Child Restraint Systems in Side Impact Crashes: Injury Patterns and Causation

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The Center for Injury Research and Prevention
Children's Hospital of Philadelphia

CIREN Public Meeting
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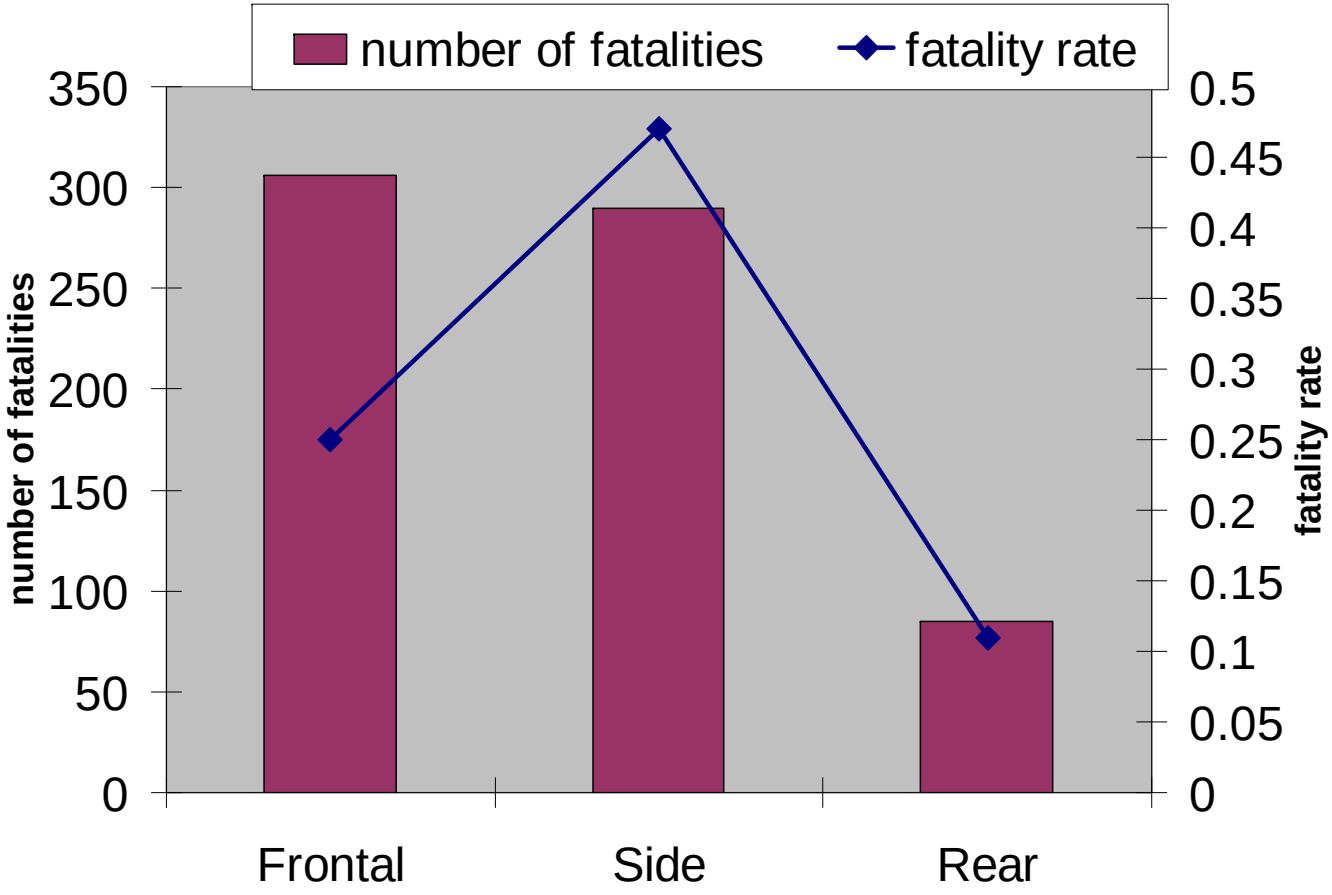
Side Impact Protection Important for Rear Seat Child Occupants



Number of Fatalities: 0-14 year olds, 2007
Fatality Rate: rear seated 0-7 year olds, 1996-2005

Previous Research Findings
Side Impact Risk Assessment

	Risk Increase
• Fatality risk	
– Nearside vs. center, rear, all restraints	2.5 [Howard, 2004]
• Injury risk	
– Nearside: front vs. rear, all restraints	2.6 [Durbin, 2001]
– Nearside vs. farside, belted rear	1.8 [Maltese, 2005]
– Nearside vs. center, rear, CRS	2.2 [Kallan, 2008]
– Nearside vs. farside, rear, FFCRS	4.2 [Arbogast, 2004]
– Nearside vs. center/farside, rear, CRS	4.2 [Howard, 2004]
– Belt vs. Booster, rear	1.7 [Arbogast, 2005]

→ Limited injury causation information

Previous Research Findings
Injury Causation Scenarios

- 19 cases of children 0 to 12 years (Howard et al. 2004)
  - Mixing of child age, restraint status, seat position
  - Injuries occurred with and without intrusion
- 14 fatal crashes of children 0 to 5 years (Sherwood et al. 2004)
  - Contributing factors: Intrusion, forward crash component, and head contact w/ external objects
- 32 cases of CRS-restrained occupants (Arbogast et al. 2005)
  - Contributing factors: Intrusion, forward crash component, and CRS rotation
- 46 cases of belt-restrained occupants (Maltese et al. 2007)
  - Injury causation grouped into common scenarios, vehicle contact map

Project Objectives

- To delineate injury causation scenarios for rear-seated, CRS-restrained children in side impact crashes
- To create a contact map of the vehicle interior

Methods

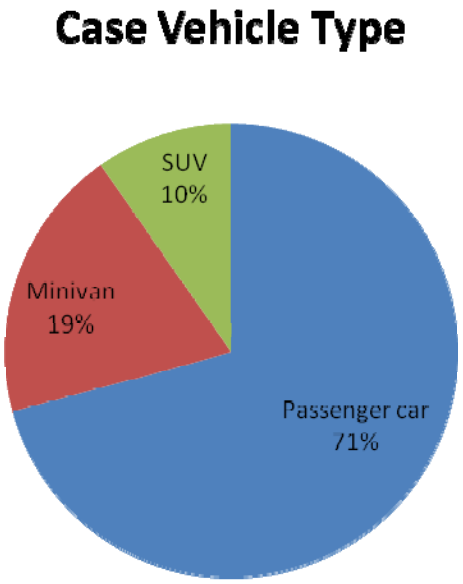
- Retrospective case review
  - Multidisciplinary case review team
- BIOTab – CIREN Method of Biomechanical Analysis
  - Injury Causation Scenario (ICS)
  - Involved Physical Components (IPC)
  - Regional/organ level mechanisms
  - Multiple ICS / IPC possible to capture all possibilities
- Contact Point Map
  - Geometrically summarize body region specific contact points

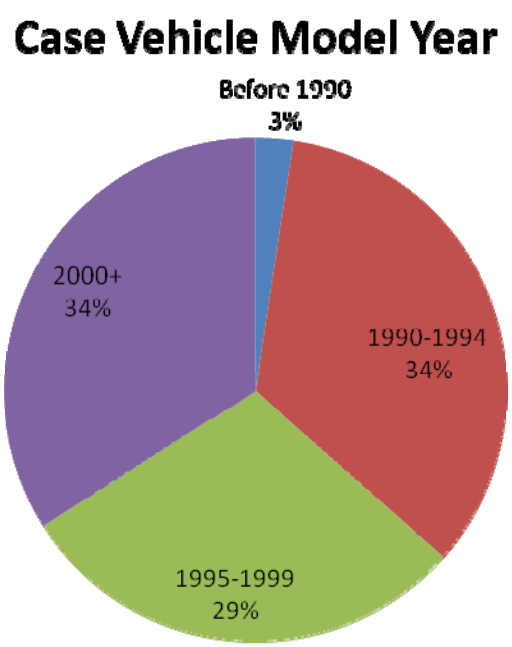
Methods – Case Selection

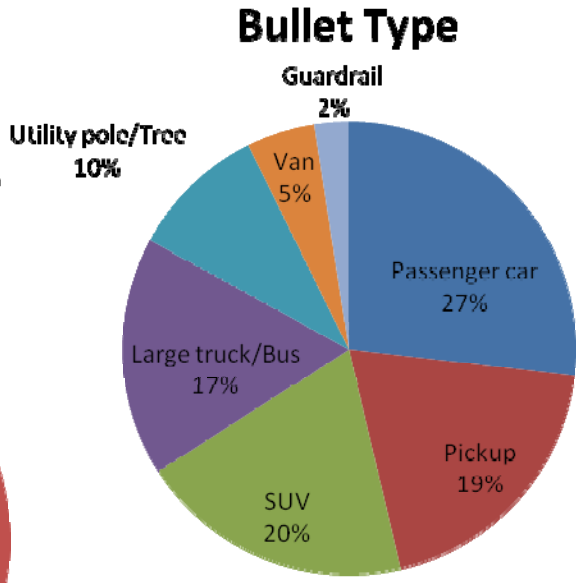
- CIREN and PCPS in-depth investigations
  - CIREN MY=current year-6 – earliest MY was 1987
  - PCPS MY =1990+
- Side impact crash defined as general area of damage = L or R
- Principal direction of force from 7 to 11 o'clock or 1 to 5 o'clock
- Child seated in the rear row(s) of the vehicle, any seat position
- Restrained by a rear- or forward-facing CRS or booster seat
- MAIS 2+ - cases with concussion as only injury excluded

