Predictors and Patterns of Pediatric Head Injury in Motor Vehicle Crashes

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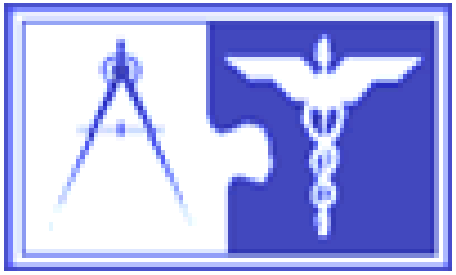
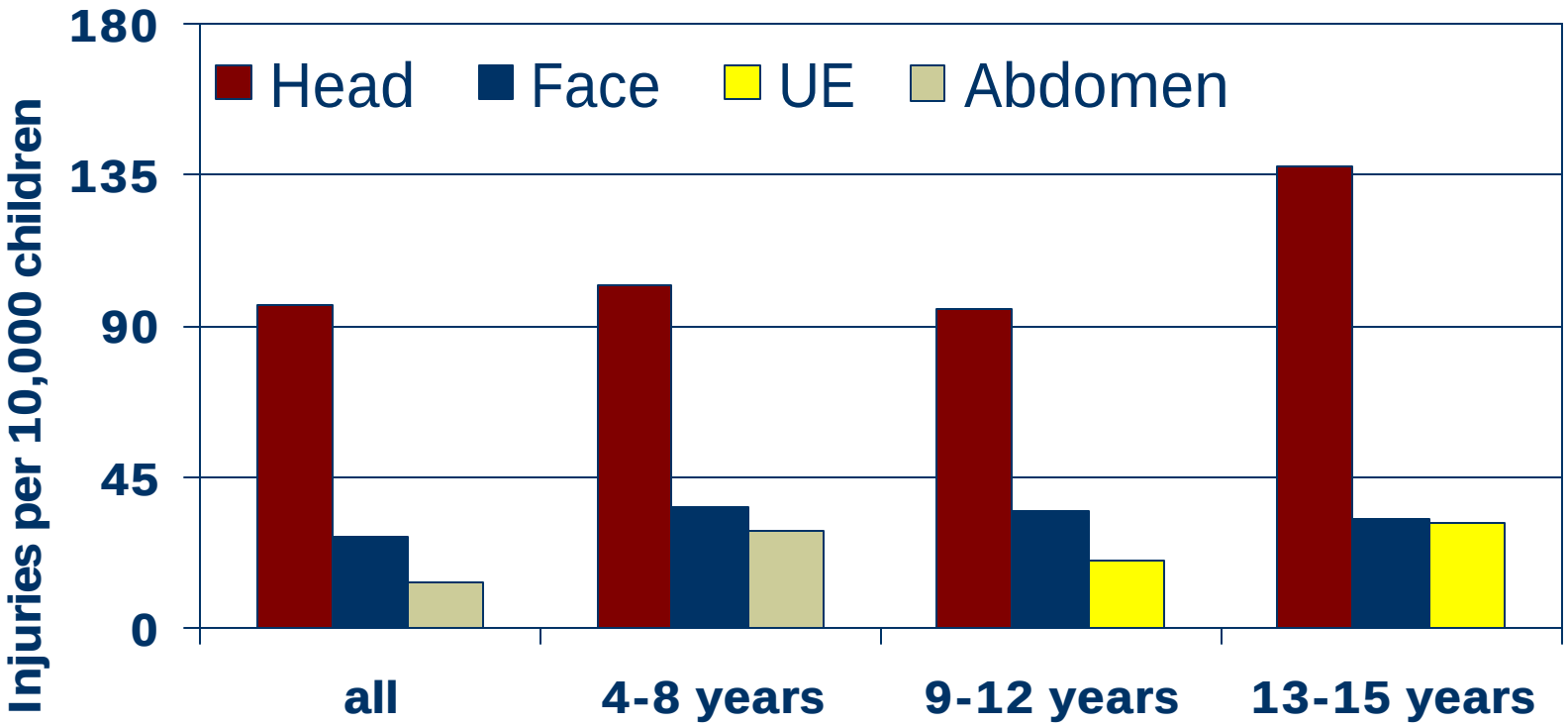


Children in Seat Belts
Top 3 Injuries by Age Group



Source: PCPS 2004

Head Injury – Regulatory Focus

- Head Injury Criteria (HIC)
  - Originally based on WSTC developed by dropping embalmed PMHS heads on rigid surfaces
  - Skull fracture and/or concussion used as the failure criterion
- HIC incorporated into all FMVSS that apply to children
  - FMVSS 208 – Frontal Crash Protection
  - FMVSS 213 – Child Restraint Systems
  - Two have slightly different values for different sized ATDs – FMVSS208 has scaled values

Objective

- Long term objective
  - To determine whether the spectrum of injuries sustained by child occupants is addressed by current regulations
- Short term goal
  - Define clinical picture of pediatric head injury – patterns and predictors
  - Mechanisms and sources of pediatric head injury

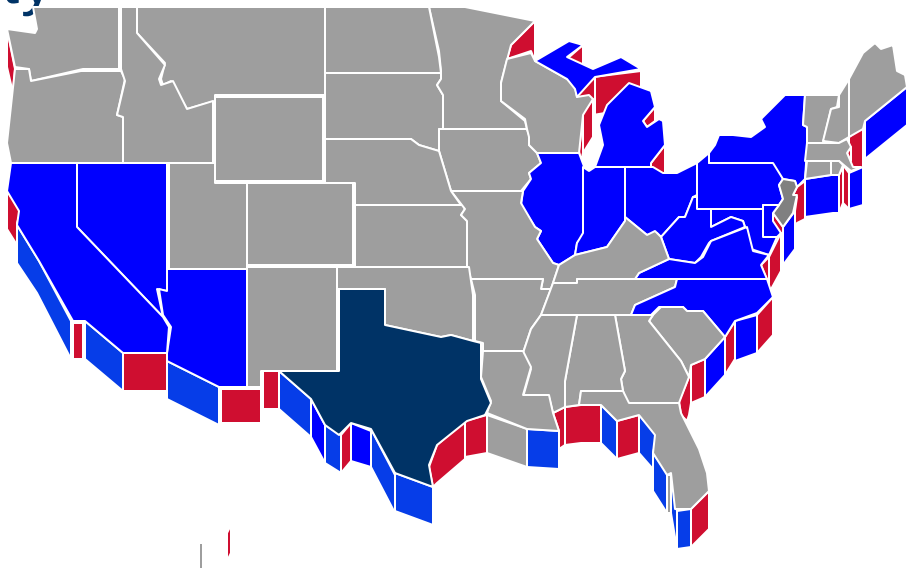
Several Data Sources

- Partners for Child Passenger Safety (PCPS) surveillance system
- PCPS crash investigations
- CIREN crash investigations

