Injury Mechanisms in Frontal Plane Corner Impacts

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Motivation For Study

Sweden: Lindquist, et.al., 2004, IJ Crash

Corner impacts 48% (29/61)
Belted Frontal Fatal Crashes

Figure 4b Frequency of front end load path usage in the 61 fatalities.
Crush and Extent
CDC-Code: Specific Longitudinal or Lateral Area

1  2  3  4  5  6  7

D  Y  Z  L  C  R
Fatalities in Frontal Impact by Crash Type

NASS Data 2000-2005 Frontal 11, 12, 1 o’clock
MAIS=3+ Trauma in Frontal Impact by Crash Type

NASS Data 2000-2005 Frontal 11, 12, 1 o’clock
Percent Risk of Fatality in Frontal Impact by Crash Type

NASS Data 2000-2005 Frontal 11, 12, 1 o’clock
Percent Risk of MAIS=3+ Trauma in Frontal Impact by Crash Type

NASS Data 2000-2005 Frontal 11, 12, 1 o’clock
Selection Criteria for CI REN Case

- Case occupant: driver or right front passenger
- Severe Injury: AIS=3+ or 2 AIS=2
- PDOF range: 340 to 0 (left); 0 to 30 (right) degrees
- Vehicle damage did not involve loading of the longitudinal structural members along the X-axis
- No other end or side-plane impacts with an extent zone at least two
- No roll-over event
- The object contacted was another vehicle, a pole or a tree
CDC-Code FLEE or FREE Crashes: CIREN Analysis

71 cases analyzed

Of the 71:
- 50 drivers, 21 passengers
- 44 Males; 27 Females
- 32 from 16-34 yrs; 15 from 55-older
- 51 belted (72%)
- 70 (99%) airbag deployed
CI REN Analysis: 71 Corner Impacts

Occupant Age

Number of Cases

- <16: 2 cases
- 16-24: 18 cases
- 25-34: 14 cases
- 35-44: 14 cases
- 45-54: 8 cases
- 55-64: 10 cases
- 65-older: 5 cases
CI REN Analysis: 71 Corner Impacts

Vehicle Model Year

Cases

CI REN Analysis: 71 Corner Impacts

Vehicle Type

- subcompact
- compact
- midsize
- large
- SUV
- LTV
- Van
CIREN Analysis:  71 Corner Impacts
Occupant Injuries

Occupants with AIS=2+ Injuries

- Head: 30
- Spine: 20
- Chest: 20
- Abdomen: 15
- Pelvis: 10
- Low Extr: 40
- Up Extr: 40

Legend:

- Light blue: Total count
- Dark blue: AIS=2+ count
CI REN Analysis: 71 Corner Impacts

Occupant Injuries

Occupants with AIS=3+ Injuries

- Head
- Spine
- Chest
- Abdomen
- Pelvis
- Low Extr
- Up Extr
Examples of Extremity Trauma: AIS S=3
71 CI REN Corner Impacts: Head Trauma

- 12 LOC or Concussion  AIS=2+
- 5 hematoma/hemorrhage  AIS=3
- 2 Basilar skull fractures  AIS=3
- 3 Cerebrum contusion  AIS=3
- 1 DAI  AIS=5
- 2 Brain Stem Lac or Head crush AIS=6
CI REN Analysis: 71 Corner Impacts
Trauma Associated with Head Injury

% of Occupants with AIS=2+ Head Injuries

Spine Chest Abdomen Pelvis Low Extr Up Extr
71 CI REN Corner Impacts: Chest Trauma

- 5 Aorta/Heart Laceration  AIS=5+
- 17 Rib Fractures  AIS=2+
- 9 Lung contusions  AIS=3+
CIREN Analysis: 71 Corner Impacts
Trauma Associated with Chest Injury

% of Occupants with AIS=2+ Chest Injuries

- Head: 45%
- Spine: 10%
- Abdomen: 45%
- Pelvis: 35%
- Low Extr: 75%
- Up Extr: 40%
71 CI REN Corner Impacts: Lower Extremity Trauma

- 33 Femur Fractures AIS=3
- 22 Tibia/Fibula Fractures AIS=2 or 3
- 24 Pelvis Fracture or Crush AIS=2, 3, or 4
CI REN Analysis: 71 Corner Impacts
Trauma Associated with Low Extremity Injury

% of Occupants with AIS=2+ Low Extremity Injuries

- Head: 35%
- Spine: 10%
- Chest: 50%
- Abdomen: 25%
- Pelvis: 30%
- Up Extr: 40%
CI REN 71 Corner Impacts: Severity

**Extent Zone vs ISS**

\[ y = 0.0628x + 17.355 \]
\[ R^2 = 0.0001 \]

**Max Crush vs ISS**

\[ y = 0.0797x + 12.079 \]
\[ R^2 = 0.0988 \]

**Delta-V vs ISS**

\[ y = 0.1404x + 11.943 \]
\[ R^2 = 0.0603 \]

