Rollovers
Configuration, Kinematics, and Injury

San Diego CIREN

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Today's Presenters

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Contributors

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Today's Presentation

- The Rollover Problem
- CIREN Statistics
- Rollover Causation/Types
- Safety Standards
- Kinematics
- Case Studies

Magnitude of the Problem

- Almost 215,000 passenger vehicles are in tow-away rollovers every year
- Rate of serious injury is 36% higher than in collisions with no rollover
- 3-4% of all crashes are rollovers, but 20% of all fatal crashes involve rollovers
- About 2/3 of rollover deaths involve occupant ejection

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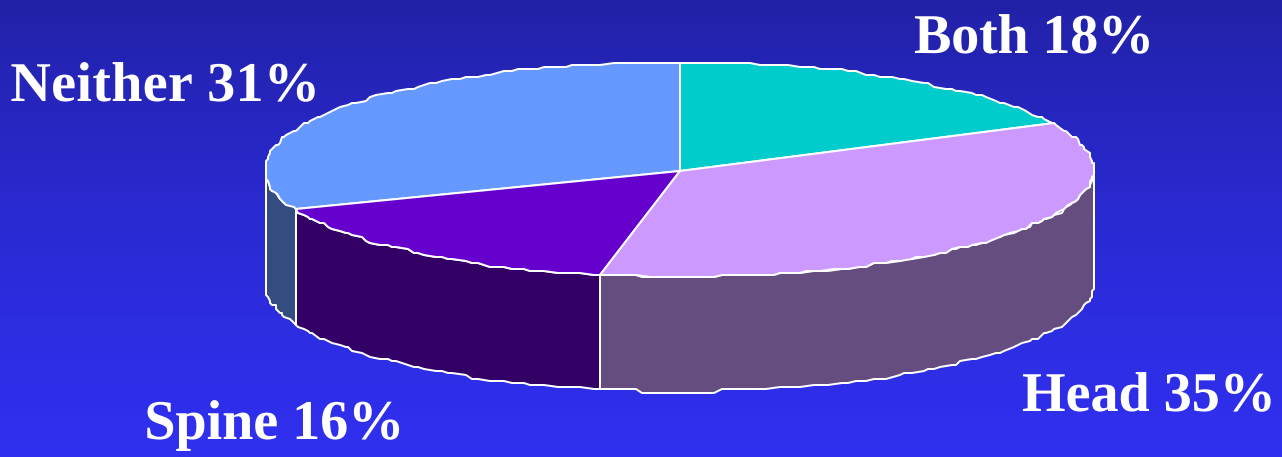
Statistics

Head and Spinal Injuries in Occupants in Rollover Crashes

(CIREN 1995-2004)



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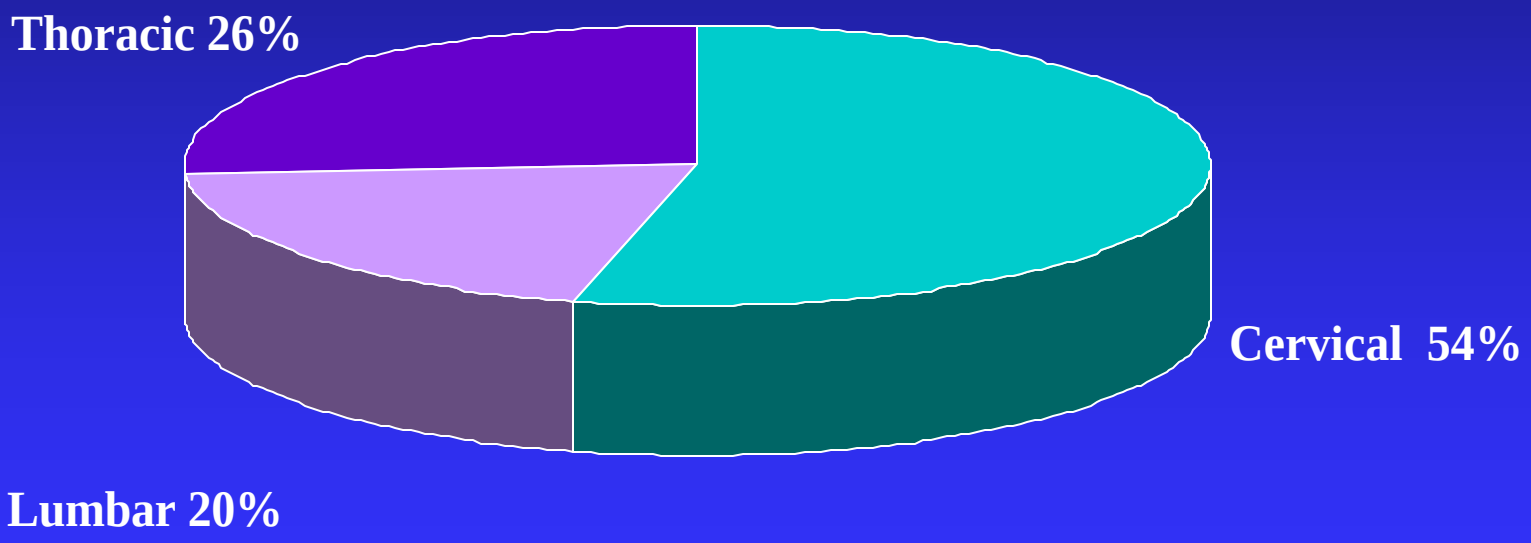
Spinal Injuries in Occupants in Rollover Crashes

(CIREN 1995-2004)



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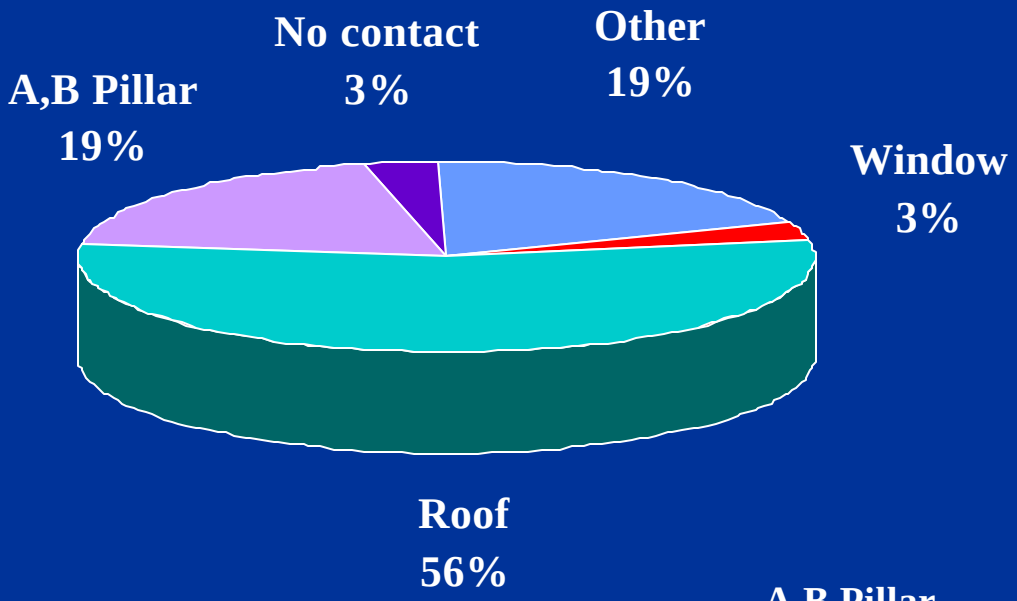
12%: Cervical and Thoracic, 7%: Lumbar and Thoracic, 5% Cervical and Lumbar

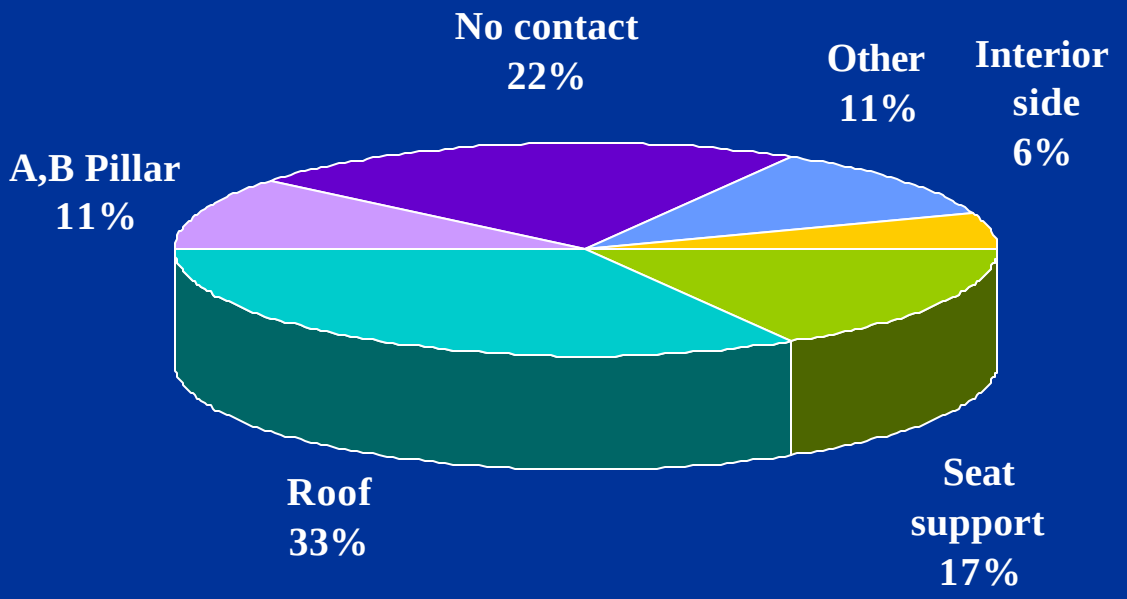
Sources of Injury for Occupants in Rollover Crashes

