Brain injuries: Does Severity, Sources, and Type of Injury vary for Distributed, Off-set, and Corner Frontal Impacts?

Presenters:
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San Diego CIREN Center

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Objectives

• Address the magnitude of the brain injury problem

• Define Distributed, Off-set, and Corner frontal crashes

• Present examples of frontal crashes, resulting in brain injury, investigated by CIREN

• Compare brain injuries associated with specific frontal crashes using CIREN data
Traumatic Brain Injury

• About 1.4 million people sustain a traumatic brain injury (TBI) every year

• Almost 50,000 die annually and people with severe TBI may have long-term disability

• Motor vehicle crashes are one of the leading causes of TBI severe enough to require hospitalization

• Brain injuries are a compelling public health and motor vehicle safety problem and a treatment challenge for trauma surgeons and other medical care providers
Why Study Brain Injuries Using CIREN Data?

• Crash tests assess safety system effectiveness and crashworthiness
  – Current Head Injury Criterion (HIC) used in crash tests is based only on linear acceleration

• NHTSA: tests distributed frontal impacts

• IIHS: tests off-set frontals

• Real world experience provides information on safety system effectiveness and crashworthiness for all types of frontal impacts (including corner)
Head Injury Criterion (HIC)

- One of the “Injury Criterion Performance Limits” for testing vehicle safety

- Used to provide a quantitative measure of head injury risk during motor vehicle crash tests

- Based on average value for linear acceleration of the head’s center of gravity during a crash
  - Previously, set at “1000” for an adult mid-size male anthropomorphic dummy
  - In 2000, set at “700” for a 15 millisecond crash
  - Currently, possible changes for children (FMVSS 213)
  - Currently, possible changes using a different brain model
Biomechanics of Brain Injury

• Different cephalic components (brain, skull, arteries, nerves) have different physical features and anatomical structure

• Rotational forces in addition to linear acceleration may cause brain injury

• Different regional and organ mechanisms of injury are associated with different types of brain injuries
  – Tissue “strain”: Compression, shearing, tension

• Mechanism of injury may differ for different components of the brain
Frontal Impact Definitions
developed for Study
In-line frontal impact

12 o’clock

11 o’clock

1 o’clock
Distributed Frontal Impact

• 1st and 2nd column of CDC = 11, 12, 1

• 3rd column of CDC=“F” and 4th column of CDC=“D”

• 6th column of CDC= “W”

The Direct Damage is distributed across 66% (or more) of the frontal plane
Examples of real-world Distributed Frontal crashes

‘Head-on’ Distributed Frontal
Comparable to the NHTSA NCAP Tests
Off-set Frontal Impact

• 1st and 2nd column of CDC = 11, 12, 1

• 3rd column of CDC="F"

• 4th column of CDC="Y" or "Z" or "L" or "R"

• 5th column of CDC= anything but "W"

Direct Damage involves 35-65% of the Front Plane and is confined to right or left 1/3 or 2/3 of frontal plane
‘Head-on’ Front Left Off-set Impacts
Comparable to IIHS Crash Tests (Drivers “Left” side)
‘Head-on’ Front Right Off-set (Passenger Side) Impacts
Corner (Extreme Off-set) Frontal Impact

- 1st and 2nd column of CDC = 01, 11, 12
- 3rd column of CDC = F and 4th column of CDC = L or R
- 5th column of CDC = anything but W
- 6th column of CDC = E

Direct Damage involves less than 41cm (16”) of the Front Plane and a corner.
Extreme Off-set (Left or Right) Impacts:
Comparable with Narrow Rigid Object corner impacts
CIREN Investigations
Case vehicle: 2000 Dodge Stratus
Struck object: Big tree
Distributed Frontal Impact

20 year old female driver
Using safety belt and steering wheel air bag deployed

Right frontal and temporal lobe intraparenchymal hemorrhage
Right subarachnoid hemorrhage

Left mandibular fx

Right pulmonary contusion

Right subtalar dislocation
Right talar head and neck fx
Right cuneiform fx and metatarsal fx
Off-set Frontal Impact

2000 Chevrolet Suburban

Warning sign (R.P.)

Final rest opposing vehicle

Final rest case vehicle

Opposing Vehicle
1992 Chrysler LeBaron
pdof - zero
2948 lbs @ 85 mph

Case Vehicle
2000 Chevrolet Suburban
pdof - zero
5123 lbs @ 65 mph

SCALE: 1 cm = 2.5 m
Off-set Frontal Impact

Front right seat passenger
34 year old female
Wearing safety belt
Front IP Air bag deployment

Right comminuted distal femur fx
Left acetabular fx
Concussion and scalp lac

Forehead
Corner Frontal Impact

Like vehicle

Case Vehicle
1997 Nissan Sentra

Case

SCALE: Not To Scale

Opposing Vehicle
1989 Ford Thunderbird
Driver
35 year old male
Wearing safety belt
Steering wheel Air bag deployment

