Injury Severity in Side Impact Mismatch

San Diego CIREN Team

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Today's Presentation

- Definition of the Topic
- Car Driver Injuries in the NASS/CDS Data
- Case Studies

- R. M. Van Auken, Dynamic Research, Inc.
- Steve Erwin, CIREN – San Diego

Vehicle Compatibility

Defined as a combination of it's:

- Crashworthiness (ability to protect occupants within the vehicle)
- Aggressivity (potential to harm occupants within the collision partner)

Crashworthiness

- Evaluated through crash tests
- Focus on minimizing injuries in the subject vehicle
- Minimizing injuries in one vehicle potentially accentuate injuries in the collision partner

Aggressivity

Comparison of Cars to LTV's

- Mass – LTV's are 900 pounds heavier than cars on average
- Stiffness – LTV's frequently use stiff frame rail design, as opposed to unibody design favored by cars
- Geometry – LTV's ride higher than cars

Gabler, Hampton C. and Hollowell, William T ., "The Aggressivity of Light Trucks and Vans in Traffic Crashes," SAE Paper No. 980908, Detroit, March 1998

Vehicle Aggressivity By Category In Side Impacts

- **Full size vans - 2.47**
- **Full-size Pickups - 2.31**
- **Sport-utility Vehicles - 1.91**
- **Small Pickups - 1.53**
- **Minivans - 1.48**
- **Large Cars - 1.15**
- **Midsize Cars - .70**
- **Compact Cars - .58**
- **Subcompact Cars - .45**

Driver fatalities in the Struck Vehicle per 1000 Police-Reported Crashes

Gabler, Hampton C. and Hollowell, William T ., “The Aggressivity of Light Trucks and Vans in Traffic Crashes,” SAE Paper No. 980908, Detroit, March 1998

The Problem

- LTV's currently account for over one-third of registered U.S. passenger vehicles (and 48 % of new sales. Polk 1980-1999)
- Collisions between cars and LTV's account for over one half of all fatalities in light vehicle to vehicle crashes
- In these crashes, over 80% of the resulting fatalities are to occupants of the passenger vehicles

Jeffrey W. Rungee, M.D., Committee On Commerce, Science And Transportation, United States Senate, February 26, 2003

Gabler, Hampton C. and Hollowell, William T ., "The Aggressivity of Light Trucks and Vans in Traffic Crashes," SAE Paper No. 980908, Detroit, March 1998

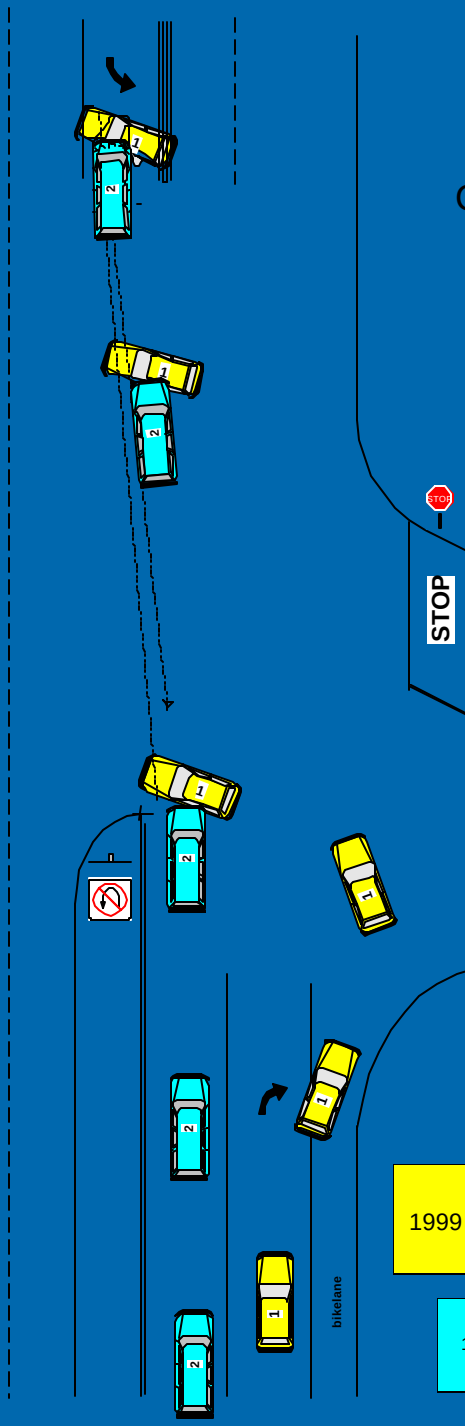
Ratio Of Fatally Injured Drivers in LTV-to-Car Left Side Impacts

The front of:	The driver side of:	Fatalities:
Pickup –	to - Car	= 1:26
SUV –	to - Car	= 1:16
Van –	to - Car	= 1:13

- Car-to-Car = 1:6.6
- Car-to-LTV = 1:1

William T. Hollowell, Stephen M. Summers, Aloke Prasad, ”NHTSA’s Research Program For Vehicle Aggressivity And Fleet Compatibility” , June 2001

- ✓ 1999 Volkswagen New Beetle vs 1994 Ford Explorer
- ✓ 8:00 PDOF @ 260 degrees
- ✓ DV *44 kmph (27 mph)



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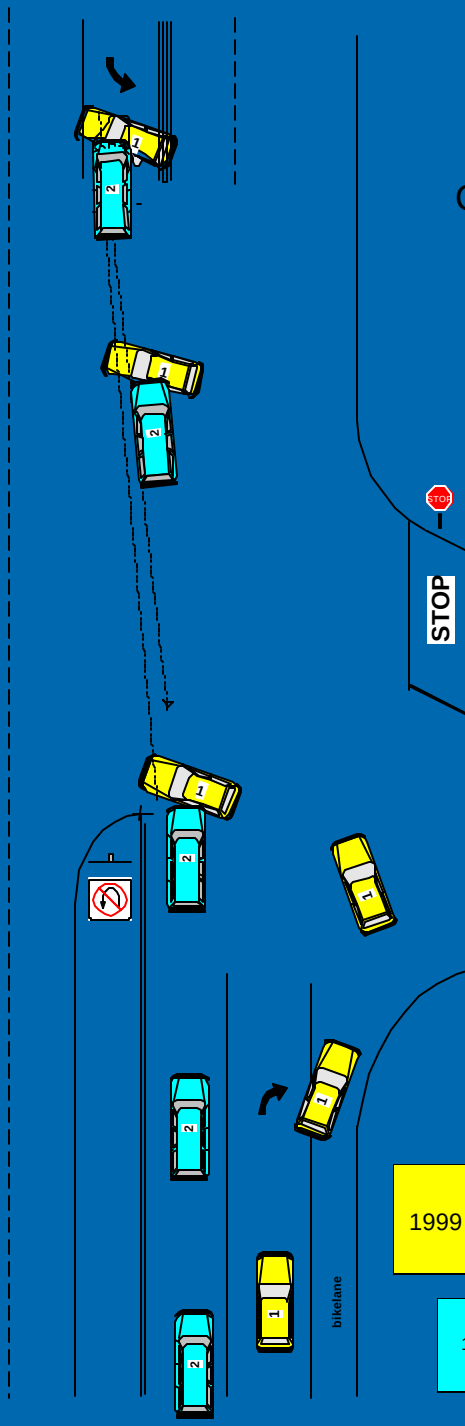
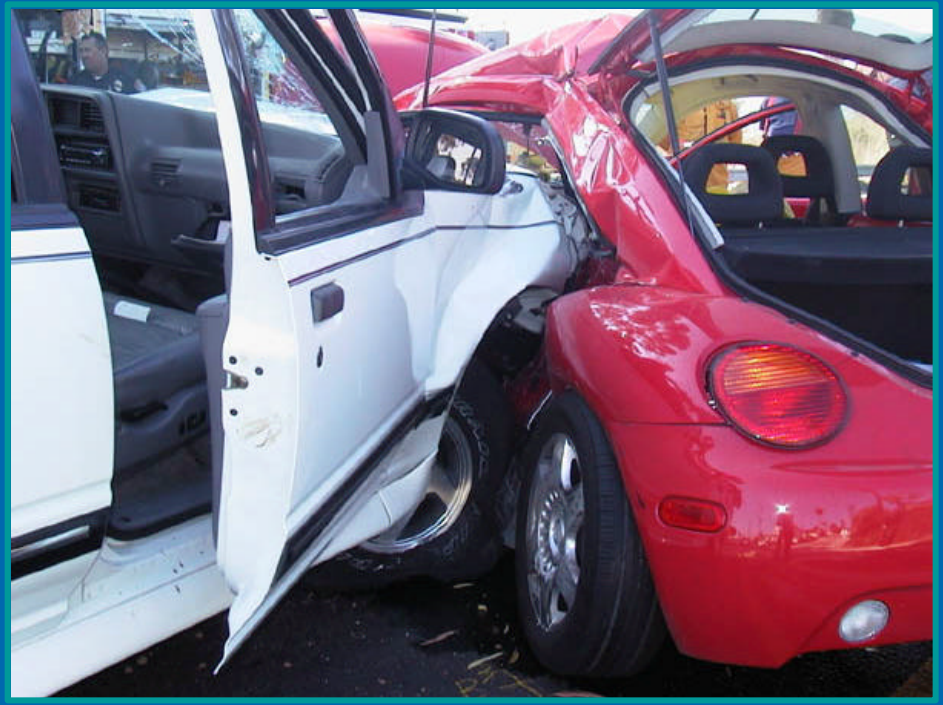
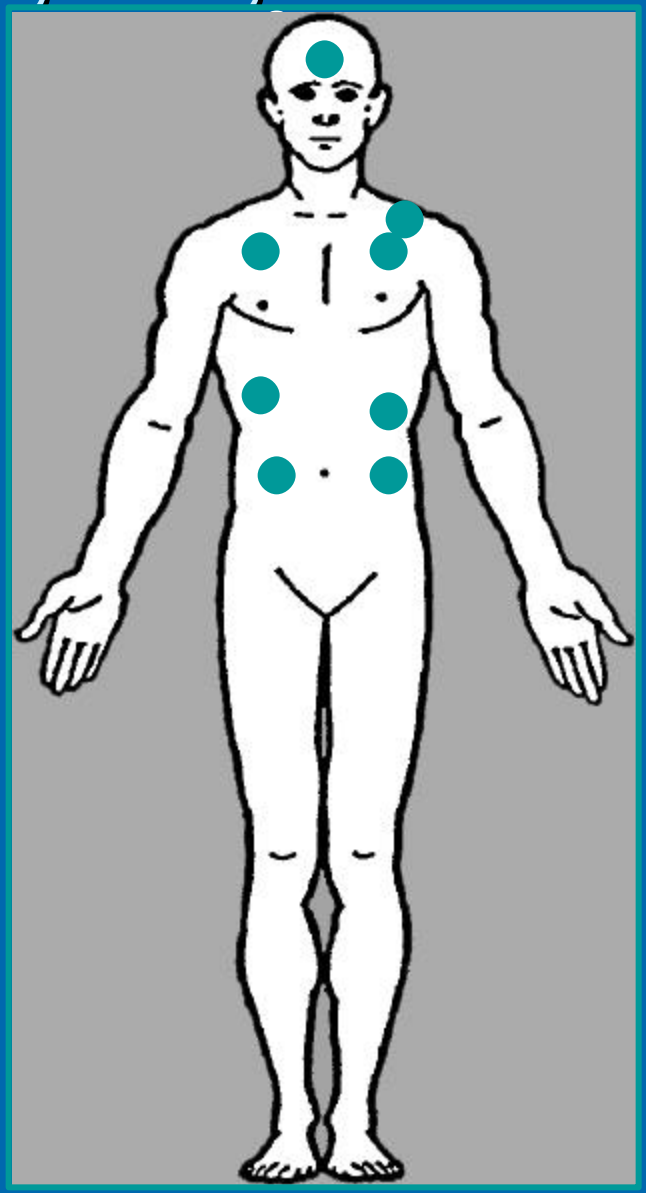