(CIREN, 1995-2004)

Head Injury



Spinal Injury



Role of safety belts in preventing head and spinal injuries to drivers in rollover crashes (CIREN, 1995-2004)

- Unbelted drivers were 2.6 times more likely to have head injury alone compared to belted drivers*
- Unbelted drivers were 1.8 times more likely to have spinal injury alone compared to belted drivers
- Unbelted drivers were 4.7 times more likely to have both head and spinal injuries compared to belted drivers*

* P <0.05

Rollover Causation

- Driver Behavior
  - Steering inputs
  - Unsafe driving speeds
- Environmental Conditions
  - Terrain
  - Road Conditions
- Vehicle Design
  - Static Stability Factor (“top heaviness”)
    - one-half the track width divided by the height of the center of gravity

Rollover Types

TRIPPED EVENTS

- Trip-Over
- Flip-Over
- Climb-Over
- Fall-Over
- Bounce-Over

UN-TRIPPED EVENTS

- Turn-Over

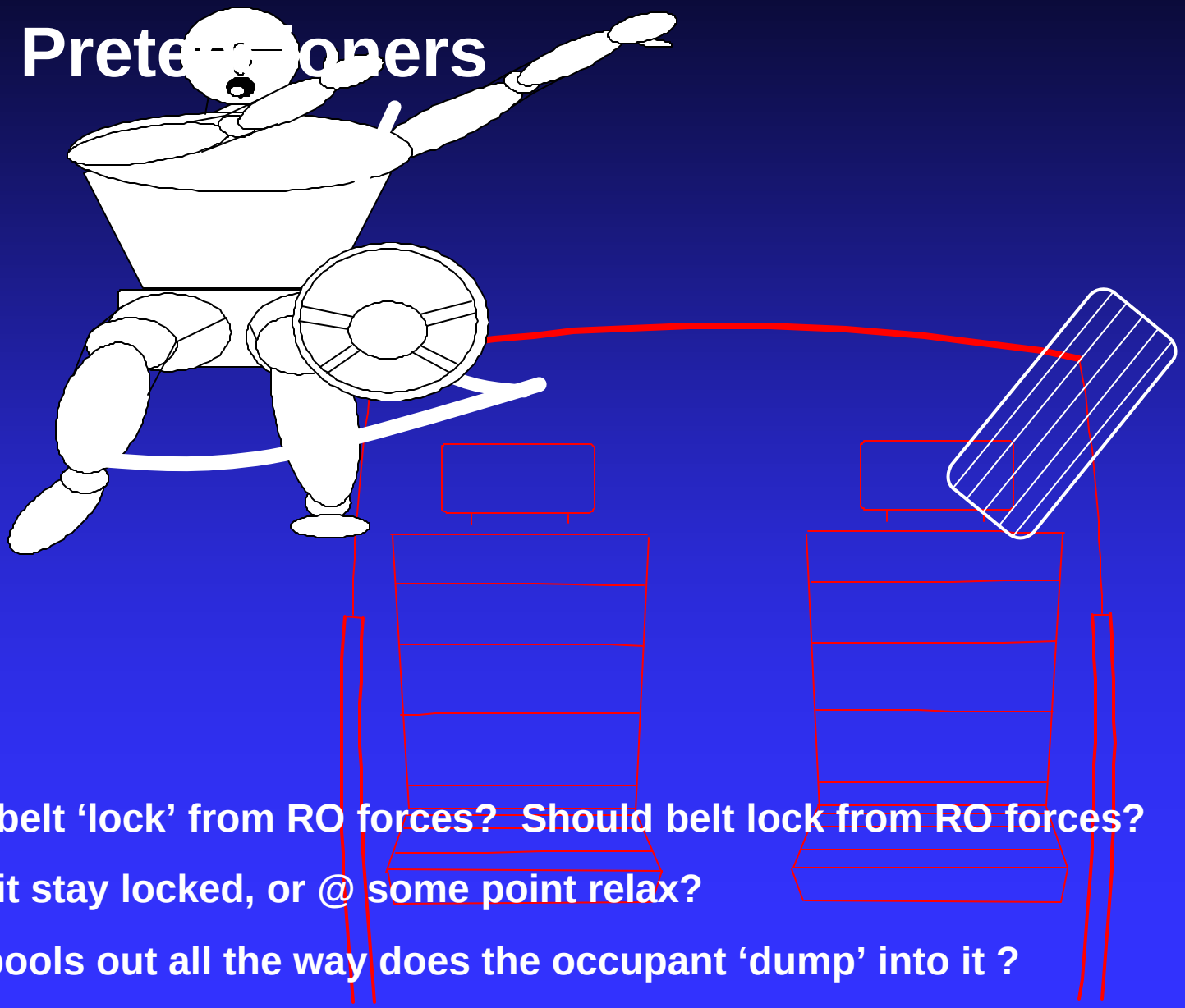
Safety Standards

- FMVSS 216 Roof Crush
- FMVSS 206 Door Locks & Door Retention
- FMVSS 201 Interior Padding
- FMVSS 205 Glazing Materials

- Curtain Airbags
- Seat Belts

Retractors - ELR/ALR

and Pretensioners



Does belt ‘lock’ from RO forces? Should belt lock from RO forces?

Does it stay locked, or @ some point relax?

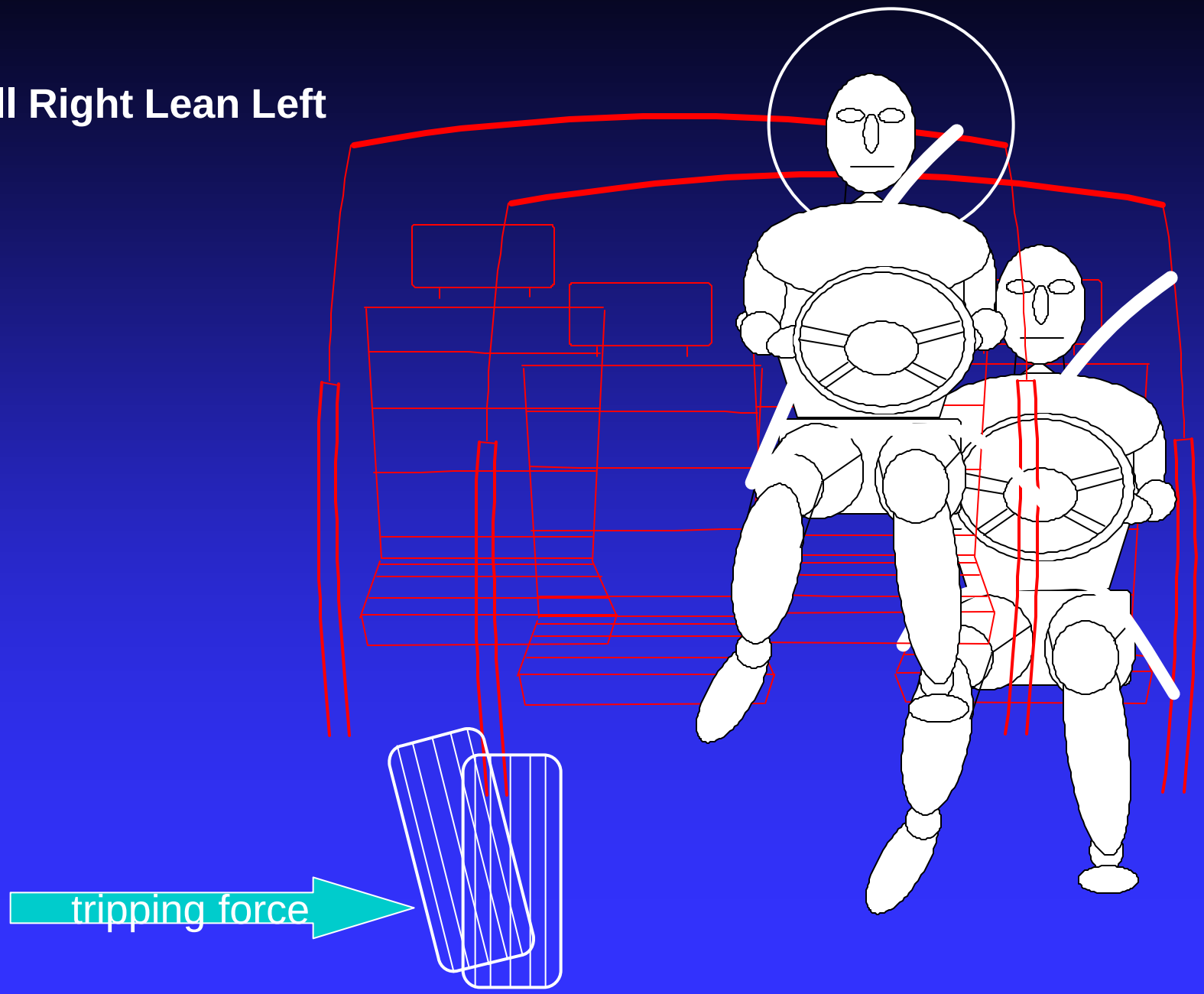
If it spools out all the way does the occupant ‘dump’ into it ?