Partners for Child Passenger Safety

Partners for Child Passenger Safety

- Studying how and why children are injured in crashes
- Telephone interviews, on-site crash investigations, in-depth analyses
- Inclusion criteria
  - 15 states and DC
  - Child occupant < 16 yrs of age
  - Insured vehicle, model year > 1990
- Comprehensive:
  - All injury and crash severities
  - Large population

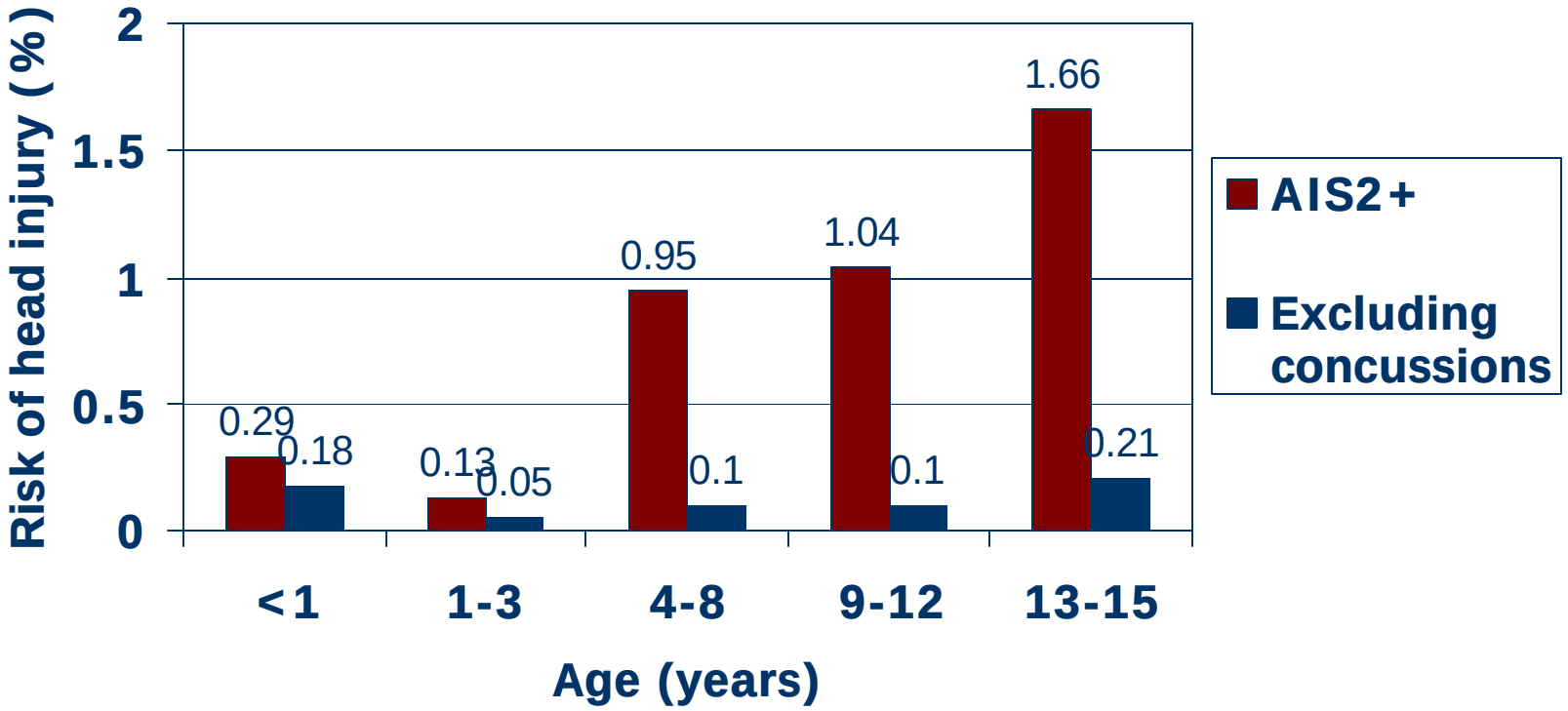


PCPS Surveillance Analysis

- Data from 12/1/98-12/31/04
- Two levels of head injury
  - AIS 2+
  - “non-concussive” - AIS2+ excluding concussions
    - Removes those excessively sleepy, difficult to arouse, whose only head injury was a concussion, those whose LOC<5 minutes
- Inclusion criteria:
  - Ages 0-15 years
  - All seat rows, vehicle types, crash directions, and restraint types
  - 25,209 children weighted to represent 345,610 children

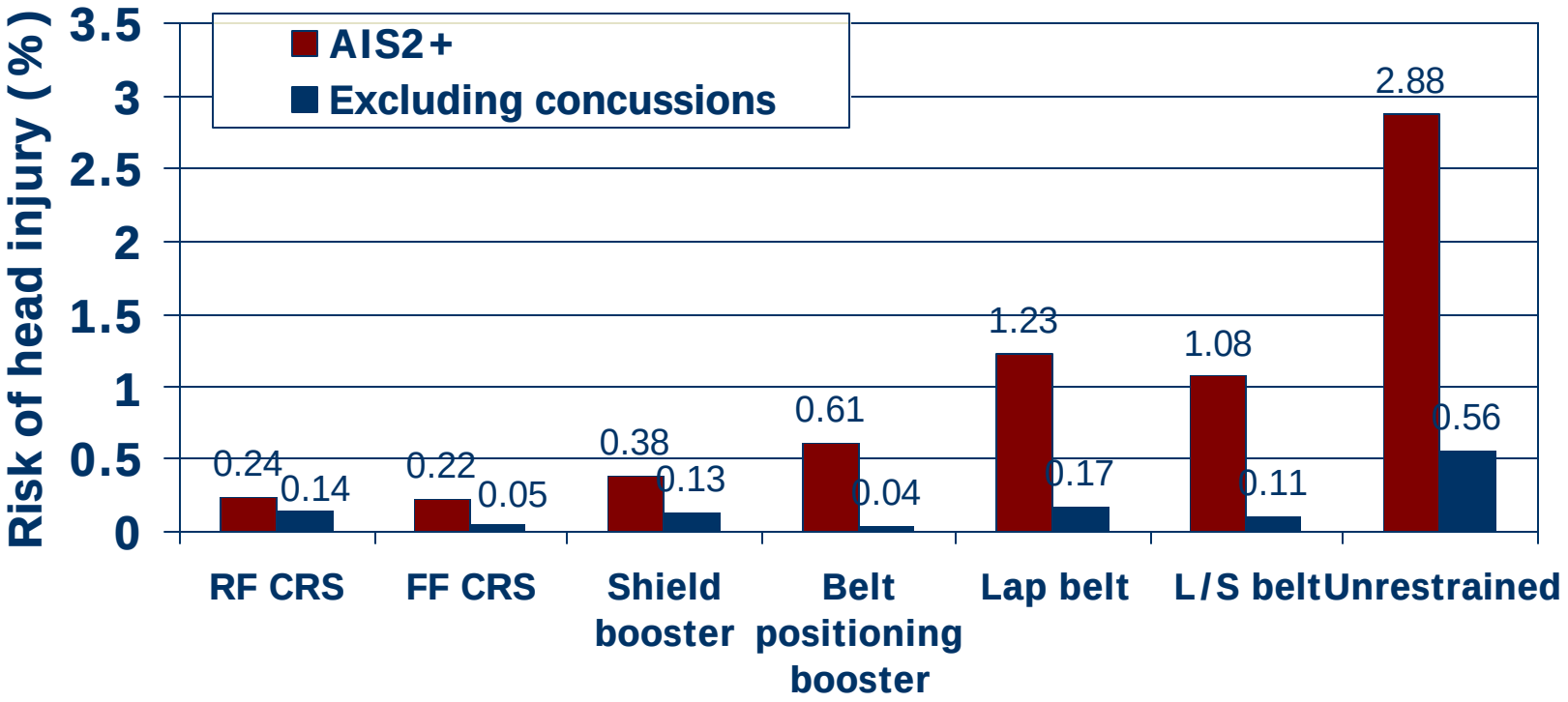
Source: Arbogast et al, 2005 IRCOBI Conference Proceedings

