Child Restraints in Side Impact Crashes

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Objectives

- Differentiate pediatric injury patterns of side impact crashes compared to other types of crashes
- Provide basic information for physicians regarding expected governmental regulations on side impact protection for children in child restraints
- Provide strategies that the child restraint industry might use to meet federal regulations.
- Provide anticipatory guidance about best practice recommendations for side impact protection in available products.
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Problem Identification

- Side impact high mortality and injury burden for rear seat occupants

2008 Fatalities (FARS)

- 41% frontal
- 36% side
- 18% rear
- 5% other

Rear seat, restrained occupants, all ages (n=563)

43% are 0-15 years
62% are 0-20 years
Children in Side Impact Injury Risk by Seat Position

- Front seat 2.6x as injurious as the rear, nearside occupants (Durbin et al. 2001)
- Nearsidé 2.5x as fatal as the center, restrained occupants – all restraints (Howard et al. 2004)
- Nearsidé 4.2x as injurious as farsidé+center, CRS-restrained (Howard et al. 2004)
- Nearsidé 1.8x as injurious as farsidé, belt-restrained (Maltese et al. 2005)
# Injury Patterns

- Detailed Crash Investigations from:
  - CIREN - NHTSA
    - Crash year 1996+, MVC Occupants @ Level 1 trauma centers
  - Partners for Child Passenger Safety – CHOP/State Farm
    - Crash year 1998+, Insured MVC Child Occupants

<table>
<thead>
<tr>
<th>Analysis</th>
<th>PDOF</th>
<th>Restraint</th>
<th>Age</th>
<th>Seat position</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis 1</td>
<td>45-135°</td>
<td>Seat belt</td>
<td>4-15 yrs</td>
<td>Rear row, near side</td>
<td>24</td>
</tr>
<tr>
<td>(Maltese et al, Stapp 2007)</td>
<td>225-315°</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Analysis 2</td>
<td>7-11 o’clock; 1-5 o’clock</td>
<td>RFCRS, FFCRS, BPB</td>
<td>0-8 yrs</td>
<td>Rear row, any seat position</td>
<td>41</td>
</tr>
<tr>
<td>(Arbogast et al, JTrauma 2011)</td>
<td></td>
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</tbody>
</table>
Results – Seat Belt Restrained Crash Conditions

- Delta V: 30 ± 14 km/h
Results – Seat Belt Restrained Occupant Characteristics

- Age: 9 ± 3 years
- Height: 139 ± 20 cm
- All restrained by 3-pt belts (no CRS/booster)
Results – Seat Belt Restrained Injured Body Regions

Body Region

- Head
- Face
- C-Spine
- Thorax
- Abdomen
- T-Spine
- Up Ext
- Pelvis
- Low Ext

Percent of Cases

- 40%
- 35%
- 30%
- 25%
- 20%
- 15%
- 10%
- 5%
- 0%

Juvenile Products Manufacturers Association
On the left, you see an artist’s rendering of the interior of a motor vehicle that was involved in a crash, with one or more numbers in the picture. The numbers signify the location inside the vehicle where an occupant contacted the vehicle interior. Your task is to estimate the position of the numbers relative to the position of the seatback, locate the corresponding cell in the image on the left, and type the number in the cell.
Results – Seat Belt Restrained Contact Points
Results – Seat Belt Restrained Head and Face Contact Points

- 50% head/face contacts were to crash partner
- 79% head/face contacts were to the rear ½ of window
- All intracranial injuries were associated with evidence of head contact
Children in CRS
Crash Characteristics - PDOF
Child Characteristics

Child Age
- 0-11 months: 27%
- 12-47 months: 49%
- 5-8 years: 24%

Seat Position
- Near side: 59%
- Center: 24%
- Far side: 17%

Restraint Type
- Booster seat: 37%
- Forward Facing CRS: 46%
- Rear facing CRS: 17%

8/41 were not in the right restraint for their age/size
3/15 booster seats were shield boosters
Body Region of Injury by Restraint Type

- 100% AIS2+
- 54% AIS3+
- 32% AIS4+

Body Region:
- Head
- Face
- Thorax
- Abdomen
- Spine
- Upper Extremity
- Lower Extremity