41 CASES INCLUDED IN FINAL ANALYSIS

Crash Characteristics

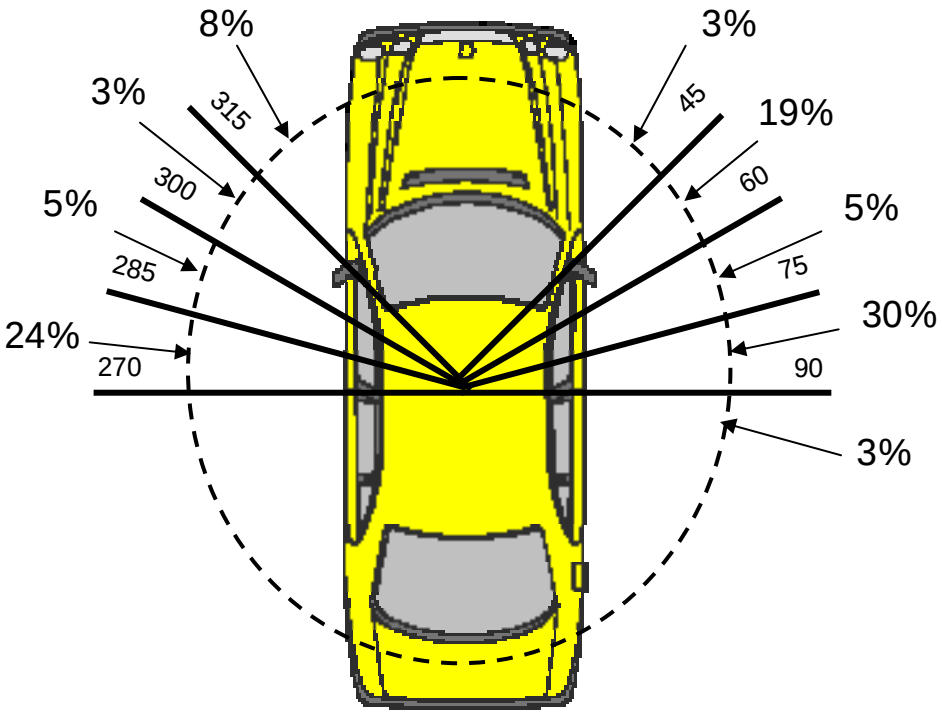




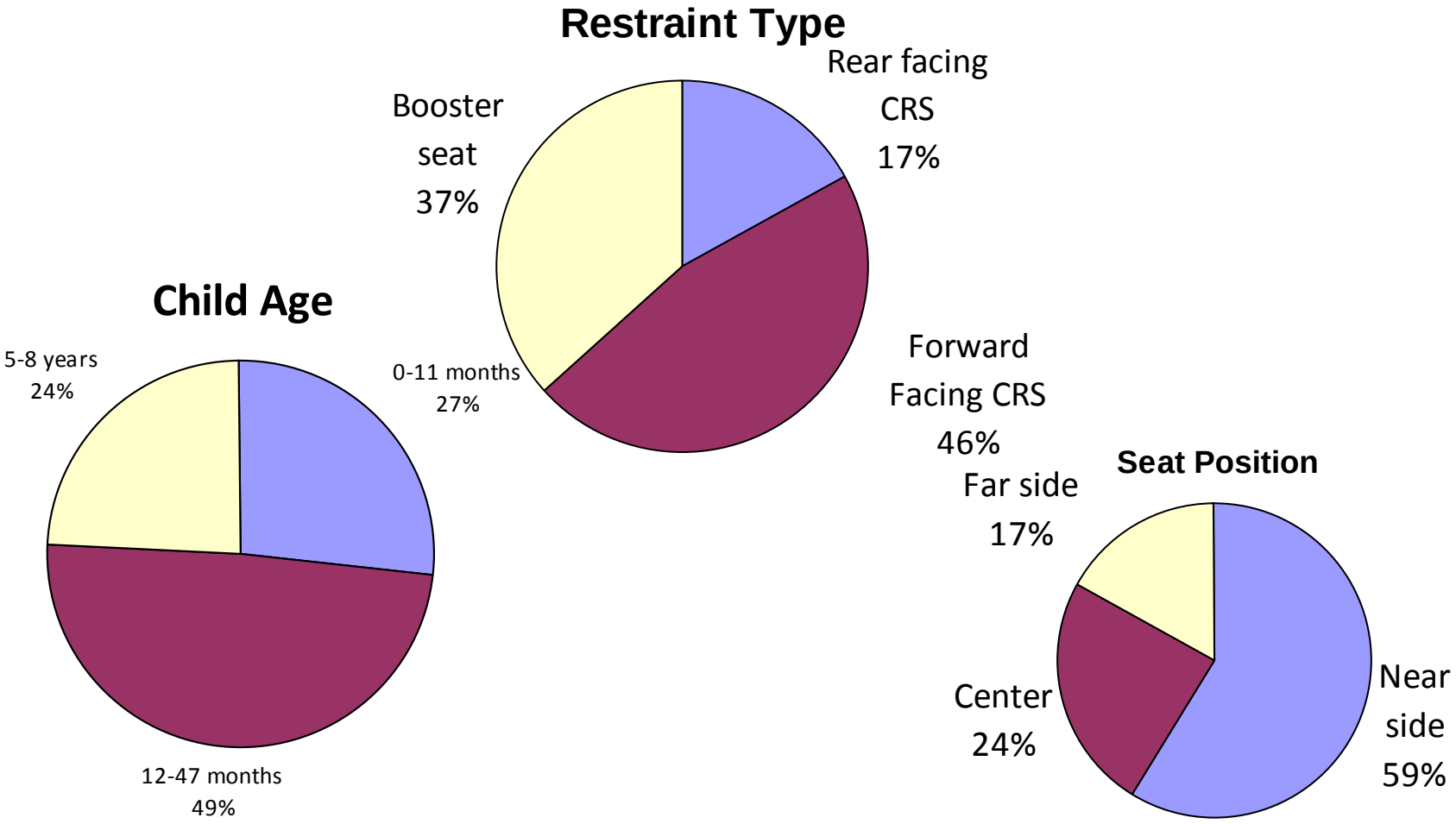


- 63% were right side impacts
- Mean Δv was 37$\pm$15 km/hr (note: mean long. Δv=10 km/hr)