PCPS Surveillance
Age effect

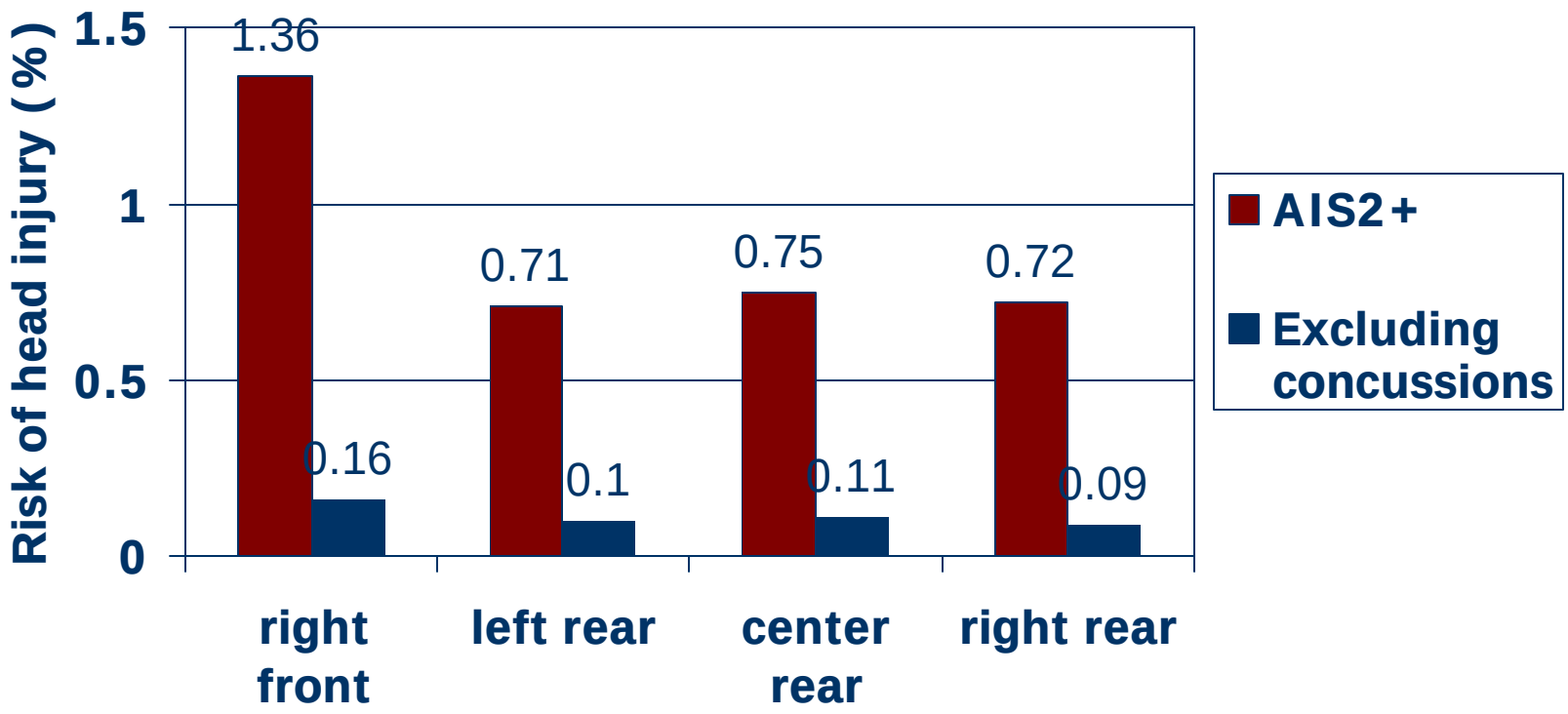


Overall risk of head injury: AIS 2+ = 0.86%, non-concussive = 0.11%

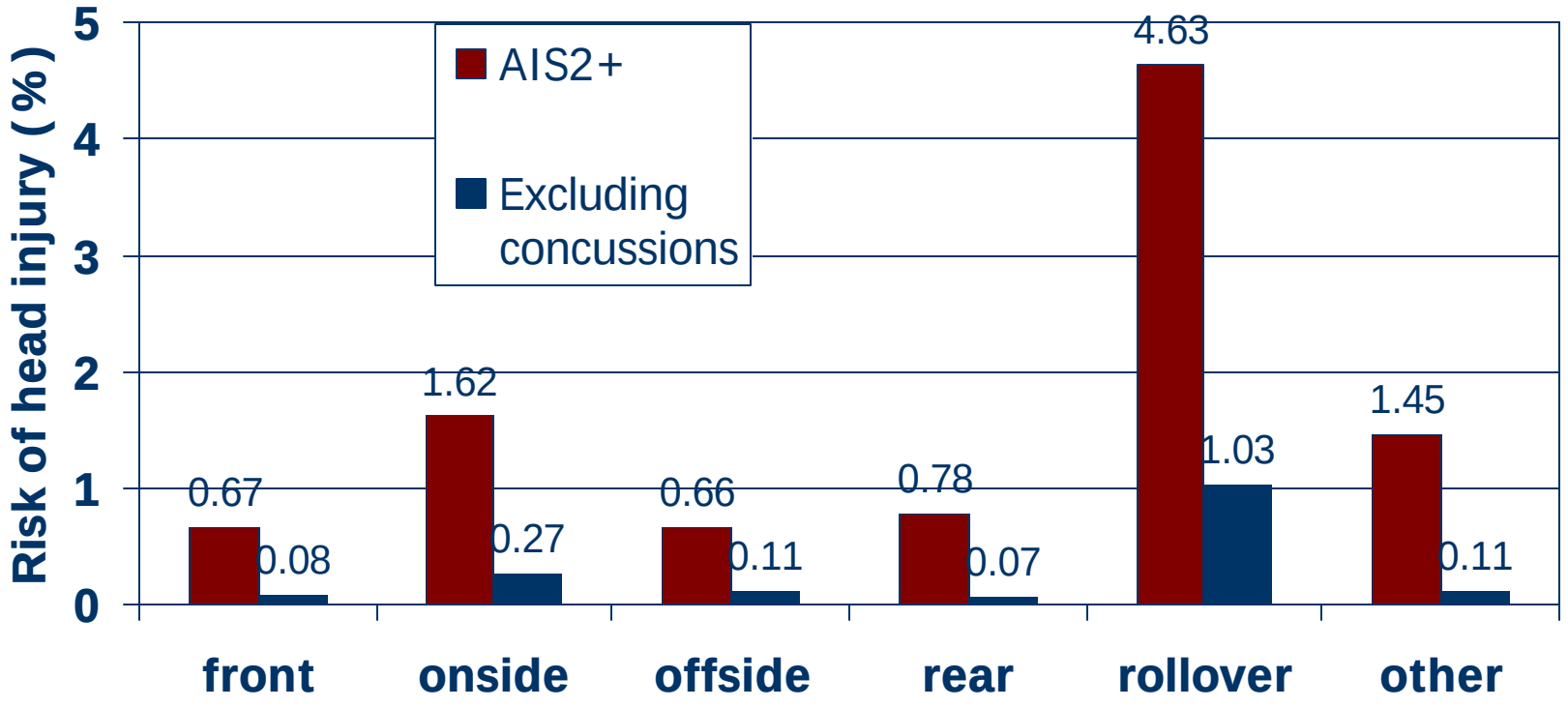
PCPS Surveillance Restraint effect



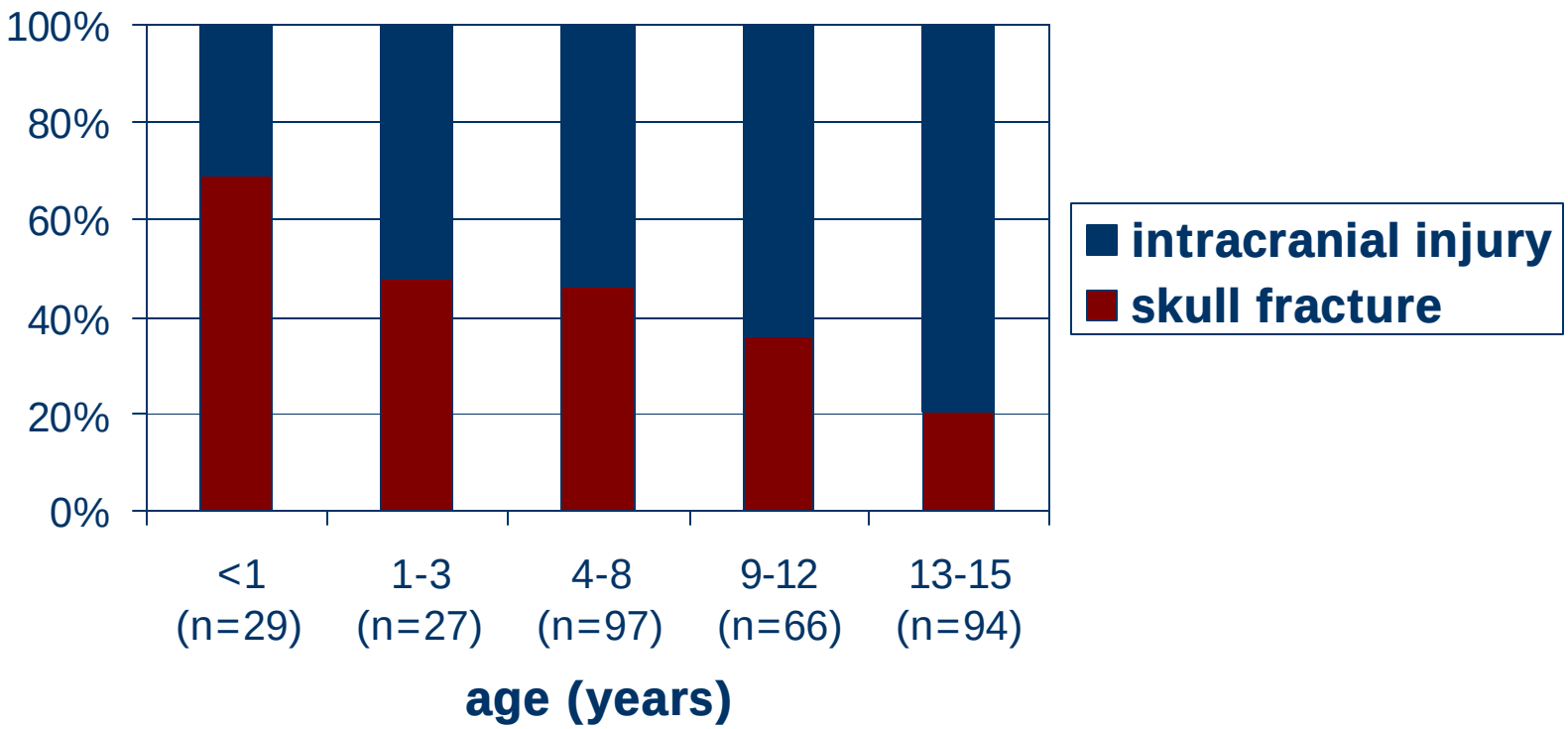
PCPS Surveillance
Seat position effect



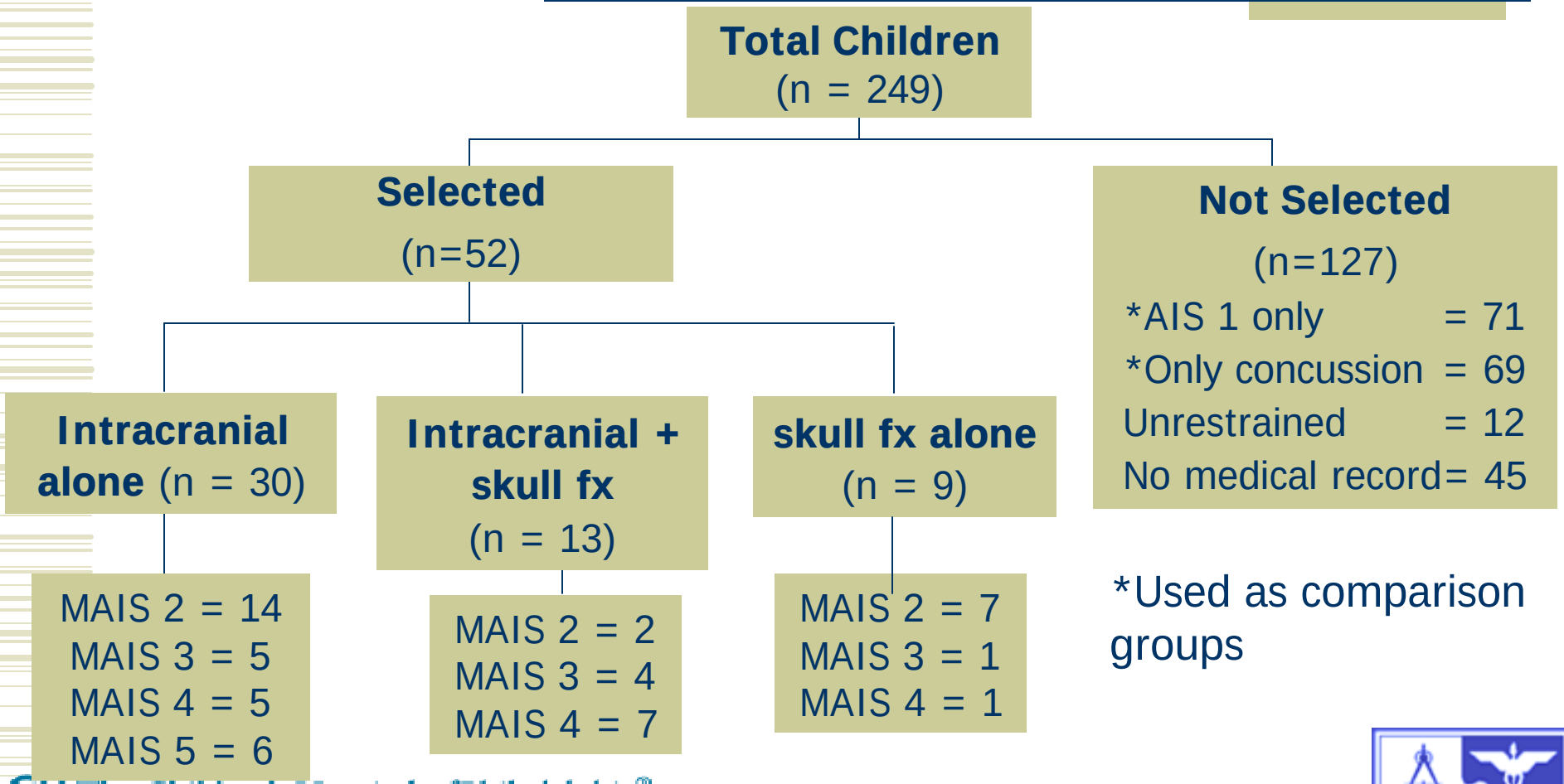
PCPS Surveillance