Number of Injured Body Regions

- Rear-facing
- Forward-facing
- Booster

100% AIS2+
54% AIS3+
32% AIS4+
Body Region of Injury by Seating Position

![Bar chart showing the number of injured body regions by seating position. The categories are Head, Face, Thorax, Abdomen, Spine, Upper Extremity, and Lower Extremity. The chart compares Nearside, Center, and Farside injuries. The Head category shows the highest number of injuries.]
Involved Physical Components Near Side Crashes

- Belt/harness
- Pillars
- CRS structure
- Door interior
- Intruding object
- Other occupant
- Roof rail
- Sill
- Unknown/other injury
- Window frame

Counts of injured body regions:
- Spine
- Lower Extremity
- Abdomen
- Thorax
- Face
- Head

Juvenile Products Manufacturers Association
Exemplar Near Side Crash

- 2002 Toyota Camry
- Making left turn
  - Delta V = 28 kph
    - Lat. Comp. = 24 kph
    - Long. Comp. = 14 kph
- PDOF = 60°
- Intrusion at occupant seating position: 39 cm

- Occupant
  - 5 year old (21 kg, 46 lbs)
  - Right rear
  - Restrained in booster seat
Exemplar Near Side Crash

- **Head**
  - Cerebral subarachnoid hemorrhage
  - Cerebellar subarachnoid hemorrhage
  - Hemorrhage in midbrain/brainstem

- **Thorax/Abdomen**
  - Bilateral pulmonary contusions
  - Diaphragm laceration
  - Liver laceration
  - Renal vein transection
# Exemplar Near Side Crash

<table>
<thead>
<tr>
<th>Injury</th>
<th>Injury Causation scenario</th>
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<tbody>
<tr>
<td>Cerebrum subarachnoid hemorrhage</td>
<td>Door interior to head</td>
</tr>
<tr>
<td>Cerebellum subarachnoid hemorrhage</td>
<td>Door interior to head</td>
</tr>
<tr>
<td>Cerebellum subdural hematoma</td>
<td>Door interior to head</td>
</tr>
<tr>
<td>Bilateral lung contusions</td>
<td>CRS shell to thorax</td>
</tr>
<tr>
<td>Diaphragm laceration</td>
<td>CRS shell to thorax</td>
</tr>
<tr>
<td>Liver venous transection</td>
<td>CRS shell to abdomen</td>
</tr>
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<td>Liver laceration</td>
<td>CRS shell to abdomen</td>
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Exemplar Far Side Crash

- 1996 Dodge Intrepid
- Straight through intersection
  - Delta $V = 34$ kph
    - Lat. Comp. = 29 kph
    - Long. Comp. = 17 kph
  - PDOF = 60°
  - Max. intrusion: 36 cm @ B-Pillar
- Occupant
  - 2 year old (89 cm, 13 kg)
  - Center rear
  - Restrained in FFCRS

Juvenile Products Manufacturers Association
Exemplar Far Side Crash

- Head/Face
  - Right frontal lobe contusion
  - Right superior, medial orbital wall fracture
  - Right maxillary fracture
- Lower Ex
  - Left fibular fracture
  - Comminuted left tibia fracture
## Exemplar Far Side Crash

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<td>Right frontal lobe contusion</td>
<td>Seatback to head</td>
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<tr>
<td>Maxilla fracture</td>
<td>Seatback to face</td>
</tr>
<tr>
<td>Right orbit fracture</td>
<td>Seatback to face</td>
</tr>
<tr>
<td>Left distal tibia fracture</td>
<td>Seatback to leg</td>
</tr>
<tr>
<td>Left fibular fracture</td>
<td>Seatback to leg</td>
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</table>
Near Side – All Body Regions
Comparison to Belted Children

CRS Children (Arbogast et al)  Belted Children (Maltese et al)
Far Side/Center – All Body Regions

Occ. here
Injury Patterns

Conclusions

• Frontal component of side impact crash important
• Head and face injury most common
• For belt restrained occupants, majority of head and face contacts
  • Horizontally in the rear half of the window
  • Vertically from the sill to the center of the window
  • Half of head/face contact points to crash partner
• For CRS restrained occupants, head and face contacts
  • Near side – CRS Structure and Door Interior
  • Far side/center – Seat back of the seat in front of them
  • Head/spine injuries without evidence of contact rare but present in all seat positions
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Current CRS Regulations and Consumer Ratings – USA/Canada

- FMVSS 213 (“CRS regulation”) – currently frontal only
- CRS Manufacturer side impact protection claims
  - Any claim of side impact protection by CRS is company-specific, not standardized.
  - Some are based on test method from Europe or Australia
  - Some based on combination FMVSS 213/FMVSS 214 (“adult side impact standard”) test method
  - Dorel/Kettering side impact test method
  - Some based on energy absorbing materials
Current CRS Regulations and Consumer Ratings – USA/Canada