Occupant Kinematics - Considerations

- Occupant position and roll direction
- Velocity changes during impact(s)
- Roof crush and restraint use
- Roll right, lean left

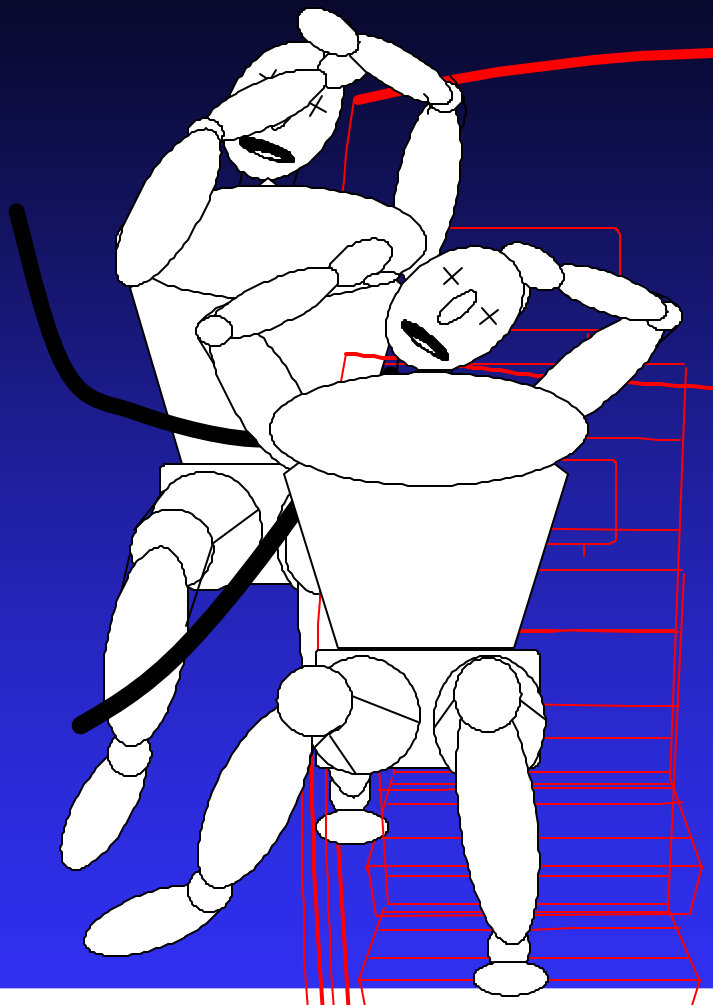
R/O Kinematics

Roll Right Lean Left



Gravity

* Fricke, Traffic Accident Reconstruction Volume 2

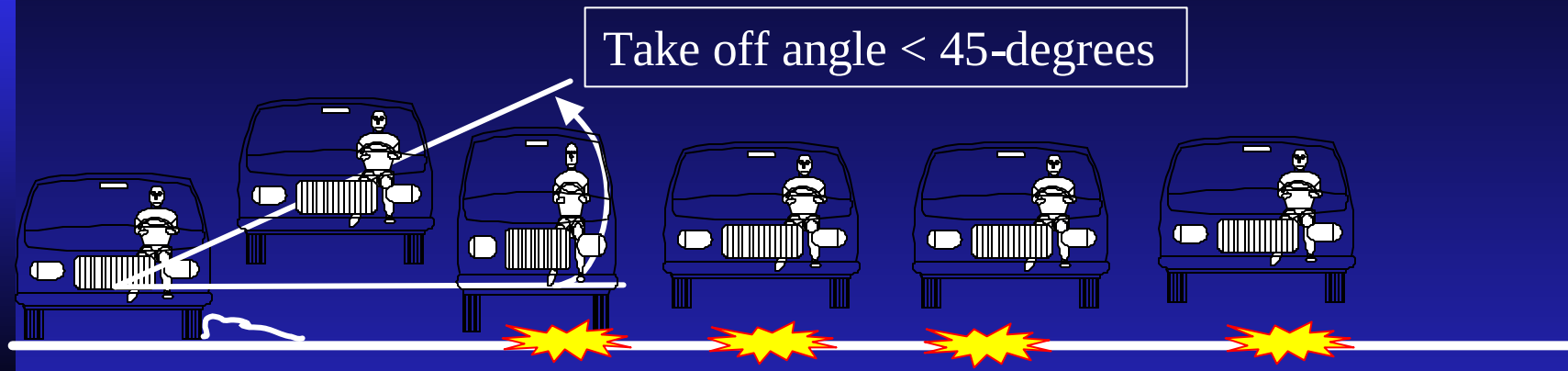


1) Roof strikes ground

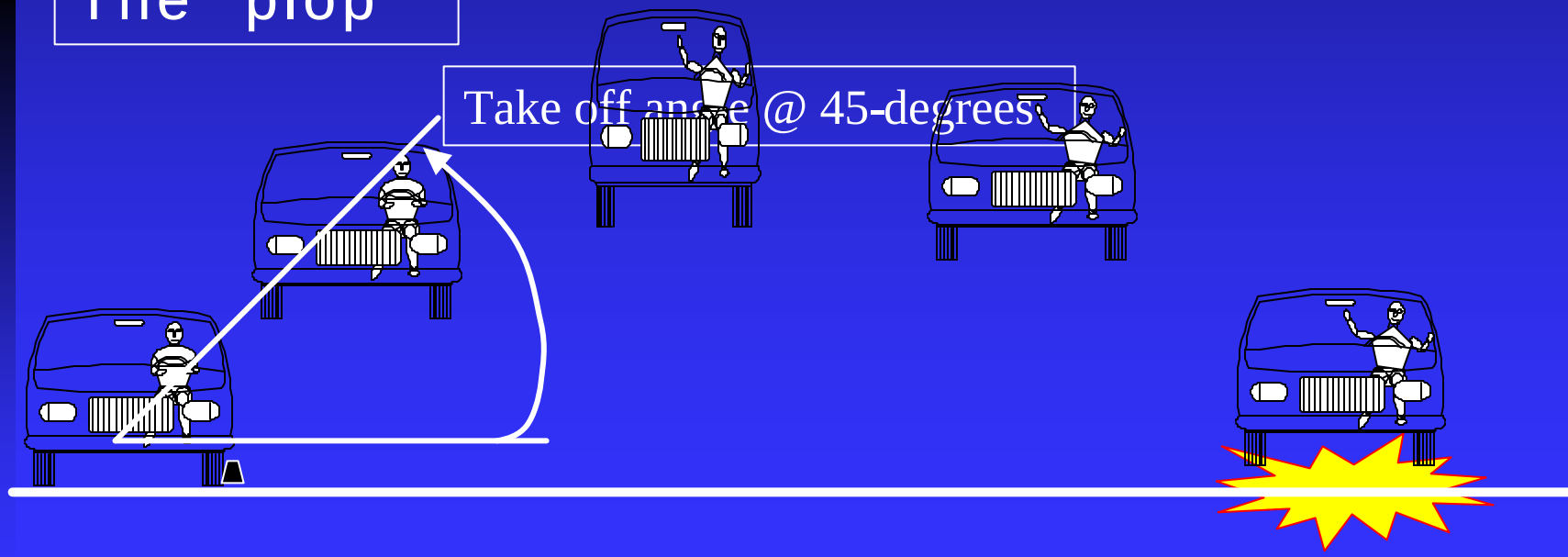
2) Body weight falls to roof

3) Weight of vehicle continues down, crushes roof while occupant lays against it

The “skipping stone”