Crash direction effect



PCPS Surveillance
Type of Non-concussive injury



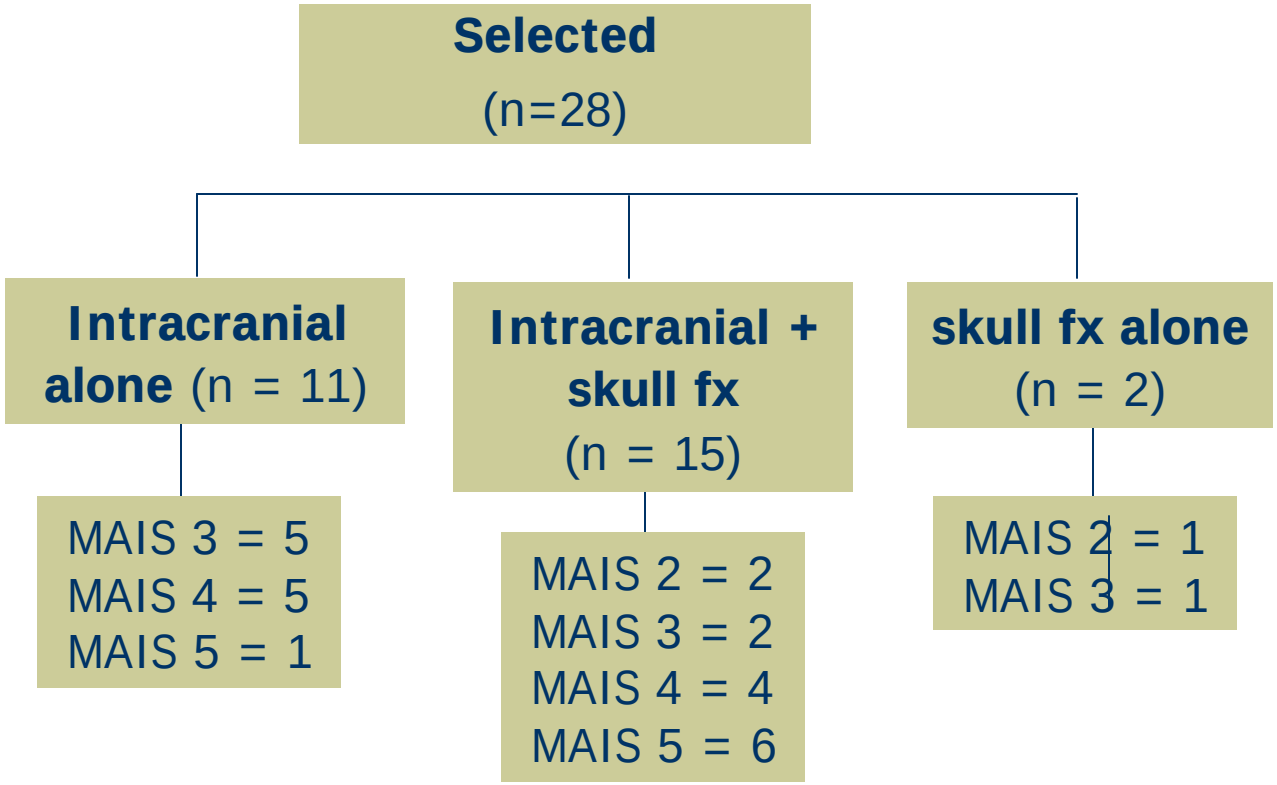
PCPS Crash Investigation Children with Head Injuries



*Used as comparison groups

CIREN Cases
Children with Head Injuries

- Inclusion criteria
  - Rear seat restrained child (0-15 years)
    - No RFCRS
  - With AIS2+ head injury
    - Excluded those with concussion or AIS 2 scalp lac alone (n=13)
  - Frontal or rear crash based on CDC
    - xxFxxxx
    - xxRxxxx



CIREN Cases
Intracranial Injury Alone (n=11)

Contact (6)

- **1 in 2 point seat belts (6 yrs)**
- **4 in a 3 point seat belt (3, 4, 7, 11 yrs)**
  - 3 with the shoulder belt behind
- **1 in a CRS (2 yrs)**

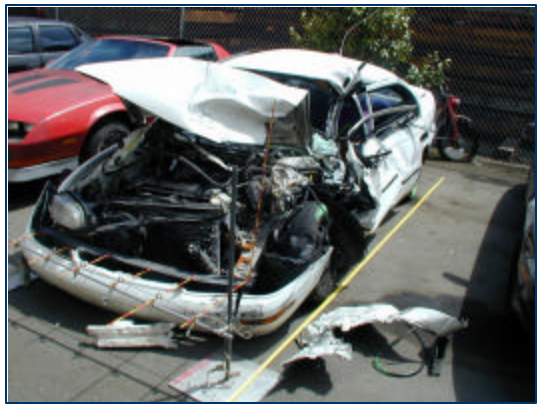
No contact (5)