Crash Characteristics - PDOF



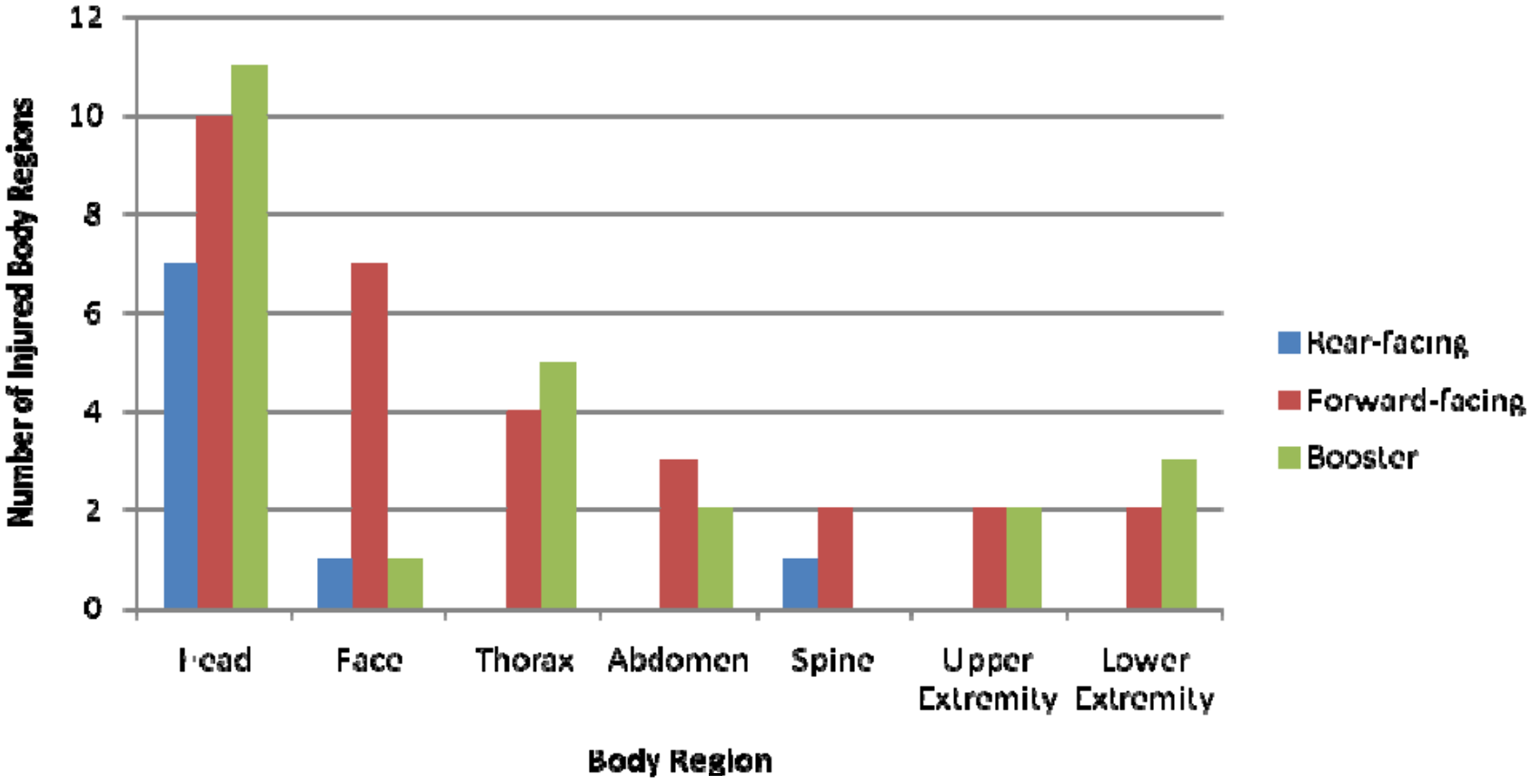
Child Characteristics



8/41 were not in the right restraint for their age/size

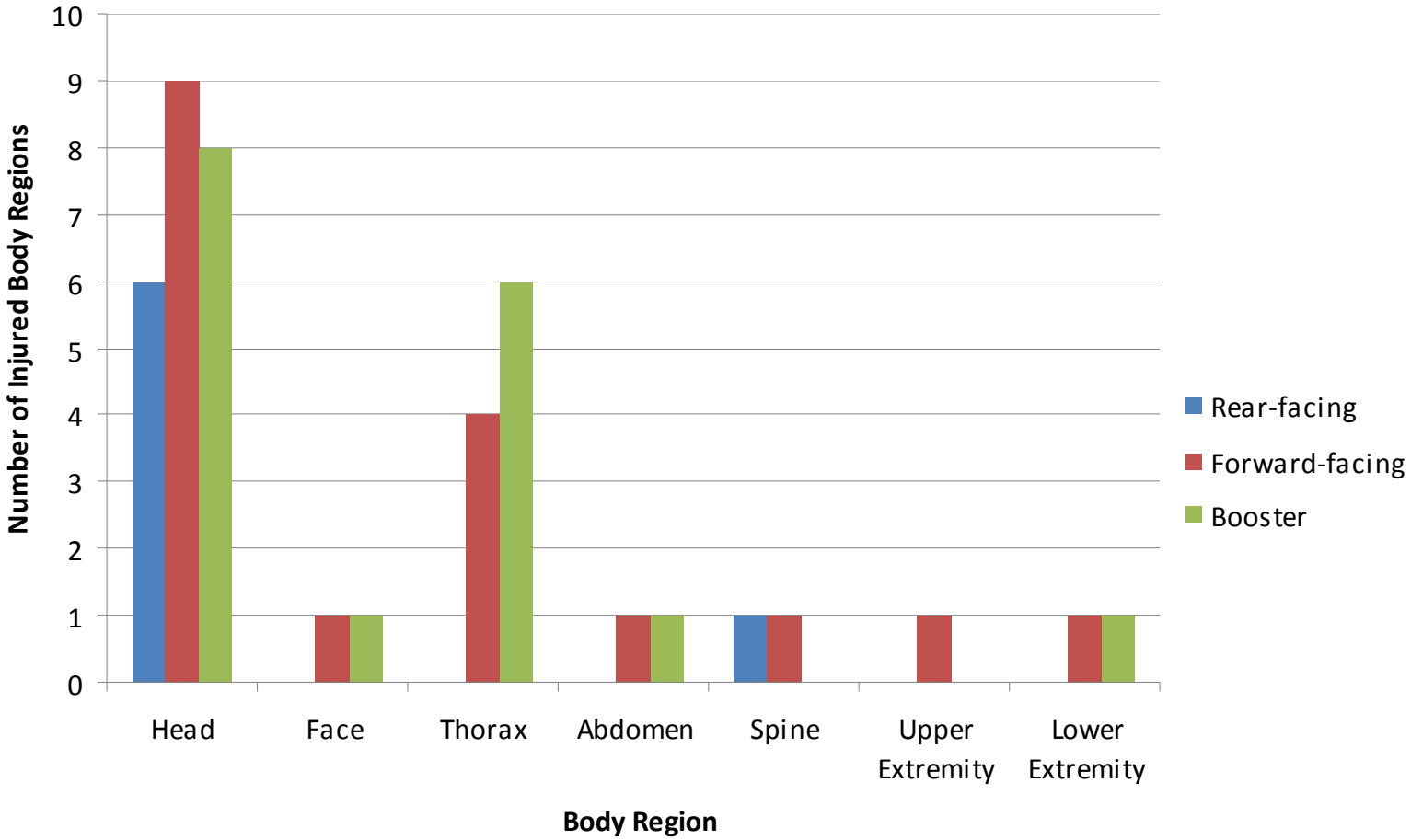
3/15 booster seats were shield boosters

Body Region of AIS2+ Injury by Restraint Type

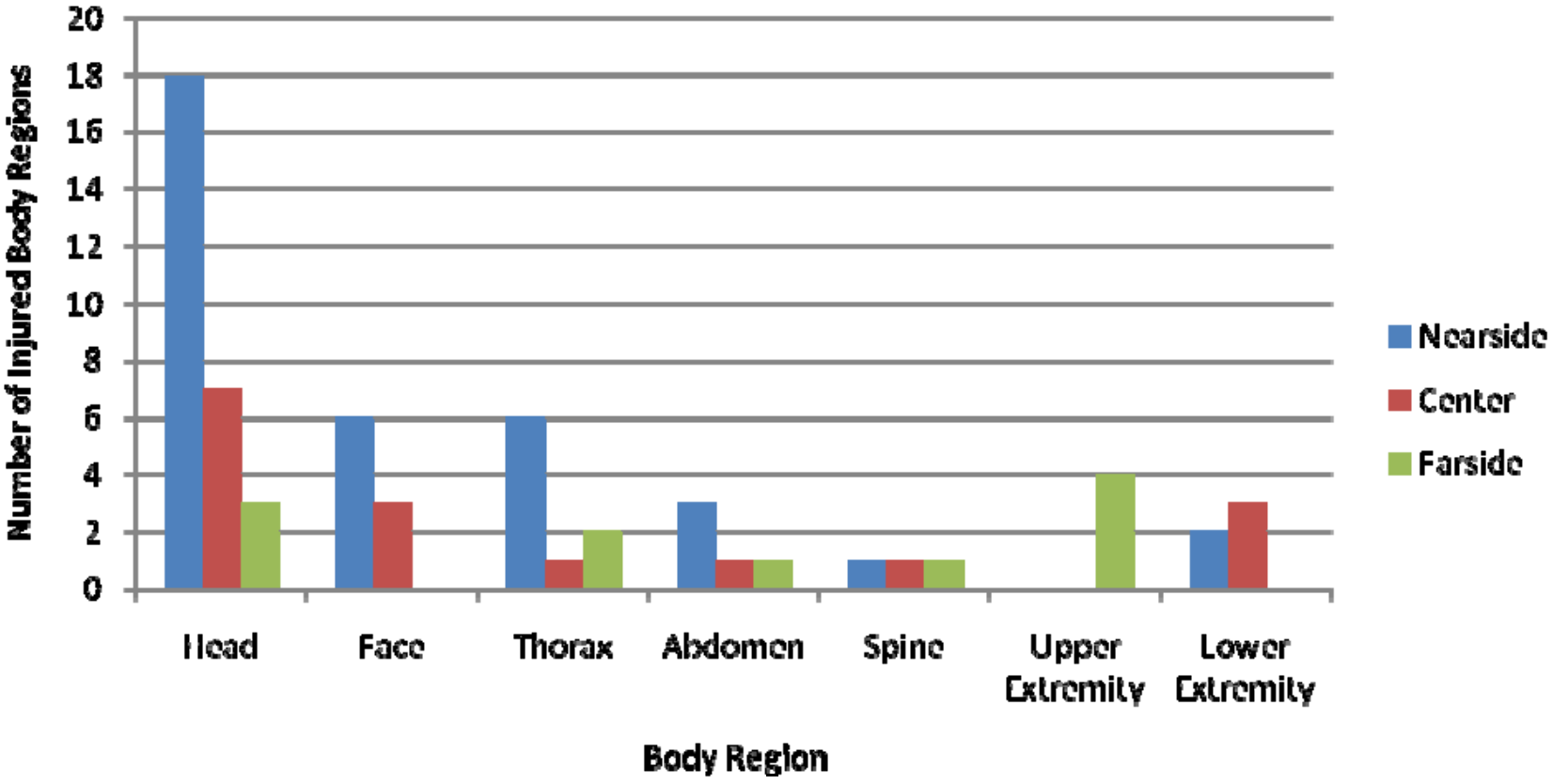


100% AIS2+
54% AIS3+
32% AIS4+

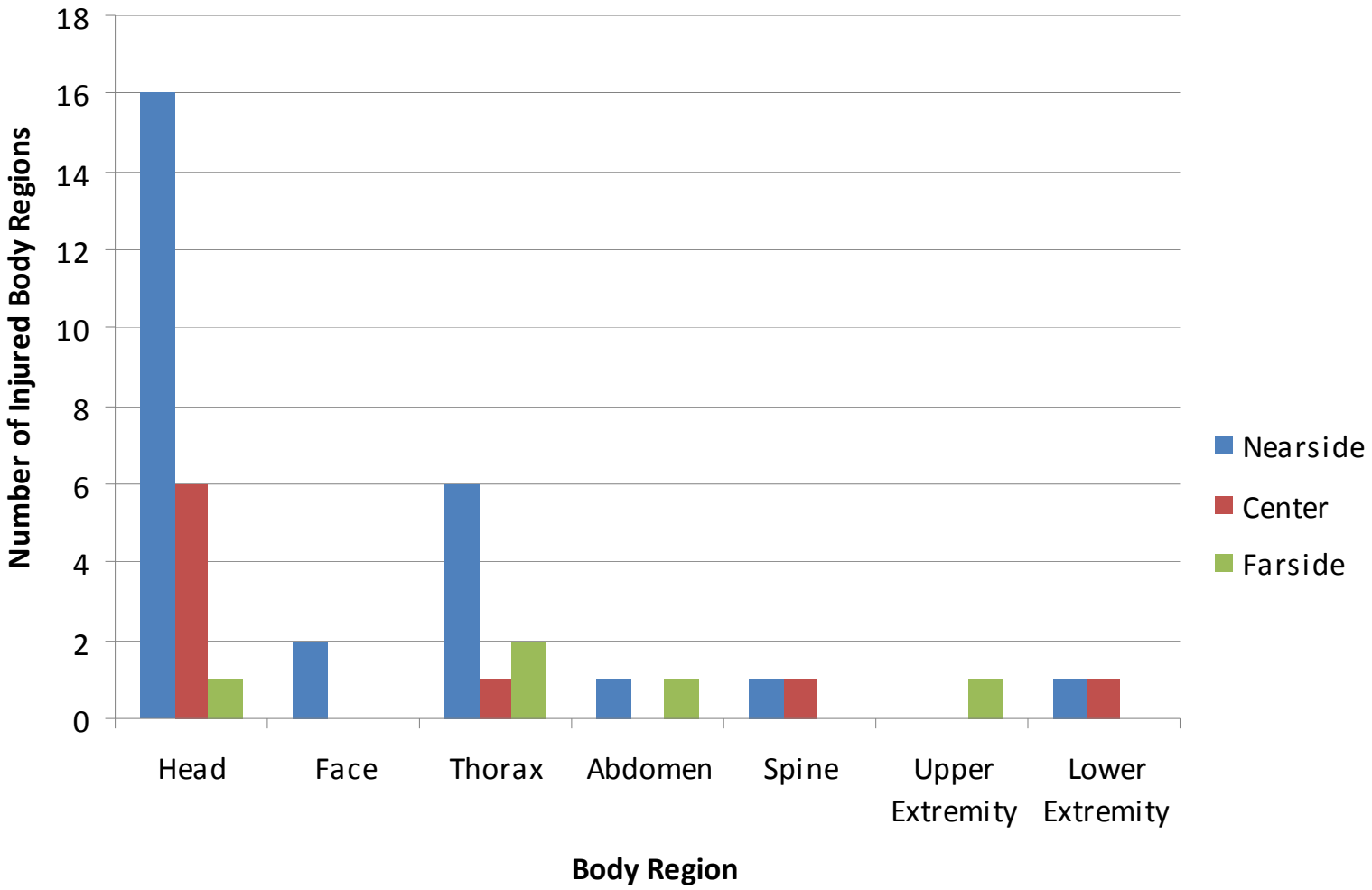
Body Region of AIS 3+ Injury by Restraint Type



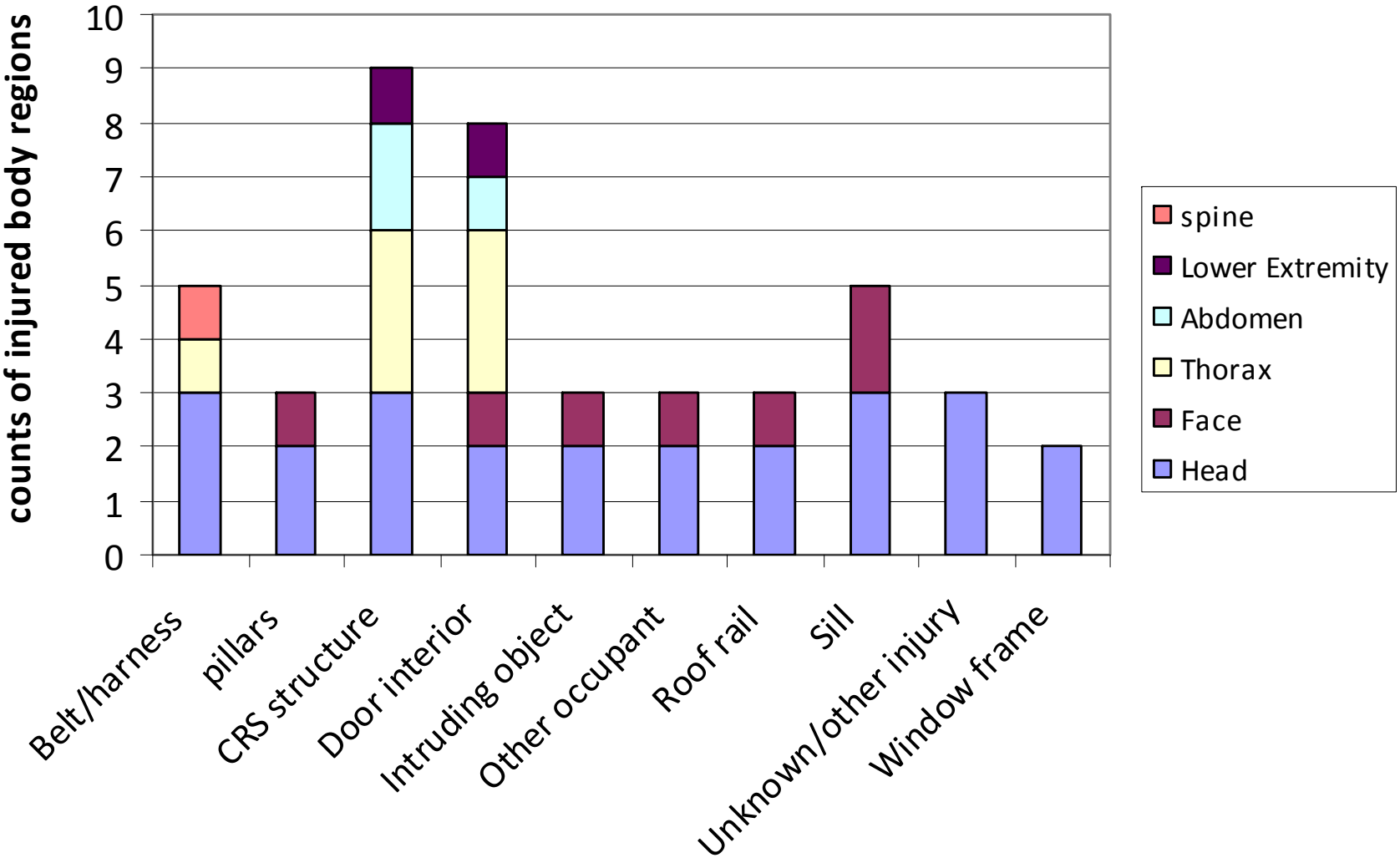
Body Region of AIS2+ Injury by Seating Position



