Rollovers
Configuration, Kinematics, and Injury

San Diego CIREN
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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)

- Head: 35%
- Spine: 16%
- Both: 18%
- Neither: 31%

n=121
Spinal Injuries in Occupants in Rollover Crashes
(CIREN 1995-2004)

- Cervical: 54%
- Thoracic: 26%
- Lumbar: 20%

n=121

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

- No contact: 3%
- A,B Pillar: 19%
- Other: 19%
- Window: 3%

Spinal Injury

- No contact: 22%
- A,B Pillar: 11%
- Roof: 33%
- Seat support: 17%
- Interior side: 6%
- Other: 11%
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
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
1) Roof strikes ground
2) Body weight falls to roof
3) Weight of vehicle continues down, crushes roof while occupant lays against it

* Fricke, Traffic Accident Reconstruction Volume 2
The “skipping stone”

Take off angle < 45-degrees

The “plop”

Take off angle @ 45-degrees
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”:
\[ V = \sqrt{\frac{g}{d-h}} \]
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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)

Right ear laceration and contusion
Left comminuted C4-5 facet fx. and C4 lamina fracture
Left abdominal contusion

Posterior scalp avulsion

Mail boxes on 1 meter high stone wall

1 cm = 2.5 m

1st touch down (greenhouse)
9.6 meters = 35 kmph
Trip point
Mail boxes 1 meter high
Right ear laceration and contusion
Posterior scalp avulsion
Left comminuted C4-5 facet fx. and C4 lamina fracture
Left abdominal contusion
San Diego Case Rollover Examples
Who has head and neck injuries?
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
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
Injuries

- Left rib fractures 7th-10th @ 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)
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
Injuries

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