- **3 in CRS (16 mo, 2 yrs, 3 yrs)**
- **2 in low back booster (4 yrs)**
- **No clear injury type**

CIREN Cases
Skull Fx Alone (n=2)

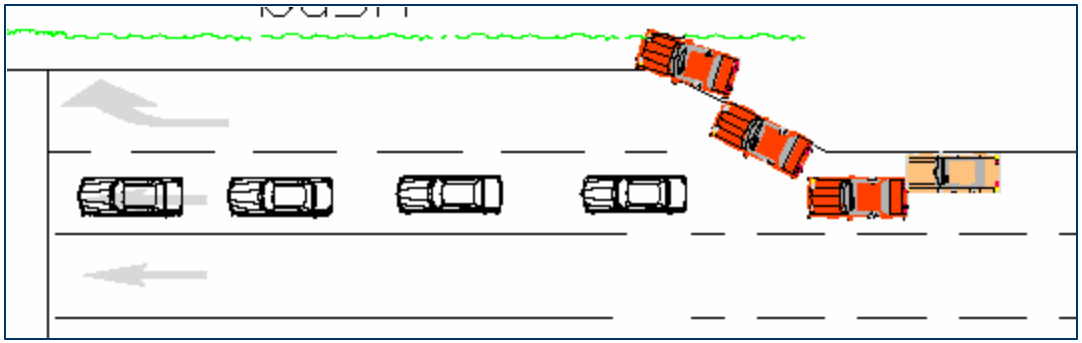
- **Moderate rear crash**
- **4 year old**
- **L/S belt**
- **Basilar skull fx, right vault fx**

- **Moderate frontal offset crash**
- **2 year old**
- **FFCRS**
- **Left temporal fx**



Case Example: Skull Fx

- Case vehicle: 1998 Hyundai Tiberon
- Struck by 2004 Toyota Corolla
- Delta V = 11 km/hr
- PDOF = 180^{o}
- CDC: 06BZEW3



Case occupant

Left rear seat

- 5 year old female, 43”, 37 lb
- Backless booster with lap and shoulder belt

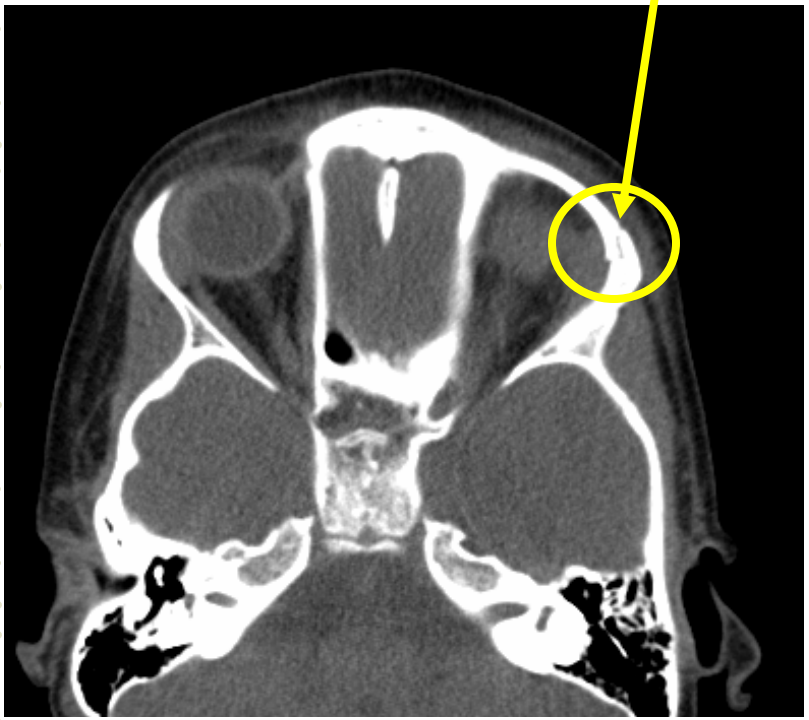
Injuries

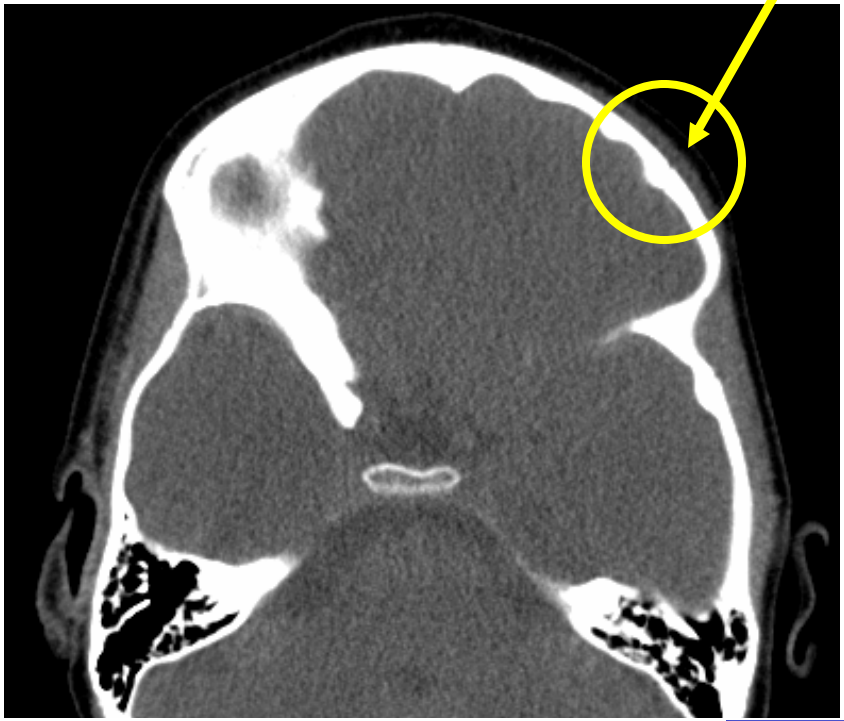
- Head
  - AIS 3: Left orbital roof fracture
  - AIS 2: Left frontal bone fracture
- Face
  - AIS 2: Left superolateral orbital ridge fracture
  - AIS 1: Left periorbital and facial edema