Body Region of AIS 3+ Injury by Seating Position



Involved Physical Components Near Side Crashes – AIS2+



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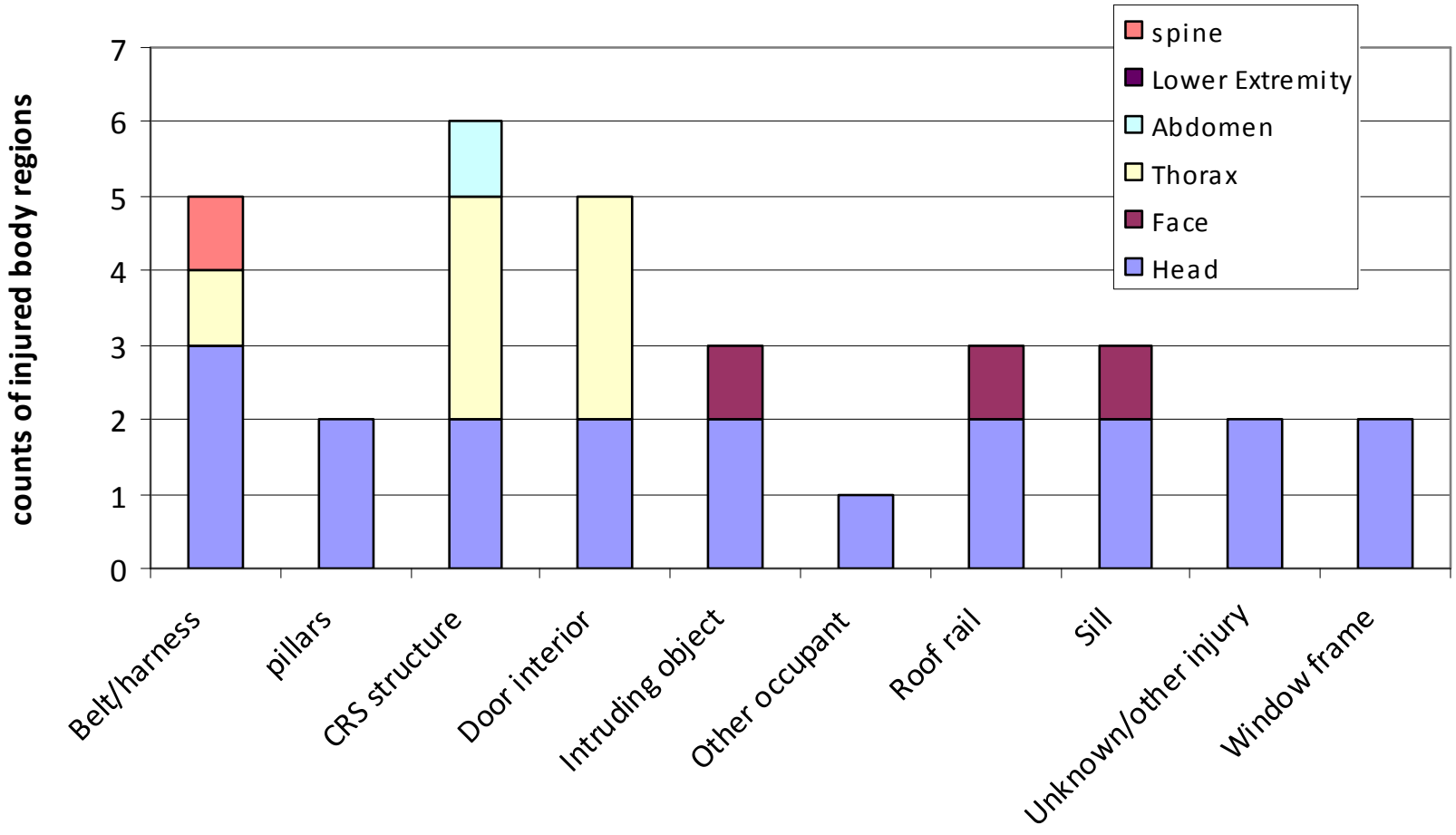
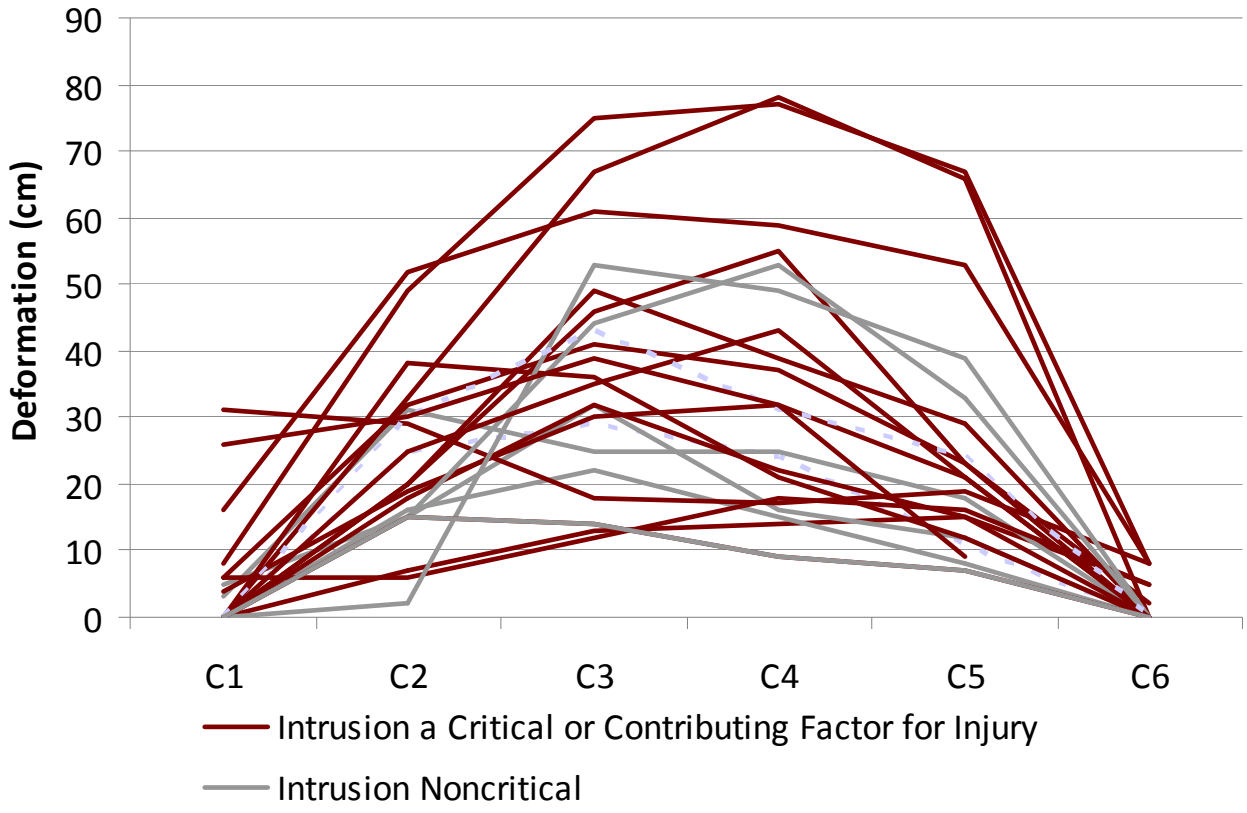