Occupant
33 yr. old female driver, 5’3”, 132 lbs

- Basilar skull fracture
- Laceration of midbrain Brainstem detached above the pons
- Basilar artery tear
- Scattered SAH
- Left pulmonary laceration
- Bilateral rib fractures
- Liver laceration
- Splenic laceration
- Left clavicle fracture
- Bilateral pubic rami fractures
- Right sacroiliac fracture



Car Driver Injuries in Near Side Impact Collisions with LTVs in the NASS/CDS Data

R. M. Van Auken, J. W. Zellner
Dynamic Research, Inc.

3 April 2003

NASS/CDS Data Analysis

- Objectives
- Technical approach
  - Assumptions
  - CDS data query criteria
- Results

Objectives

- Assess the distributions of struck car driver injuries in near side impacts in NASS/CDS collisions:
  - Striking vehicle: Light truck or van
    - Size: small, large
  - Struck vehicle: Passenger car
    - Size: small, large
    - Side impact protection
      - Dynamic FMVSS 214
        (assumed to begin for all cars in 1995 for this analysis)
      - Side-impact airbag

Assumptions

- NASS/CDS case sampling
  - Passenger cars are sampled from tow-away crashes with equal probability
  - Light trucks and vans are sampled from tow-away crashes with equal probability

NASS/CDS Data Query Criteria

- Two vehicle crashes with:
  - Left side struck passenger car
  - Striking LTV
  - Driver and exterior vehicle record for each vehicle
- Calendar years: 1993-2001
  - 1993 - first year for AIS 90 coding
  - 2001 - most recent data available

Left Side Struck Car Criteria

- Deformation location: Left
- NASS body types: 1-9 (automobiles)
- Model years: 1985-2001
- Driver age: 16-55 years
- Size categories:
  - Small: wheelbase < 265 cm* (e.g., subcompact, compact)
  - Large: wheelbase ≥ 265 cm* (e.g., intermediate, large)

*based on NASS definitions of vehicle class

Striking
LTV Criteria

- Deformation location: Front
- NASS body types: 14-39 (utilities, vans, pickups)
- Model years: 1985-2001
- Driver age: all
- Size categories:*
  - Small: compact utility, pickup, or minivan
  - Large: large utility, pickup, or van

* based on the NASS body type

NASS/CDS Data Analysis Results

NASS/CDS Vehicle Involvement

Striking Vehicle	Number of Struck Vehicles		
	Small Car	Large Car	Total Car
Small LTV	143	88	231
Large LTV	57	50	107
Total LTV	200	138	338

Sources and Notes:
1993-2001 NASS/CDS data
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size

- Specific vehicle size combinations (eg., large LTV-small car crash) are not significantly under- or over-represented in these data
  - $X^2 = 1.9$ (with Yates adjustment)
  - Probability value = 0.17
  - Consistent with assumptions

Struck Car Driver Injury Distributions

Struck Car Driver MAIS	Number of NASS/CDS Cases								
	Head	Face	Neck	Thorax	Abdom	Spine	Upper Ext.	Lower Ext.	Any Region
0 - No Injury	187	207	328	209	258	263	167	154	38
1 - Minor	65	129	18	51	30	66	130	100	130
2 - Moderate	53	10	0	7	27	14	38	44	56
3 - Serious	10	0	0	42	20	1	11	48	64
4 - Severe	15	0	0	27	7	1	0	0	30
5 - Critical	12	0	0	5	4	0	0	0	18
6 - Maximum	4	0	0	5	0	1	0	0	10
Total	346	346	346	346	346	346	346	346	346

Sources and Notes:
1993-2001 NASS/CDS data
1985-2001 Model year vehicles

- Head and thorax have more severe injury potential

Note: more severe and fatal injuries may be over-represented in the unweighted NASS/CDS case counts due to the stratified NASS/CDS crash sampling criteria

Head Injury Severity vs Striking LTV Size

Struck Car Driver Head MAIS	Number of Striking Vehicles		
	Small LTV	Large LTV	Total LTV
0 - No Injury	136	49	185
1 - Minor	42	22	64
2 - Moderate	30	22	52
3 - Serious	8	1	9
4 - Severe	6	8	14
5 - Critical	7	4	11
6 - Maximum	2	1	3
Total	231	107	338

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size

- MAIS≥2 head injuries associated with "large striking LTVs" are over-represented in these data
  - $X^2=3.8$
  - P=0.05

Head Injury Severity vs Striking LTV Size

Struck Car Driver Head MAIS	Number of Striking Vehicles		
	Small LTV	Large LTV	Total LTV
0 - No Injury	178	71	249
1 - Minor			
2 - Moderate	53	36	89
3 - Serious			
4 - Severe			
5 - Critical			
6 - Maximum			
Total	231	107	338

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size
Shading indicates over represented factor at the 5% level of significance

- Large striking LTVs are associated with:
  - 32% of the striking LTV cases
  - 40% of the striking LTV cases with struck car driver MAIS≥2 head injuries

Head Injury Severity vs Struck Car Size

Struck Car Driver Head MAIS	Number of Struck Vehicles		
	Small Cars	Large Cars	Total Cars
0 - No Injury	106	81	187
1 - Minor	38	27	65
2 - Moderate	37	16	53
3 - Serious	7	3	10
4 - Severe	9	6	15
5 - Critical	7	5	12
6 - Maximum	2	2	4
Total	206	140	346

Sources and Notes:
1993-2001 NASS/CDS data (towaway crashes)
1985-2001 Model year vehicles
Shading indicates over represented factor at the 5% level of significance

