

# Injury Risk to Children in Rear Impact Crashes: Role of the Front Seat Occupant


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# Introduction

## Rear seating for children

**USA TODAY INVESTIGATION**



Six of the victims: Nathan German, 9; Jordan West, 5; Alison Sanders, 7; Jessica Patterson, 3; Cody McNeel, 9; Breanne Wide, 4.

### LEADLY AIR BAGS

#### How a government prescription for safety became a threat to children

By James R. Healey and Jayne O'Donnell  
USA TODAY

Imagine a heavy-weight boxer busting a child in the face. That's how accident investigators described the force of the passenger air bag that killed 9-year-old Nathan German in March 1993.

"The pastor had to hold me up when I saw how swollen his head was in the casket," says Nathan's father, Ken German, a physiotherapist in Houston.

Nathan is one of 23 people — 22 of them children — who, since 1983, have been killed by what is supposed to be a safety device: the passenger air bag. Most deaths occurred in crashes so minor that everyone else walked away.

"Americans remain in the dark as to the terrible danger to which their children are exposed," says Robert Sanders of Baltimore, father of 7-year-old Alison Sanders. Alison was killed by a passenger air bag last October in a low-speed crash.

In the dark, indeed. Passenger air bags are killing twice as many children as they are saving, according to an analysis of government data done for USA TODAY. If current trends continue, the data say 20 children will be killed by passenger bags this year, 18 saved. The auto industry and the government do not dispute the analysis.

Most victims won't be properly belted, according to the analysis. But unrestrained occupants are the very group air bags are designed to save. And there is new evidence that even properly belted children are in jeopardy.

Eight children are known to have been killed by passenger bags this year. The past two years, two children — both prop-

**COVER STORY**



The image: The popular perception is that air bags provide a soft, gentle pillow during a wreck, as they appear to do in slow-motion video with these crash-test dummies.

#### Why air bags are killing children

The government's occupant protection regulation — Federal Motor Vehicle Safety Standard 208 — is designed to protect the average male not restrained by a seat belt in a 30 mph head-on crash.


To cushion that 5-foot-6-inch, 165-pound man hurtling toward the dashboard in a crash, a passenger air bag inflates at up to 200 mph. That's enough force to counteract much of the momentum of the ruin and save him from a fatal collision with the car's interior. But it's also enough force to snap a child's neck, deform a child's head, or, in the worst cases, tear the head nearly off the child's body.

A child is supposed to be safe from air-bag harm if the child is properly restrained by a lap-shoulder belt or child seat, as far back from the bag as possible and to sit in a rear-facing child seat.

But the National Transportation Safety Board has investigated one crash in which a properly belted child was killed. That is disputed by another federal agency, the National Highway Traffic Safety Administration, which says the child was not wearing the belt.

Martin Eichelberger, a Washington, D.C., pediatric surgeon studying crashes involving children, says he knows of two cases where properly restrained children were seriously injured by passenger bags.

By James R. Healey and Jayne O'Donnell



Reality: The explosive force of air bags can kill children, as it did in the 1993 crash that took the life of Diana Zahra, 5, of Canton, Ohio, here, the spent air bags after the crash.

National Transportation Safety Board

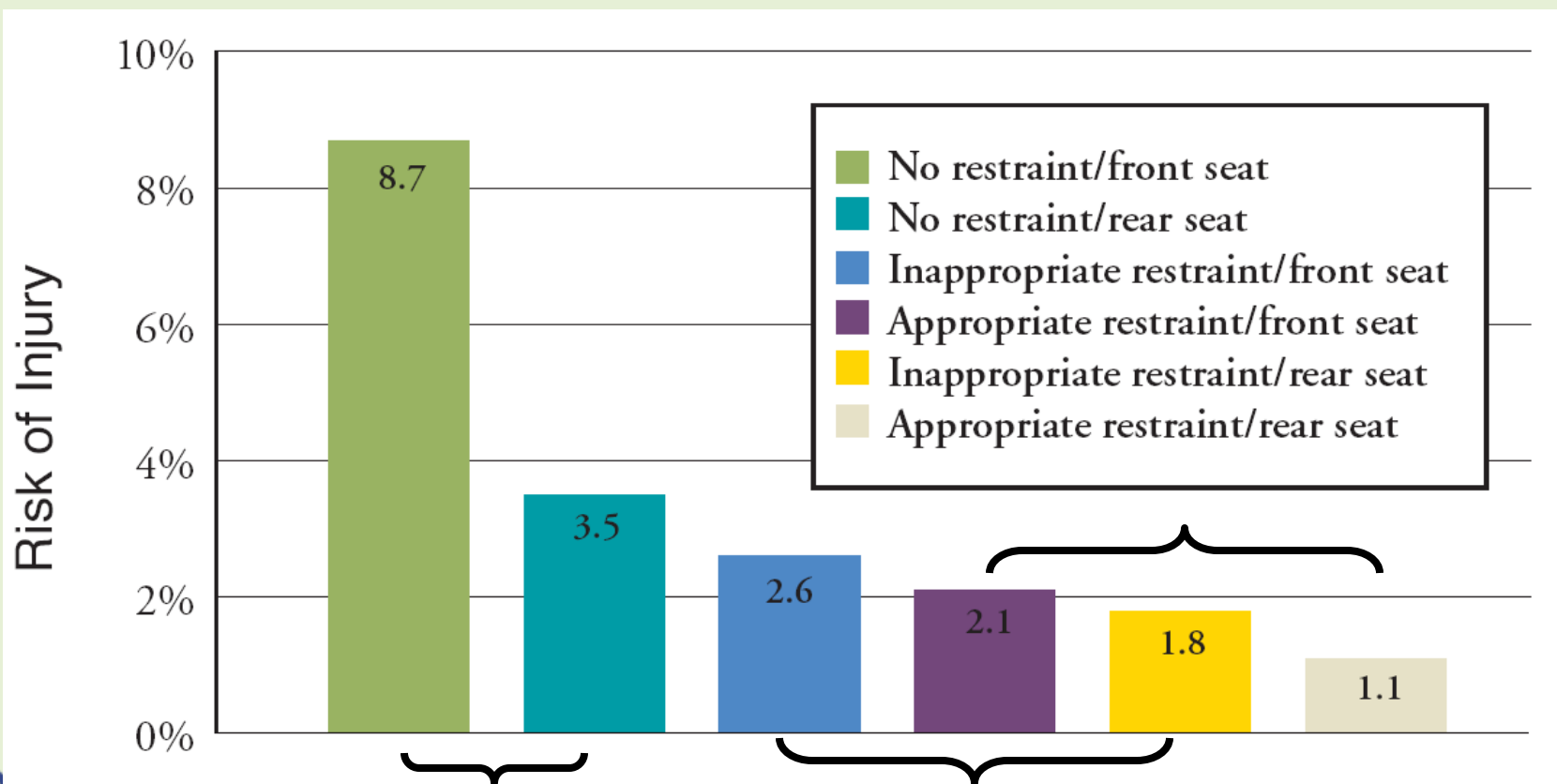
COVER STORY next page ▶

- Increased national attention on rear seating for children since mid 1990s
- Lower risk for fatal and nonfatal injuries to children < 13 years old in the rear.



