Moving Deformable Barrier Test Procedure for Evaluating Small Overlap/Oblique Crashes

James Saunders, NHTSA
Dan Parent, NHTSA
Matthew Craig, NHTSA

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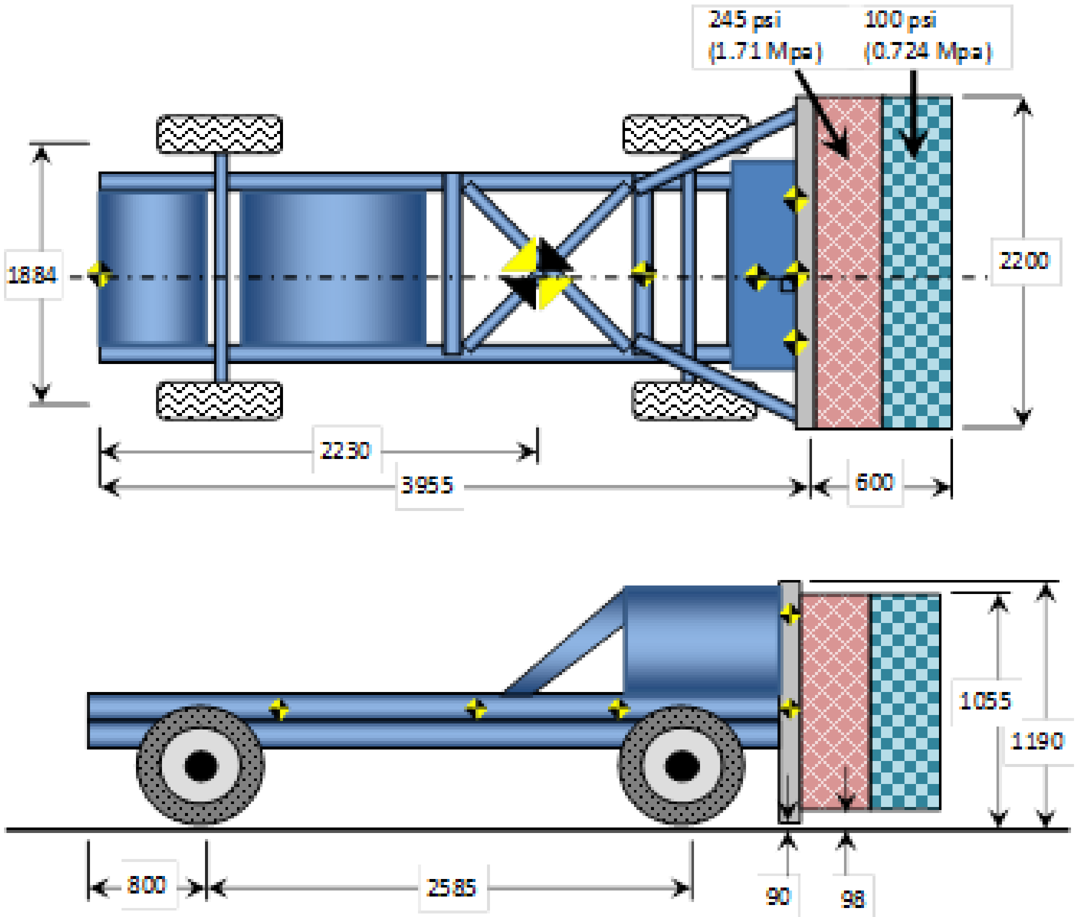
Presentation Outline

- Background
- Part 1: Vehicle Characteristics
  - Compare Oblique Vehicle-to-Vehicle to Oblique RMDB-to-Vehicle
  - Results of new vehicle design testing
    - Small Overlap / Oblique
    - Compare Small Overlap to Oblique
- Part 2: Dummy Characteristics

Background

- Bean et al, 2009: Poor structural engagement resulted in largest number fatalities, excluding exceedingly severe crashes
- Rudd et al, 2011: NASS/CIREN study showed Knee Thigh Hip AIS 3+ most frequent injuries followed by chest and lower leg
- Saunders et al, 2011: Demonstrated that the use of the current FMVSS 214 barrier was not suitable for this type of test procedure

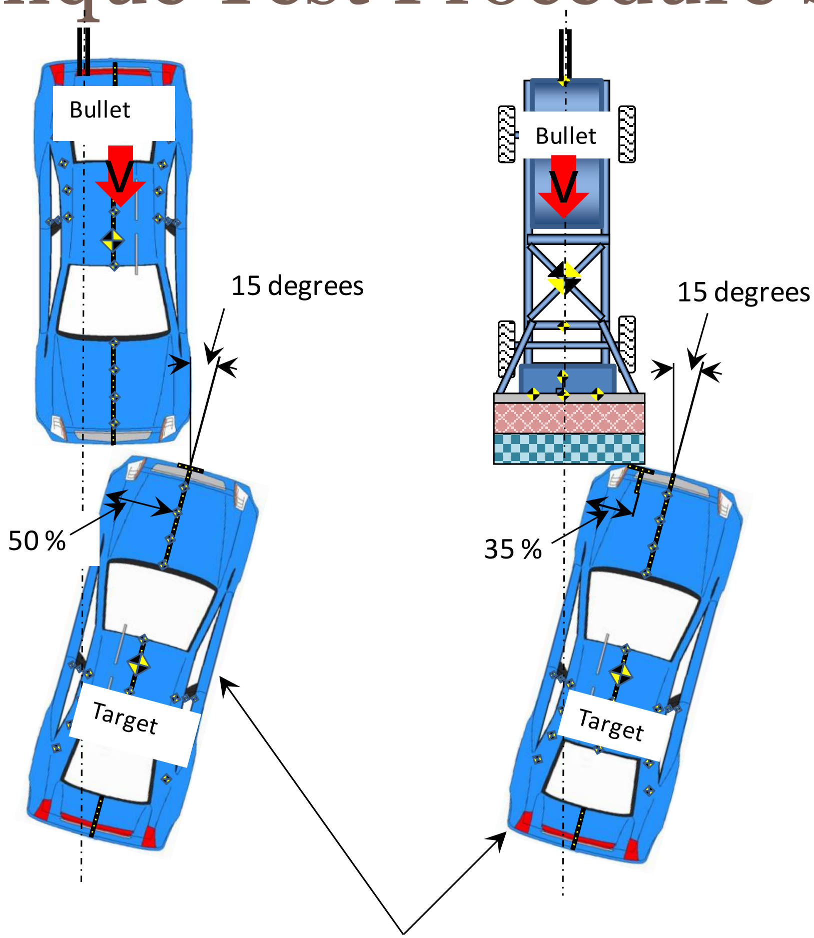
RMDB Barrier Characteristics



All dimensions are in mm

- Oblique Vehicle-to-Vehicle comparison to RMDB-to-Vehicle

Oblique Test Procedure Setup



Bullet vehicle speed was determined to achieve a 35 mph DV, in full frontal, in the stationary vehicle