- Head injuries in large or small cars are not over- or under-represented in these data

Head Injury Severity vs Struck Car Model Year

Struck Car Driver Head MAIS	Number of Struck Vehicles		
	'85-'94 Cars	'95-'01 Cars	Total Cars
0 - No Injury	114	73	187
1 - Minor	48	17	65
2 - Moderate	39	14	53
3 - Serious	7	3	10
4 - Severe	12	3	15
5 - Critical	11	1	12
6 - Maximum	3	1	4
Total	234	112	346

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles

- MAIS≥2 head injuries in 1985-94 (pre Dynamic FMVSS 214) struck cars are over-represented in these data
  - $X^2=4.2$
  - P=0.04

Head Injury Severity vs Struck Car Model Year

Struck Car Driver Head MAIS	Number of Struck Vehicles		
	'85-'94 Cars	'95-'01 Cars	Total Cars
0 - No Injury	162	90	252
1 - Minor			
2 - Moderate	72	22	94
3 - Serious			
4 - Severe			
5 - Critical			
6 - Maximum			
Total	234	112	346

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Shading indicates over represented factor at the 5% level of significance

- 1985-94 model year cars are associated with:
  - 68% of the struck car cases
  - 77% of the struck car cases with struck car driver MAIS≥2 head injuries

Injury Severity vs Side Impact Airbag

- Only one struck car had a side-impact airbag
- Insufficient data to discern injury trends

Thorax Injury Severity vs Striking LTV Size

Struck Car Driver Thorax MAIS	Number of Striking Vehicles		
	Small LTV	Large LTV	Total LTV
0 - No Injury	144	62	206
1 - Minor	31	18	49
2 - Moderate	6	1	7
3 - Serious	33	8	41
4 - Severe	11	15	26
5 - Critical	3	2	5
6 - Maximum	3	1	4
Total	231	107	338

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size

- MAIS≥4 thorax injuries associated with large striking LTVs are over-represented in these data
  - $X^2=6.1$
  - $P=0.01$

Thorax Injury Severity vs Striking LTV Size

Struck Car Driver Thorax MAIS	Number of Striking Vehicles		
	Small LTV	Large LTV	Total LTV
0 - No Injury	214	89	303
1 - Minor			
2 - Moderate			
3 - Serious			
4 - Severe	17	18	35
5 - Critical			
6 - Maximum			
Total	231	107	338

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size
Shading indicates over represented factor at the 5% level of significance

- Large striking LTVs are associated with:
  - 32% of the cases with striking LTV
  - 51% of the cases with striking LTV and struck car driver MAIS≥4 thorax injuries

Overall Maximum Injury Severity vs Striking LTV Size

Struck Car Driver MAIS (all regions)	Number of Striking Vehicles		
	Small LTV	Large LTV	Total LTV
0 - No Injury	30	8	38
1 - Minor	90	39	129
2 - Moderate	36	18	54
3 - Serious	46	17	63
4 - Severe	15	14	29
5 - Critical	9	8	17
6 - Maximum	5	3	8
Total	231	107	338

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size

- MAIS≥4 injuries due to striking by large LTVs are over-represented in these data
  - $X^2=5.6$
  - P=0.02

Overall Maximum Injury Severity vs Striking LTV Size

Struck Car Driver MAIS (all regions)	Number of Striking Vehicles		
	Small LTV	Large LTV	Total LTV
0 - No Injury	202	82	284
1 - Minor			
2 - Moderate			
3 - Serious			
4 - Severe	29	25	54
5 - Critical			
6 - Maximum			
Total	231	107	338

Sources and Notes:
1993-2001 NASS/CDS data (tow away crashes)
1985-2001 Model year vehicles
Table does not include 8 cases with unknown LTV size
Shading indicates over represented factor at the 5% level of significance

- Large striking LTVs are associated with:
  - 32% of the cases with striking LTV
  - 46% of the cases with striking LTV and struck car driver MAIS≥4 injuries

Summary of NASS/CDS Data Analysis Results

- Examined effects of:
  - Striking LTV
    - Size: Large vs small
  - Left Struck Car
    - Size: Large vs small
    - Side impact protection: 1985-94 vs 1995-01 model year (1995-01 assumed to meet Dynamic FMVSS 214 requirements)

Summary of NASS/CDS Data Analysis Results (contd)

- Results:
  - Striking LTV size
    - Large LTVs are associated with a greater risk of the following struck car driver injuries in near side collisions:
      - Head MAIS≥2
      - Thorax MAIS≥4
      - Upper Extremity MAIS≥1
      - Overall MAIS≥4
    - No statistically significant effects on injuries to other body regions were observed in these data

Summary of NASS/CDS Data Analysis Results (contd)

- Results:
  - Struck car size
    - No statistically significant effects on struck car driver injuries were observed in these data
  - Struck car side impact protection
    - Struck car drivers of 1985-94 model year cars (pre Dynamic FMVSS 214) have increased risk of head MAIS≥2 injury in near side collisions
    - No statistically significant effects on injuries to other body regions were observed in these data

CIREN Case Studies

Steve Erwin, Sharon Pacyna
San Diego CIREN
3 April 2003

San Diego Case Studies

- Side impact
- Subject vehicles as passenger cars
- Striking vehicle as LTV

Bullet Vehicle:

- ✓ 3 cases of light trucks
- ✓ 2 cases of vans
- ✓ 2 more cases of SUV

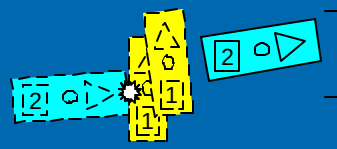
- ✓ 1997 Honda Accord vs 1979 GMC “pick up”
- ✓ 9:00 PDOF @ 280 degrees
- ✓ 20 kmph 13 mph

N

V1 - 1997 Honda Accord

V2 - 1979 GMC Pickup

- ✓ 1997 Honda Accord vs 1979 GMC “pick up”
- ✓ 9:00 PDOF @ 280 degrees
- ✓ 20 kmph 13 mph