# Rear seat for children <13

## Risk of injury by seat row & restraint type



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

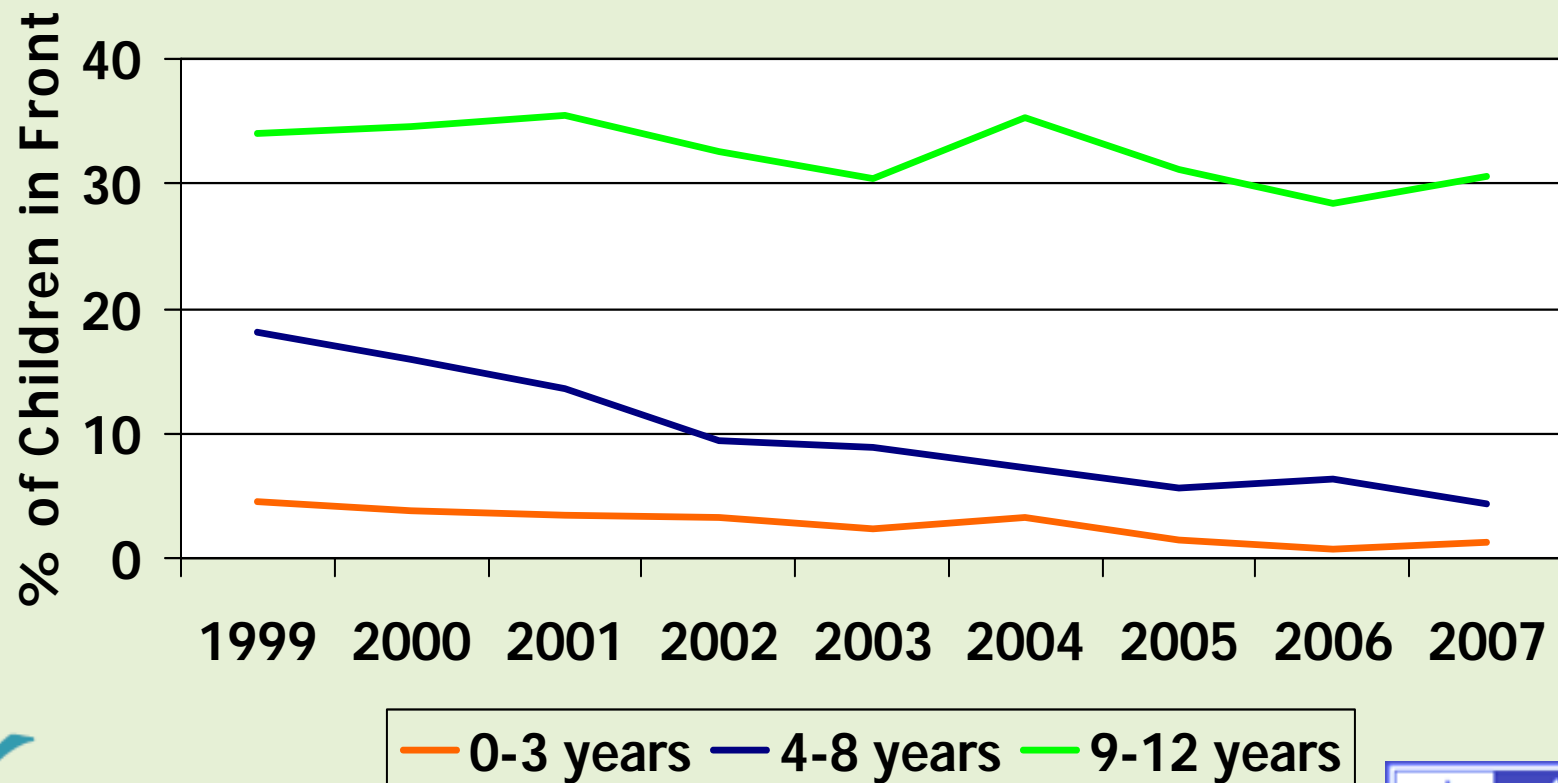
*Durbin et al, Pediatrics, March 2005*



# Introduction

## Front row seating trends

### Trends in Front Row Seating Over Time



# Industry Debate

## Stiff vs. yielding seat backs

- Stiff seat back
  - Improves occupant retention in severe rear impacts – reduces risk of serious injuries
  - Increases risk of hyper-extension without adequate head support
- Yielding seat back
  - Allows torso, neck and head to move together – reduces soft tissue neck injuries in more common low severity events
  - Increases risk of excursion for more severe rear impacts



# Introduction

## Injury risk to rear seated children

- Current debate on front seat back structure (i.e. yielding versus rigid) focused on lowering injury risk to the front seat occupant.
- Anecdotal case reports of rear seated children injured by interaction with front seat occupants or seat back.
- Regulatory discussion about rear seat protection (for children) focused on frontal impacts
  - i.e. FMVSS 213, inclusion of pediatric ATD in NCAP





# Research aims

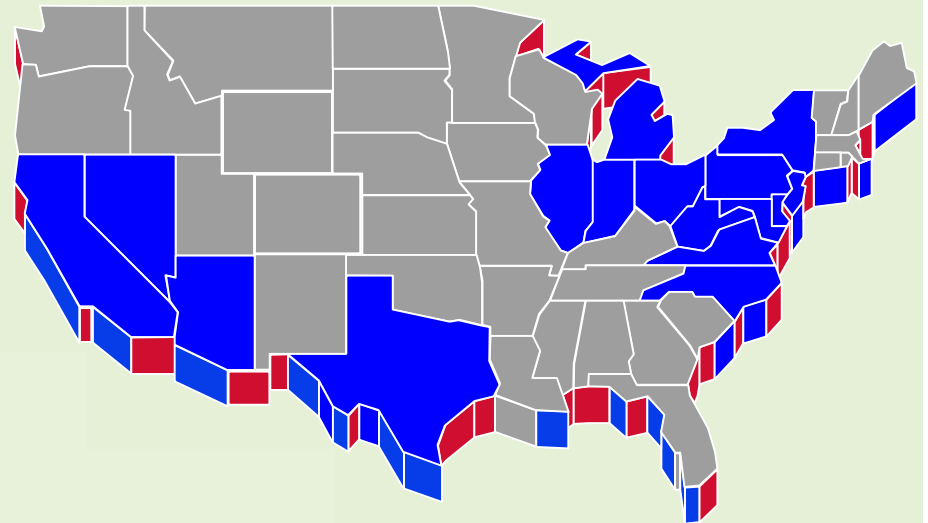
- To determine the risk of AIS2+ injury to restrained children in rear rows in rear impact crashes.
- To determine the association between front seat occupants and reported front seat deformation and risk of injury.