Case Occupant Injuries

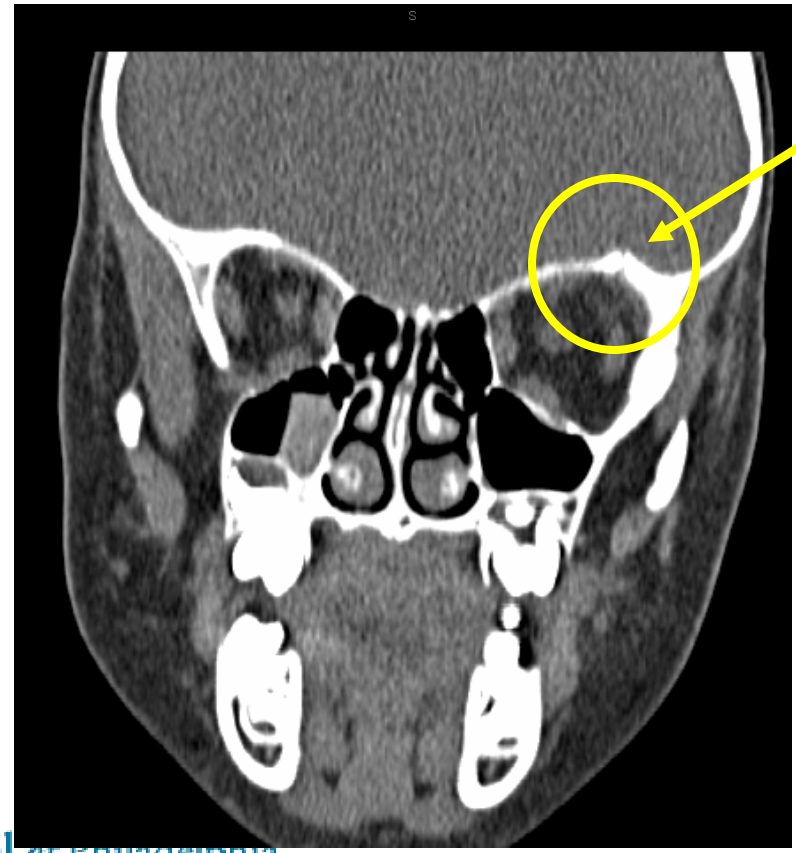
L superolateral orbital ridge fx

L Frontal bone fx





Case Occupant Injuries



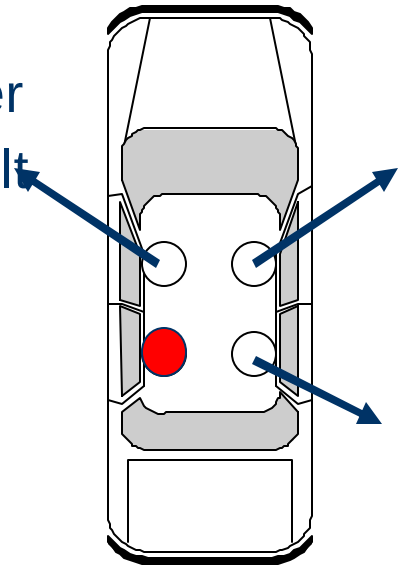
L orbital roof fx

Other Occupants

- 33 year old male
  - 186 cm and unk wt
  - Front left seat, Driver
  - Lap and shoulder belt

  Minor Head contusion

  Cervical Strain



- 33 year old female
  - Unk ht and wt
  - Front right seat
  - Lap and shoulder belt

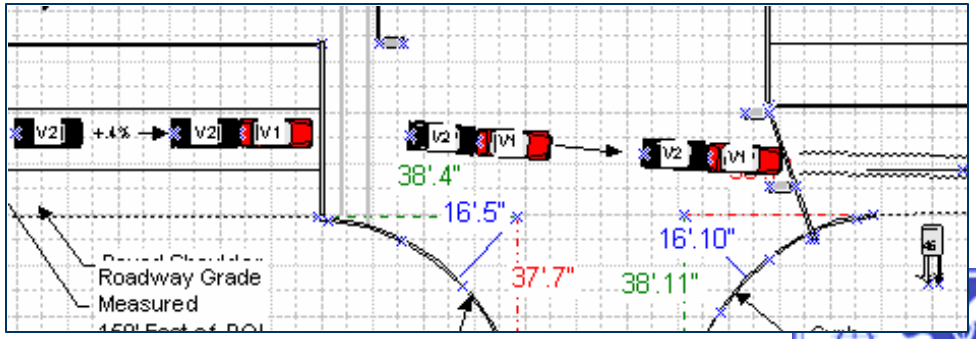
  L shoulder and chest strain, minor contusion

- 6 year old female
  - 121 cm, 23 kg
  - Right rear seat
  - Backless booster
  - Lap and shoulder belt

  Minor tongue laceration

Case Example: Intracranial Injury

- Case vehicle: 2002 Geo Prism
- Struck by 2002 Jeep Wrangler
- Delta V = 31 kph
- PDOF = 180°
- CDC: 06BDAW6



Case occupant 1

Left rear seat

- 5 year old male, 42”, 45 lbs
- High back booster with Lap/Shoulder belt

Injuries

- Head
  - AIS 4: Two subdural hematomas in left temporal and parietal regions
- Multiple other AIS 2 and 3 injuries – dental fx, iliac wing fx, bilateral tib/fib fx

Case occupant 2

Right rear seat

- 7 year old male, 50”, 67 lbs
- High back booster with Lap/Shoulder belt

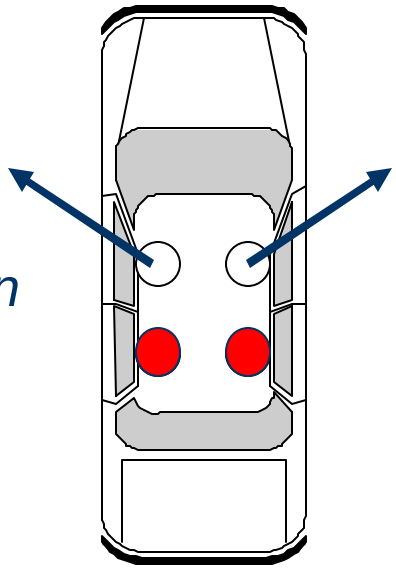
Injuries

- Head
  - AIS 2: Mild concussion with brief LOC – grade 3

Other Occupants

- 39 year old female
  - 63” and 130 lbs
  - Front left seat, Driver
  - Lap and shoulder belt