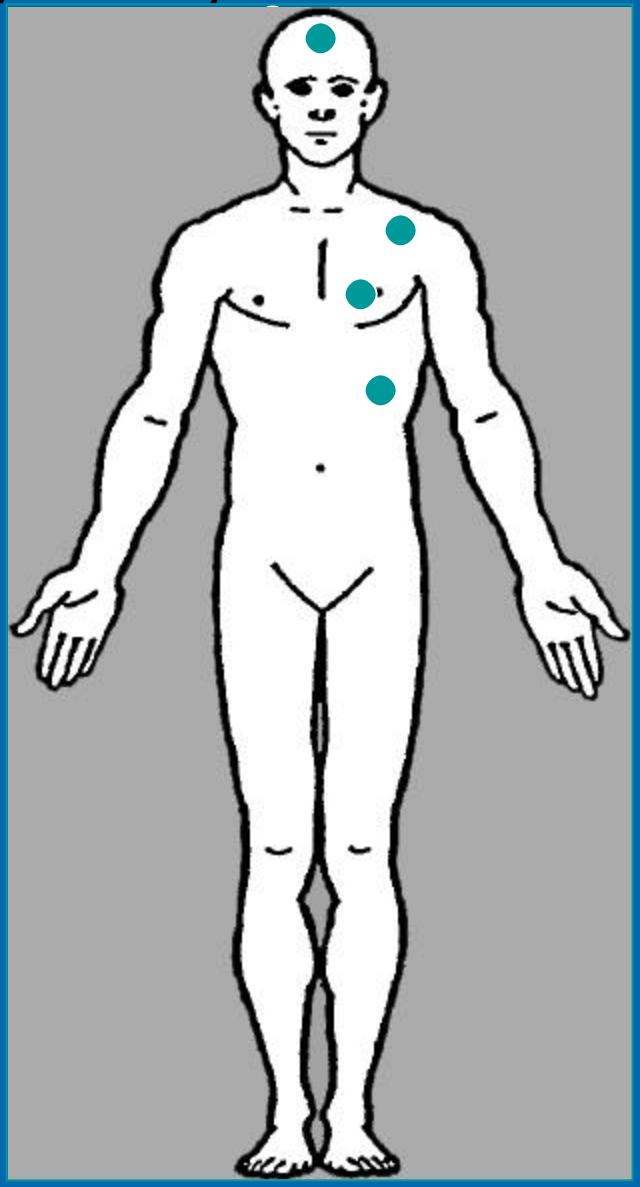


V1 - 1997 Honda Accord

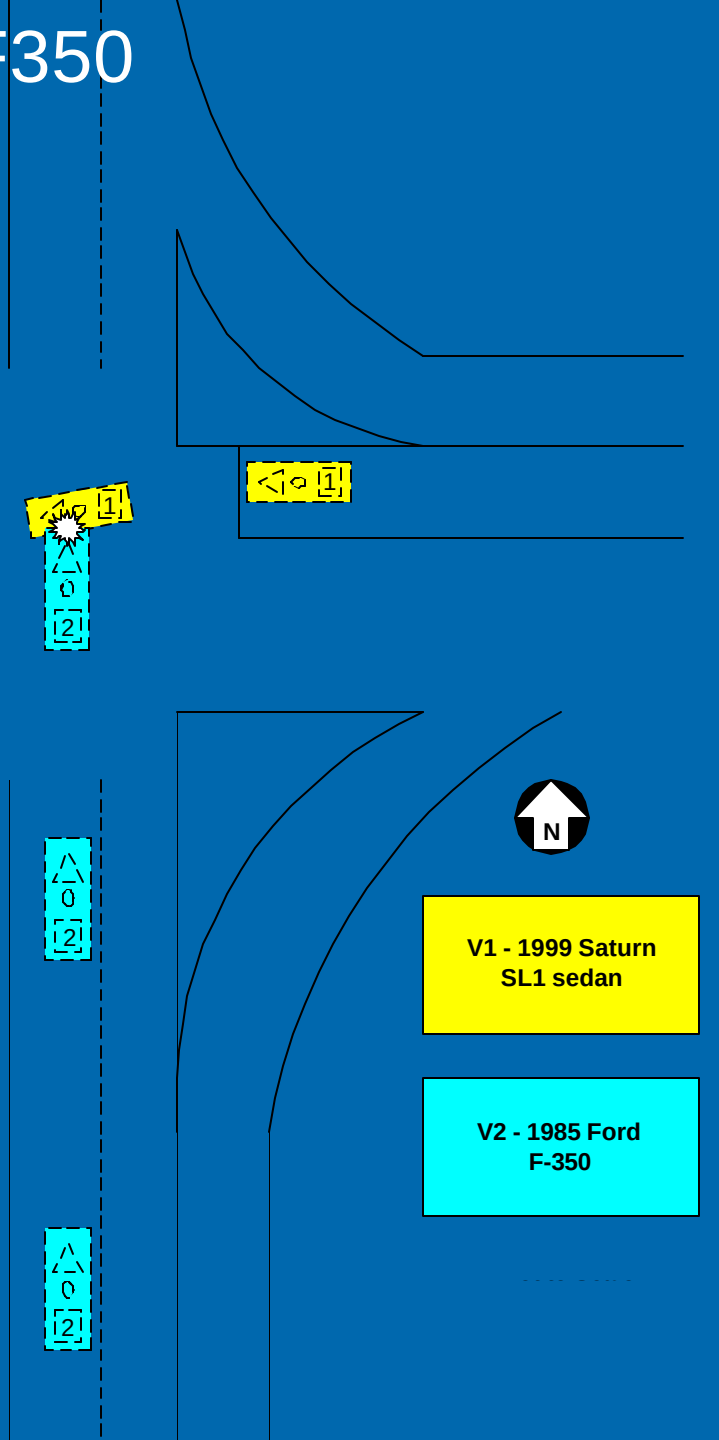
V2 - 1979 GMC Pickup

Occupant
53 yr. old male driver, 5’7”, 185 lbs

- **Concussion**
- **Left pulmonary contusion**
- **Left rib fractures**
- **Left glenohumeral dislocation**
- **Left scapula** fracture



- ✓ 1999 Saturn SL1 vs 1985 Ford F350
- ✓ 9:00 PDOF @ 280 degrees
- ✓ DV 42 kmph* (26 mph)



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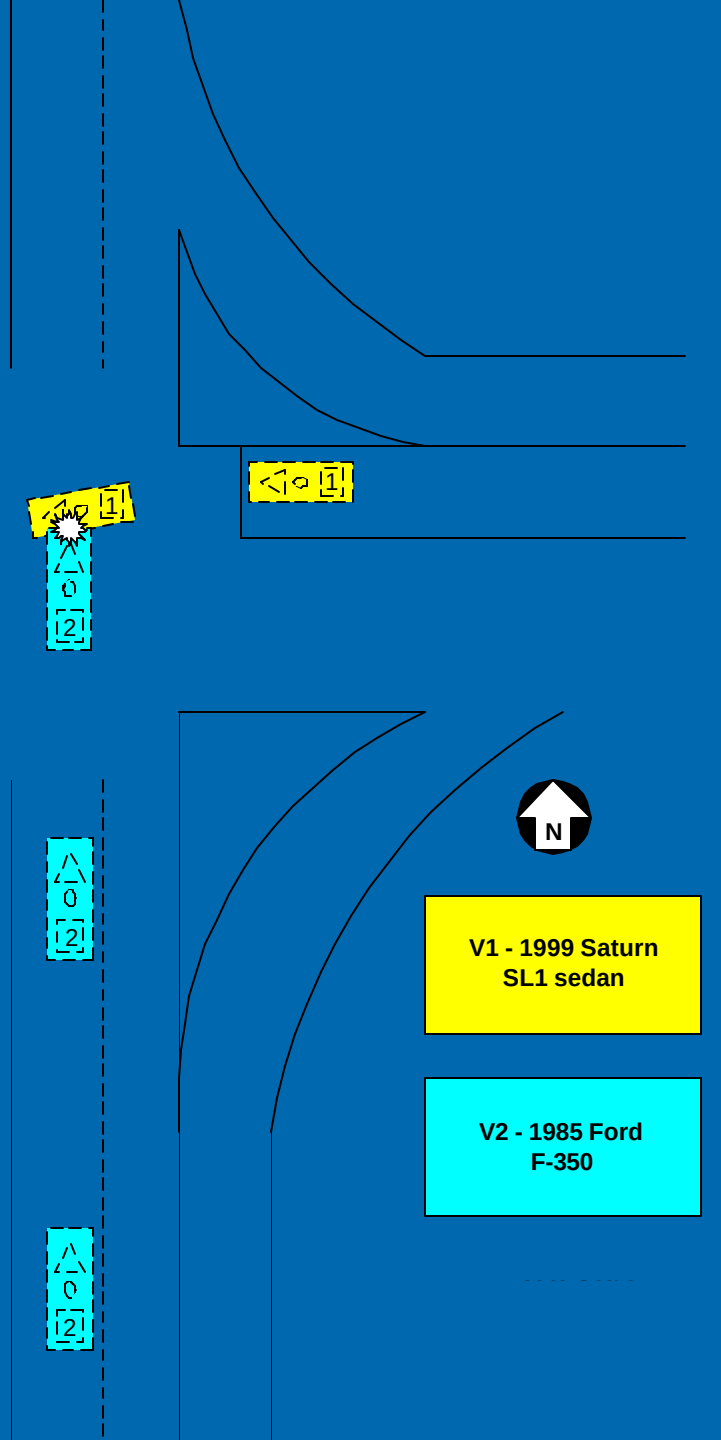
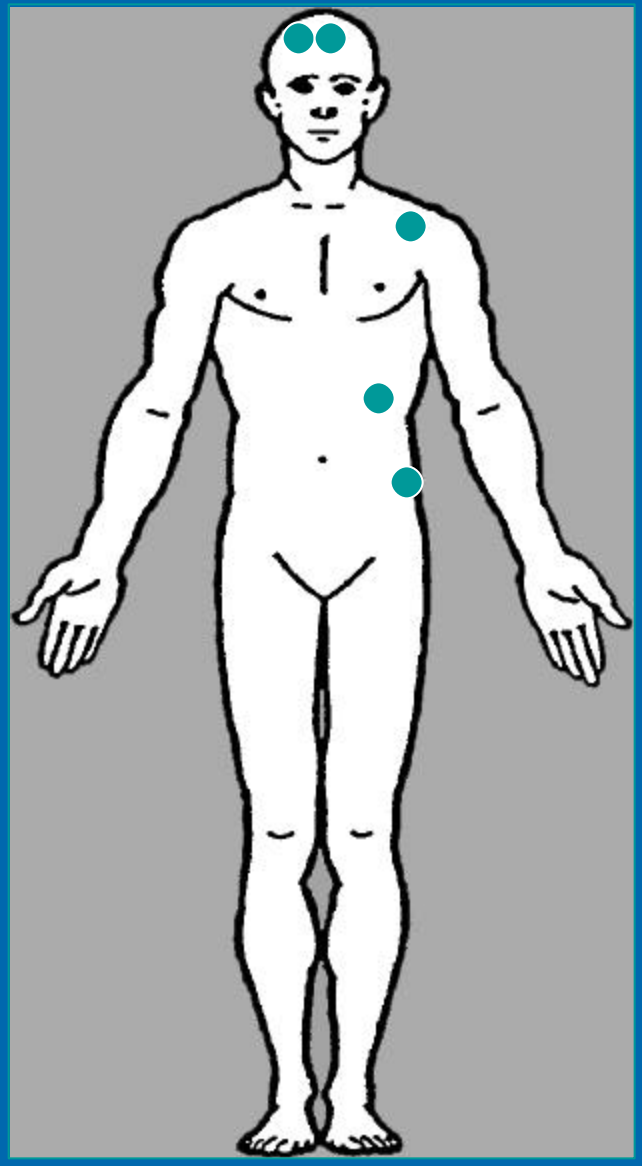
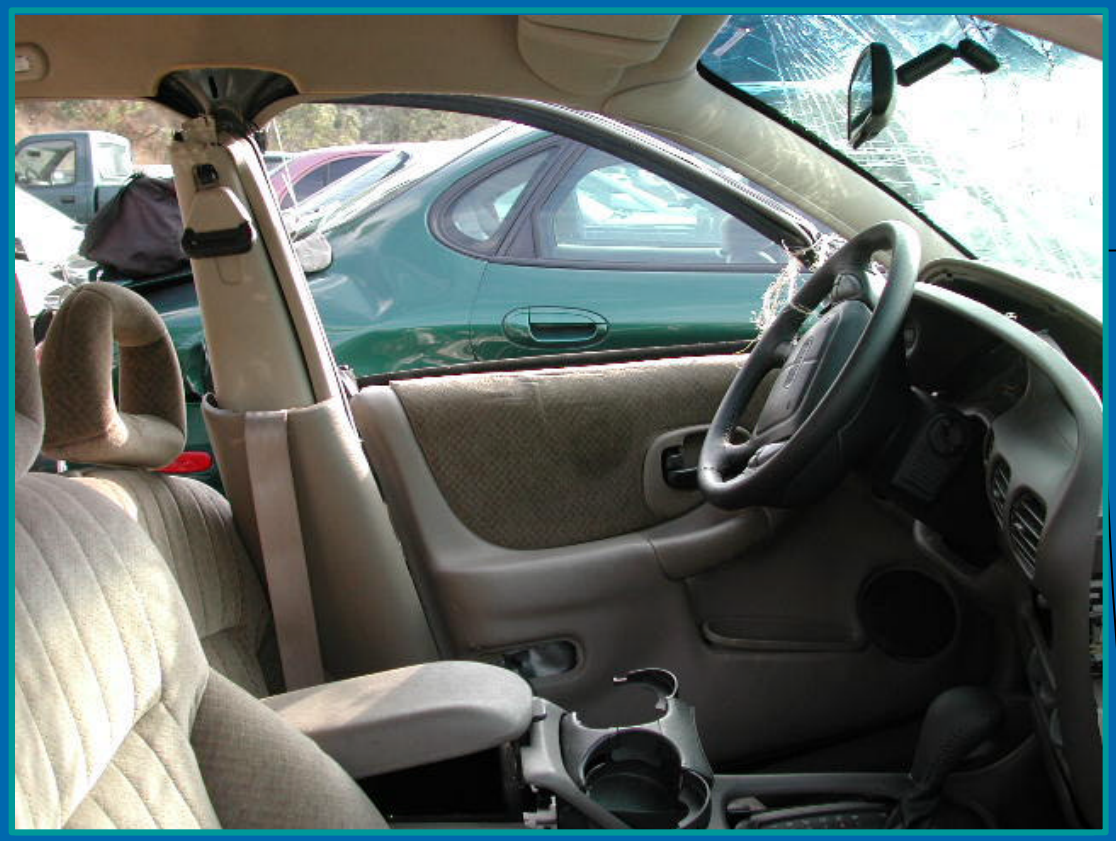