# Source of Data

## Partners for Child Passenger Safety

- Unique academic/industry research partnership
- Largest study of children in MVC
  - 442,000 crashes
  - 650,000 children
- Inclusion Criteria
  - Child occupant < 16 years of age
  - State Farm insured
  - Model year  $\geq$  1990



 The Children's Hospital  
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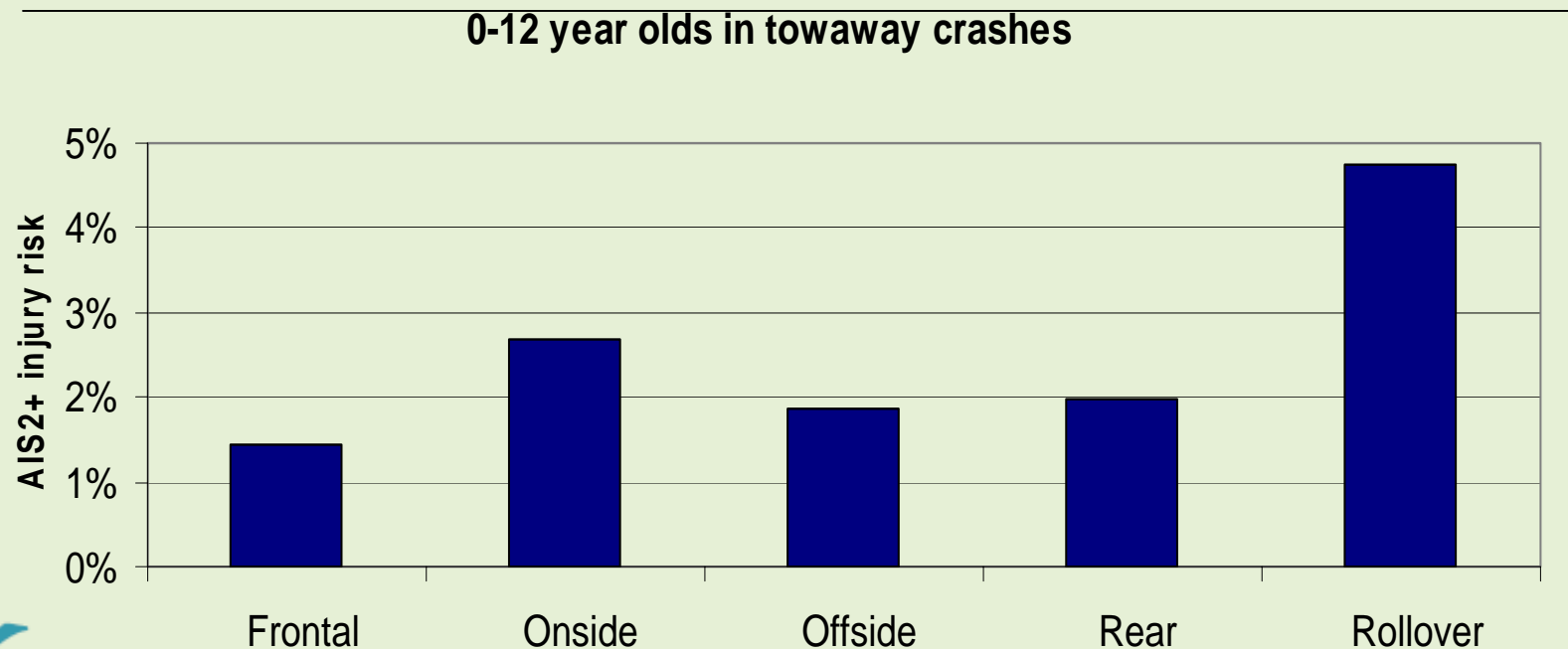




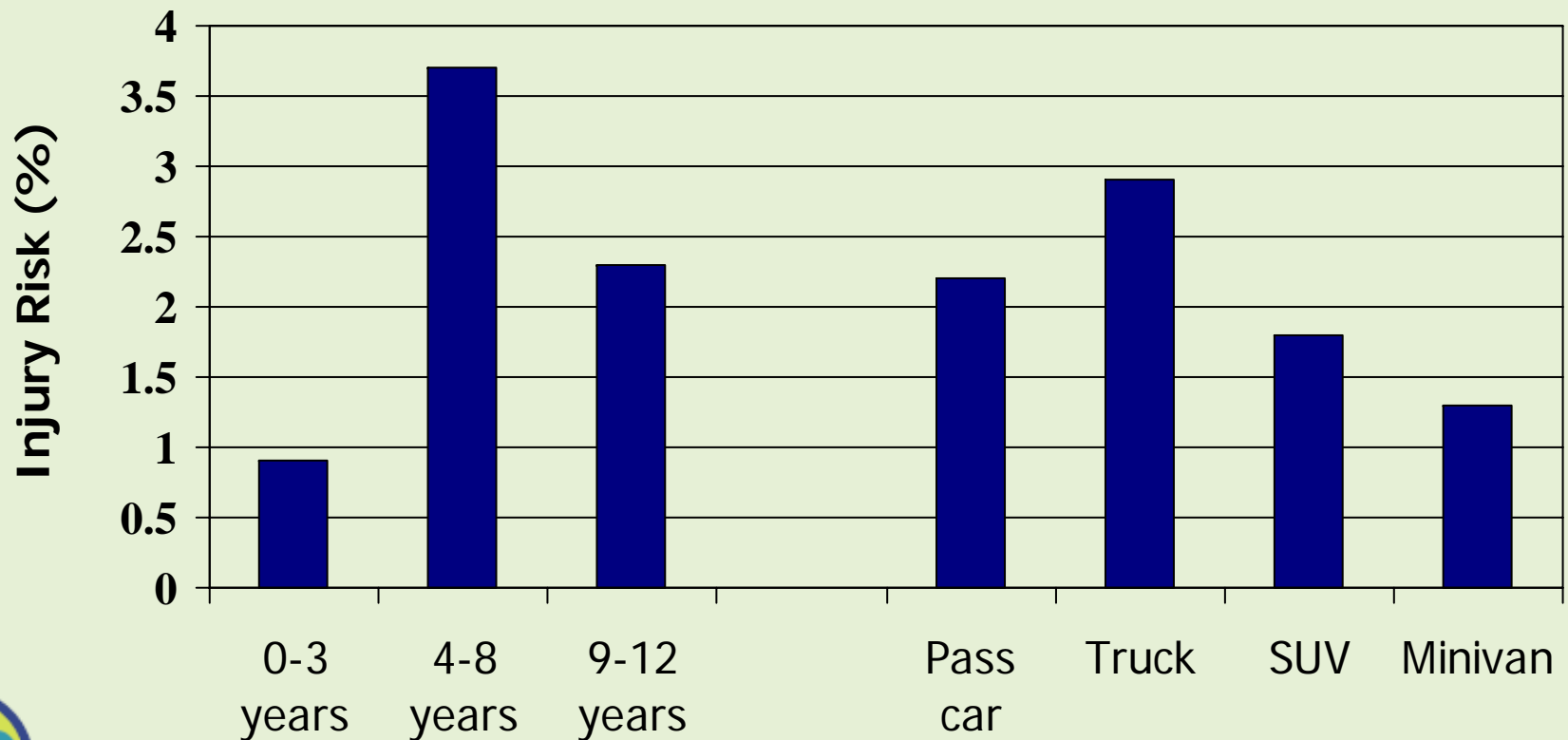
# Rear impact crashes

## Entire PCPS sample

- Rear impacts represent 31% of all crashes and 15% of towaway crashes



# Injury Risk in Rear Impact Towaway Crashes



# Methods

## Study sample

- Inclusion Criteria
  - Data from 3/1/00-12/31/06
  - Age 0-12 years, restrained in rear (second row) outboard position
  - Rear impact tow-away crash
  - 1032 children weighted to represent 9989 children