Top View of VtV to RMDBtV comparison

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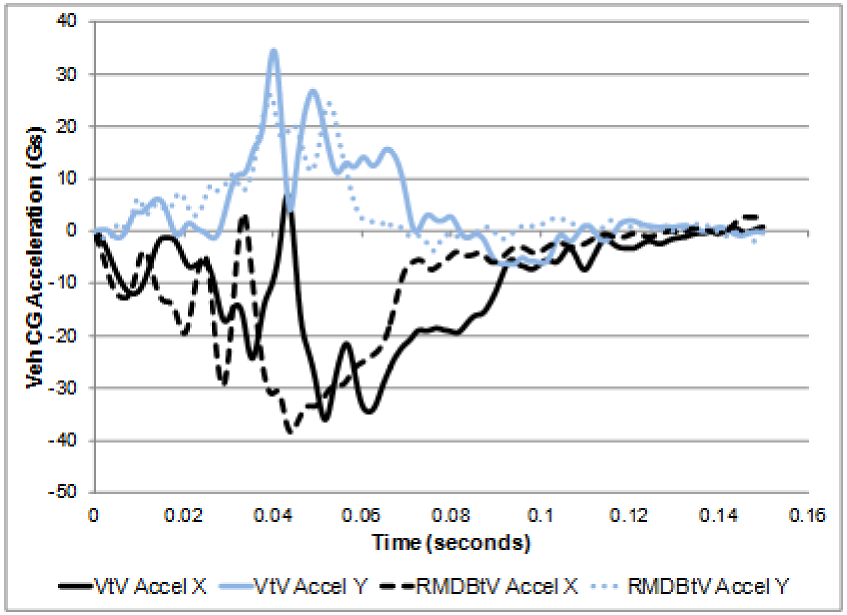
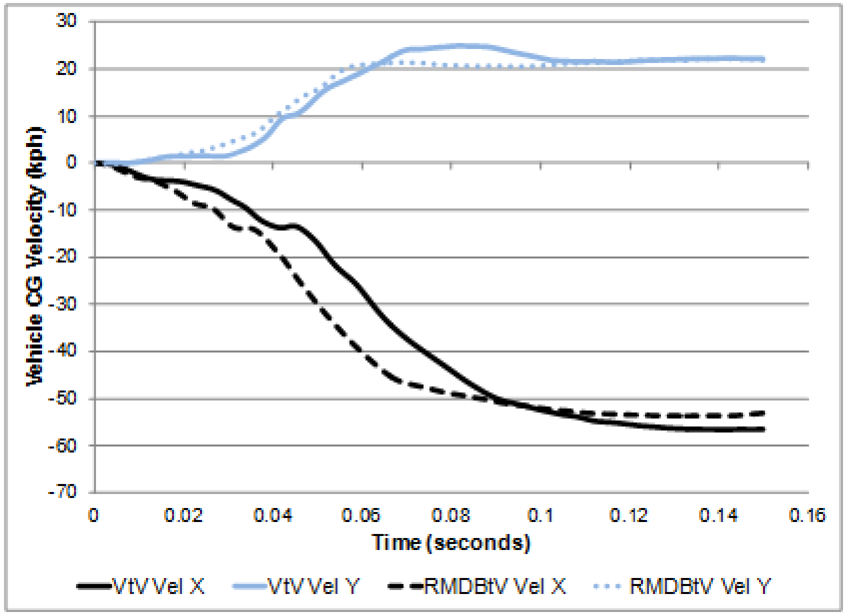
Acceleration and Velocity PCb





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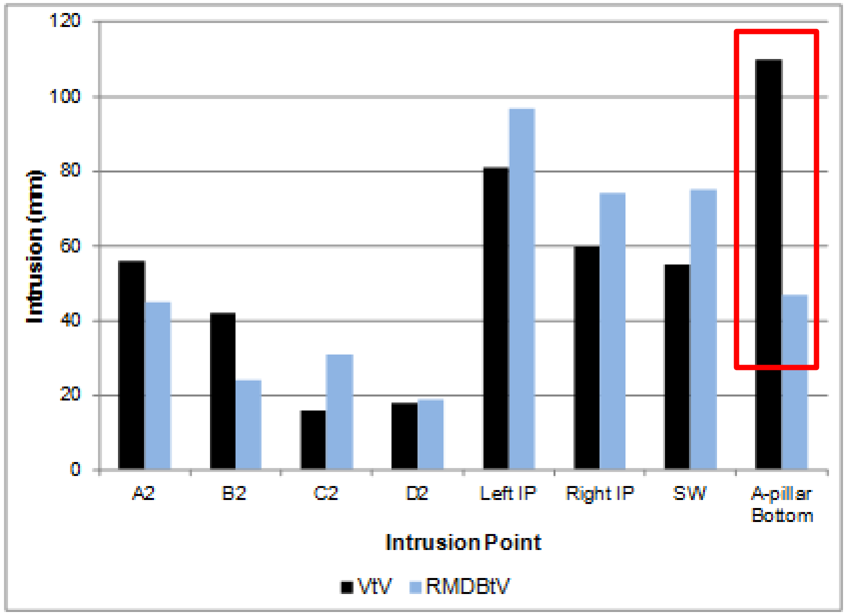
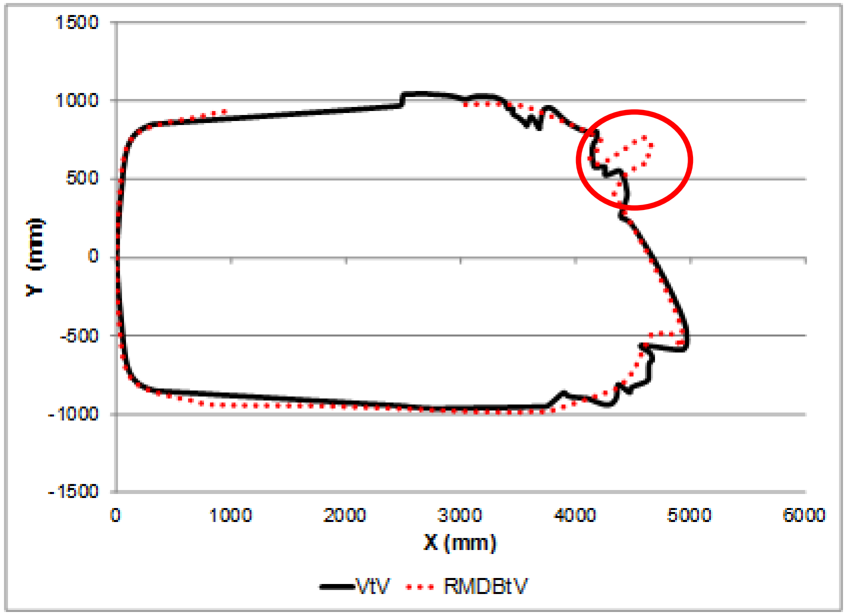
Interior Intrusion and Exterior Crush





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- New Model Testing

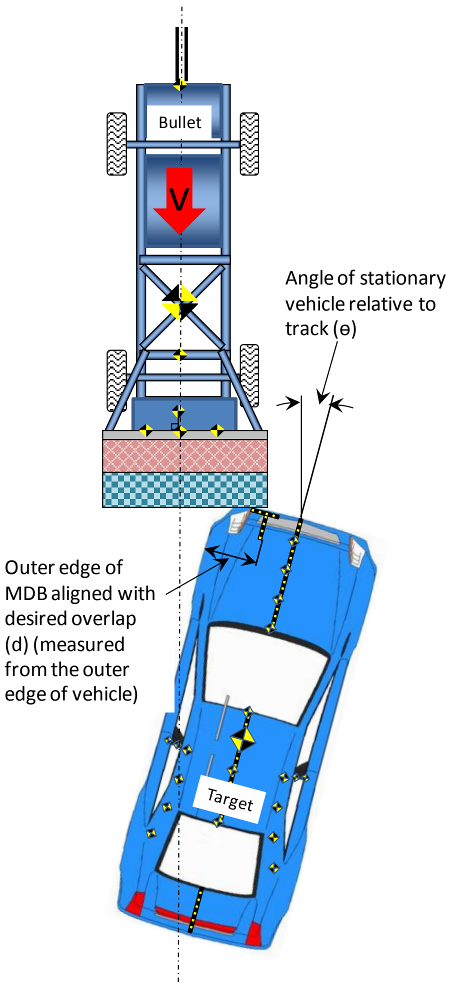
Constant-energy test procedure

- Moving deformable barrier impacts each vehicle at the same velocity
  - Compare results across the fleet
  - Procedure is more severe for smaller cars
  - Potential to drive convergence of vehicle front-end stiffness