The “plop”



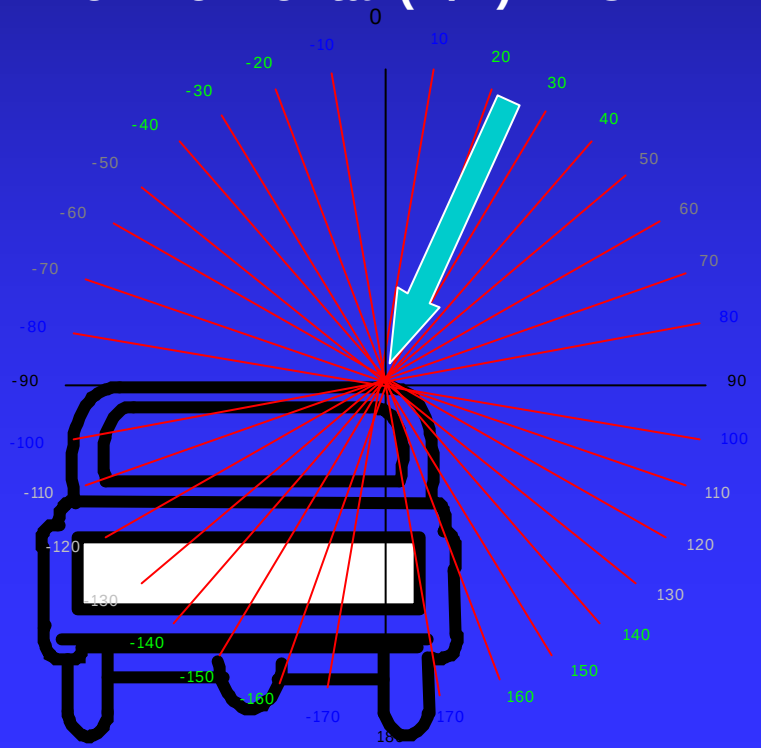
Additional Data Collection on Rollover Crashes

1. Location (on vehicle) of first ‘touchdown’
2. Velocity @ trip
3. Distances:
   * trip to 1st touchdown
   * trip to FRP
4. Bending of roof structures
5. Number of impacts to the ‘greenhouse’.
6. ‘Sub CDC’s’ for non-horizontal impacts to the greenhouse within the sequence
7. Categorize them according to the DV dispersal: “Skipping stone & the plop”

Velocity from “FLIP”:

$$V = d\sqrt{\frac{g}{d-h}}$$

Non-horizontal (N/H) PDOF ?



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Case Presentations


Subject – Driver
Right side leading-tripover

Crash

Case Vehicle

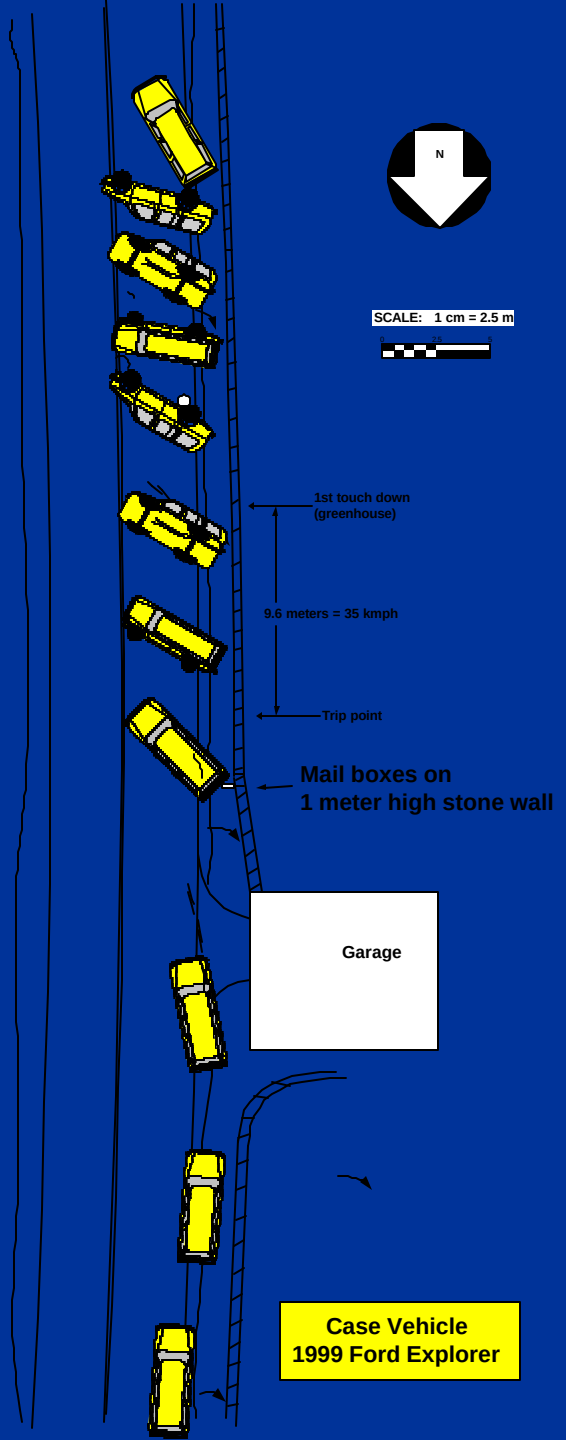
* 1999 Ford Explorer
* Max. Crush 43 cm @ driver roof/A pillar
* 2 greenhouse impacts

Rollover -

* right side leading
* 8 quarter-turns (2 complete Overturns)
* FRP on wheels
* 35 kph (22 mph) velocity @ trip

Scene -

Clear, dry, daylight,
slight downgrade, bituminous



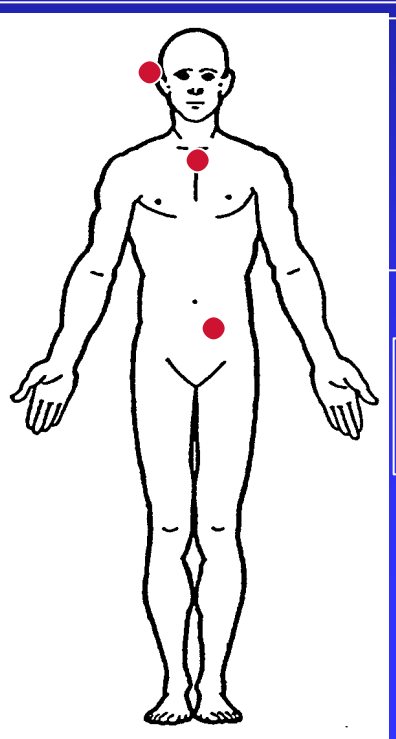
Subject:

Driver, sole occupant

- 53 y/o male, 6', 230 lbs.
- Lap & shoulder belt in use (not pre-10, not integrated)
- Front impact airbag not deployed (no side bags)