# Methods

## Statistical analyses

- Outcome of interest
  - AIS 2+ injuries excluding concussion
- Risk factors for injury risk in rear seat
  - Age, restraint type,
  - Vehicle type, MY and intrusion
  - Presence of a front seat occupant
  - Reported seat back deformation
- Bivariate and Multivariate Logistic regression



# Results

## Study sample characteristics

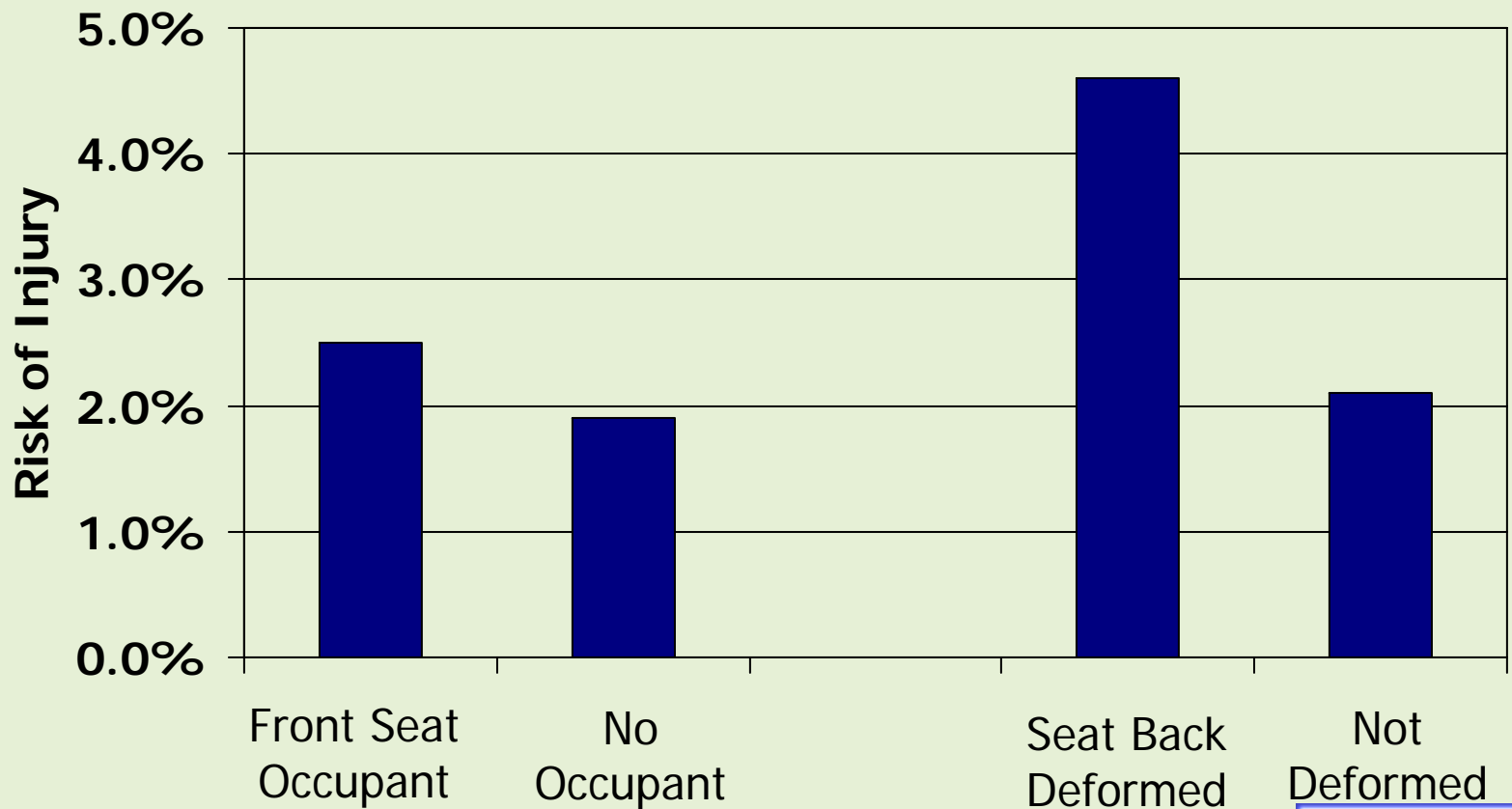
Variable		Number (wt %)
Age Group	0-3 years	353 (40%)
	4-8 years	412 (37%)
	9-12 years	267 (23%)
Restraint Type	Child Restraint System	502 (54%)
	Vehicle Seat Belt	533 (46%)
Vehicle Type	Passenger Car	546 (48%)
	Minivan	228 (27%)
	SUV	206 (22%)
	Pick-up Truck	40 (3%)
Vehicle Model Year	1990- 1997	415 (36%)
	1998- 2006	617 (64%)
Intrusion		339 (25%)
Front Seat Occupant Present		764 (71%)
Reported Front Seat Back Deformation		125 (8%)



# Results

## Injury risk in rear seat

Overall injury risk = 2.3%



# Results

## Logistic Regression Analyses

Variable		OR (95 % CI)
Age Group	0-3 years	0.5 (0.2- 1.3)
	4-8 years	1.8 (0.9- 3.7)
	9-12 years	Reference
Restraint Type	Child Restraint System	0.8 (0.3- 2.0)
	Vehicle Seat Belt	Reference
Vehicle Type	Passenger Car	Reference
	Minivan	0.3 (0.1- 0.9)
	SUV	0.3 (0.2- 0.7)
	Pick-up Truck	2.1 (0.8- 5.9)
Vehicle Model Year	1990- 1997	1.0 (0.6- 1.9)
	1998- 2006	Reference
Intrusion		1.5 (0.6- 2.7)
Front Seat Occupant Present		1.0 (0.5- 1.9)
Reported Front Seat Back Deformation		2.3 (1.2- 4.7)





# Results

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Reported Front Seat Back Deformation		2.3 (1.2- 4.7)