• Rating Programs
  • NHTSA New Car Assessment Program – NCAP “stars”
    – Side impact stars do not describe child safety
  • IIHS Vehicle Ratings
    – Side impact ratings do not describe child safety
  • Consumer Reports child seat ratings
    – Ratings based on frontal impact only
Current CRS Regulations and Consumer Ratings – Europe/AU

- **Europe**
  - Currently no EU regulation for side impact
    - Sled test regulation for side impact in development
  - Consumer Group Rating - ADAC
    - Test in a single vehicle body; 90° impact
  - EuroNCAP
    - Test 18 mo and 3 yr dummy in CRS in side impact
    - Part of vehicle rating

- **Australia**
  - AU Regulation – Sled test, 90° impact with and without door
  - Consumer Group Rating - RTA and RACV
    - Sled test, at both 90° and 45° impact with door
Vehicle Testing – Oblique Test

• Show oblique vehicle test video
NHTSA - Current Regulatory Activity for CRS Side Impact Impact

- NHTSA is developing side impact standard
  - Test is based on method proposed by Takata
  - Requires development of new side impact test dummy
  - Estimated implementation in 2013
Takata Side Impact Test Method
Takata Side Impact Test Method

• Show video of Takata Side Impact Test Method
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Recent CRS enhancements for improved side impact protection

- **Vehicle/CRS Interaction**
  - Air cushions on outside of CRS

- **CRS/Child Interaction**
  - Deeper sides
  - Energy absorbing materials
  - Air cushions
Future design strategies
Rear-facing CRS

• Vehicle/CRS Interaction
  • Increased energy absorbing design
  • Optimize for worst case vehicle pairing
  • Increased use of rigid LATCH

• CRS/Child Interaction
  • Expanded use of energy management/materials
  • Narrower/adjustable headrests

• Considerations
  • AAP recommendation-Rear-facing to 2 yrs
  • Side airbags
Future design strategies
Forward-facing CRS

• Vehicle/CRS Interaction
  • Deeper side support surfaces – head and torso
  • Accommodation for interaction with vehicle side airbags

• CRS/Child Interaction
  • Expanded use of energy management/materials
  • Narrower/adjustable headrests
  • Increased energy absorbing - mechanical design
Future design strategies
Belt-positioning Booster

• Vehicle/BPB Interaction
  • Deeper side support surfaces – head and torso
  • Accommodation for interaction with vehicle side airbags
  • Potential creation of two distinct groups of BPB
    – For use with side airbags
    – For use without side airbags

• BPB/Child Interaction
  • Narrower/adjustable headrests

• Installation:
  • Increase use of LATCH to secure BPB into vehicle
Future design strategies
All CRS

- CRS/Child Interaction
  - More adjustability for fit to child
  - Harness design

- Vehicle Installation
  - More seats with Rigid LATCH
  - Non—rigid LATCH improvements
  - Potential use of RF technology
  - Increased use of “Y” tether or two tethers

Note: Viable design countermeasures to reduce upper and lower extremity injuries are not available at this time.
Other potential design impacts

- Changes targeted at far side and center seat locations
  - Rear-facing
  - Forward-facing
  - Booster Seat
  - All CRS
Potential consequences

• **Use**
  - May make installation more complicated and more onerous
  - Deeper side wings combined with narrower headrest may cause child to lean forward increasing exposure of head

• **Increased retail price**
  - Additional material and design costs
  - Additional testing costs
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Key messages

- Side impact protection is about protecting and managing the energy experienced by the head
  - Minimize contact to hard structures
  - Cushioning for the head
  - Control distance and speed of head movement
  - Off-loading the crash forces as much as possible through energy management

- Until standard is developed, difficult to compare “side impact protection” offered by CRS
Messages to Families

- **Use**
  - Use an age-appropriate child restraint on every trip
  - Adjust the harness and CRS to snugly fit the child

- **Installation**
  - Secure installation in vehicle is a must
  - Use a tether to help control forward movement and rotation of child restraint in side impact

- **Design**
  - Side padding/cushioning offers added protection
  - Large sidewings offer added protection however may encourage forward leaning. Ensure the harness is tight and child sits back

- **Side curtain air bags likely help with child head protection**