**Damaged Wheel Base vs ISS**

\[ y = 0.0046x + 15.821 \]
\[ R^2 = 0.0004 \]
Extent

Front-end plane

Measurement axis

Zone 6  Zones 7 & 8

Zones 1-5
Cl REN Analysis: 71 Corner Impacts

Front Tree/Pole Crashes

- 31 cases
- Extent Zone
  - Zone-2-5: 21 cases
  - Zone-6-9: 11 cases
- Average ISS = 18
CI REN Analysis: 71 Corner Impacts

Front-to-front Crashes
- Matched Vehicles

- 22 cases
- Extent Zone
  - Zone-2-5: 7 cases
  - Zone-6-9: 15 cases
- Average ISS = 18
Front-to-front Crashes – Mismatched Vehicles

- 16 cases
- Extent Zone
  - Zone-2-5: 4 cases
  - Zone-6-9: 12 cases
- Average ISS = 24
CI REN Analysis: 71 Corner Impacts

Zones 1-5

Zones 6-9

Percent Occupants with AIS=2+ Injuries

- Extent 2-5
- Extent 6-9

Head | Spine | Chest | Abdomen | Pelvis | Low Extr | Up Extr
---|---|---|---|---|---|---

Bar Chart: Comparison of injury distribution across different anatomical regions for Extent 2-5 and Extent 6-9.
CI REN Analysis: 71 Corner Impacts

Zones 1-5
Zones 6-9

Percent Occupants with AIS=3+ Injuries

- Extent 2-5
- Extent 6-9

- Head
- Spine
- Chest
- Abdomen
- Pelvis
- Low Extr
- Up Extr
Injury Mechanism Theory: Corner Impacts

Extent Zone 1-5

Occupant
Side Impact

Extent Zone 6-9

Occupant
Frontal Impact
Conduct Corner Impact Crash Test
Corner Impact Crash Test Results

Crash test video
Corner Impact Crash Test Results

Crash test video
Corner Impact Crash Test Result

- Vehicle linear acceleration (x)
- Vehicle linear acceleration (y)
- Vehicle angular velocity (z)

Extent zone = 4
Corner Impact Crash Test Results

Driver Response

Passenger Response

TTI = 6.9
Corner Impact Crash Test Results

Passenger Chest Deflections

RibEye® Instrumentation

Front-to-Back Deflections

LEFT CHEST

<table>
<thead>
<tr>
<th>Rib</th>
<th>Displacement (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LX</td>
<td>19.7</td>
</tr>
<tr>
<td>2 LX</td>
<td>19.1</td>
</tr>
<tr>
<td>3 LX</td>
<td>18.3</td>
</tr>
<tr>
<td>4 LX</td>
<td>17.6</td>
</tr>
<tr>
<td>5 LX</td>
<td>17.5</td>
</tr>
<tr>
<td>6 LX</td>
<td>15.0</td>
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</tbody>
</table>

RIGHT CHEST

<table>
<thead>
<tr>
<th>Rib</th>
<th>Displacement (mm)</th>
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</thead>
<tbody>
<tr>
<td>1 RX</td>
<td>7.0</td>
</tr>
<tr>
<td>2 RX</td>
<td>5.2</td>
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<tr>
<td>3 RX</td>
<td>5.7</td>
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<tr>
<td>4 RX</td>
<td>4.5</td>
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<tr>
<td>5 RX</td>
<td>3.8</td>
</tr>
<tr>
<td>6 RX</td>
<td>3.8</td>
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</tbody>
</table>
Corner Impact Crash Test Results

Passenger Chest Deflections
RibEye® Instrumentation
Left-to-Right Deflections

<table>
<thead>
<tr>
<th>LEFT CHEST</th>
<th>RIGHT CHEST</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIB 6 LY</td>
<td>RIB 1 RY</td>
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<tr>
<td>5.8 mm</td>
<td>8.0 mm</td>
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<tr>
<td>RIB 5 LY</td>
<td>RIB 2 RY</td>
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<tr>
<td>6.1 mm</td>
<td>8.0 mm</td>
</tr>
<tr>
<td>RIB 4 LY</td>
<td>RIB 3 RY</td>
</tr>
<tr>
<td>5.4 mm</td>
<td>8.4 mm</td>
</tr>
<tr>
<td>RIB 3 LY</td>
<td>RIB 4 RY</td>
</tr>
<tr>
<td>5.1 mm</td>
<td>8.1 mm</td>
</tr>
<tr>
<td>RIB 2 LY</td>
<td>RIB 5 RY</td>
</tr>
<tr>
<td>5.0 mm</td>
<td>8.0 mm</td>
</tr>
<tr>
<td>RIB 1 LY</td>
<td>RIB 6 RY</td>
</tr>
<tr>
<td>4.9 mm</td>
<td>8.5 mm</td>
</tr>
</tbody>
</table>

Displacement (mm)
Summary: 71 Corner Impact Crashes

- Frontal corner impacts a significant percentage of fatalities/severe trauma
- Severe lower extremity trauma with chest and pelvis trauma
- Impact type matters
  - Tree/pole or Matched vehicles: ISS=18
  - Mismatched vehicles: ISS=24
- Delta-V, crush measures not good predictors of trauma severity
- Extent zone crush may cause different occupant kinematics and interaction with airbag
- Recommend vehicle structural inspection with crush measures
Acknowledgment

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