# Results

## Analysis of NASS-CDS

- Insufficient number of children in NASS-CDS (2000-2006)
- Included all age occupants
  - Rear row, restrained in rear impact crash
  - 424 occupants (211 children) representing 254,077 total

# Results

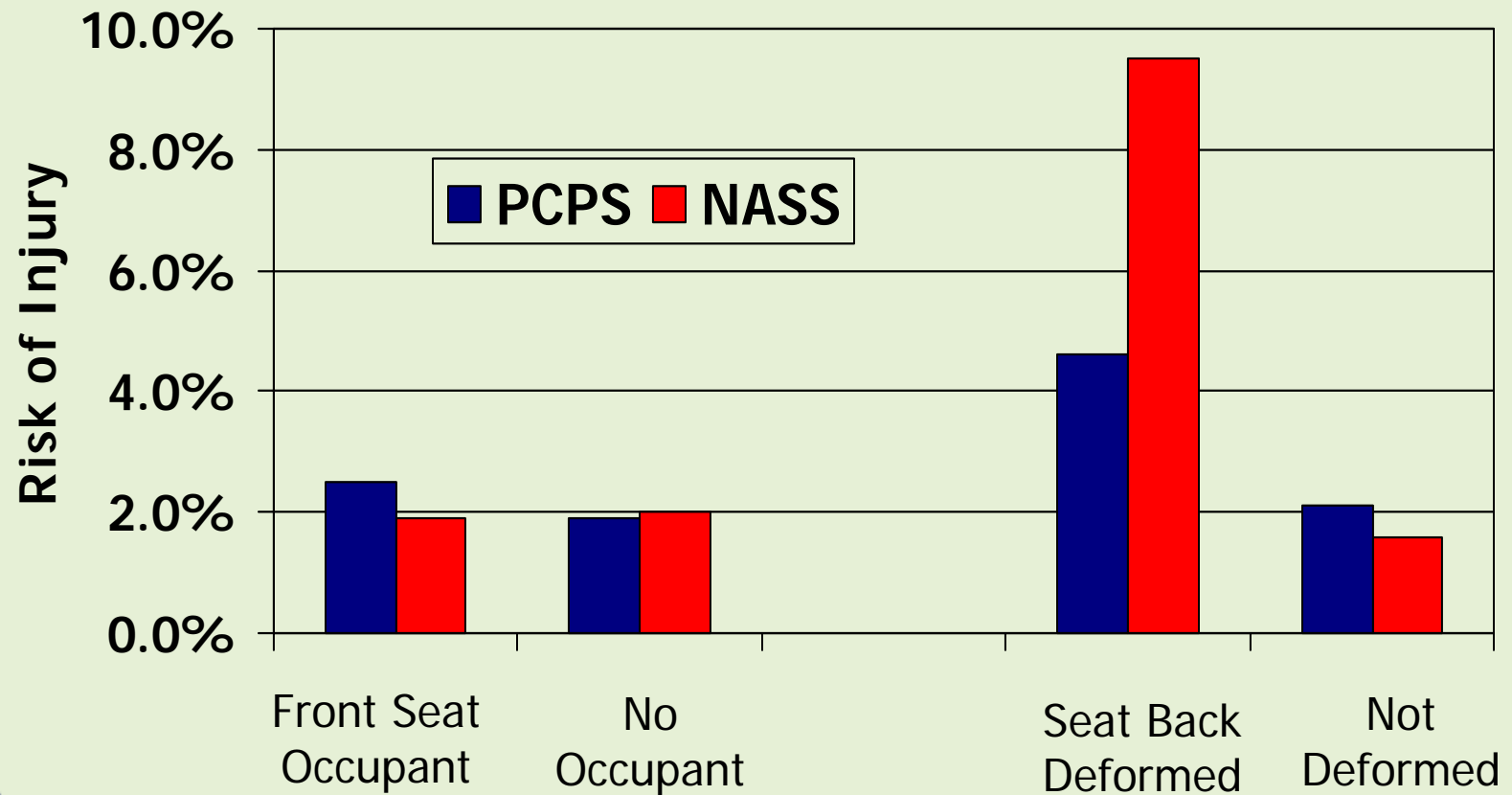
## PCPS vs. NASS characteristics

Variable		Number (wt %)	
Age Group	0-3 years	353 (40%)	
	4-8 years	412 (37%)	
	9-12 years	267 (23%)	
Restraint Type	Child Restraint System	502 (54%)	
	Vehicle Seat Belt	533 (46%)	
Vehicle Type	Passenger Car	546 (48%)	76% NASS
	Minivan	228 (27%)	8% NASS
	SUV	206 (22%)	15% NASS
	Pick-up Truck	40 (3%)	
Vehicle Model Year	1990- 1997	415 (36%)	54% NASS
	1998- 2006	617 (64%)	
Intrusion		339 (25%)	23% NASS
Front Seat Occupant Present		764 (71%)	88% NASS
Reported Front Seat Back Deformation		125 (8%)	3% NASS



# Results

## Injury risk in rear seat



# Results

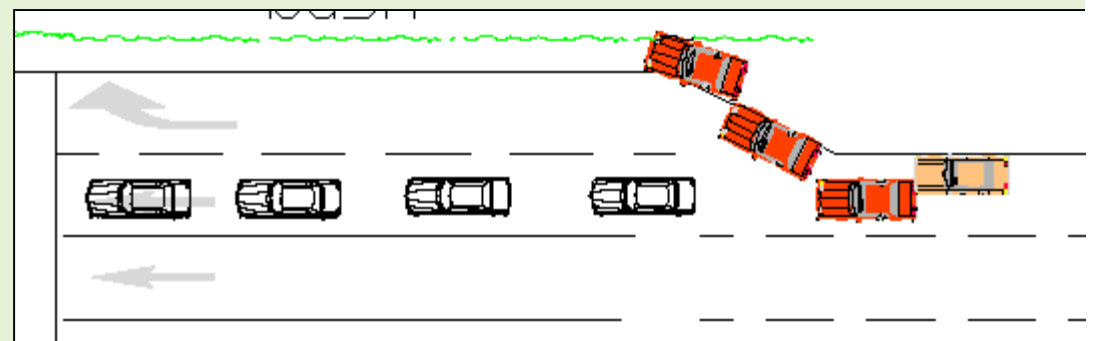
## PCPS vs. NASS Analyses

Variable		OR (95 % CI)
Age Group	0-3 years	0.5 (0.2- 1.3)
	4-8 years	1.8 (0.9- 3.7)
	9-12 years	Reference
Restraint Type	Child Restraint System	0.8 (0.3- 2.0)
	Vehicle Seat Belt	Reference
Vehicle Type	Passenger Car	Reference
	Minivan	0.3 (0.1- 0.9)
	SUV	0.3 (0.2- 0.7)
	Pick-up Truck	2.1 (0.8- 5.9)
Vehicle Model Year	1990- 1997	1.0 (0.6- 1.9)
	1998- 2006	Reference
Intrusion		1.5 (0.6- 2.7)    2.3 (0.2- 30) NASS
Front Seat Occupant Present		1.0 (0.5- 1.9)    0.4 (0.2- 1.0) NASS
Reported Front Seat Back Deformation		2.3 (1.2- 4.7)    4.1 (0.5- 38) NASS