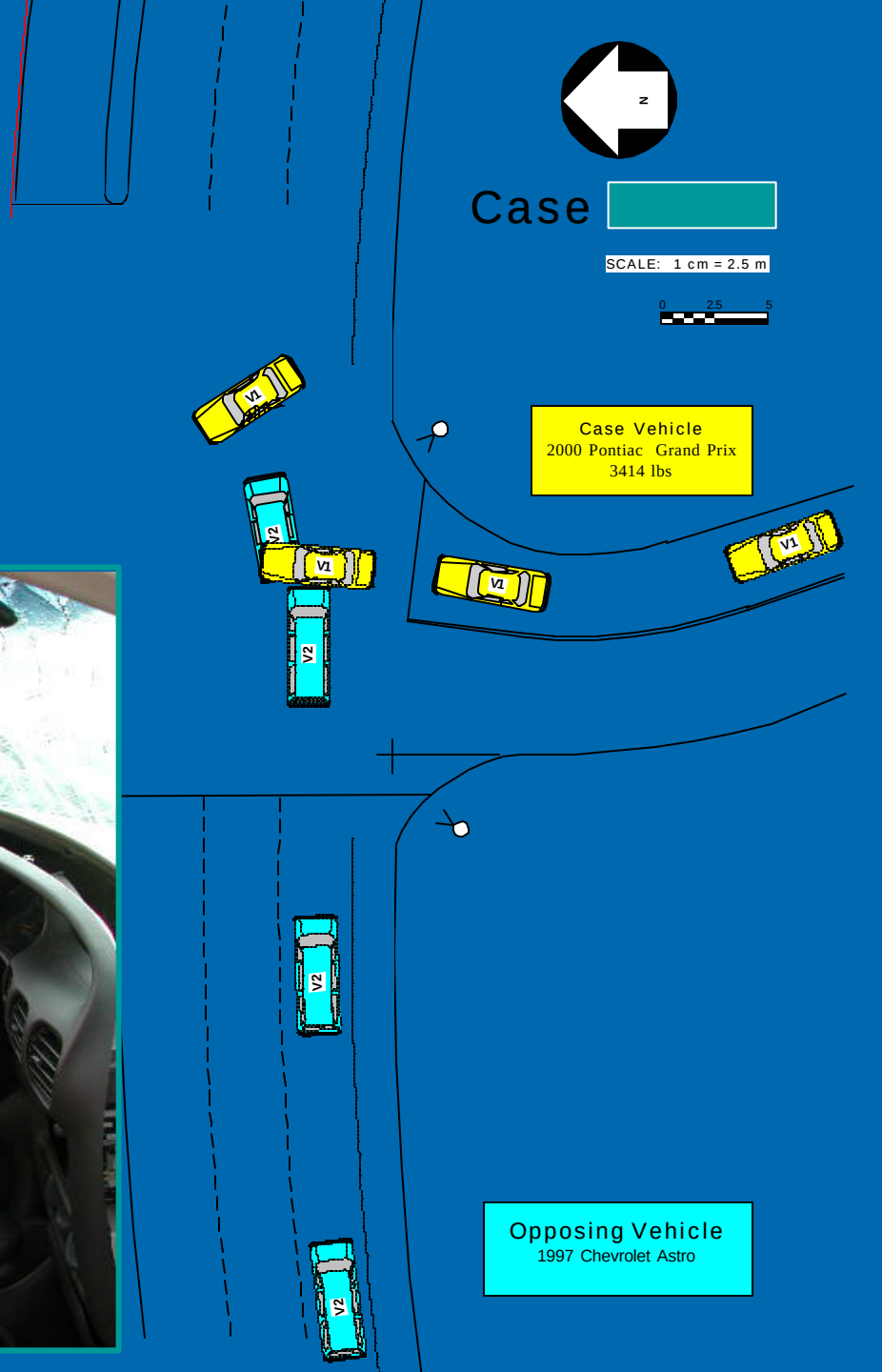
Occupant
18 yr. old female driver, 5’7”, 125 lbs

- **Basilar skull fracture**
- **Right frontal hematoma**
- **Ruptured spleen**
- **Left scapula fracture**
- **Left ischial ramus fracture extending into anterior acetabulum**
- **Left sacral fracture**
- **Left symphysis pubis fracture**



