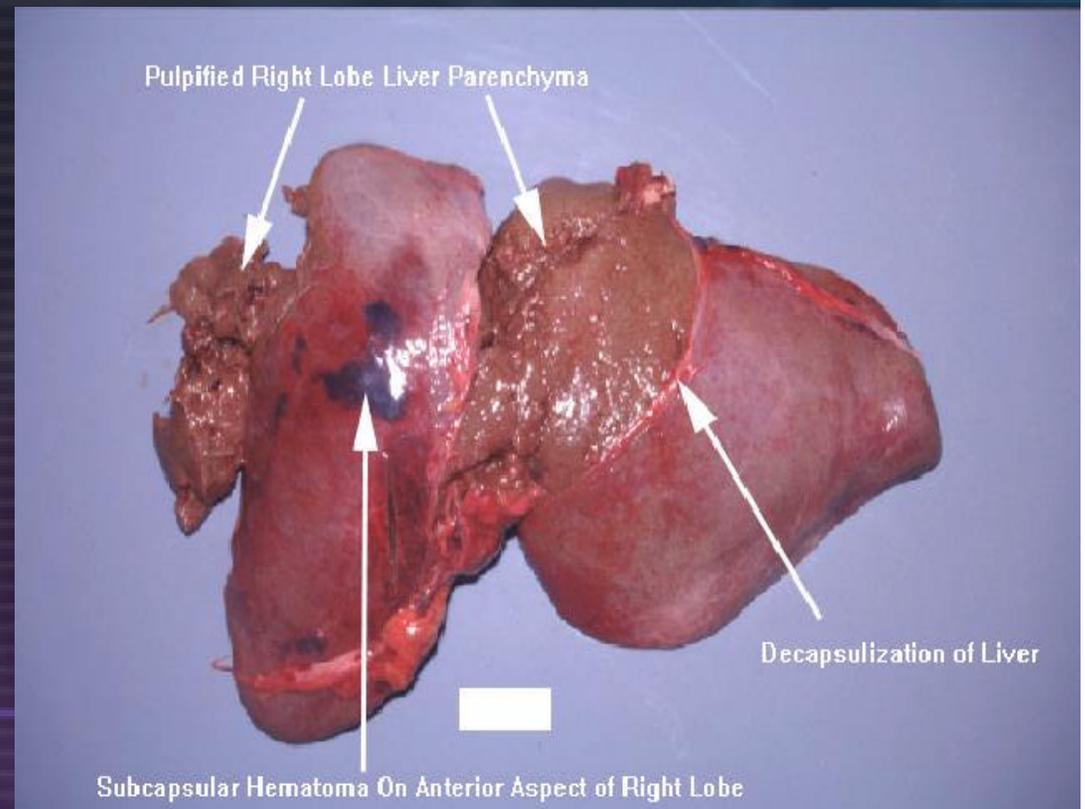
Belt Restraint

- Laceration, Liver AIS-5
- Laceration, Vena Cava AIS-4
- Fx Ribs, Right AIS-3
- Laceration, Lung Right AIS-3
- Compression Injury
Lumbar Spine AIS-3
- Fx Lumbar Vertebra AIS-2

Steering Wheel Rim

- Fx Ribs, Left AIS-2
- Laceration, Lung AIS-3

Case #98-046





Complications

- Severe Chest Trauma In Elderly Female
- Severe Liver Laceration From Belt Loading
Liver Pulpified In Multiple Lobes

Case #98-046

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Case Significance

- Restraint Geometry Unfavorable To Short Female
- Multiple Impact Crash Produced Increase Belt Load On Driver
- Moderate Impact With Fatal Results To Elderly Driver
- Off-side Frontal Crash



RF Passenger and 3-Point Restraint

11 O'clock PDOF

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Vehicle Damage

- Case Vehicle: 1989 Oldsmobile 98
- PDOF: 11 O'clock
- DeltaV: 25 mph
- Max Crush: 33"
- Type: Frontal Offset
Barrier Impact

Case #98-011





Occupant Information

- Case Subject: 70 Year Old Female
62" 130 lbs.
- Position: Right Front Passenger
- Restraint: Lap And Shoulder
No Air Bag
- Admitted
LOS: 9 Days

Case #98-011





Injuries



Belt Restraint

- Fx Thyroid Cartilage AIS-2
- Fx Arytenoid Cartilage AIS-2
- Abrasions/Contusions, Multiple AIS-1

Toe Pan

- Fx Malleolus, Media, I Left AIS-2
- Fx Fibula, Distal, Left AIS-2

Case #98-011





Complications

- Multiple Left Lower Extremity Injuries
- Neck Injuries From Belt Loading

Case #98-011

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Case Significance

- Restraint Geometry Unfavorable To Short Female
Resulted In Neck Injury
- Barrier Impact Crash Produced Clockwise Rotation
Increased Belt Load On Right Front Passenger
- Moderate Speed Impact With Favorable Results For
Passenger
Discharged In 9 Days
- Off-side Frontal Crash

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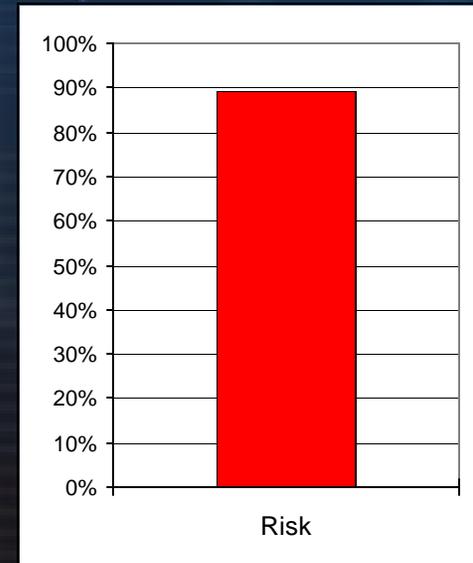
Conclusions

CIREN Data Needs to be Used to Improve Injury Prediction and Treatment

Crash Information Could Improve Triage and Outcome

Risk

89%



SUSPECT LIVER INJURY

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