# Case Example #1

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



# Case occupant

## Left rear seat

- 5 year old female, 43", 37 lb
- Backless booster with L/S belt

## Injuries

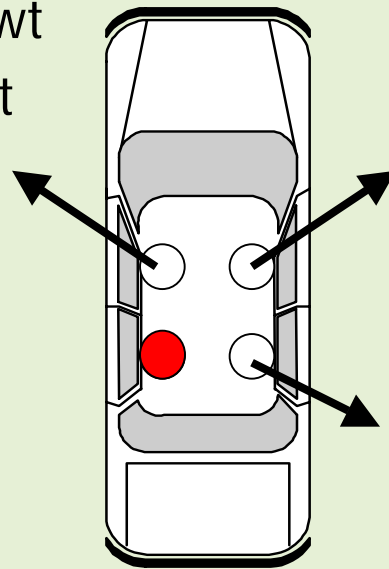
- Head
  - AIS 3: Left orbital roof fracture
  - AIS 2: Left frontal bone fracture
- Face
  - AIS 2: Left superolateral orbital ridge fracture
  - AIS 1: Left periorbital and facial edema





# Other Occupants

- 33 year old male
  - 186 cm (73") & unk wt
  - Lap and shoulder belt
  - Scalp contusion*
  - Cervical Strain*

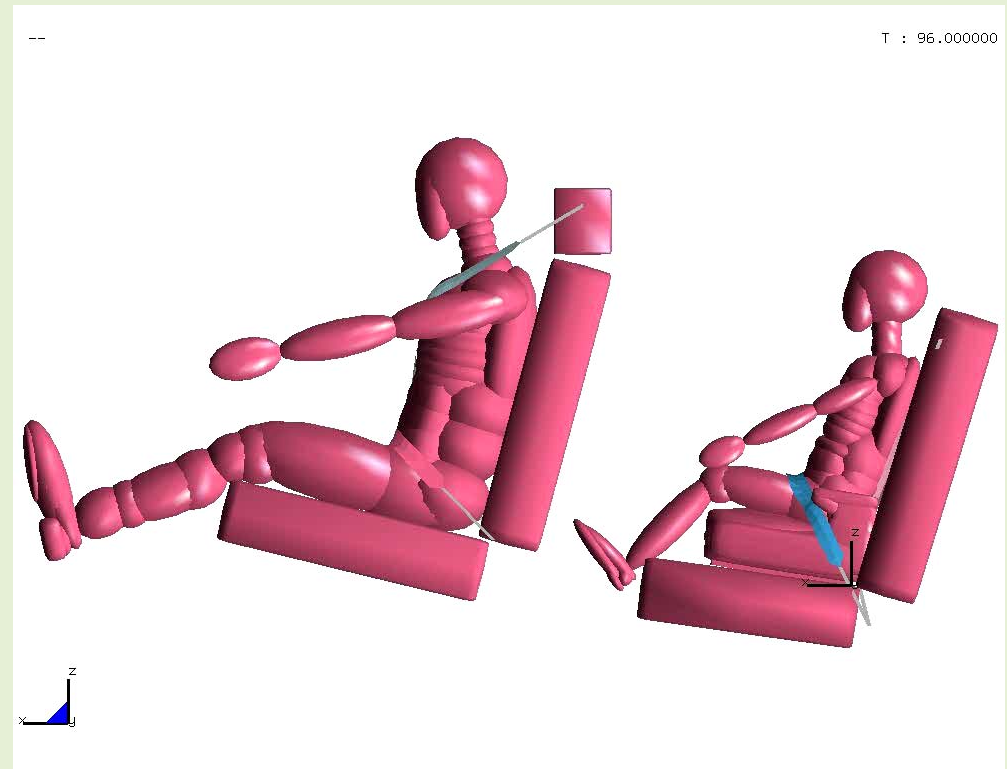


- 33 year old female
  - Unk ht and wt
  - Lap and shoulder belt
  - L shoulder and chest strain,*
  - minor contusion*
- 6 year old female
  - 47", 50 lbs.
  - Backless booster
  - Lap and shoulder belt
  - Minor tongue laceration*



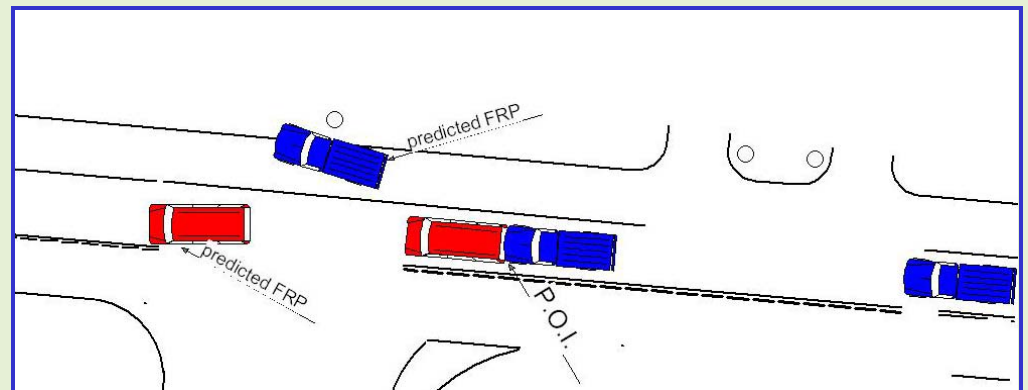
# Occupant Kinematics

- HIC 36 = 960
- Linear accel =  $1019 \text{ m/s}^2$
- Angular accel =  $7481 \text{ rad/s}^2$



# Case Example #2

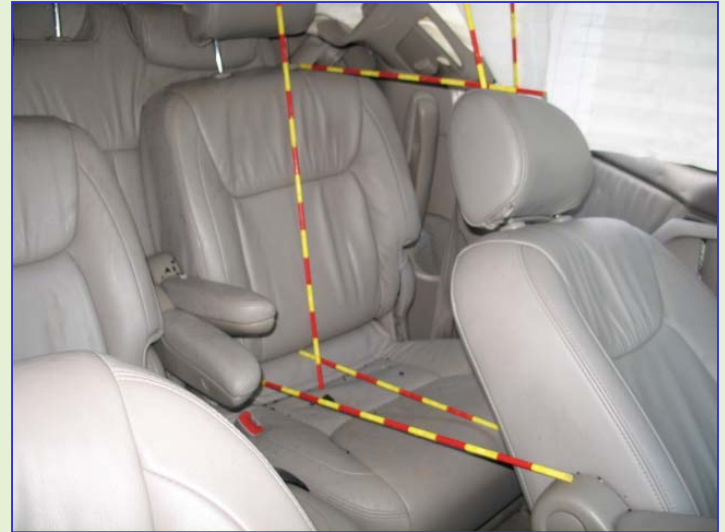
- Case vehicle:  
2004 Toyota Sienna
- Struck by  
1995 Ford F150
- $\Delta V = 55 \text{ km/hr}$
- PDOF = 6 o'clock
- CDC: 06BDAW4