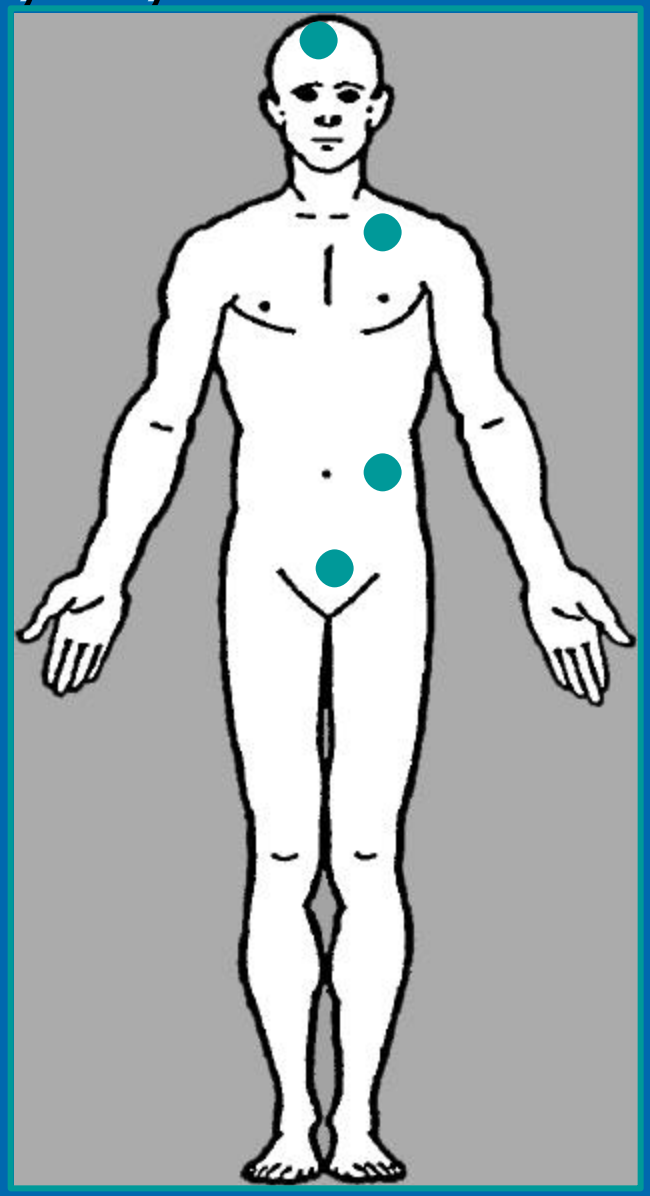
- ✓ 2000 Pontiac Grand Prix vs 1997 Chevrolet Astro van
- ✓ 10:00 PDOF @ 290
- ✓ DV 24 kmph (15 mph)



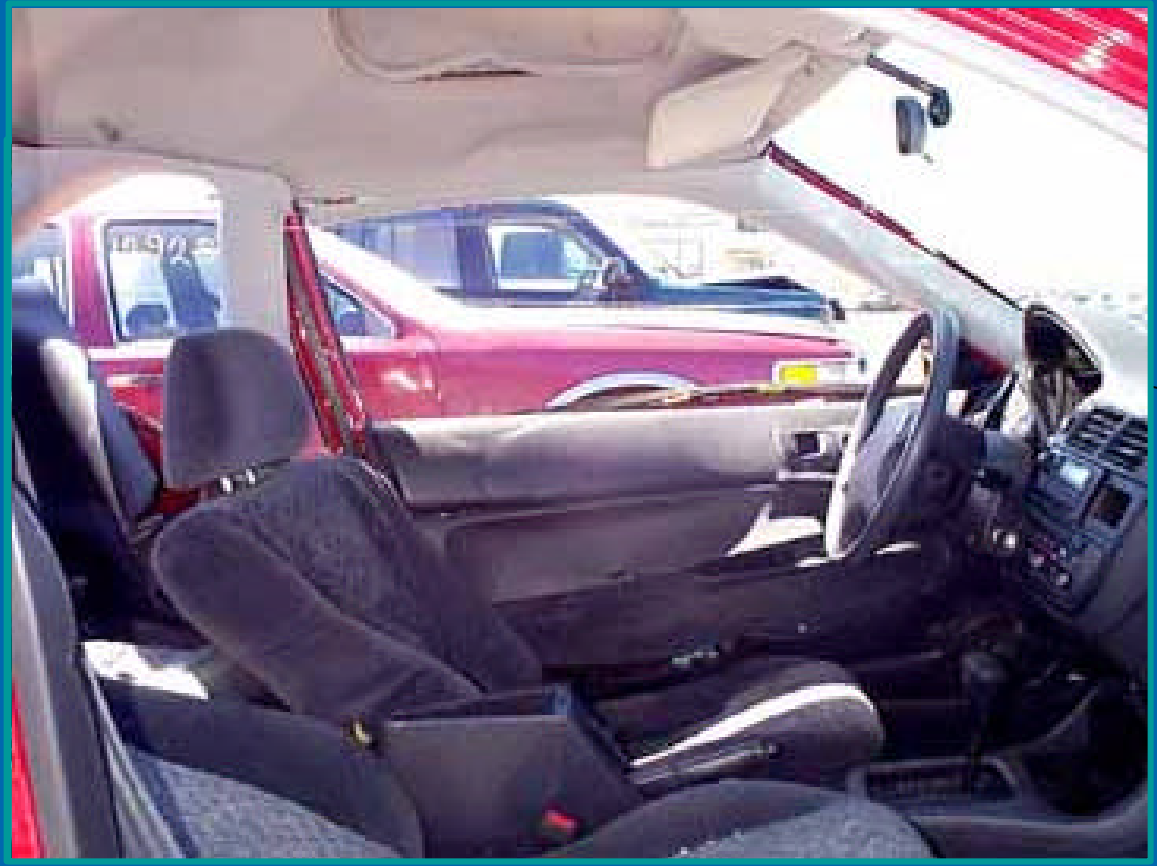


Occupant
42 yr. old male driver, 6’, 200 lbs.

- **Concussion**
- **Left rib fractures with left pneumothorax**
- **Left small lung contusion**
- **Partial tear posterior urethra @ level of pelvic fracture**
- **Left inferior/superior pubic rami fracture**

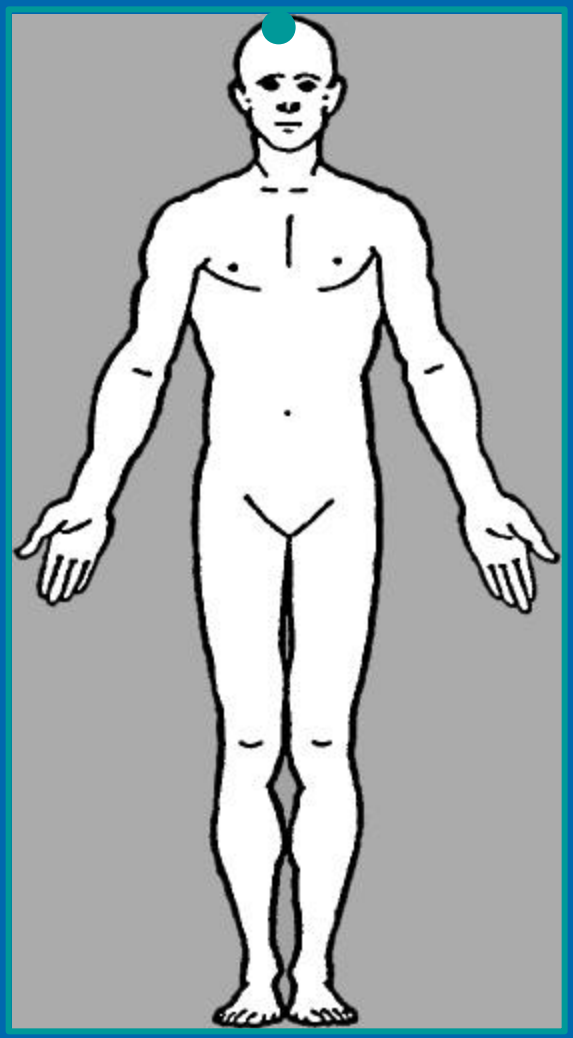


- ✓ 1997 Honda Civic vs 1999 Ford “van”
- ✓ 10:00 PDOF @ 290 degrees
- ✓ *DV 39 kmph (27mph)

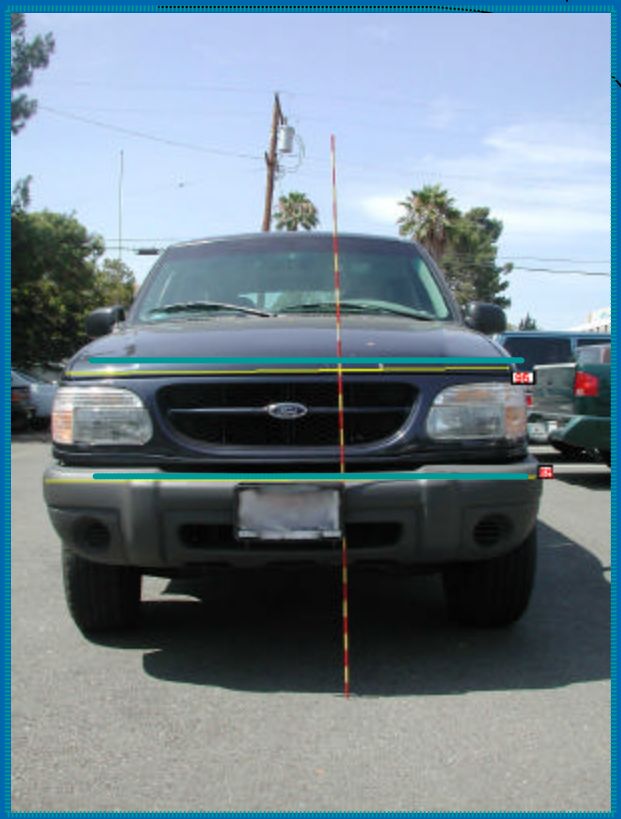


Occupant
27 yr. old male driver, 5’7”, 150 lbs.