Vehicle Selection

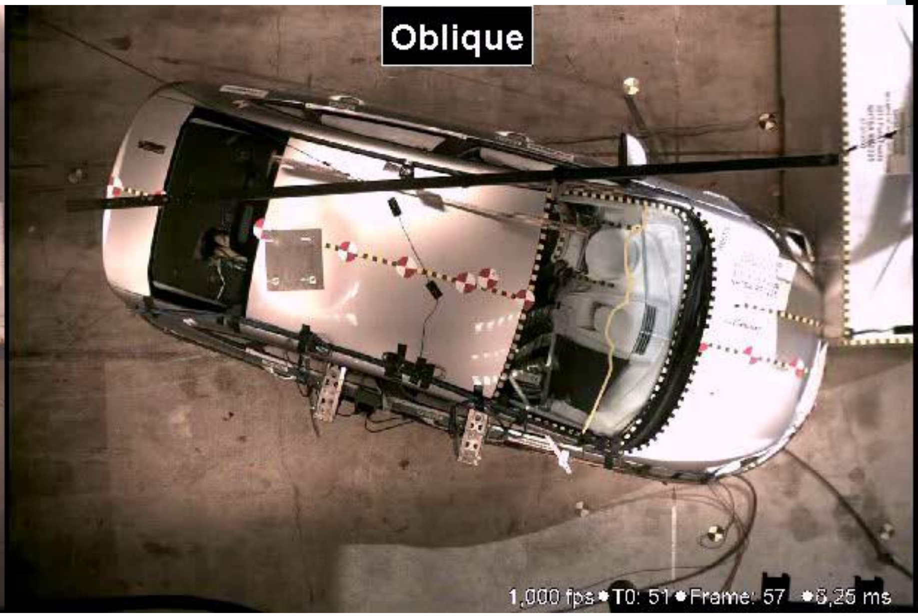
- Vehicles introduced or redesigned in 2010-2011
- Good structural rating from IIHS
- Different classes of vehicles ranging from the lightest to the heaviest
- Compare heavy vehicle with body-on-frame and uni-body design
- 8 SOI and 7 Oblique

Test Setup



	Small Overlap (SOI)		Oblique	
	Test Setup	Rationale	Test Setup	Rational
Barrier Closing Speed	56 mph	Achieve 35mph Delta-V in average-mass passenger car	56 mph	Achieve 35mph Delta-V in average-mass passenger car
Overlap	20%	Engage structure outboard of longitudinal rail for most vehicles	35%	Represent vehicle-to-vehicle test with 50% overlap (engagement of one longitudinal rail)
Angle Relative to Track	7 degrees	0 degrees bounced off 15 degrees deformed rail inboard	15 degrees	PDOF of 10-20 degrees most prominent in field after full frontal

PC2 SOI and Oblique Top View



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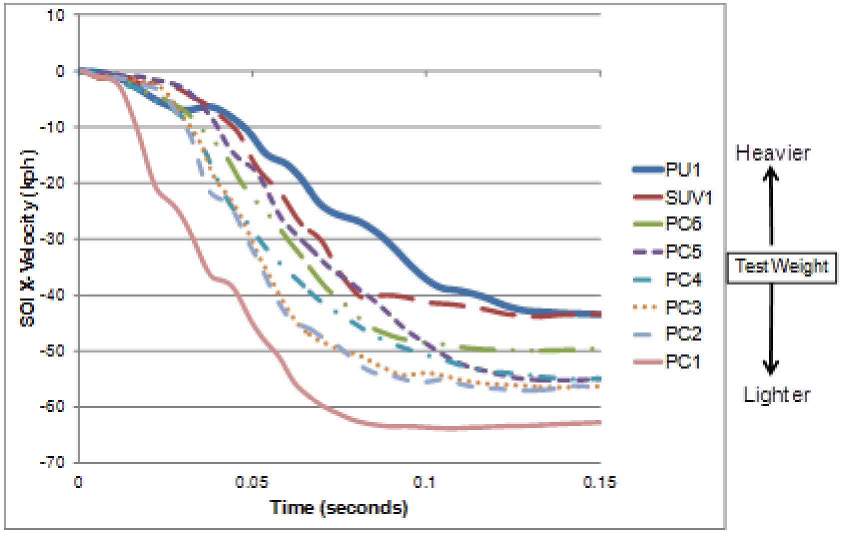
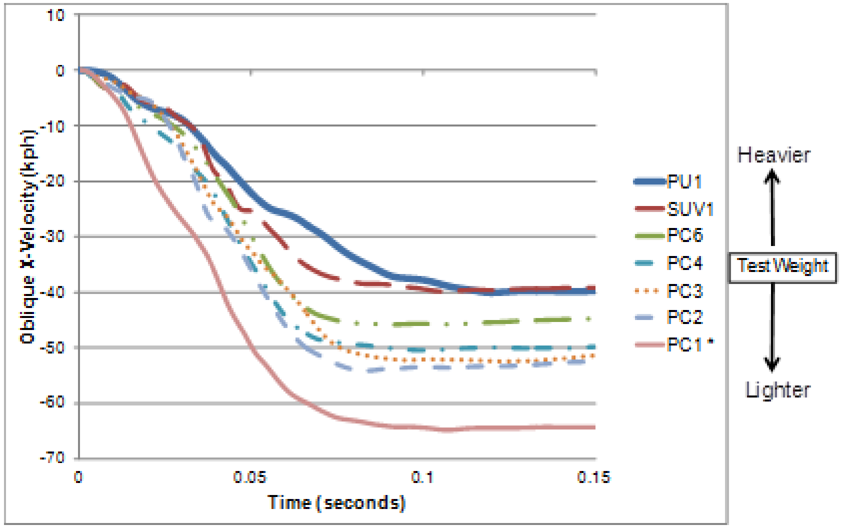
PU1 SOI and Oblique Video