# Case Occupant

2<sup>nd</sup> row left seat

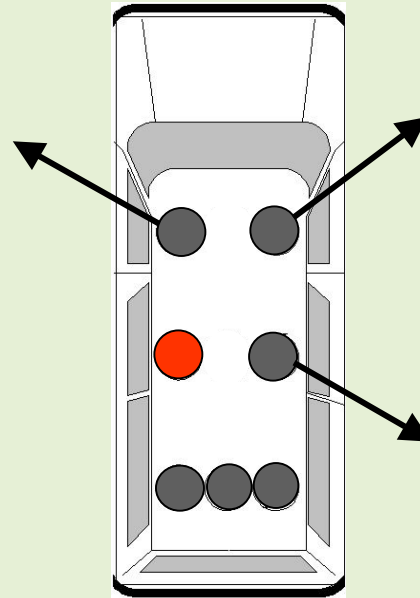
- 3 year old male
  - 105cm: >75%
  - 22kgs: 95%
- High-back booster & L/S belt
- Head and Face Injuries
  - AIS 4: Right frontal SDH
  - AIS 3: Left parietal depressed skull fracture  
Left frontal and parietal SAH
  - AIS 2: Right frontal, parietal skull fracture  
Left pterion fracture  
Mandible fractures
  - AIS 1: Multiple face/head superficial injuries



# Other Occupants

- 32 year old male
- 180 cm, (70") 88 kg
- Lap and Shoulder belt

*Injuries:* Superficial Head, Facial, Extremity injuries  
R occipital scalp hematoma  
R peri-auricular contusion



- 33 year old female
- 165 cm, 79 kg
- Lap and Shoulder belt

*Injuries:* Superficial Hip abrasions

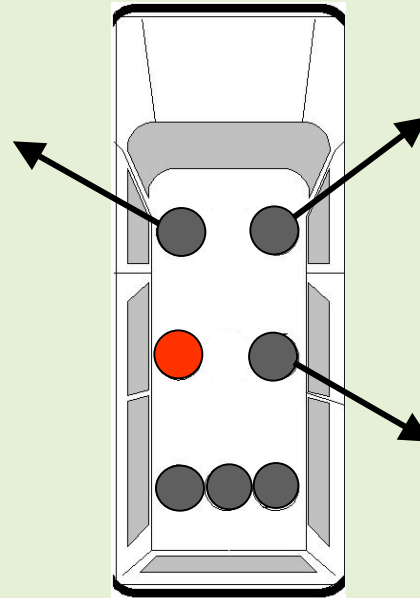
- 1 year old female
- 11 kg: 75%, Unk Ht
- FFCRS 5pt harness, LATCH

*Injuries:* Superficial Hip abrasions

# Other Occupants

- 32 year old male
- 180 cm, 88 kg
- Lap and Shoulder belt

*Injuries:* Superficial Head,  
Facial, Extremity injuries  
R occipital scalp hematoma  
R peri-auricular contusion



- 33 year old female
- 165 cm, 79 kg
- Lap and Shoulder belt

*Injuries:* Superficial Hip  
abrasions

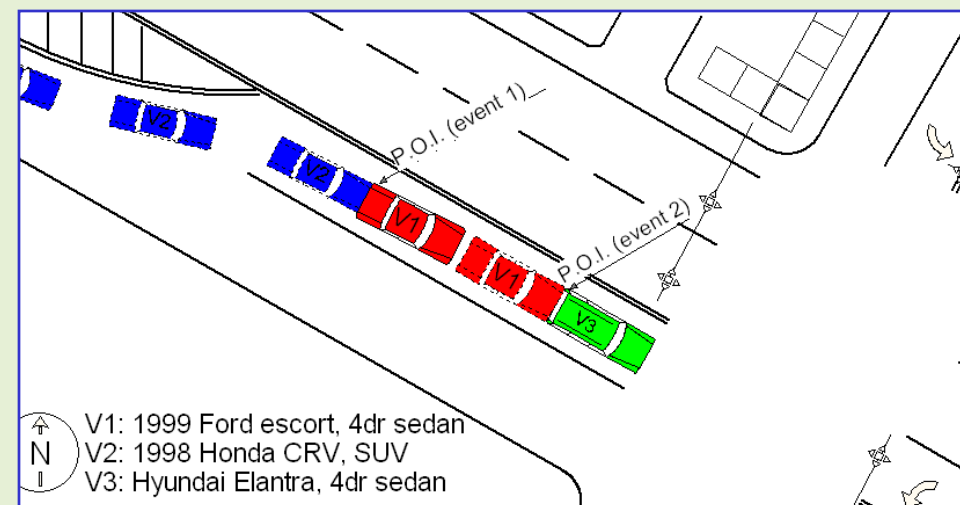
- 1 year old female
- 11 kg: 75%, Unk Ht
- FFCRS 5pt harness,  
LATCH

*Injuries:* Superficial Hip  
abrasions



# Case Example #3

- Case vehicle:  
1999 Ford Escort
- Struck by  
1998 Honda CRV
- $\Delta V = 28 \text{ km/hr}$
- PDOF = 6 o'clock
- CDC: 06BDEW5

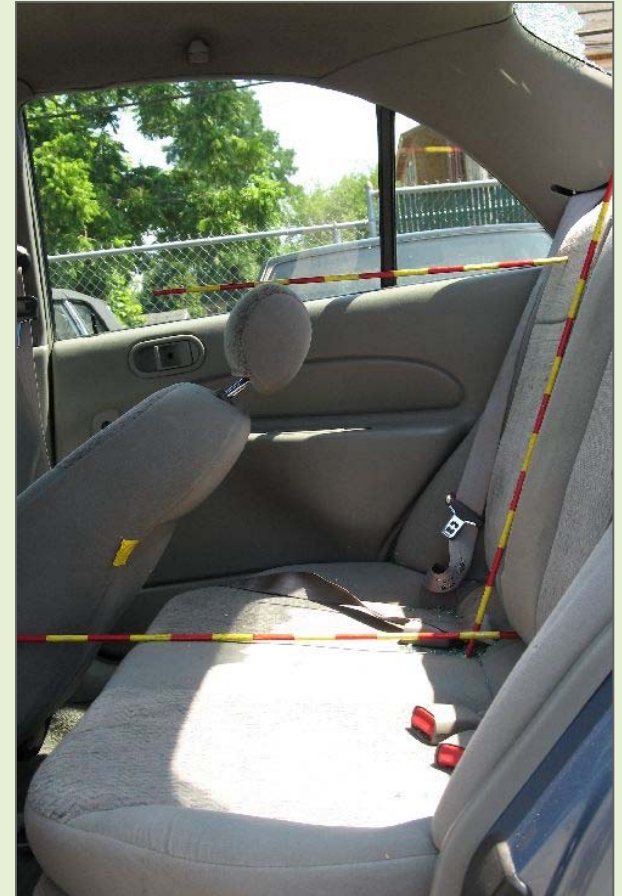




# Case Occupant

## Right rear seat

- 3 year old male
  - 93 cm: 10%
  - 12 kgs: <5%
- FFCRS with tray shield
- Head and Face Injuries
  - AIS 3: R frontal depressed skull fracture  
R orbital roof comminuted fx
  - AIS 2: L orbital roof non displaced fx
  - AIS 1: B/L periorbital contusions