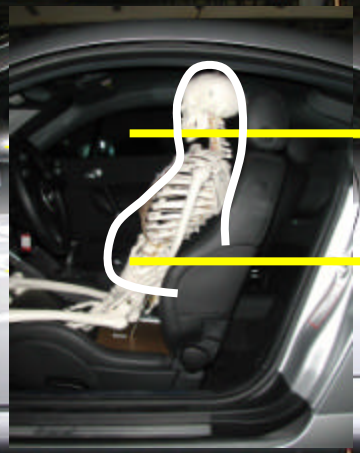
- **Fracture foramen magnum**
- **Cerebral contusion**
- **SAH of basal cisterns**

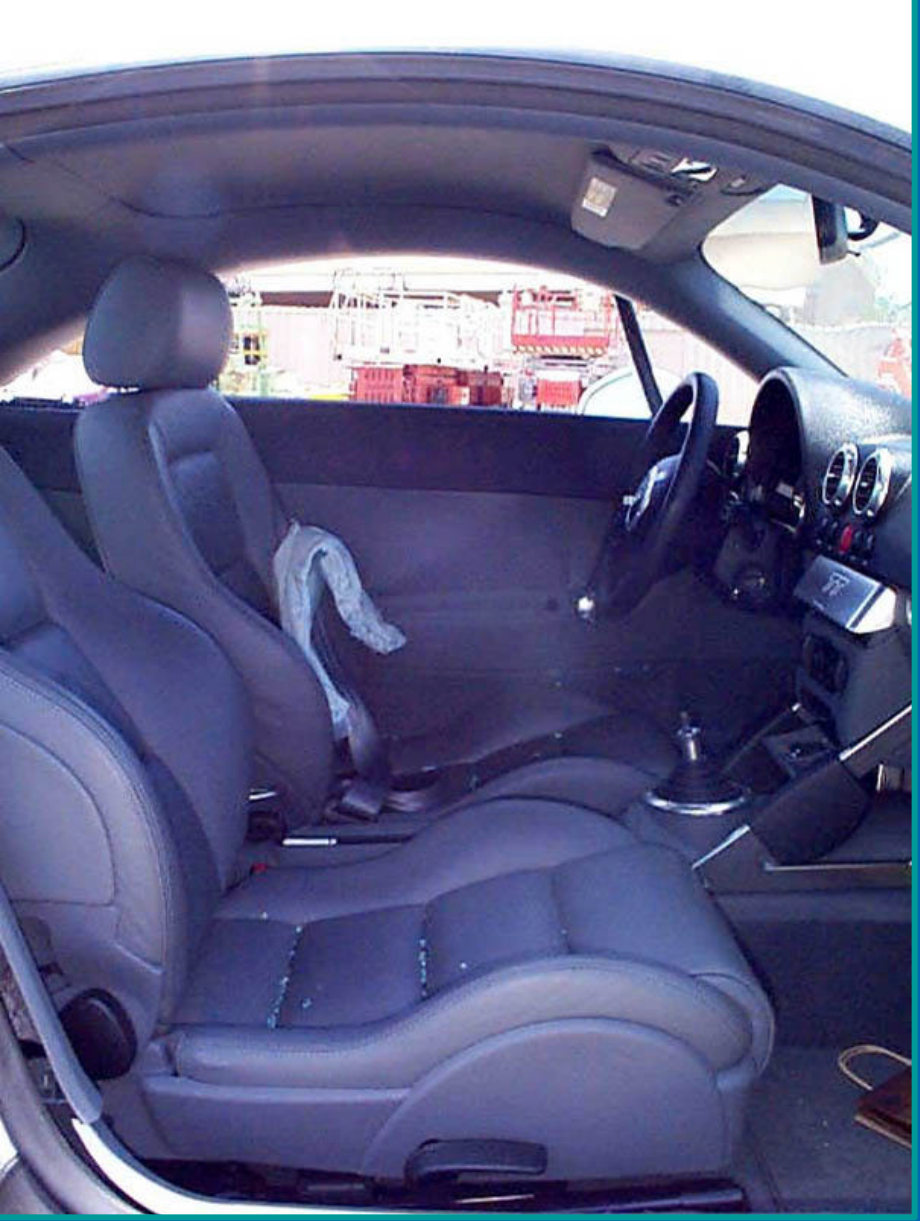


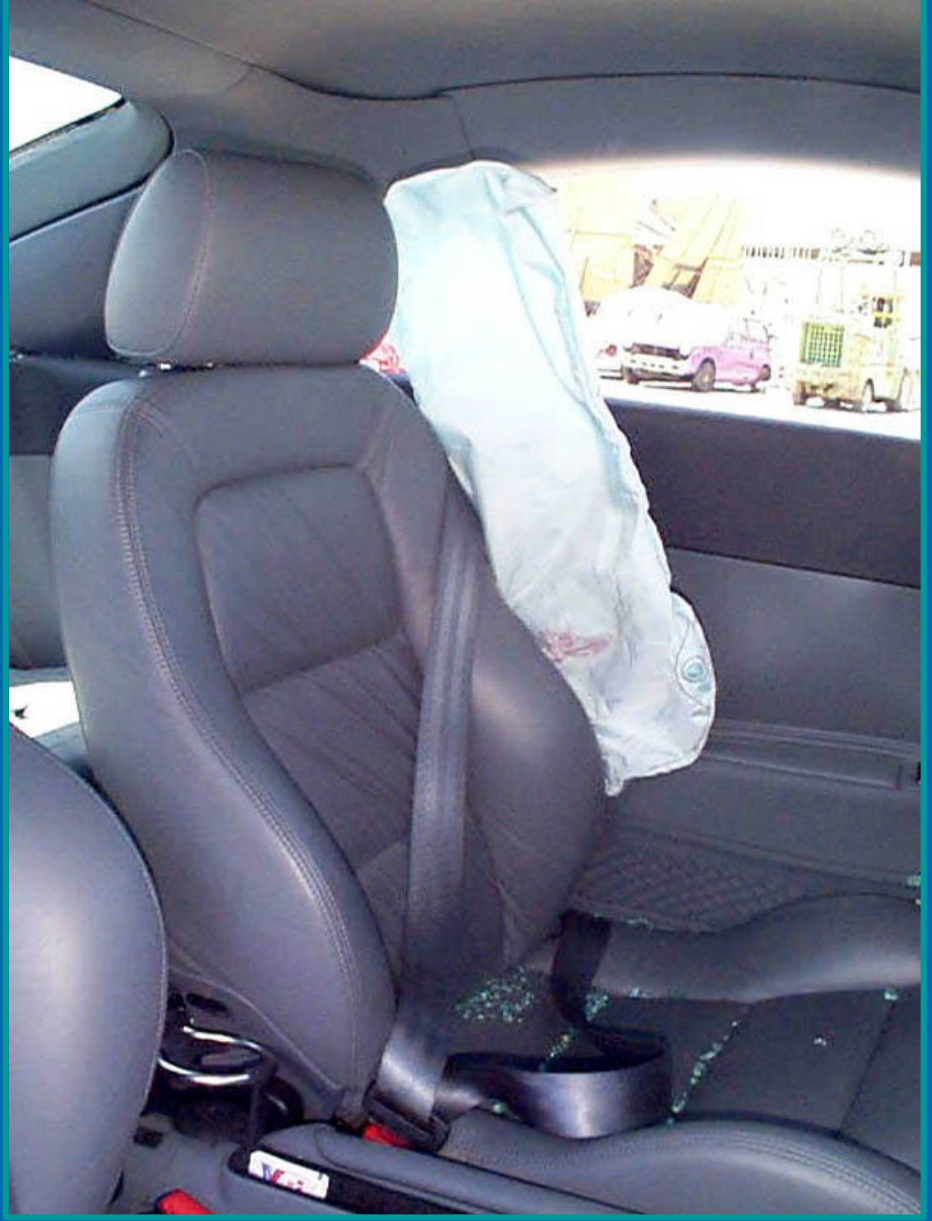
- ✓ 2000 Audi TT vs 1998 Ford Explorer
- ✓ 10:00 PDOF @ 290 degrees
- ✓ DV 26 kmph (16 mph)