PC1 and SUV1 SOI Video

Velocity Traces

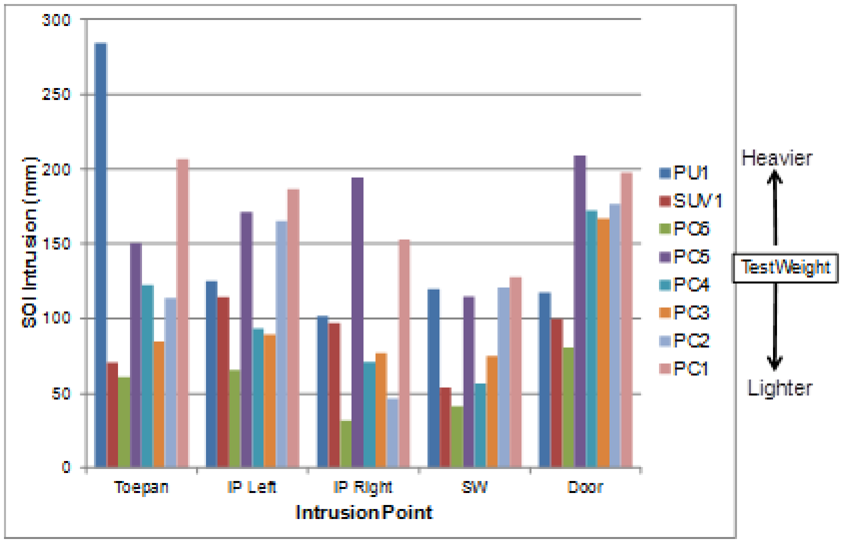


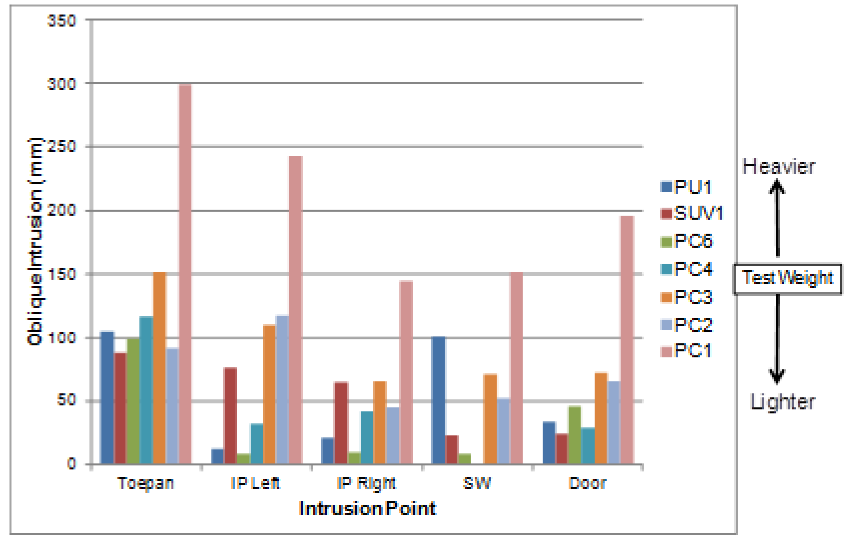
Small Overlap

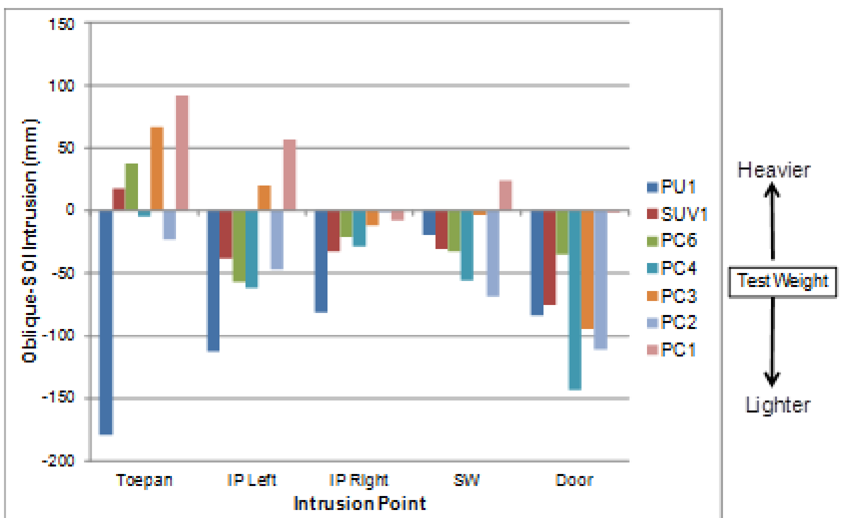


Oblique

Intrusions







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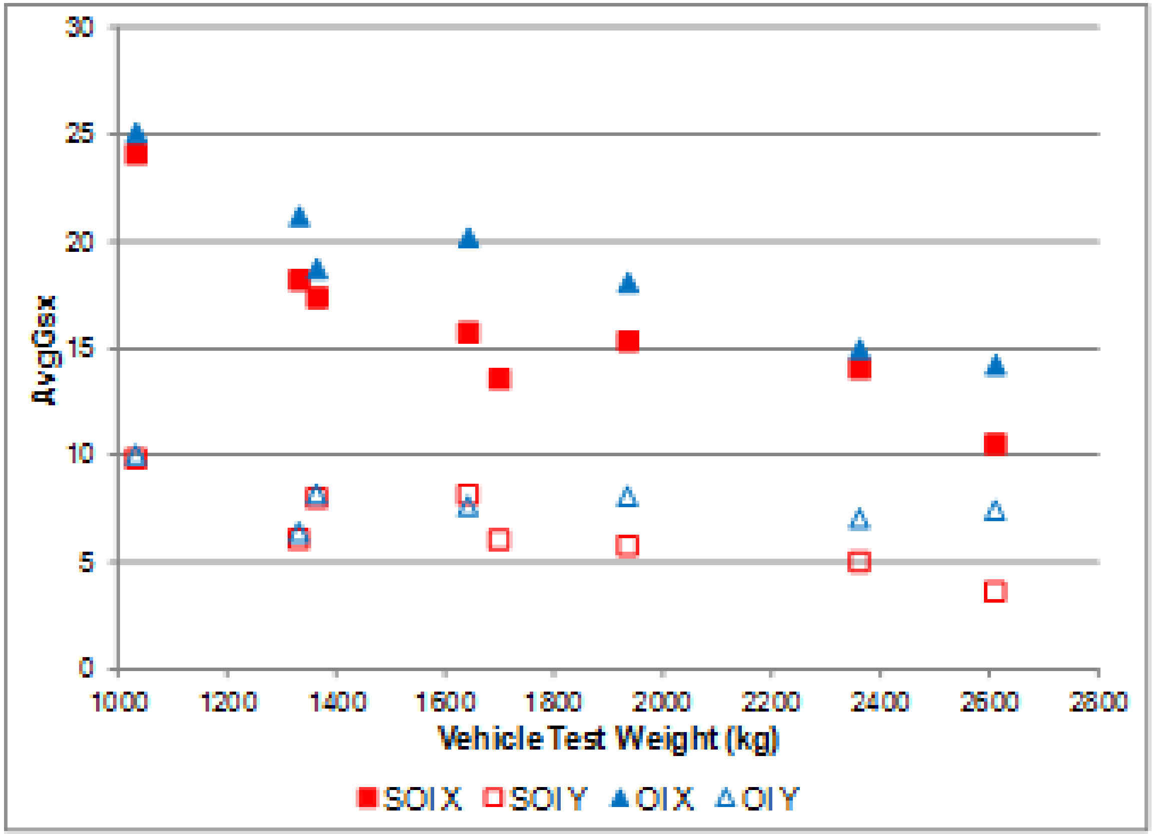
AvgGs comparison between SOI and Oblique



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Summary

- VtV to RMDBtV Comparison
  - Oblique test procedure using the RMDB as a surrogate for a vehicle was generally able to replicate VtV
- New Vehicle Study
  - DV decreased as mass of the vehicle increase
  - SOI condition did not always produce greater intrusion when compared to Oblique test procedure

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Part 2: Occupant Response

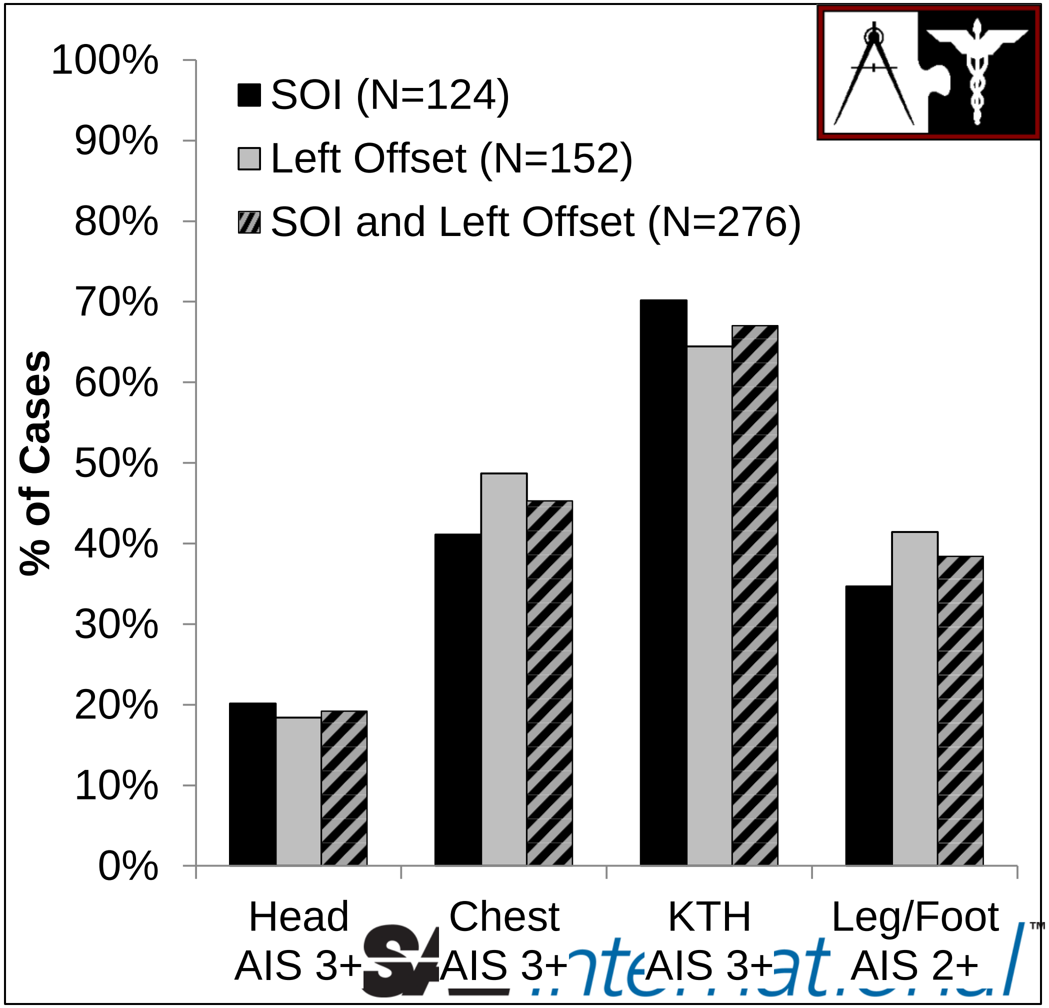
SAE 2012 World Congress
Detroit, Michigan
4/25/2012