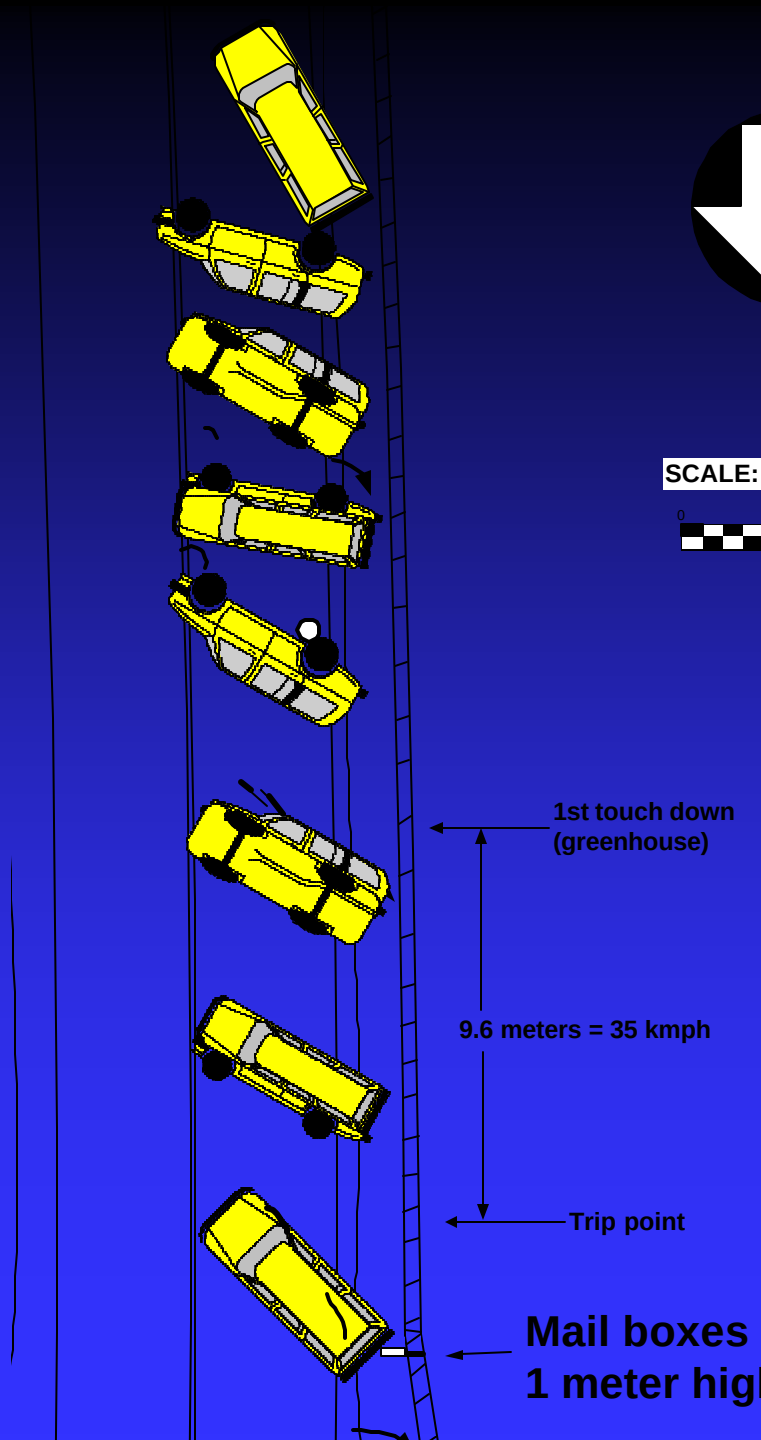
Posterior scalp avulsion

Right ear laceration and contusion



Left comminuted C4-5 facet fx. and C4 lamina fracture

Left abdominal contusion

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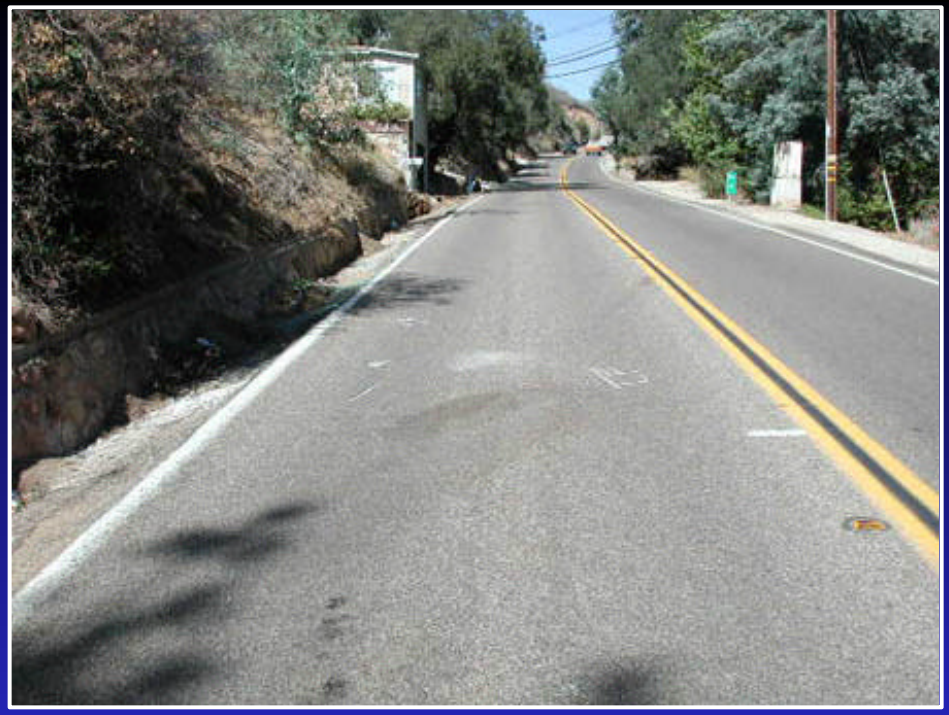
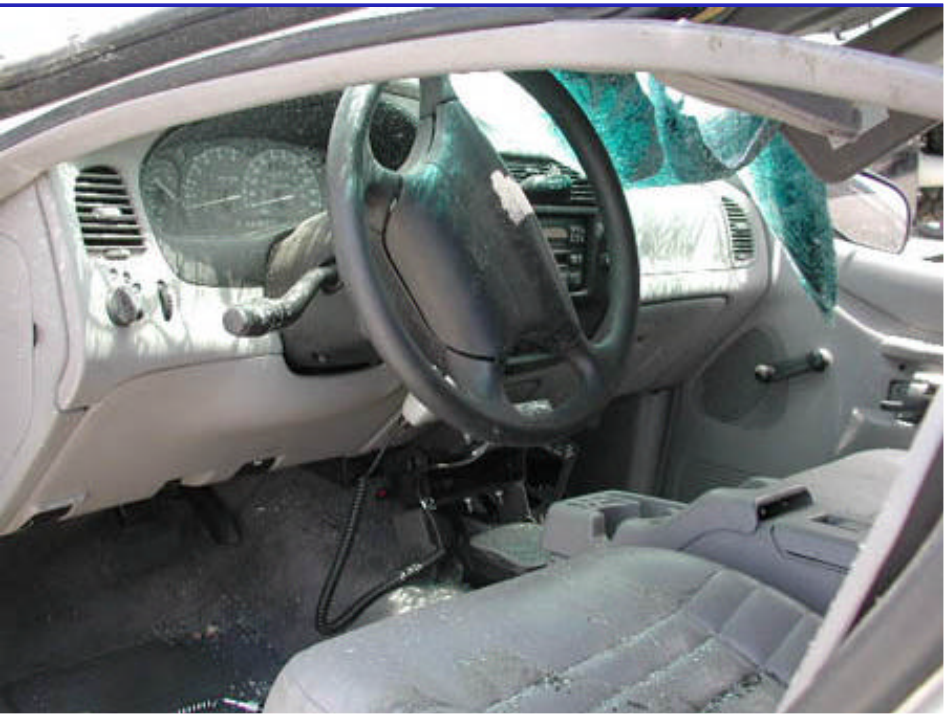