Case Vehicle Cross Section

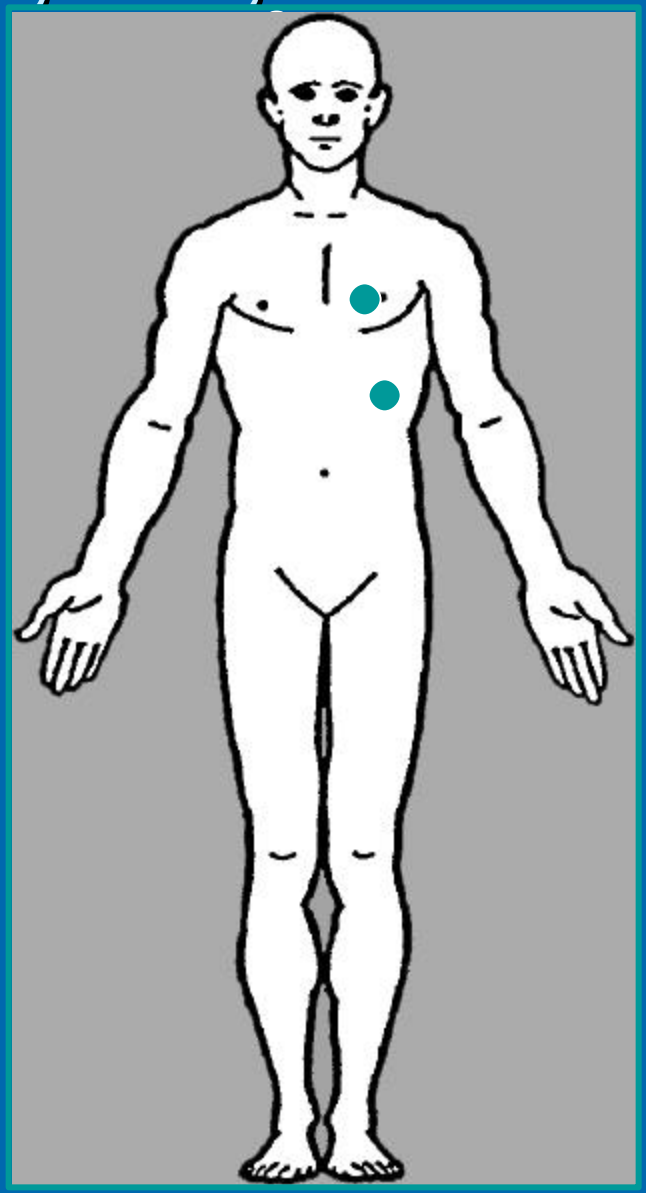




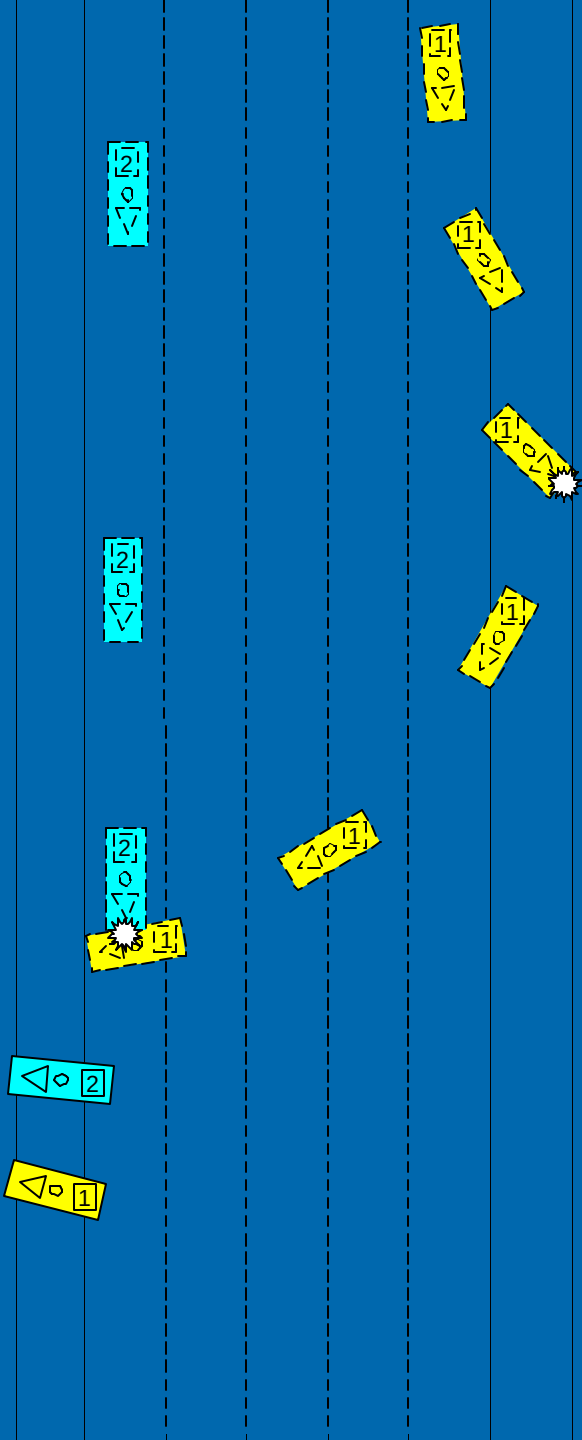


Occupant
23 yr. old female driver, 5’4”, 110 lbs

- **Left pulmonary contusion**
- **Left rib fractures with pneumothorax**
- **Multiple splenic lacerations**



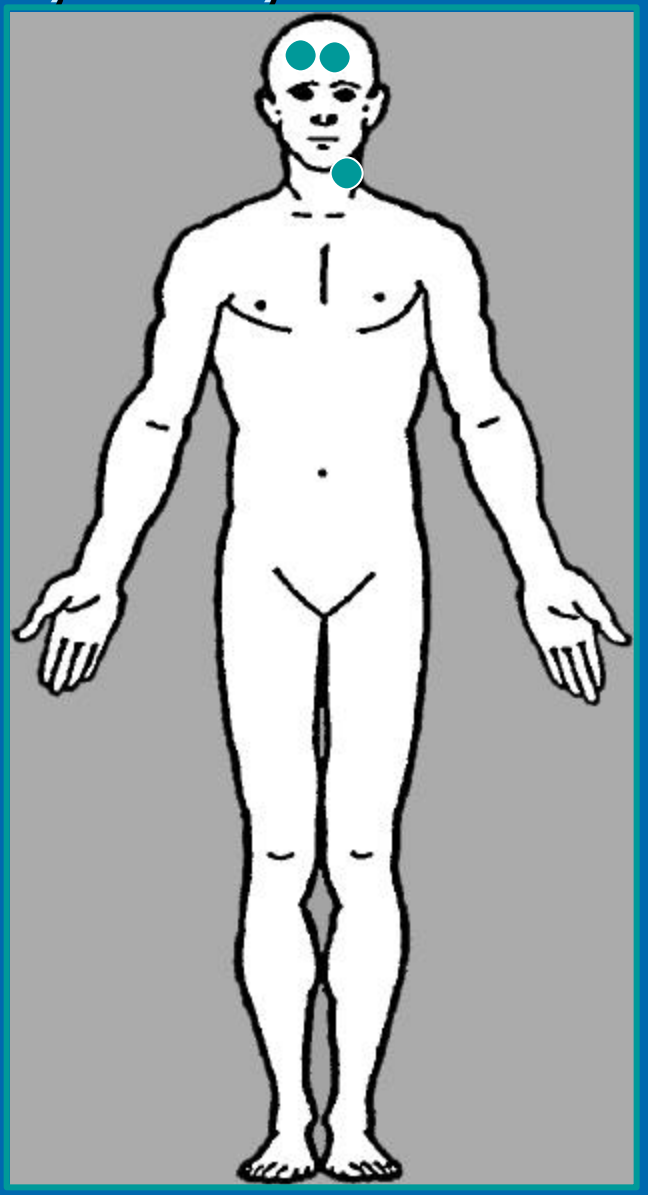
- ✓ 1994 Toyota Corolla vs 1992 Ford Explorer
- ✓ 3:00 PDOF @ 80 degrees
- ✓ DV 60 kmph (35 - 37 mph)



Occupant

34 yr. old female driver, 5’5”, 165 lbs

- **Multifocal SAH**
- **Right temporal contusion**
- **Left basal ganglia hematomas**
- **Intraventricular hemorrhage**
- **Left dissected internal carotid artery**



Summary

- Striking LTV size
  - Many CIREN cases with large strike LTVs
    - Head injuries, e.g.,
      - Concussion
      - Basilar skull fracture
    - Thorax injuries, e.g.,
      - Pulmonary contusion
      - Rib fracture
    - Upper Extremity
      - Scapula fracture, left
      - Clavicle fracture, left
- Struck car size
  - Both large and small struck cars are represented in the CIREN data