Presentation Overview

- Field exposure
- Description of test device (THOR)
- Vehicle-to-vehicle vs. RMDB
- Occupant response
  - SOI Kinematics
  - SOI Restraint interaction
  - SOI Injury Assessment
  - Oblique vs. SOI
- Summary

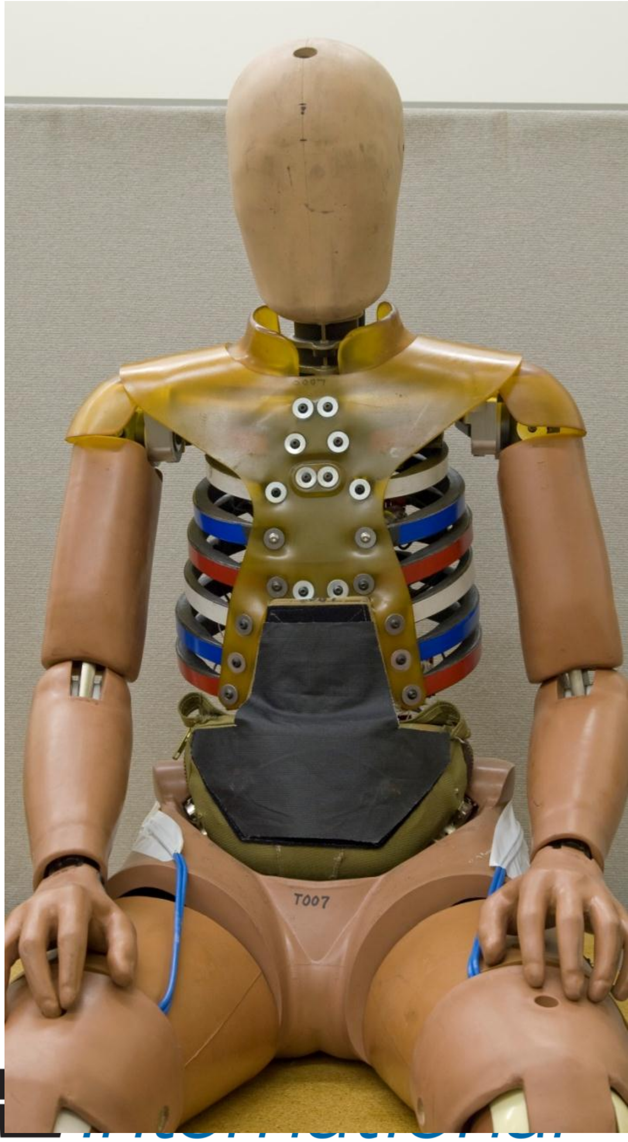
Review of CIREN and NASS Cases (Rudd 2011)

- Requirements
  - Belted drivers with at least one AIS 3+ injury
  - Vehicle model year 1998 and newer
  - Front or left side damage
  - 320º < PDOF < 0º
  - No under-, over-ride
- SOI
  - Engagement outside of left longitudinal
- Left Offset
  - Left longitudinal engaged
- AIS 3+: KTH > Chest > Head
  - Independent of mode



Occupant Response Assessment: THOR ATD

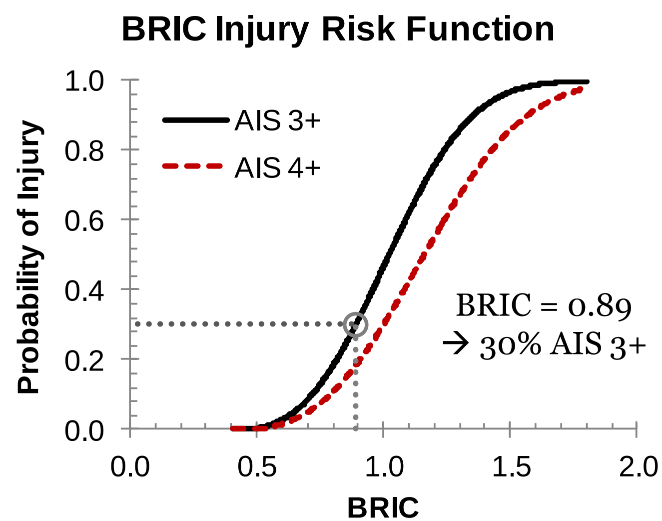
- THOR-NT with Mod Kit (Ridella, 2011)
  - Improvements to biofidelity, repeatability, durability, usability
- Designed to demonstrate improved biofidelic kinematics vs. Hybrid III
  - Flexible joints in thoracic and lumbar spine
  - Improved restraint interaction
- Increased measurement capability vs. Hybrid III
  - Thorax: 4-point, 3-dimensional chest deflection
  - Abdomen: 2-point, 3-dimensional lower abdomen deflection
  - Knee-thigh-hip: Acetabulum load cells
  - Lower Extremity: Upper, lower tibia loads; ankle rotations
- Limitation: Injury Assessment Reference Values (IARVs) not yet established
  - Provisional IARVs used for this study
  - THOR-specific IARVs to be developed 2012-2013
  - Example: Rotational Brain Injury Criterion (BRIC)



Rotational Brain Injury Criterion (BRIC)

$$BRIC = \frac{\omega_{\max}}{\omega_{cr}} + \frac{\alpha_{\max}}{\alpha_{cr}}$$

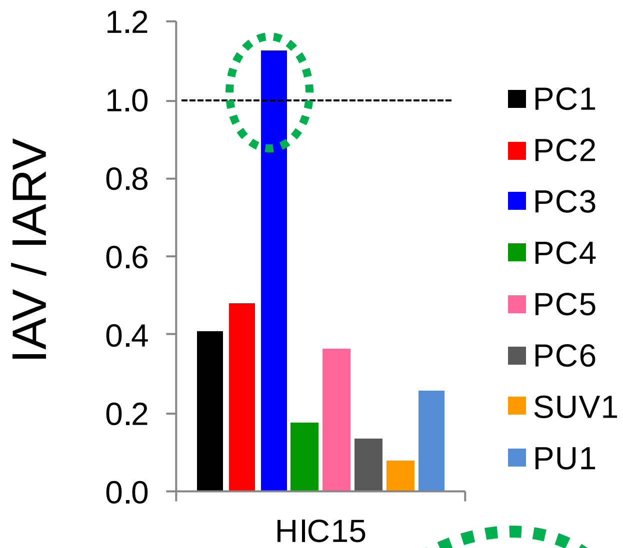
$$\begin{aligned} \omega &= \text{angular velocity at head CG} \\ \alpha &= \text{angular acceleration at head CG} \\ \max &= \text{maximum resultant value} \\ cr &= \text{critical value} \end{aligned}$$