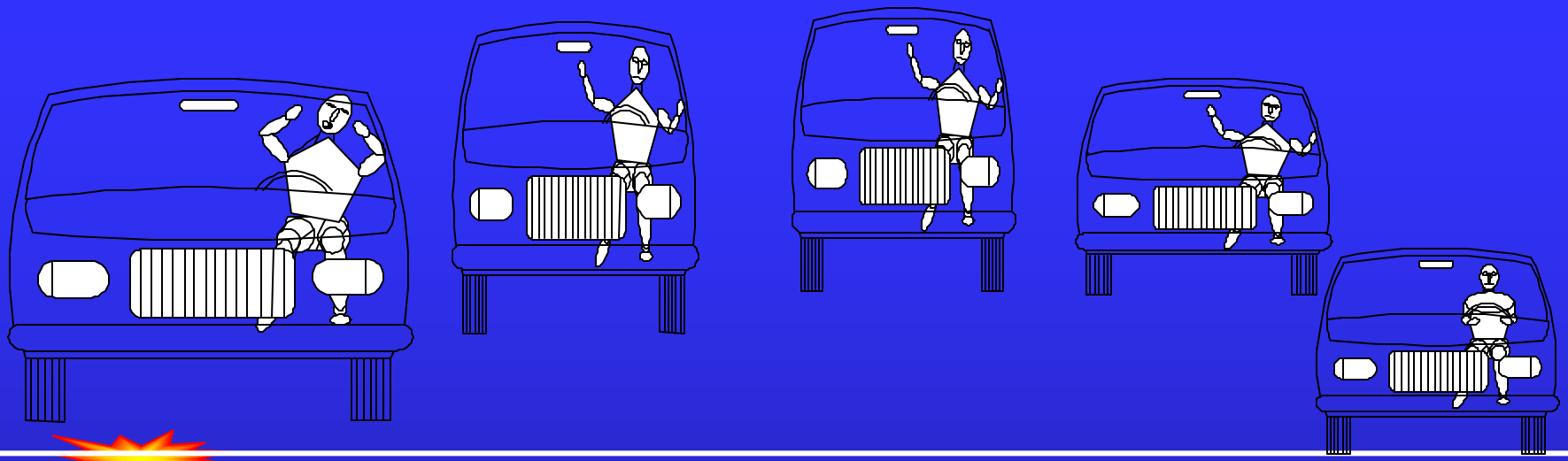

MaxCrush 43 cm


Like Vehicle

Like Vehicle

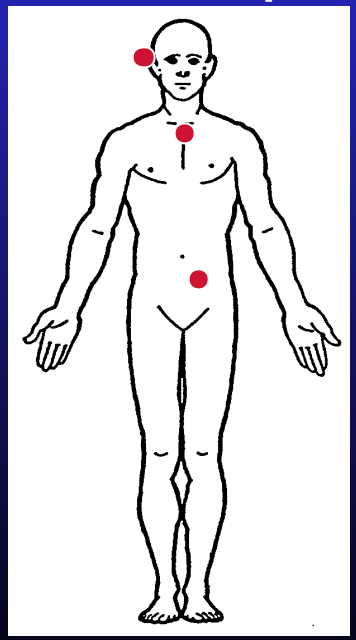

43 cm intrusion





Posterior scalp avulsion

Right ear laceration and contusion



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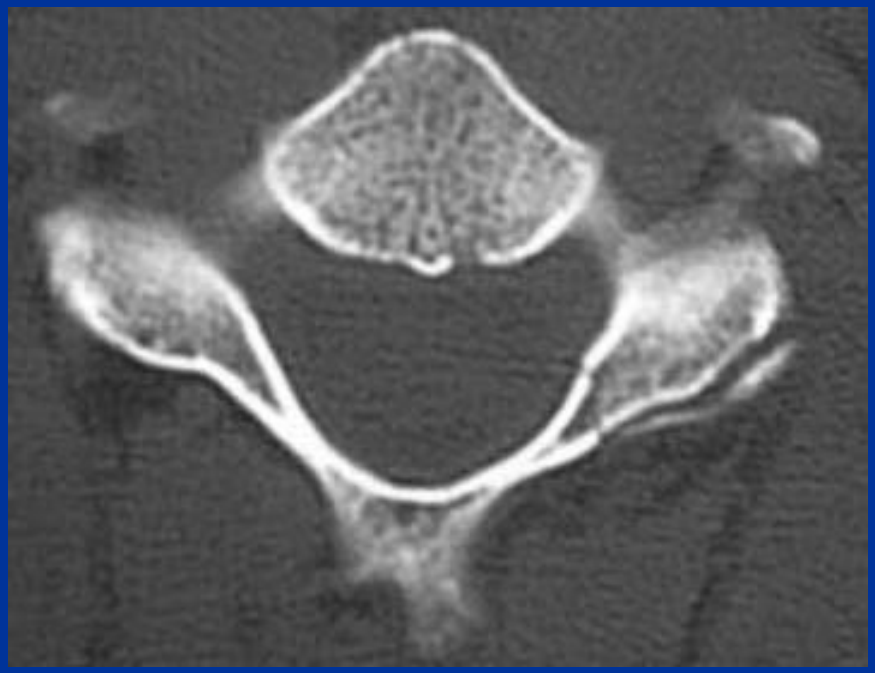
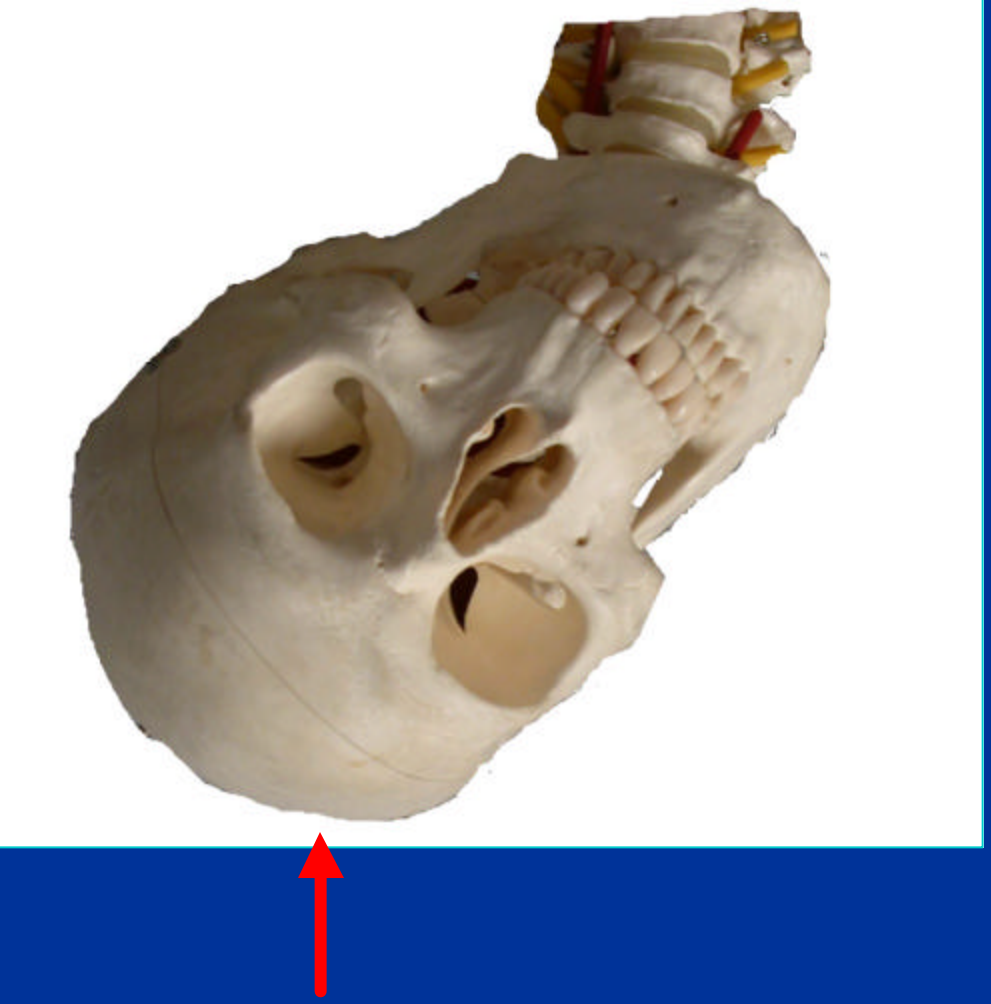


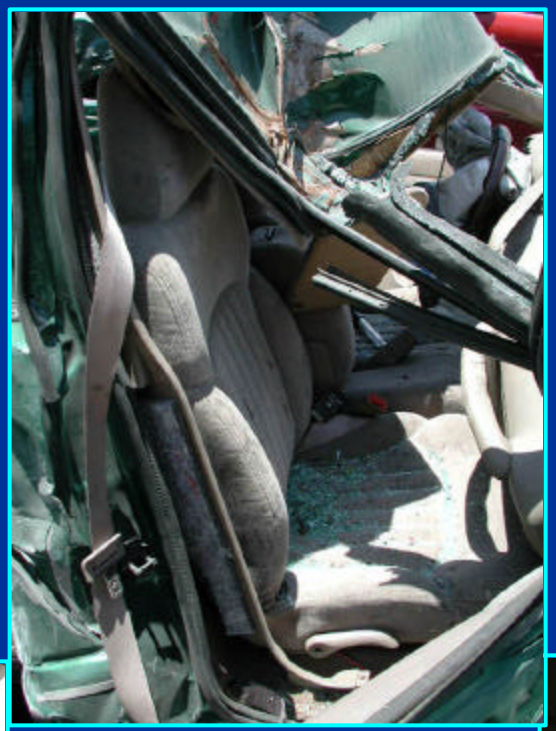


San Diego Case Rollover Examples

Who has head and neck injuries ?