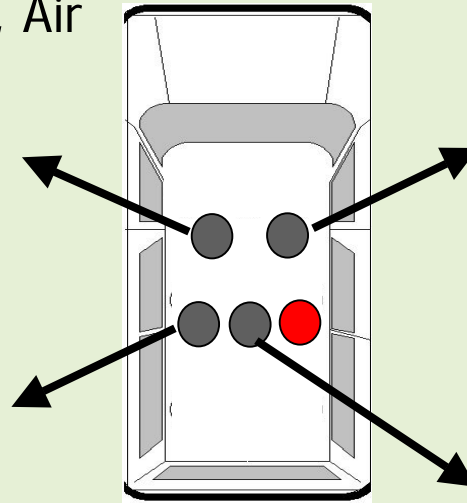
# Other Occupants

- 21 year old female
- 168 cm, 48 kg
- Lap and Shoulder belt, Air bag

*Injuries:* Back pain

- 3 year old male
- 93 cm, 12 kg
- FFCRS 5pt Harness w/  
Lap and Shoulder belt

*Injuries:* Jaw injury



- 45 year old male
- 191 cm, 127 kg
- Lap and Shoulder belt, Air bag

*Injuries:* R Extremity contusions

- 6 year old male
- Unk ht, 18 kg
- Low Back Booster seat w/ Lap and Shoulder belt

*Injuries:* No significant injuries



# Conclusions

## Statistical analyses

- Rear impacts account for 15% of child-involved tow-away crashes and have a risk of AIS 2+ injury similar to frontal crashes.
- Presence of a front seat occupant does not increase risk of injury to rear-seated child.
- Front seat back deformation doubles risk of injury to rear-seated child.



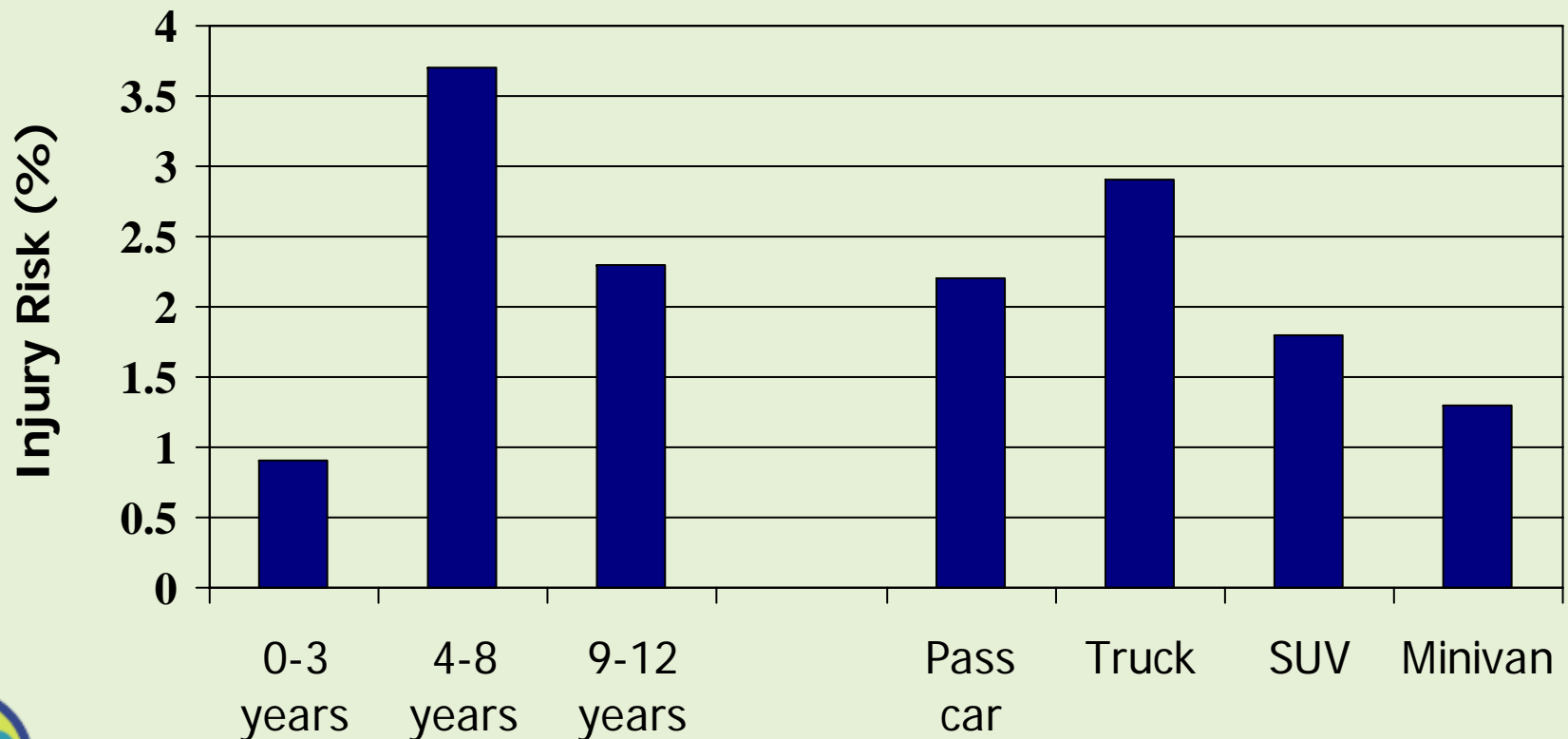
# Conclusions

## Case reviews

- Primarily head and face injuries to children
  - Contact with front seat occupant
- Occurrence of injury possibly related to size of front seat occupant
  - Smaller front seat occupants with no seat deformation and no injury to rear seated children
- Injuries to young children in child restraints



# Injury Risk in Rear Impact Towaway Crashes



26% 17% 6% with seat back deformation



The Center for Injury  
Research and Prevention  
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# Implications

- Not only a pediatric problem – anyone in the rear?
  - Are children at greater risk?
    - Sit forward
    - Less use of shoulder belt – more torso movement
    - Relative size – more room to move
- Rear impact regulatory and industry focus currently on front seat occupants
- Difficult design dilemma – does focusing on front seat occupants alone put rear seat occupants at risk?
  - Must evaluate pediatric ATD biofidelity in this impact mode