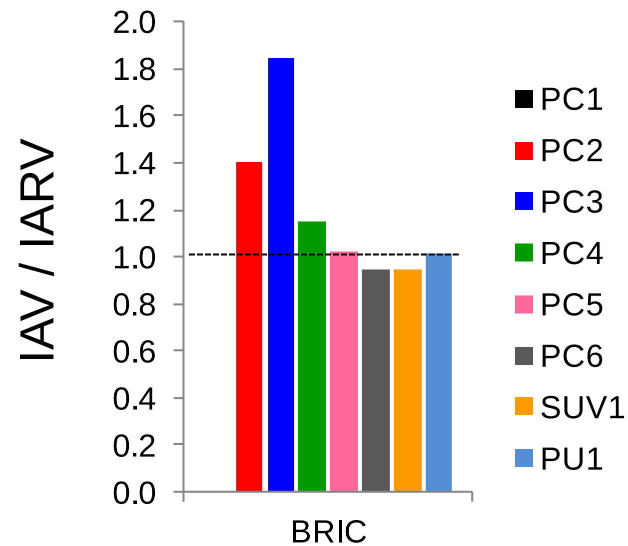


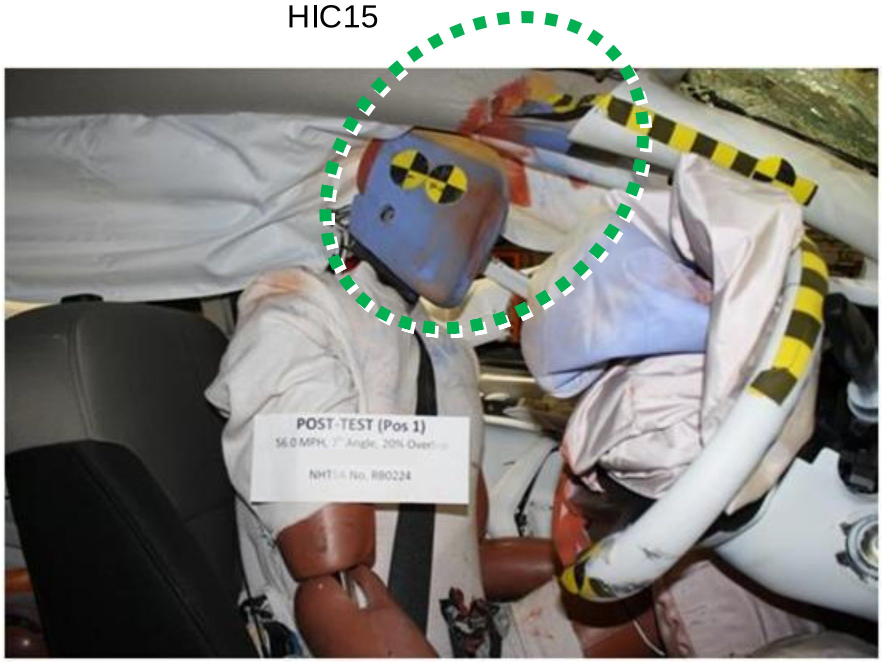
- THOR-specific critical values determined (per Takhounts 2011)
  - Basis = 31 THOR small overlap/oblique tests
  - Result = injury risk curves
    - f(BRIC) = p(AIS 3+) and p(AIS 4+)

Critical Values	ω_{cr} (rad/s)	α_{cr} (rad/s²)
Hybrid III	46.41	39,775
THOR	63.5	19,501

SOI: Head Response



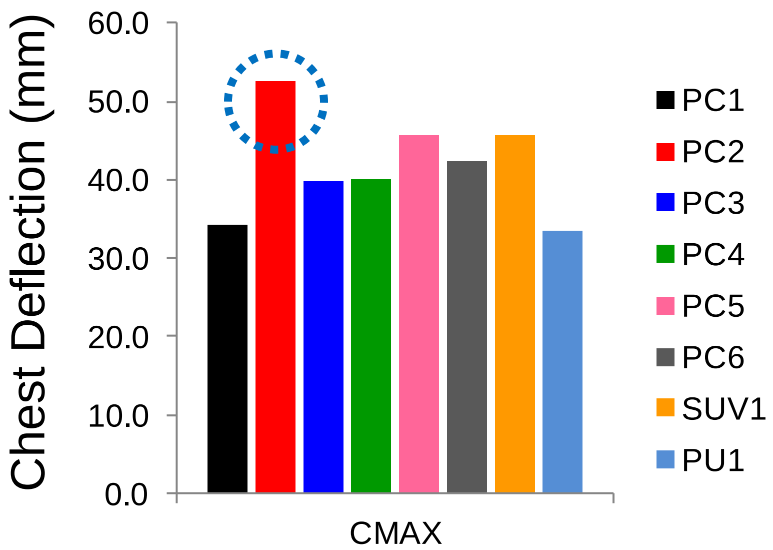




Test: Head Contact Locations

Vehicle	Airbag	Side Curtain	Roof Rail	Door Panel	IP
PC1	X				
PC2	X		X	X	X
PC3	X	X	**X**		
PC4	X	X			
PC5	X				
PC6	X	X			
SUV1	X	X			
PU1	X				
Field Injury Source (Rudd, 2011)	4%		28%		12%

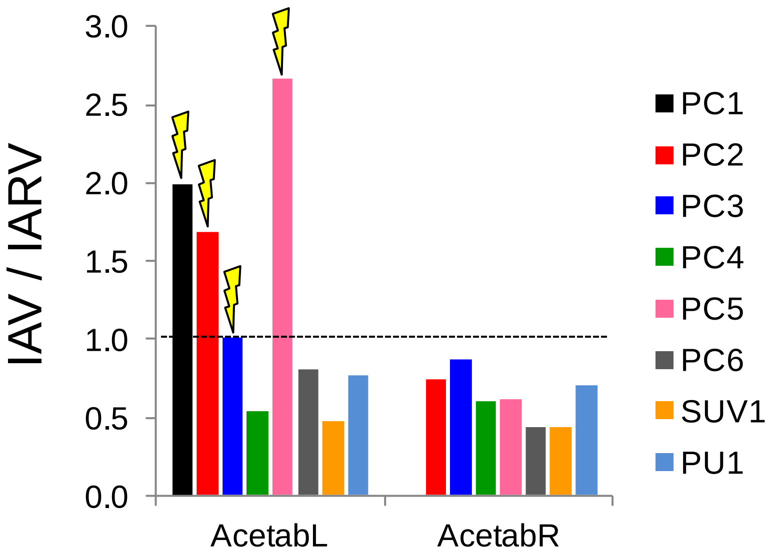
SOI: Chest Deflections

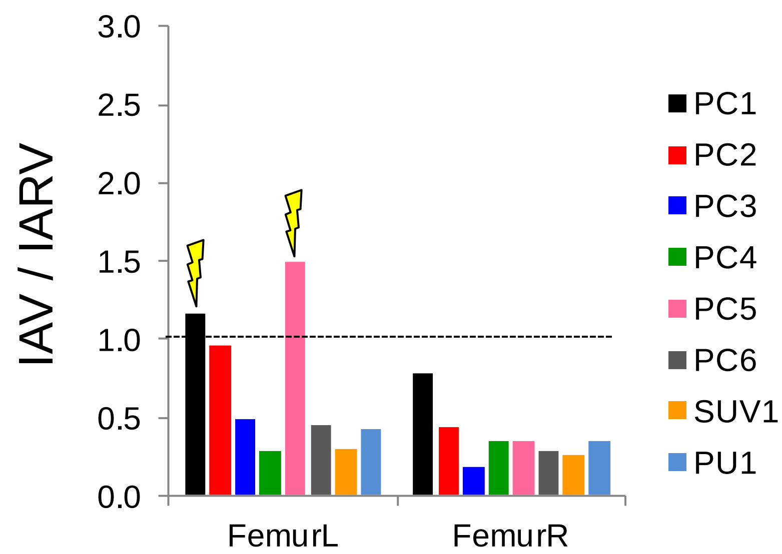


- NASS/CIREN SOI: Chest injury sources
  - Belt: 38%
  - Door: 32%
  - Steering wheel: 16%

- SOI Tests: Chest deflection sources
  - Primarily belt interaction
  - No evidence of door contact
    - Door often deformed outward
  - Evidence of steering wheel interaction in smaller vehicles (e.g. PC2)