A

B



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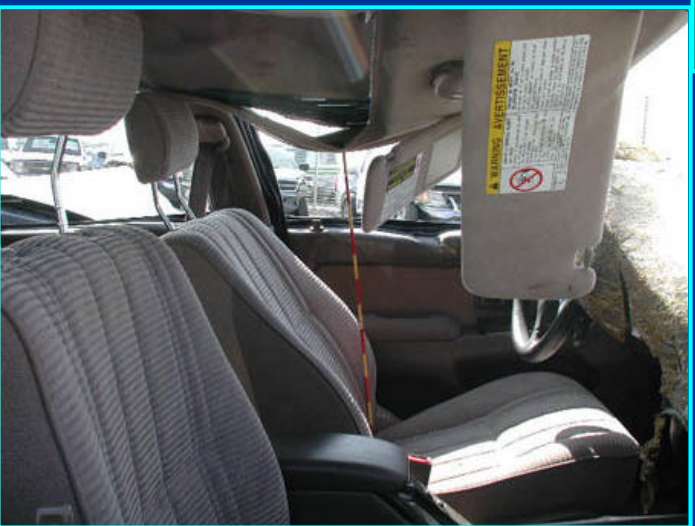
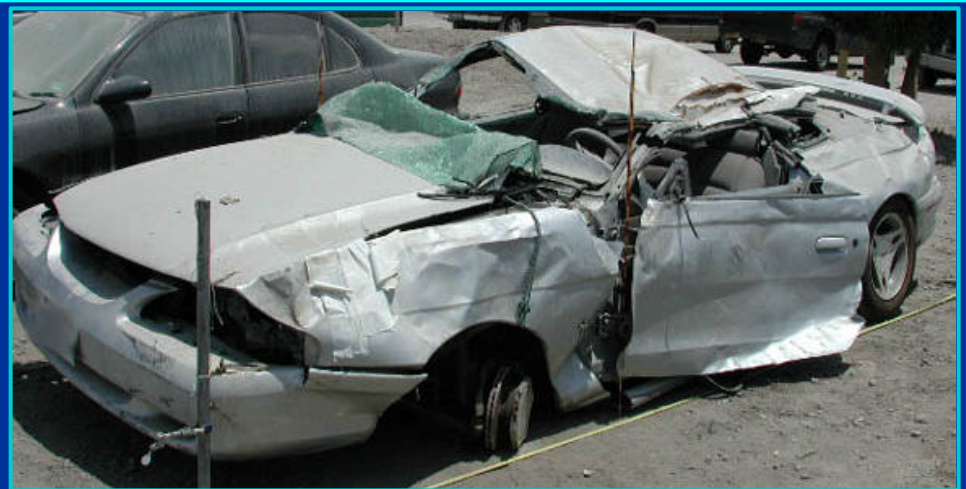


D

E

Patient A

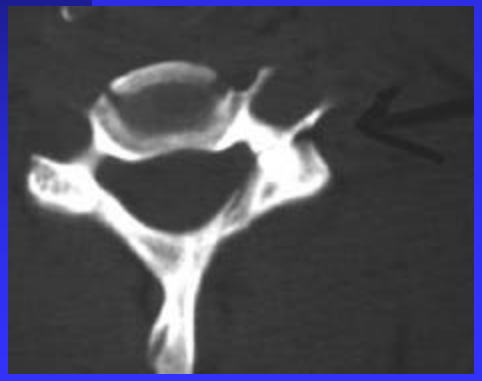


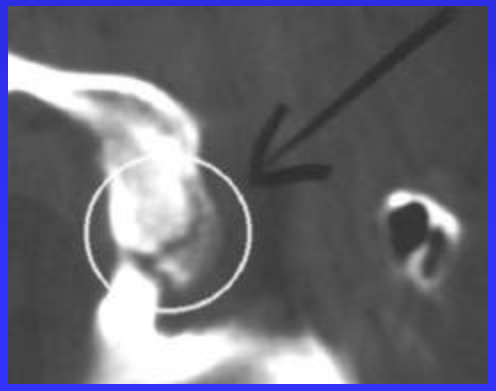
- Driver - 19 y/o male
- Lap & shoulder belt
  - (no pre-10, not integrated)
- Right roll
- 8 ¼-turn, trip-over
- FRP on wheels
- ‘Velocity @ Trip’ 58 kph (36 mph)
- Downward embankment
- 1998 Ford Mustang
- 40 cm M/C @ roof
- 1 greenhouse impact

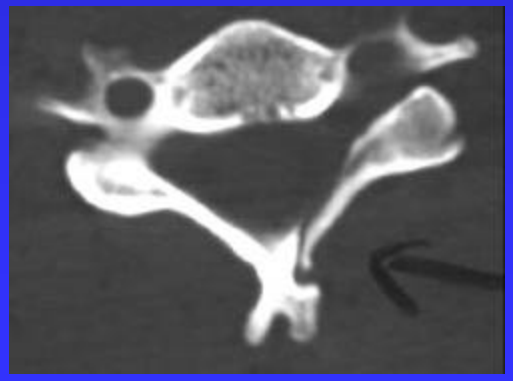
Yes

Injuries

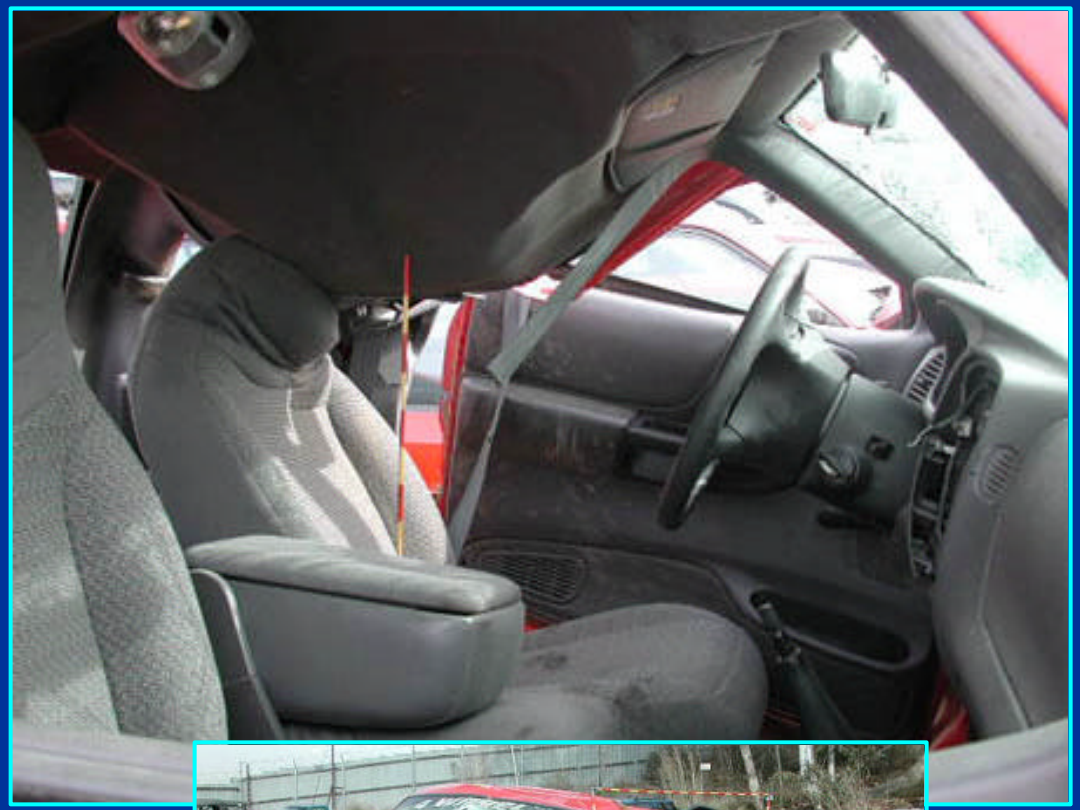
- **Concussion**
- **Left basilar skull fracture (articular condyle)**
- **C1 burst fracture**
- **C5-6 pedicle and lamina fractures**







Patient B



- Driver - 24 y/o male
- Lap & shoulder belt
  - (no pre-10, not integrated)
- Left Roll
- 10 ¼ turn ‘trip-over’
- Impact with rock during roll
- FRP on top
- Roadside = small embankment with large rocks
- 1999 Ford Ranger XLT
- 40 cm M/C @ left roof
- 2 greenhouse impacts

No

Injuries

- **Left rib fractures 7^{th}-10^{th} @ costotransverse junction**
- **Splenic laceration, Grade 3**