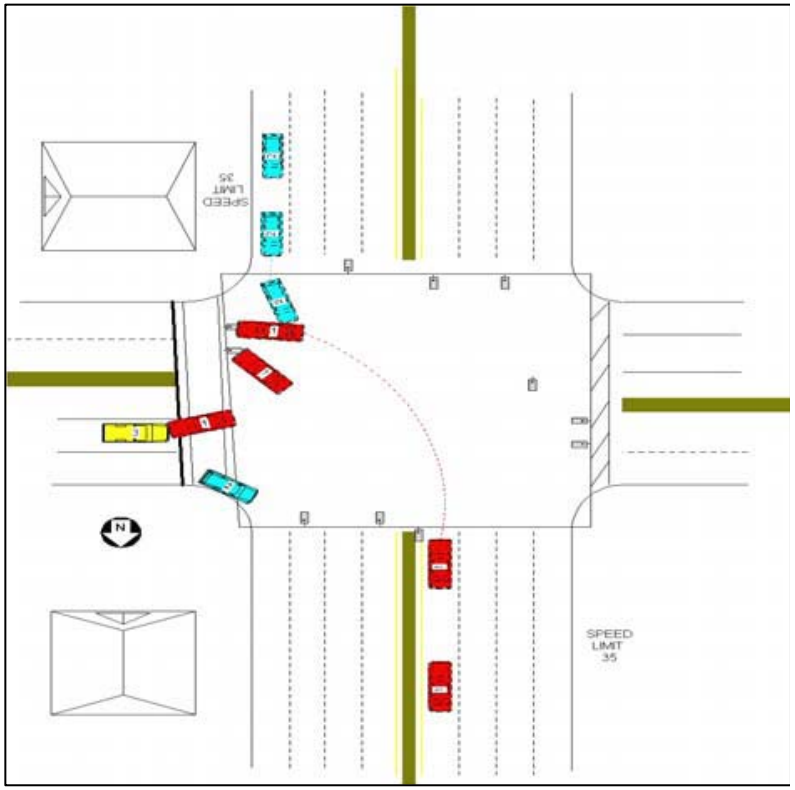
Near Side Crush Profile



Avg Max intrusion (as critical or contributing factor)=34±17 cm

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



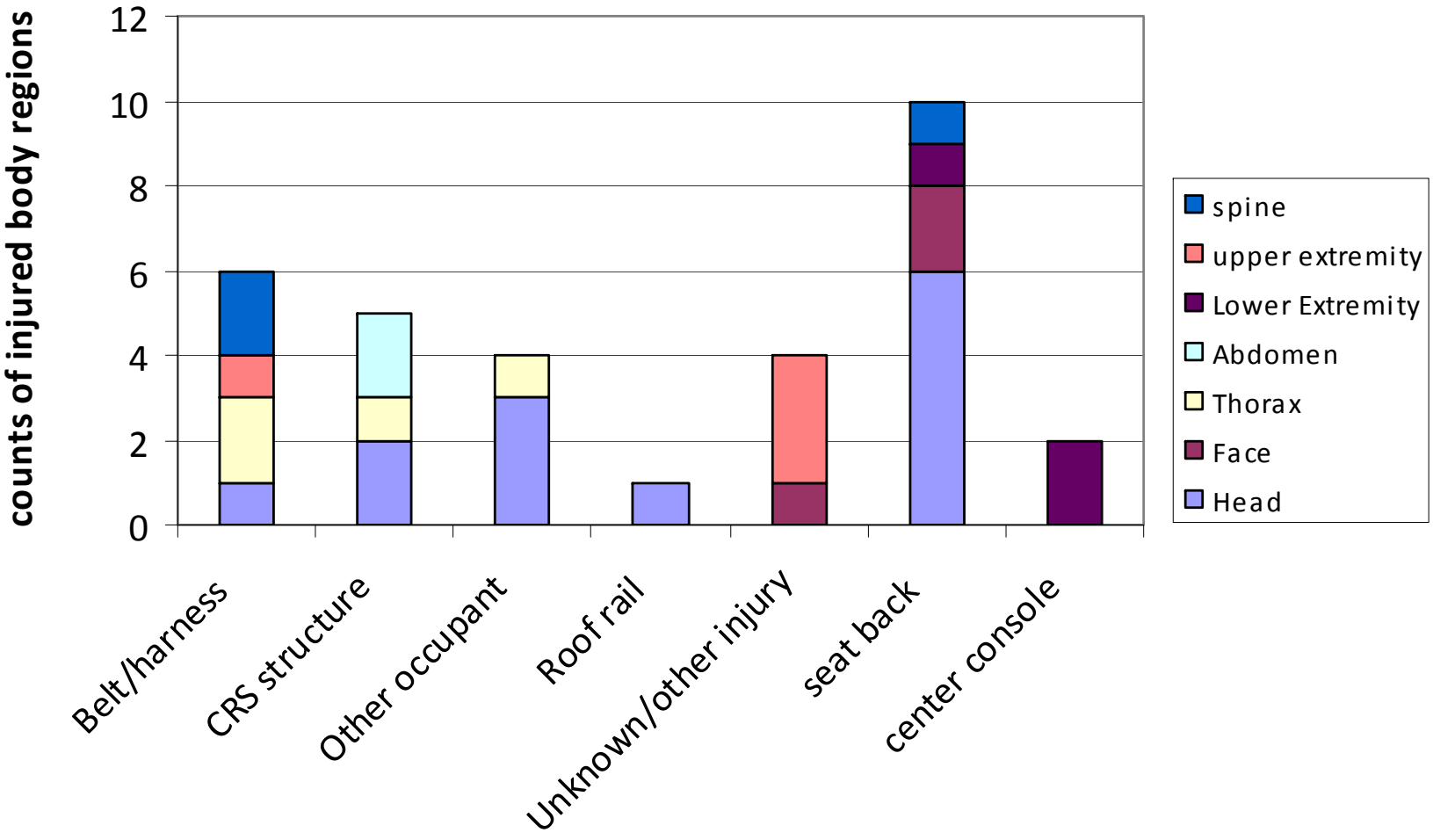
Exemplar Near Side Crash

- Head
  - Cerebral subarachnoid hemorrhage
  - Cerebellar subarachnoid hemorrhage
  - Hemorrhage in midbrain/brainstem
- Thorax/Abdomen
  - Bilateral pulmonary contusions
  - Diaphragm laceration
  - Liver laceration
  - Renal vein transection

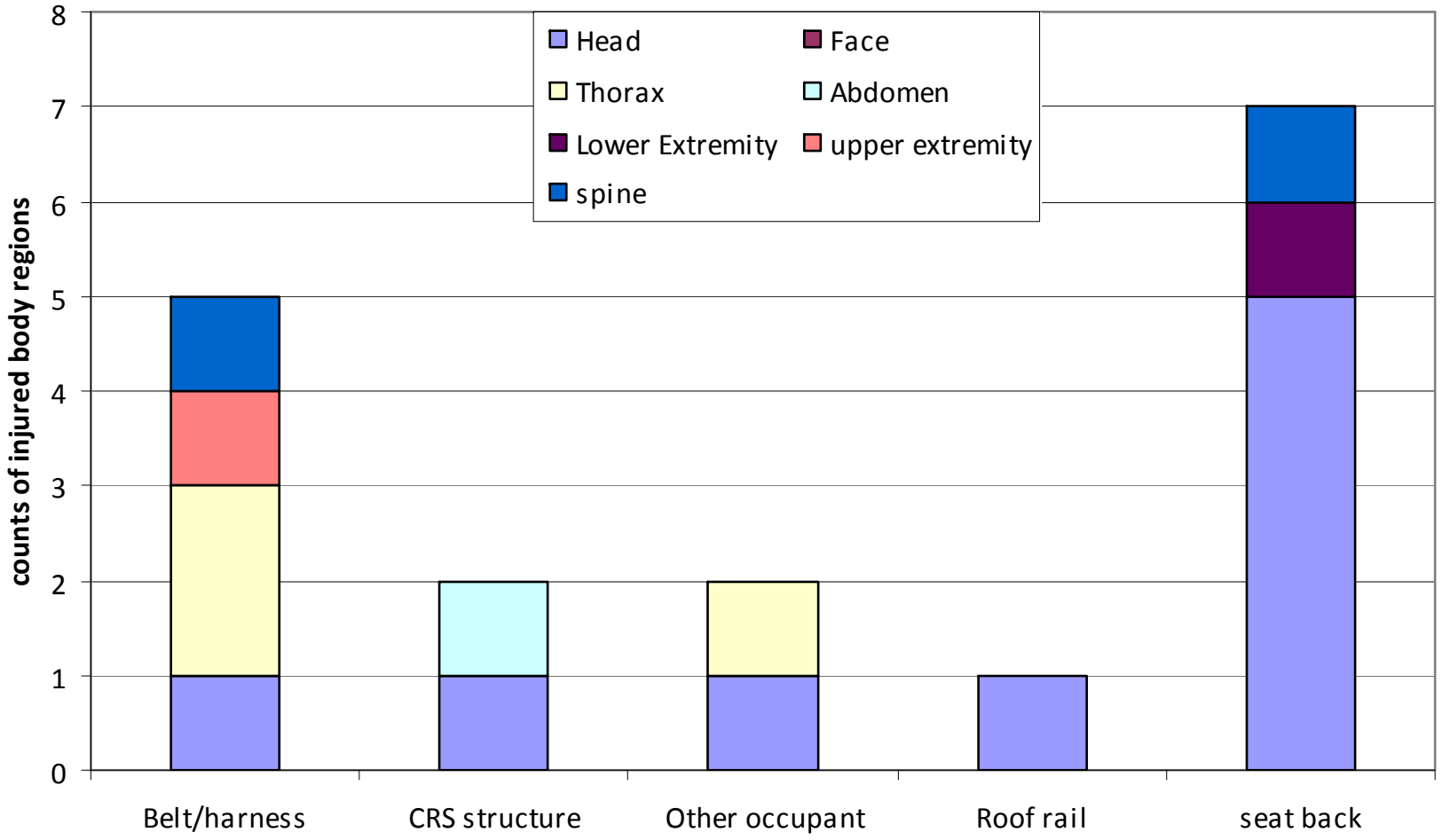
Exemplar Near Side Crash

Case Number	Impact Side	Body Region	ICS	IPC to Body Region Contacted	IPC Confidence	Specific Injury Description	AIS Code
377044651	R	Head	Contact with vehicle interior	Door interior to head	Probable	Cerebrum subarachnoid hemorrhage	140684.3
						Cerebellum subarachnoid hemorrhage	140466.3
						Cerebellum hematoma/hemorrhage subdural small	140442.4
		Thorax	Contact with CRS shell	CRS shell to thorax	Probable	Lung contusion bilateral with or without hemo-/pneumothorax	441410.4
						Diaphragm laceration (OIS Grade II thru IV)	440604.3
		Abdomen	Contact with CRS shell	CRS shell to abdomen	Probable	Liver venous transection	521499.3
						Liver laceration minor (OIS Grade I or II)	541822.2