SOI: Knee-Thigh-Hip

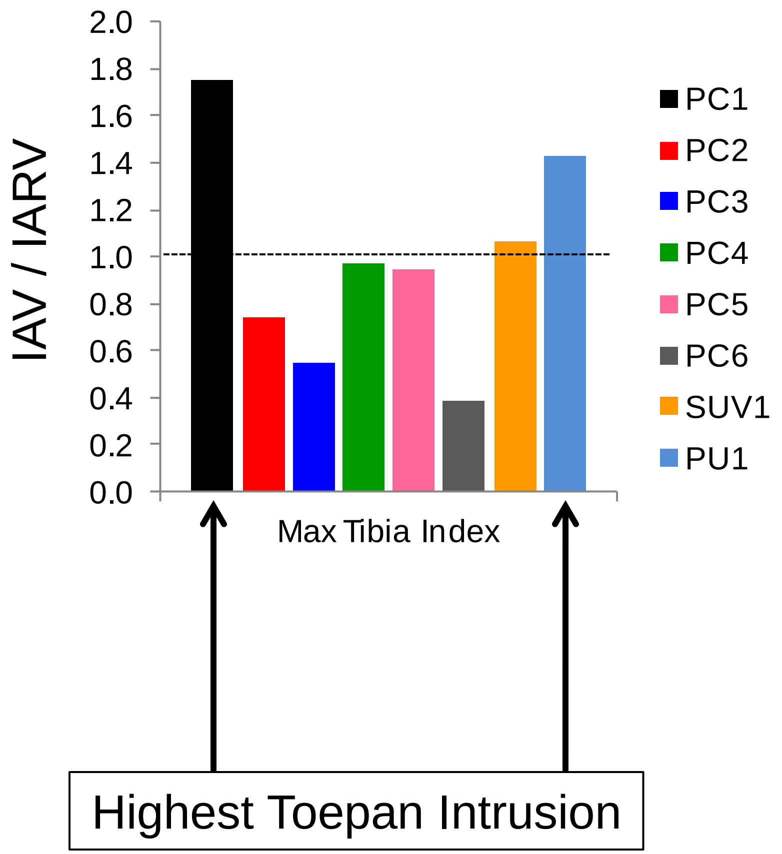


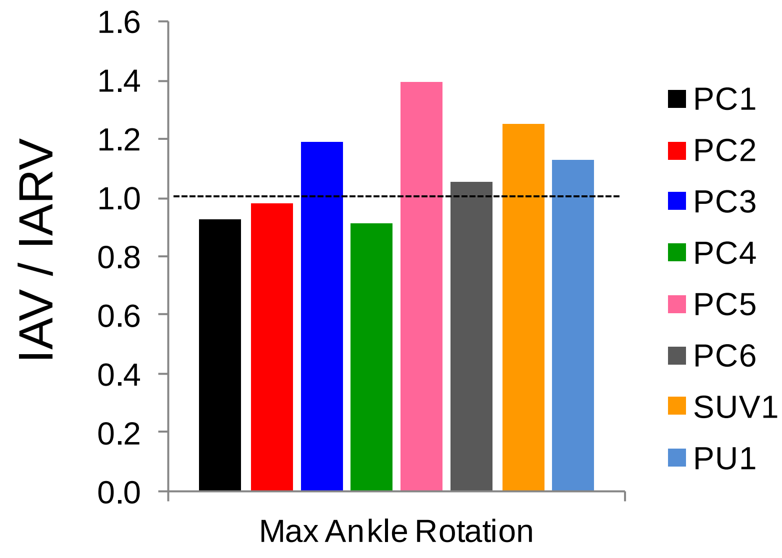


- 4 test exceeded acetabulum IARV
- 2 tests exceeded femur IARV

- 2 tests that exceeded acetabulum IARV did not exceed femur IARV
  - Rudd (2011) showed that over half of acetabulum injuries occurred in absence of femur injury

SOI: Lower Extremity

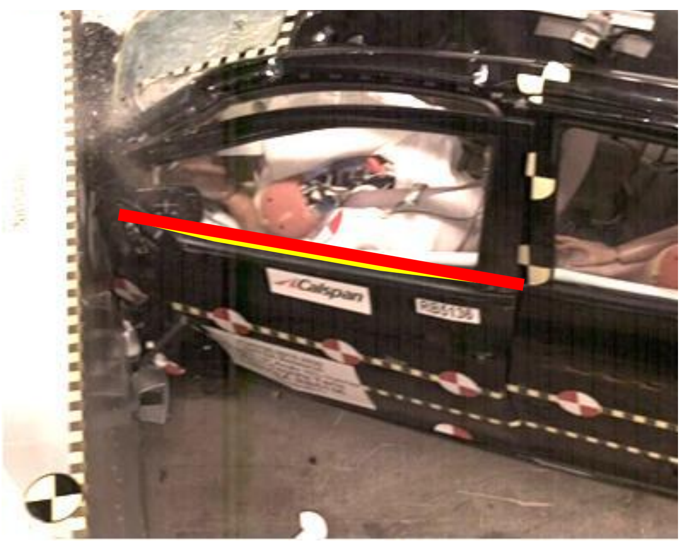


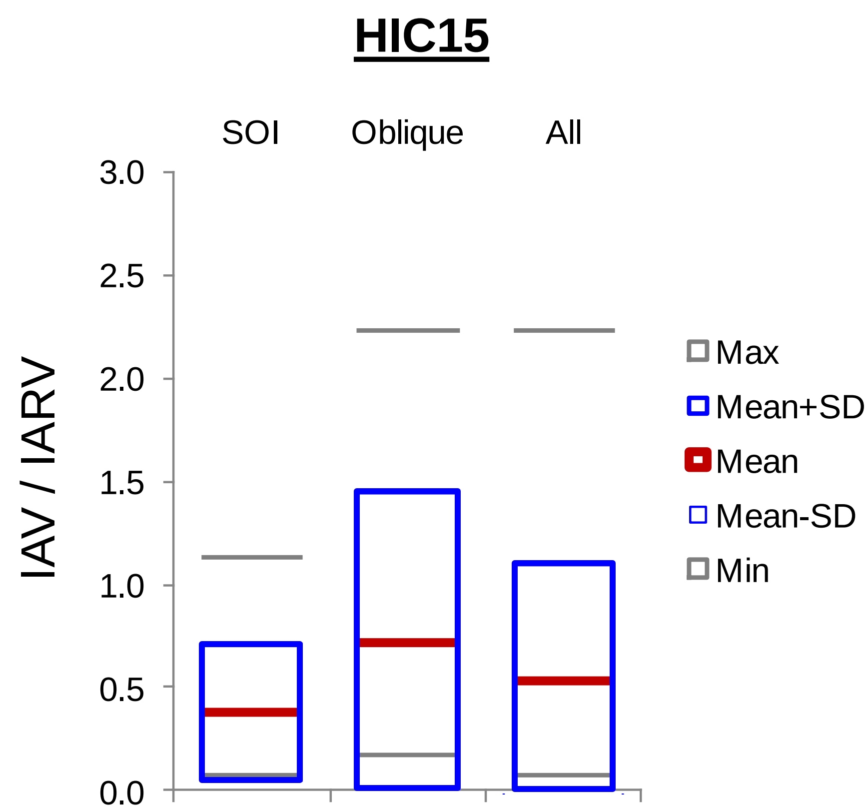


Head response, SOI vs. Oblique

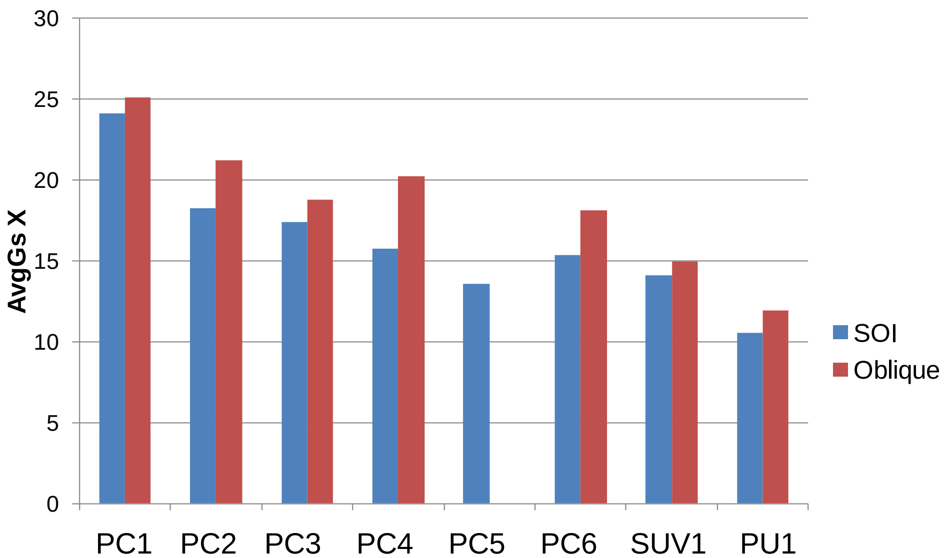
SOI (PC2)