Injuries:
Left SAH
Left SDH
Left tibial plateau fx
CIREN Database

Used to compare brain injury patterns for Distributed, Off-set, Corner frontal impacts

- Severity
- Sources
- Types of brain injuries
Study Inclusion Criteria

- AIS ≥ 2 brain injury severity
  - Scalp lacerations excluded
  - Cranial nerve injuries excluded
  - Secondary injury (e.g., compression) excluded

- First row drivers and outboard passengers
  - Adults (>13 years old)

- Frontal in-line impacts ranked #1
  - Only Distributed, Off-set, Corner impacts
Brain Injuries Studied

- **Skull fractures**
  - Vault, Base

- **Focal Injury**
  - **Hemorrhage**
    - Subdural
    - Epidural
    - Subarachnoid
    - Intracranial
  - **Contusions/Lacerations**
    - Cerebrum (Frontal, temporal/parietal, occipital), cerebellum

- **Diffuse Injury**
  - Diffuse Axonal Injury (DAI)
  - Concussion/Loss of Consciousness (LOC)
Occupants with Brain Injury

418 Occupants

- 171 Distributed
  - 95 (56%) Belted
  - 72 (43%) Not Belted

- 177 Off-set
  - 98 (55%) Belted
  - 79 (45%) Not Belted

- 70 Corner
  - 45 (65%) Belted
  - 24 (35%) Not Belted
# Characteristics of Occupants with Brain Injury

<table>
<thead>
<tr>
<th></th>
<th>Distributed</th>
<th>Off-set</th>
<th>Corner</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>40</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>Median</td>
<td>37</td>
<td>36</td>
<td>35</td>
</tr>
<tr>
<td>Range</td>
<td>13 - 86</td>
<td>13 - 85</td>
<td>16 - 94</td>
</tr>
<tr>
<td><strong>delta V (kmph)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>51</td>
<td>49</td>
<td>30</td>
</tr>
<tr>
<td>Median</td>
<td>47</td>
<td>46</td>
<td>25</td>
</tr>
<tr>
<td>Range</td>
<td>15 - 137</td>
<td>12 - 126</td>
<td>12 - 94</td>
</tr>
<tr>
<td><strong>Safety belt used</strong></td>
<td>56.2%</td>
<td>55.4%</td>
<td>65.2%</td>
</tr>
<tr>
<td><strong>Front bag deployed</strong></td>
<td>94%</td>
<td>96%</td>
<td>96%</td>
</tr>
<tr>
<td><strong>Male</strong></td>
<td>49.4%</td>
<td>57.5%</td>
<td>64.7%</td>
</tr>
<tr>
<td><strong>Driver</strong></td>
<td>81.9%</td>
<td>85.3%</td>
<td>87.1%</td>
</tr>
</tbody>
</table>
Brain Injuries

- Concussion/LOC
- Artery
- Hemorrhage
- DAI
- Contusions
- Lacerations
- Fractures

Distributed | Distributed | Offset | Offset | Corner | Corner
---|---|---|---|---|---
Yes | Yes | No | No | Yes | No
Fracture vs. Intracranial Brain Injury

- Intracranial only
- Both
- Fractures only
Focal Brain Injury vs. Diffuse Brain Injury

![Bar chart comparing Focal and Diffuse Brain Injuries](chart.png)

- **Yes Distributed:** 100%
- **No Distributed:** 100%
- **Yes Offset:** 60%
- **No Offset:** 40%
- **Yes Corner:** 80%
- **No Corner:** 20%

Legend:
- **Diffuse**
- **Focal**
- **Fractures**
Conclusions

- Restraint use (wearing safety belt) may influence sources of brain injuries for all types of frontal impacts studied
  - Restrained: More non-contact brain injuries
  - Unrestrained: More hard-contact brain injuries caused by roof, roof rails, windshield, instrument panel

- Corner impacts may have different sources of injury (more hard contact with the windshield and instrument panel) compared to distributed and offset frontal impacts (more soft contact air bag related brain injuries)

- Brain injuries from corner impacts were more severe (based on GCS and more intracranial hemorrhage)

- Suggests head model incorporating angular acceleration may be important for crash testing

- Supports use of CIREN data and “real world” crash investigations to study brain injuries
San Diego CIREN Team

Principal Investigators

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Team

Sharon Pacyna, RN, BSN, MPH
Steve Erwin
Carol Conroy, MPH, PhD
MarSue May, RN, BSN
Barbara Frasier
Questions?
Unused slides
Skull Fractures

- Yes: Distributed
- No: Distributed
- Yes: Offset
- No: Offset
- Yes: Corner
- No: Corner

- Base fx
- Vault fx
Brain Contusions and Lacerations

- Brain stem
- Cerebellum
- Cerebrum

<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distributed</td>
<td>90%</td>
<td>10%</td>
</tr>
<tr>
<td>Offset</td>
<td>80%</td>
<td>20%</td>
</tr>
<tr>
<td>Corner</td>
<td>70%</td>
<td>30%</td>
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