Involved Physical Components Far Side/Center Crashes – AIS2+

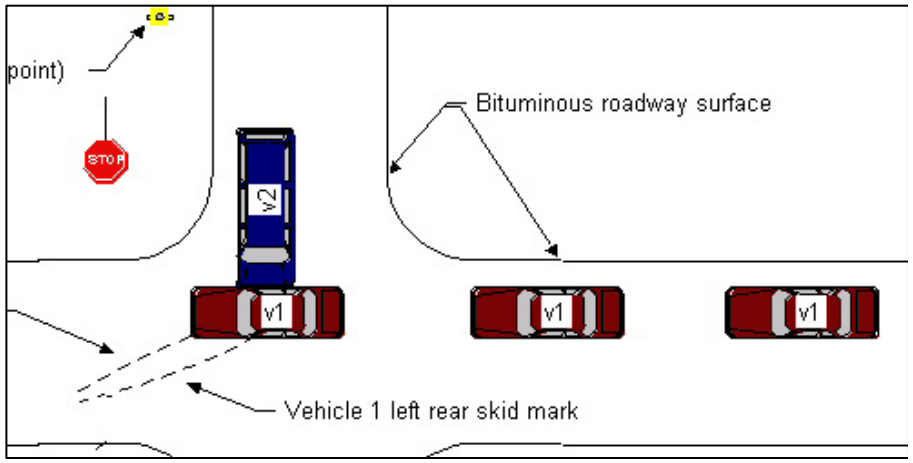


Involved Physical Components Far Side/Center Crashes – AIS3+



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



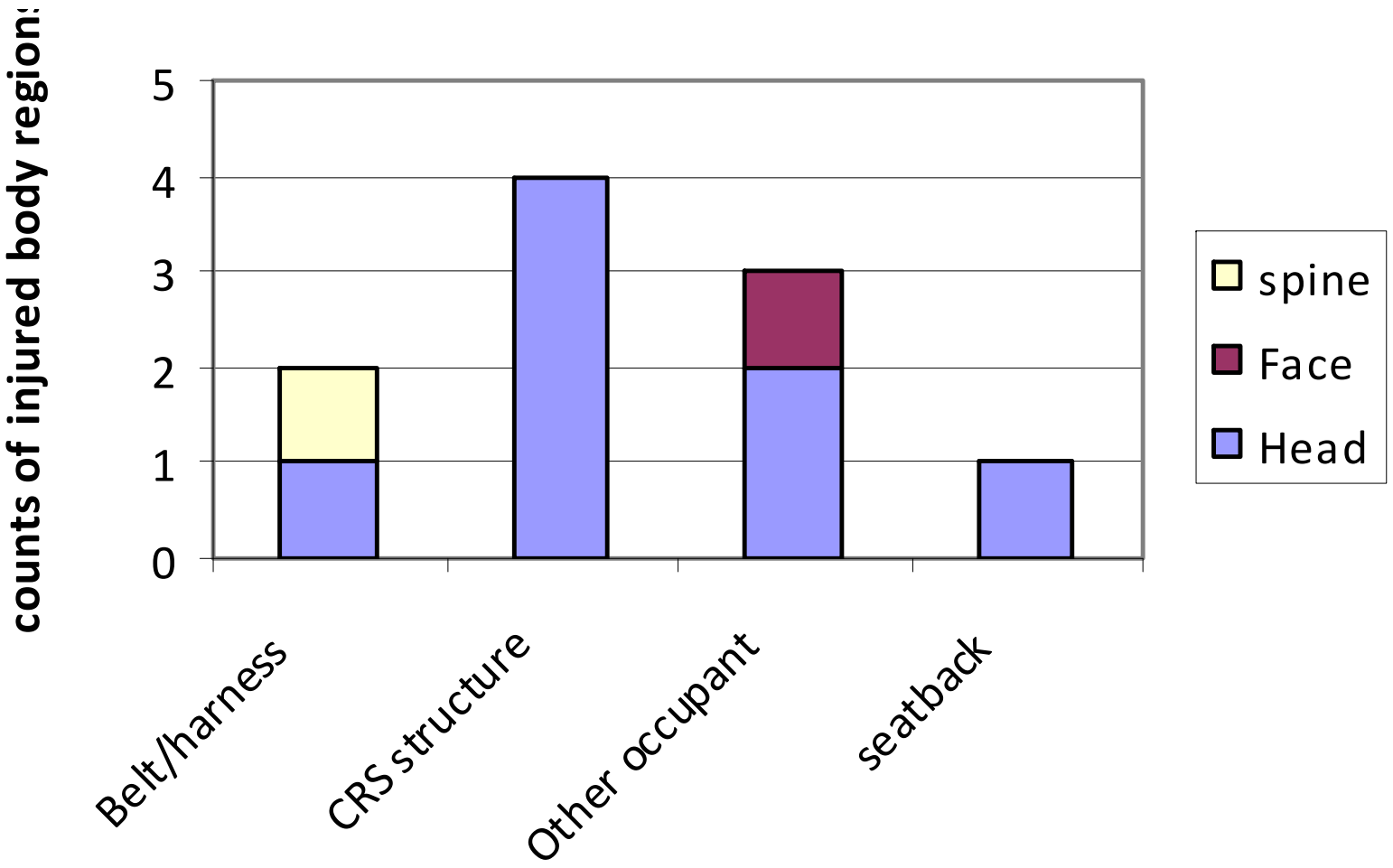
Exemplar Far Side Crash

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

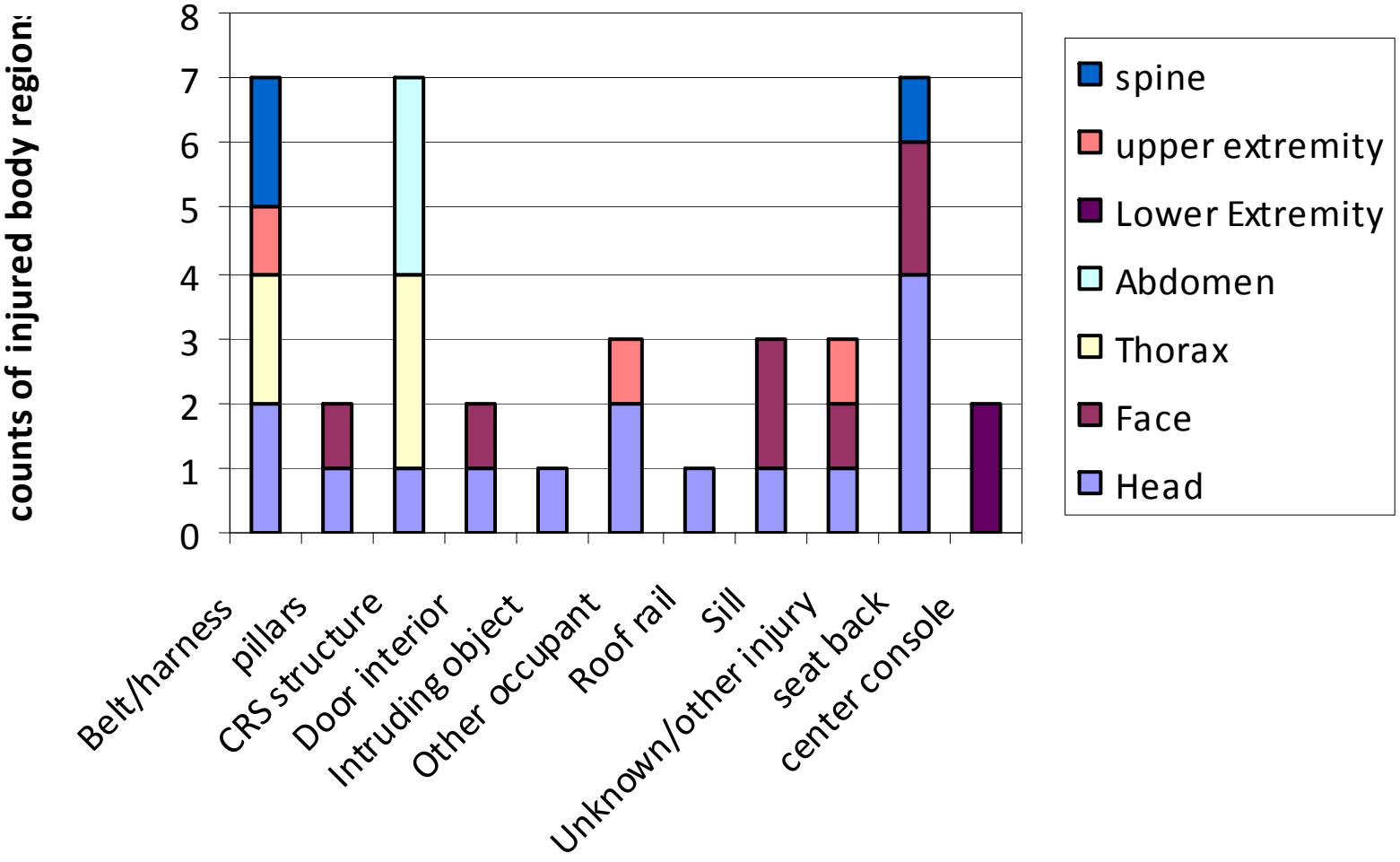
Exemplar Far Side Crash

Case Number	Impact Side	Relation to Crash	Body Region	ICS	IPC to Body Region Contacted	IPC Confidence	Specific Injury Description
1061256	R	Center	Head	Contact with vehicle interior	Seatback to head	Probable	R frontal lobe contusion
			Face	Contact with vehicle interior	Seatback to face	Probable	Maxilla fracture R Orbit fracture
			L Extremity	Contact with vehicle interior	Seatback to leg	Probable	Salter-Harris type fracture of L distal tibia
							L fibula fracture

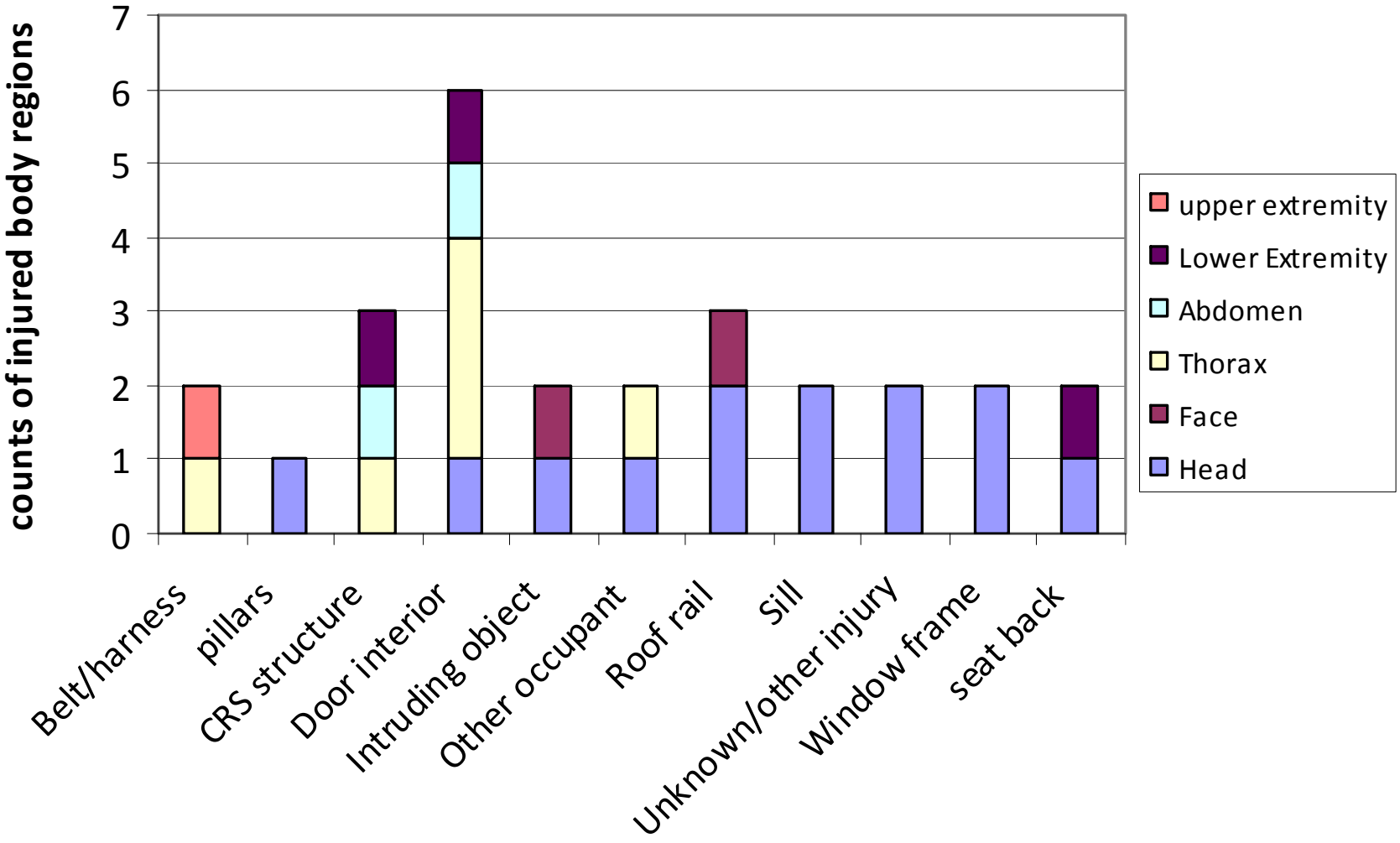
Involved Physical Components
Rear Facing CRS – AIS2+