Patient C

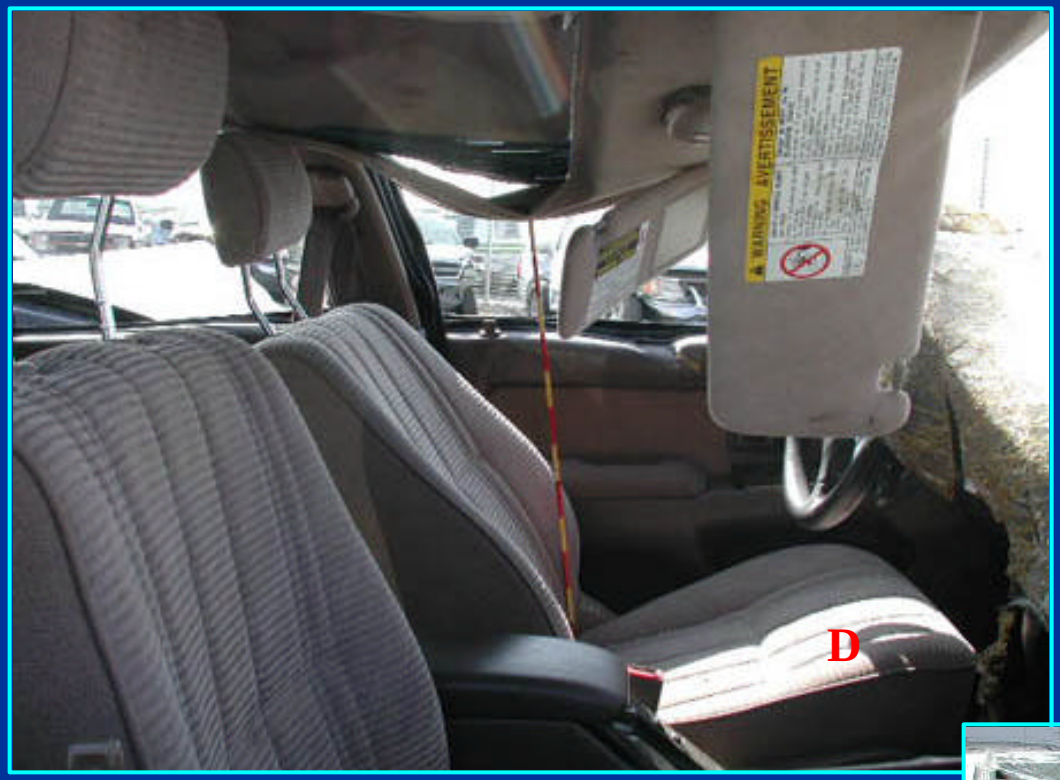
- RF passenger, 25 yo female
- Lap/shoulder belt used
  - (no pretensioner, not integrated)
- Right Roll
- 8 quarter-turn fall-over
- Steep embankment with large rocks
- 1999 Chevrolet S-10 pick-up
- 50 cm max crush
- 2 greenhouse impacts (rock)

No

Injuries

- **Left forehead abrasions**
- **Left proximal humerus fracture**

Patient D



- Driver - 36 y/o female
- Lap & shoulder belt used
  - (no pre-10, not integrated)
- Right Roll
- 10 quarter-turns
- ‘Overturn’ on roadway
- FRP on top
- 1998 Toyota 4Runner
- 35 cm M/C @ left roof
- 2 greenhouse impacts

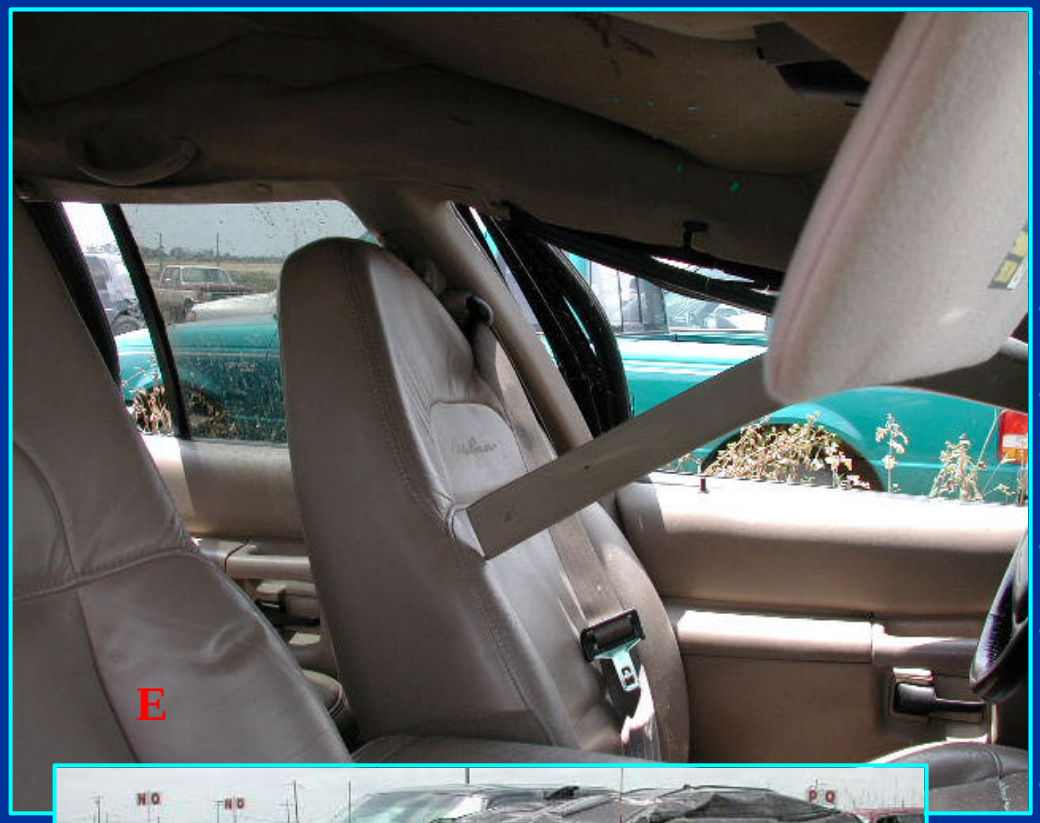
Yes

Injuries

- **Right small frontal SDH**
- **Right frontal cephalohematoma**
- **Right parietal scalp laceration**

Right eye

Patient E

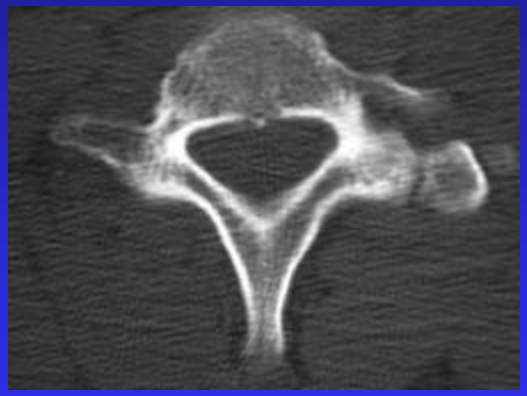


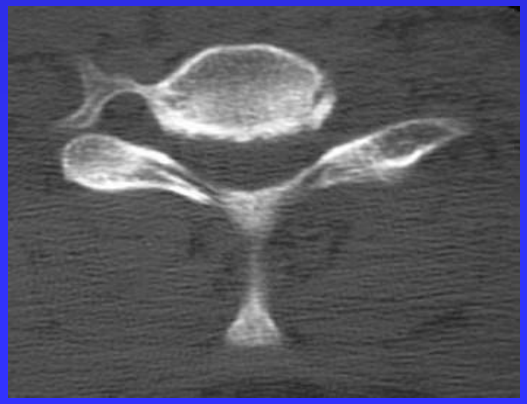
- Driver - 44 y/o female
- Lap & shoulder belt
  - (no pre-10, not integrated)
- Left Roll
- 10 ¼ turn, ‘trip-over’ tripped on roadside median
- FRP on top
- Velocity @ ‘Trip’ 27 kph (17 mph)
- 1999 Ford Explorer
- 35 cm M/C @ ‘A’ pillar/roof rail/roof

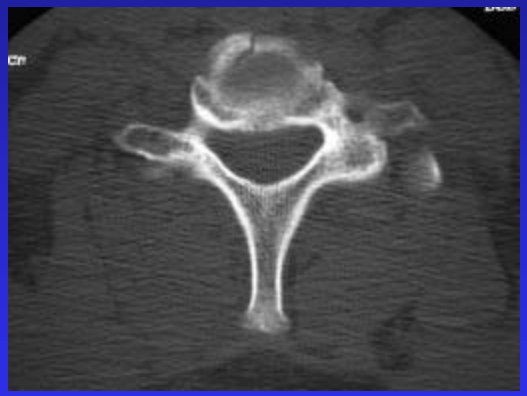
Yes

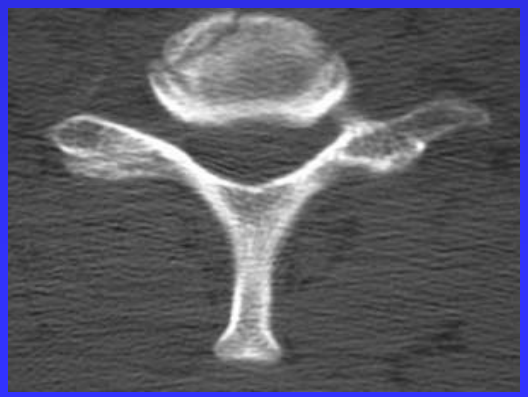
Injuries

- **Concussion**
- **Left ear laceration**
- **C6 vertebral body fracture**









Implications for Triage & Treatment

- Even in the Absence of Roof Crush:
  - Think spinal injury !!
  - Patients often self-extricate

Research Questions

- What is the optimal seat belt design?
  - Pretensioners
  - 5 point harness
- What is the interaction between roof crush and occupant kinematics
- How can we best classify skipping stone and plop rollovers?

Does NASCAR Have The Solution To Crash Safety?