Concussion, minor head contusion, lumbar strain



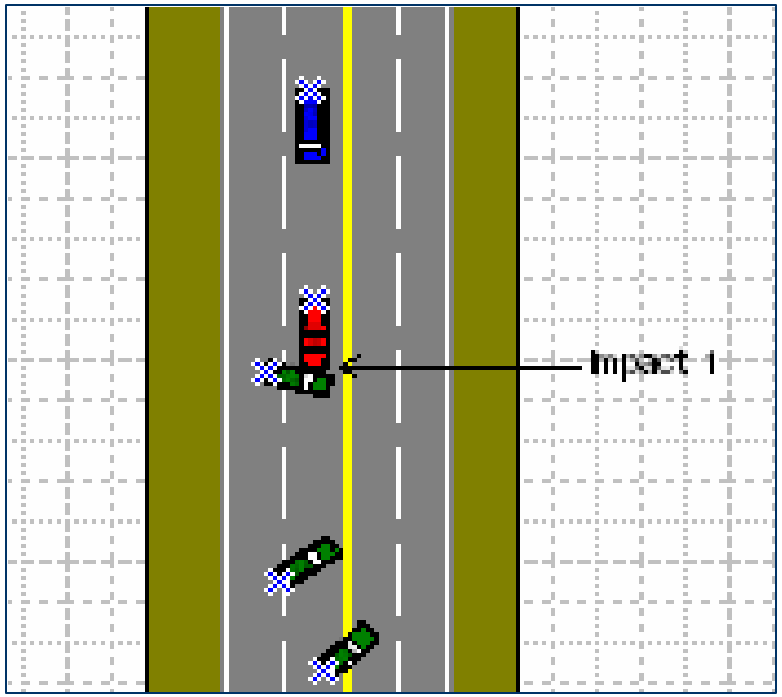
- 33 year old female
  - 63” and 160 lbs
  - Front right seat
  - Lap and shoulder belt

Contused heart, collapsed R lung, Rt shoulder dislocation

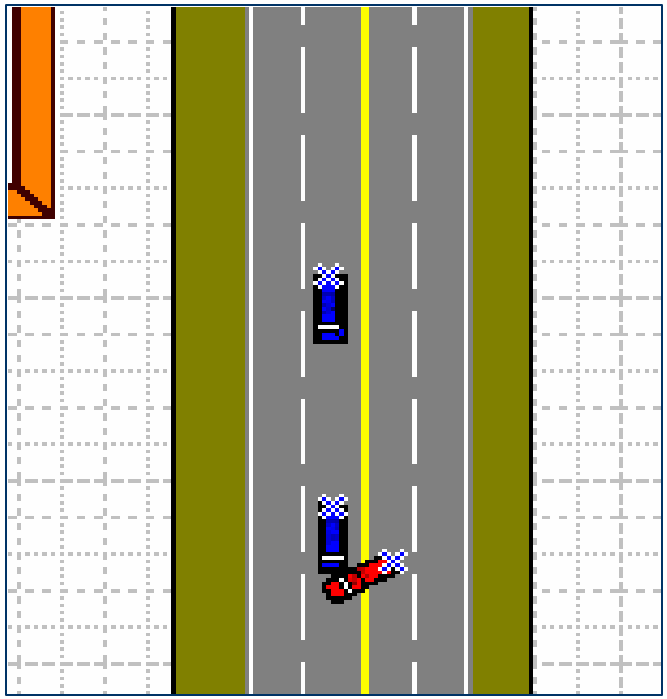
Case Example: Both Injury Types

- Case vehicle: 1999 Toyota Tacoma
- Struck by
  - 1995 2 door coupe (1st Impact)
  - 1997 Maxivan (2nd Impact)
- Delta V
  - 79 kph (1st Impact)
  - 45 kph (2nd Impact)
- PDOF
  - 340° (1st Impact)
  - 105° (2nd Impact)
- CDC: 11FDEW3, 03RYEW3

Scene Diagram



Impact 1



Impact 2

Case occupant

Right front seat

- 5 year old female, 50”, 55 lbs
- Lap/Shoulder belt – shoulder belt behind back

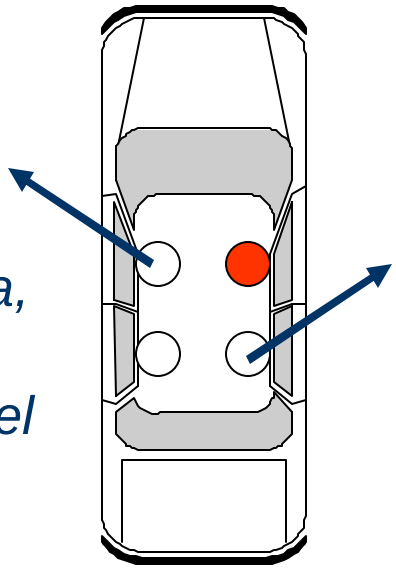
Fatally Injured

- Head
  - Basilar skull FX extending to temporal bone
  - Left temporal FX
  - Right frontal intracerebral hematoma
- Abdomen
  - Mesenteric laceration of small intestine
  - Mesenteric laceration of sigmoid colon
- Pelvis/lumbar spine
  - L4 spinous process FX
  - Right iliac crest avulsion FX

Other Occupants

- 31 year old male
  - 75” and 230 lbs
  - Front left seat, Driver
  - Lap and shoulder belt

  Closed comminuted FX of distal tibia and left fibula, multiple lacerations of mesentery of small bowel



- 8 year old male
  - 55” and 65 lbs
  - Right rear seat
  - Lap and shoulder belt

  Right pleural effusion with lower lobe consolidation – “pulmonary injury”

Discussion – Age effects

- Except for infants, injury risk increases with age
  - 1-3 year olds have lowest head injury risk – effectiveness of forward facing CRS
  - 4-8 year olds – many in adult seat belts not booster seats
  - 9-12 year olds – front seating becoming more common
  - 13-15 year olds – front seating, lower restraint use, riding with peers

Discussion – Infant Head Injury

- Second lowest AIS2+ risk but second highest non-concussive injury risk
- Data showed an increase in skull fractures in this age group
  - Munoz-Sanchez et al (2005) studied 2000 pediatric head injuries from all mechanisms and found infants were 3 times more likely to sustain a skull fracture than those 2-13 years

Discussion – Seat Position and Restraint Effects

- All child restraints showed low head injury risk
  - BPB about 2X that of FFCRS and RFCRS
- Front seat AIS2+ injury risk 2x that of all three rear seat positions
- Center rear no reduction in injury risk compared to rear outboard
  - Maltese et al, 2005 – similar result for belted children
  - Lund et al, 2005 – similar result for CRS children

Discussion – Head Injury Patterns

- Over half of children sustained intracranial injuries alone
  - PCPS: 55%
- Examined this issue in two data sets of more seriously injured children
  - CHOP Trauma Registry - 51% sustained intracranial injuries alone
  - CIREN – 11/28 (40%) sustained intracranial injuries alone

Discussion - Modeling Summary

Injuries to case occupant	HIC	Injury scenario
Concussion with brief LOC (MAIS 2)	219	Contact with CRS on rebound
Multiple skull fx (MAIS 3)	960	Impact with driver's head
Subdural hematomas (MAIS 4)	1060	Contact with CRS on rebound
Spectrum of intracranial injuries and skull fx (MAIS 4)	6444	High velocity IP impact

Conclusions

- Predictors of elevated head injury risk
  - Lap belt only
  - Right front seat position
  - Rollovers and struck side crashes
- Increasing age led to increasing head injury risk
  - Except infants – elevated non-concussive head injury risk – especially skull fractures
- Approximately half of the head injuries for children 1-12 were intracranial injuries alone
  - Ongoing efforts to explore accuracy of HIC and other head injury metrics in predicting these injuries

Acknowledgements

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