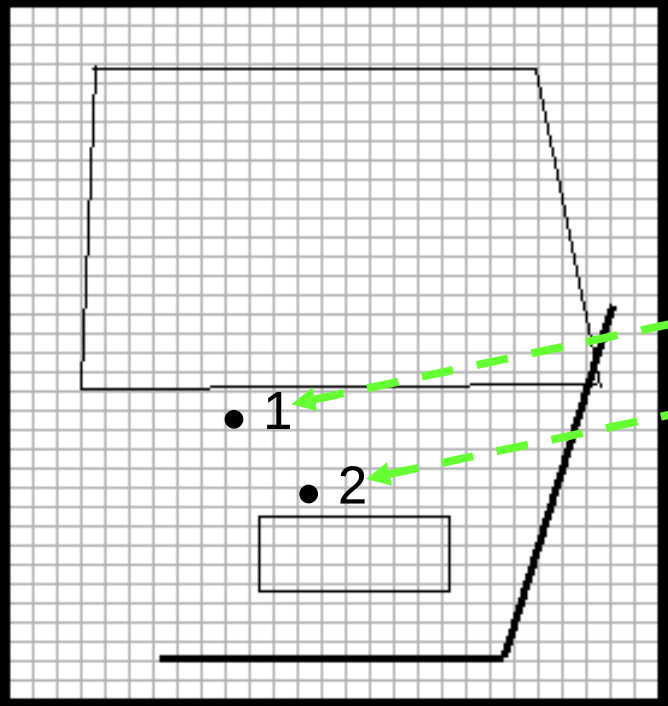
Involved Physical Components Forward Facing CRS – AIS2+



Involved Physical Components Booster Seats – AIS2+



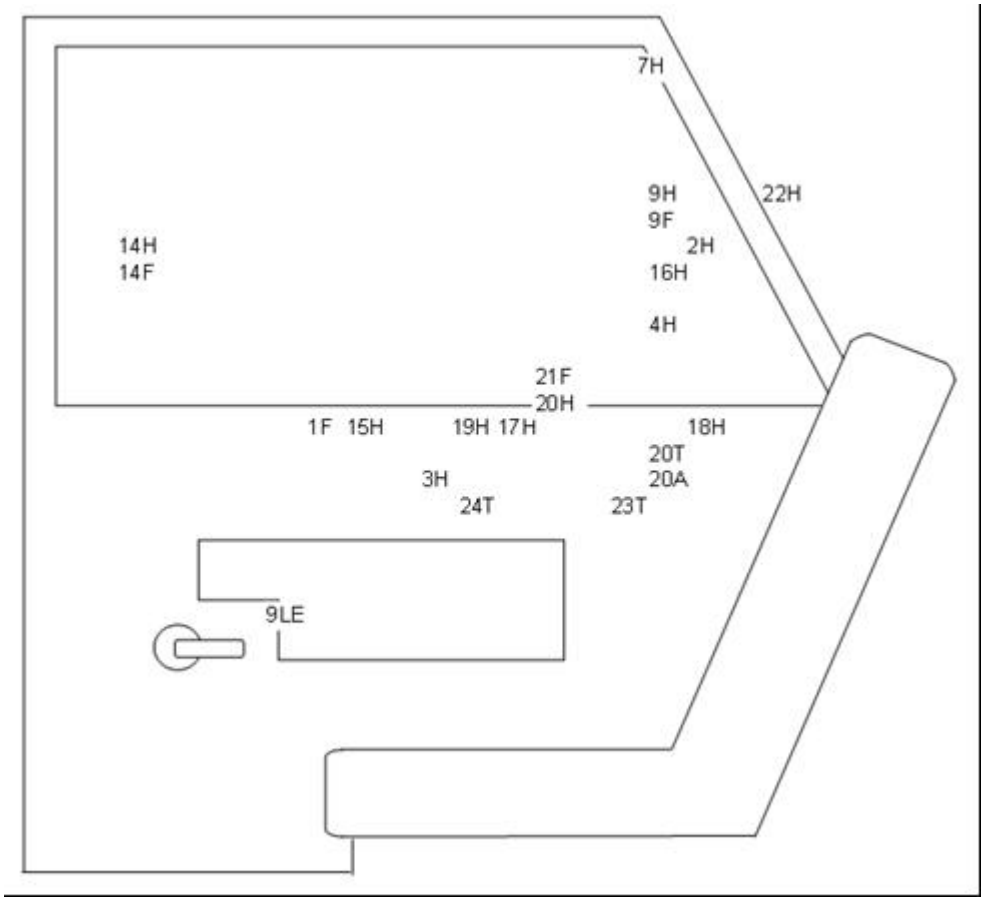
Contact Point Map



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.

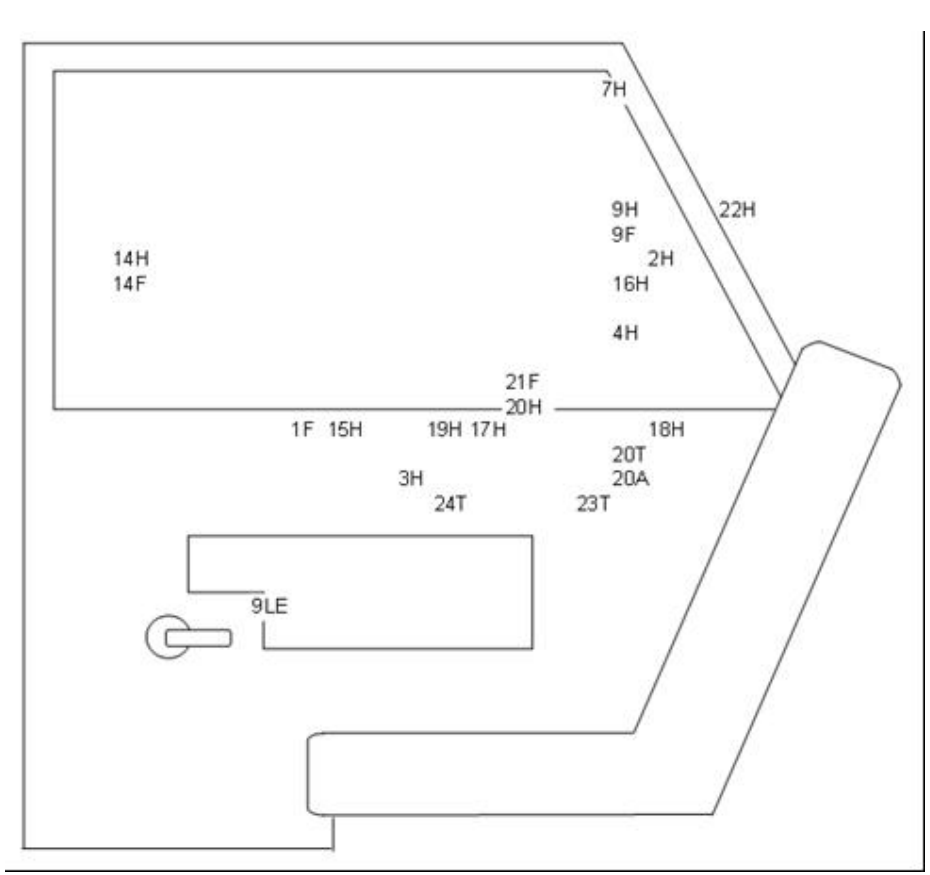
<= Back | Next =>

Near Side – All Body Regions

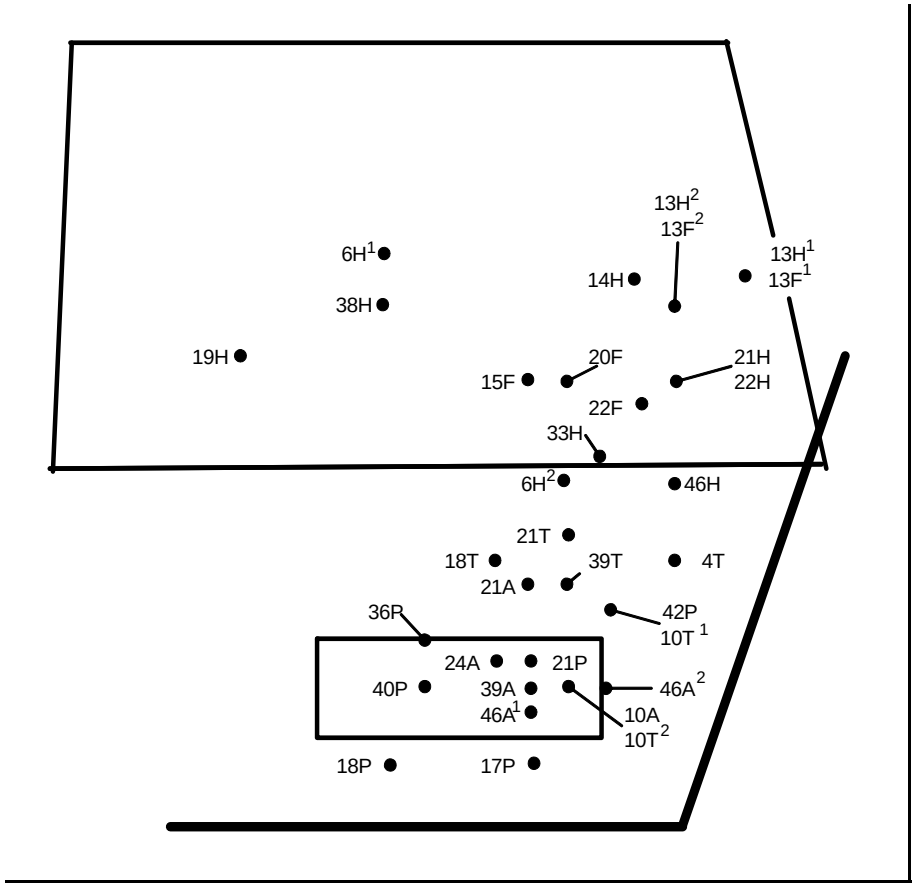


Comparison to Belted Children

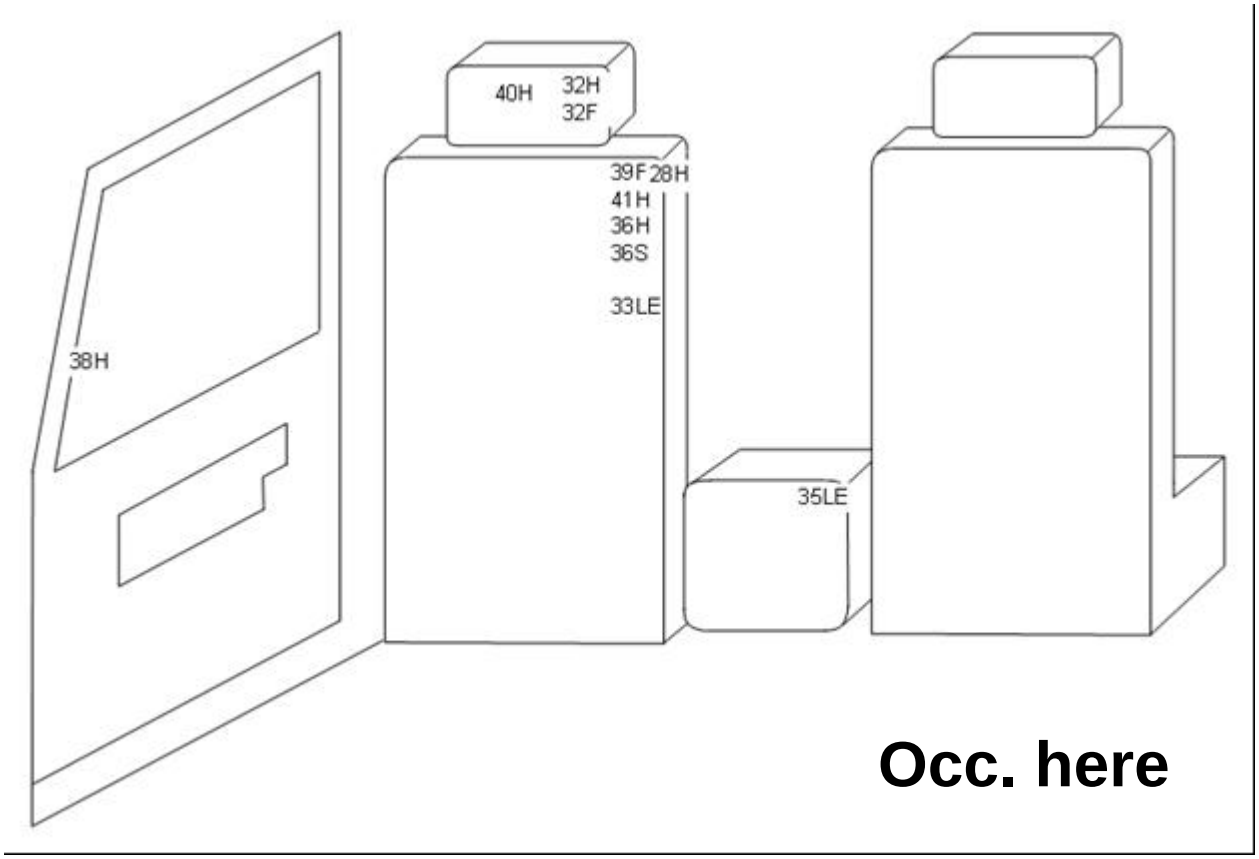
Current Study



Belted Children (Maltese et al)

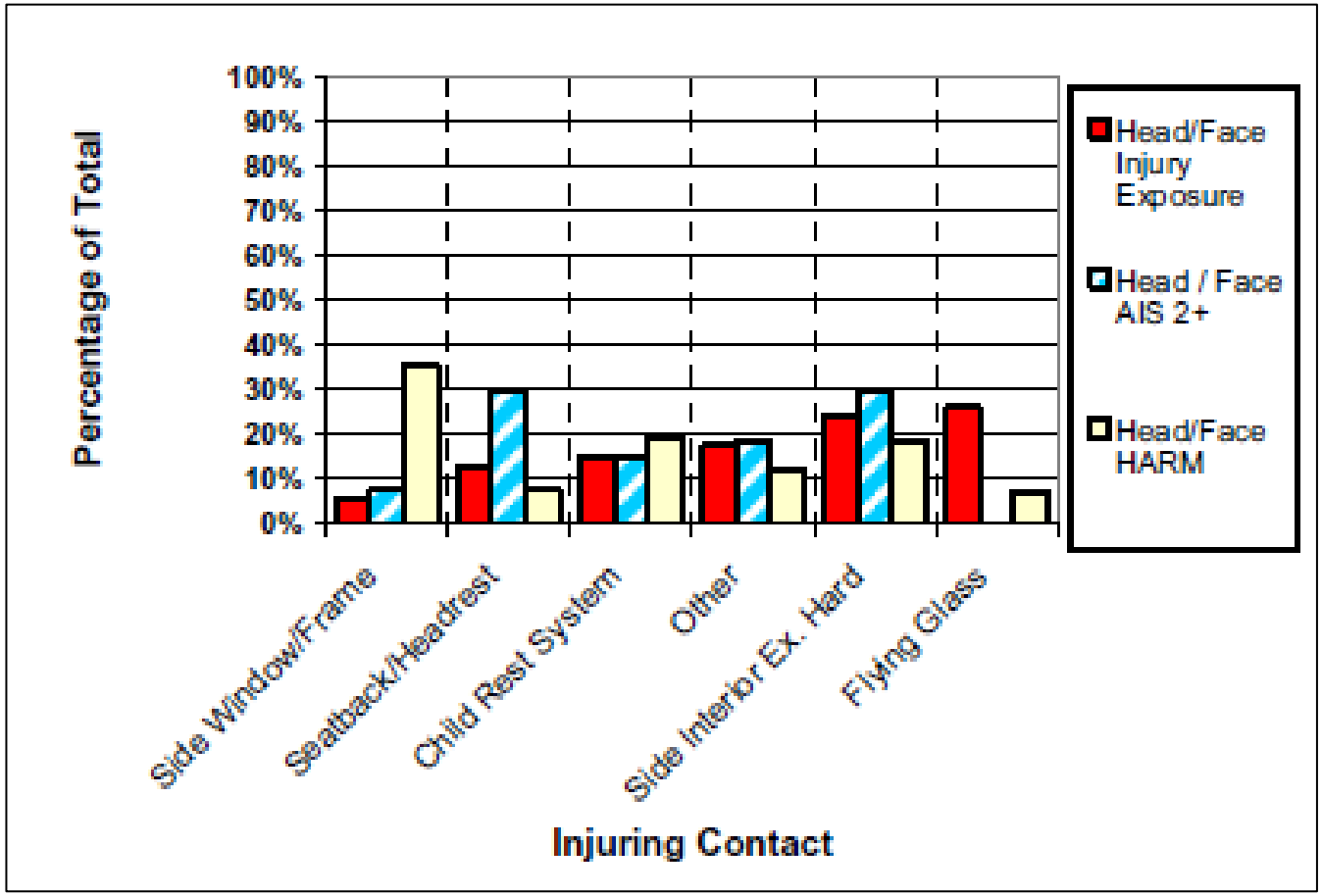


Far Side/Center – All Body Regions



Previous Research
NASS-CDS 1993-2007

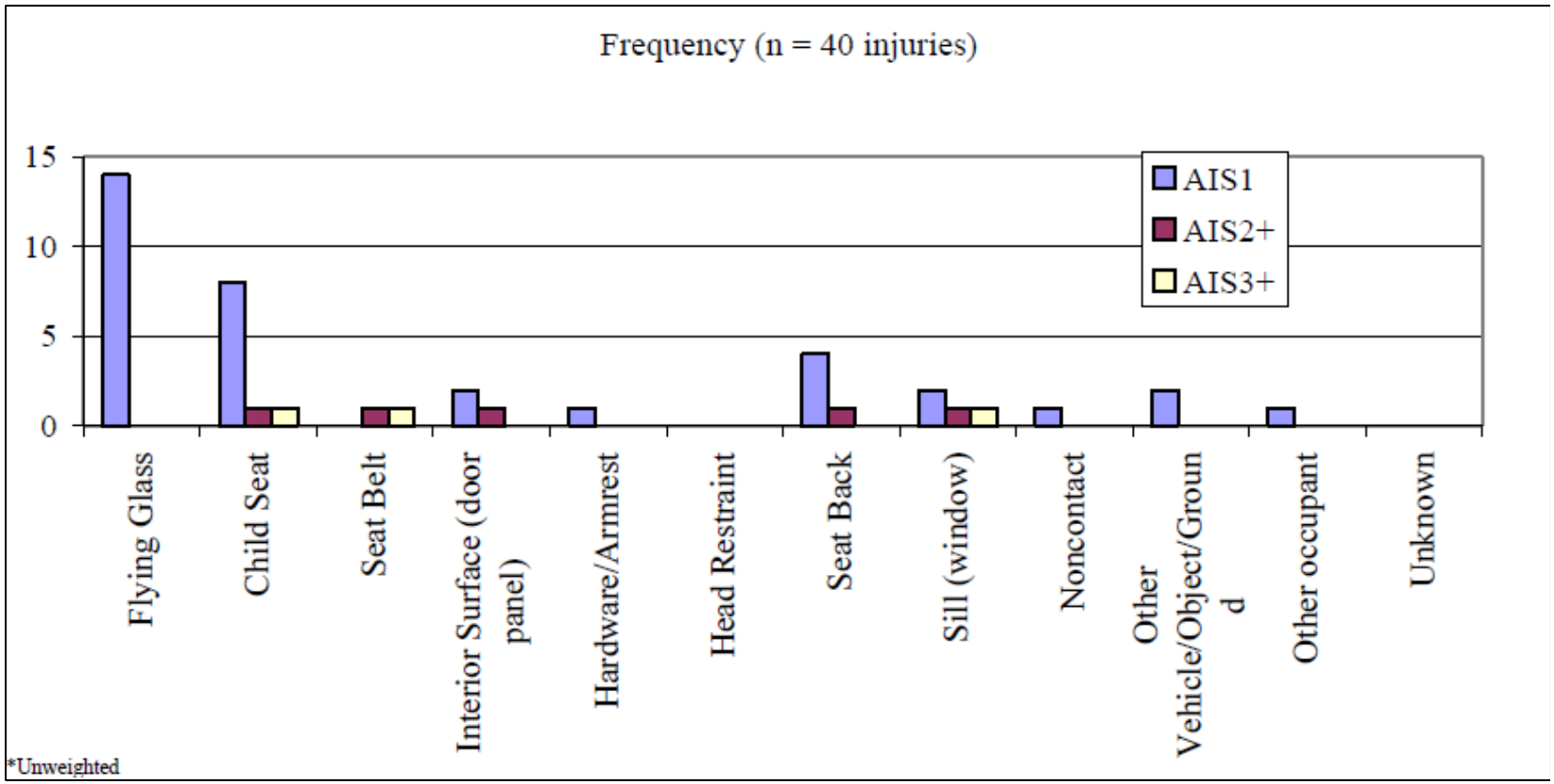
Head and Face Contacts for Children in CRS – Near Side Impacts



Scullion et al., 2009

Previous Research
NASS-CDS 1995-2007

Injury Sources – Side Impacts, Δv>30 kph
1 to 3 year olds in FFCRS



McCray et al., 2007

Conclusions

- Head and face injury most common – all restraints/seat position
  - Far side more equal distribution among body regions
- Non-contact inertial head/spine injuries rare but present in all seat positions
  - Often accompanied by lung contusions
  - May indicate frontal loading
- Common IPC
  - Near side – CRS Structure and Door Interior
  - Far side/center – Seat back and Harness/Belt

Acknowledgements

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NHTSA Crash Injury Research & Engineering Network

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