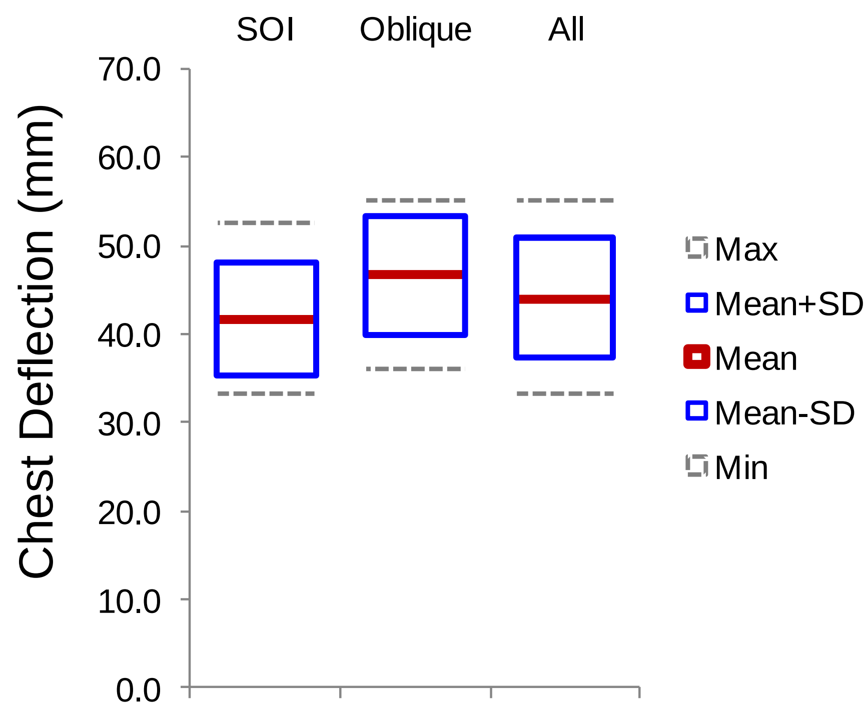
Oblique (PC2)



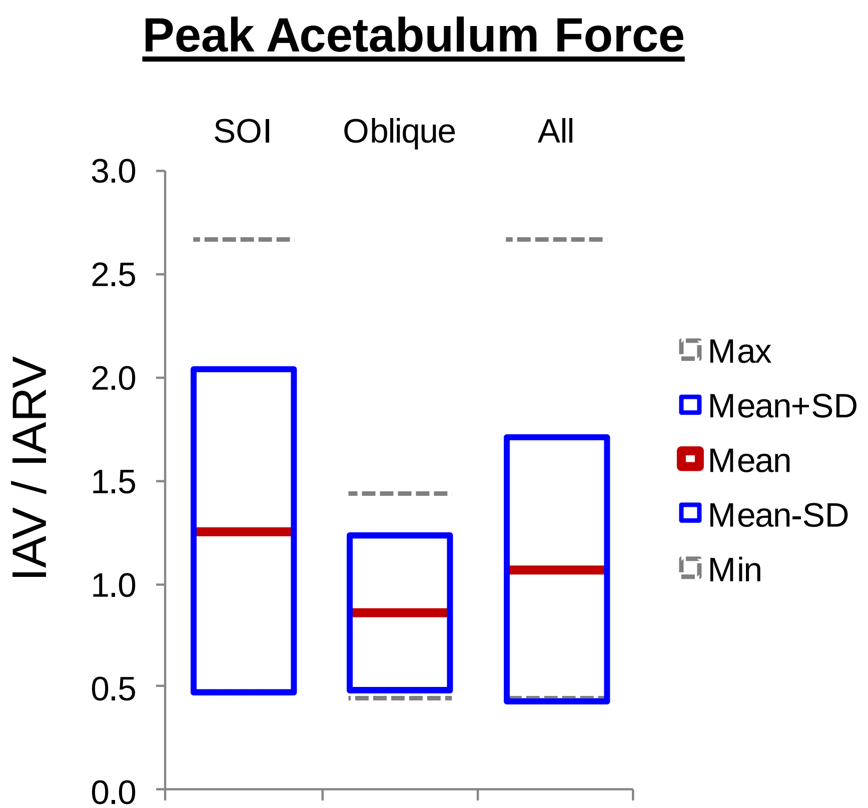


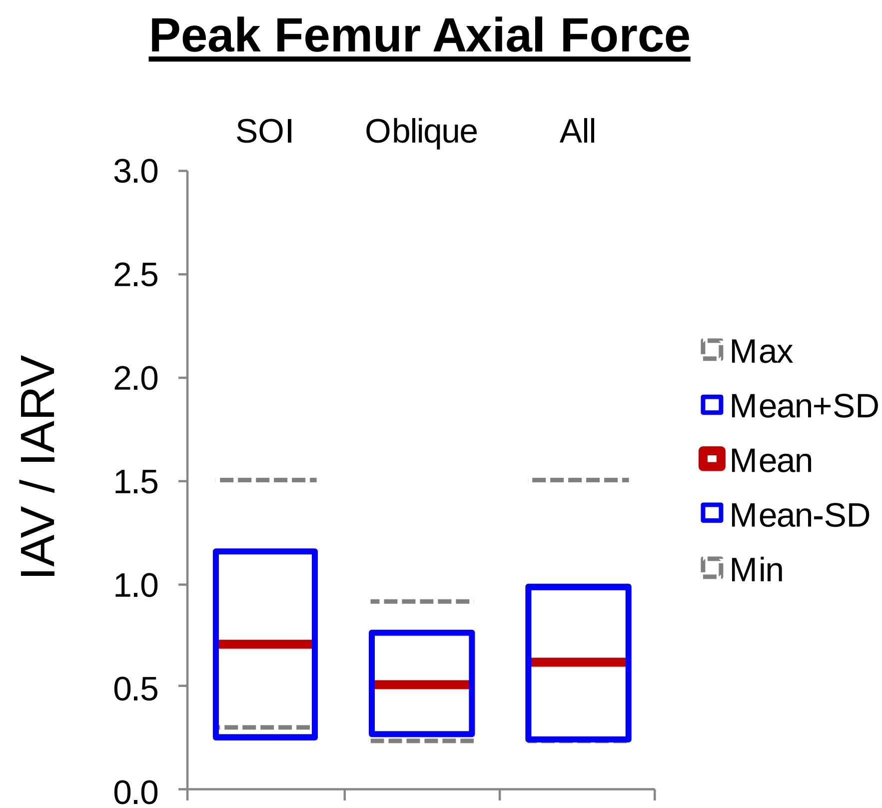
Oblique vs. SOI: Head, Chest



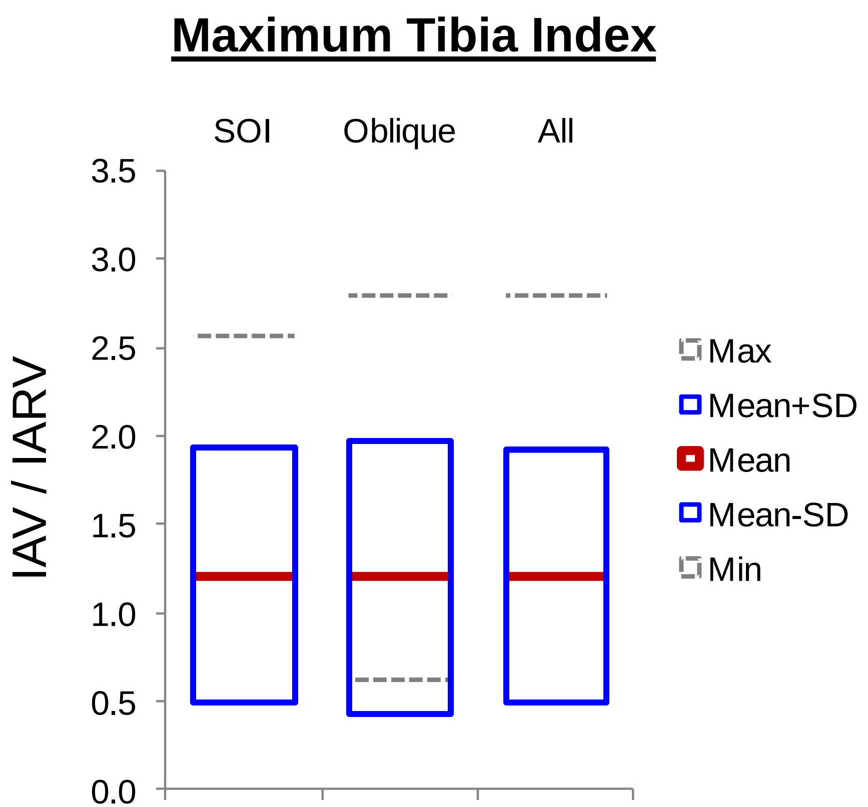


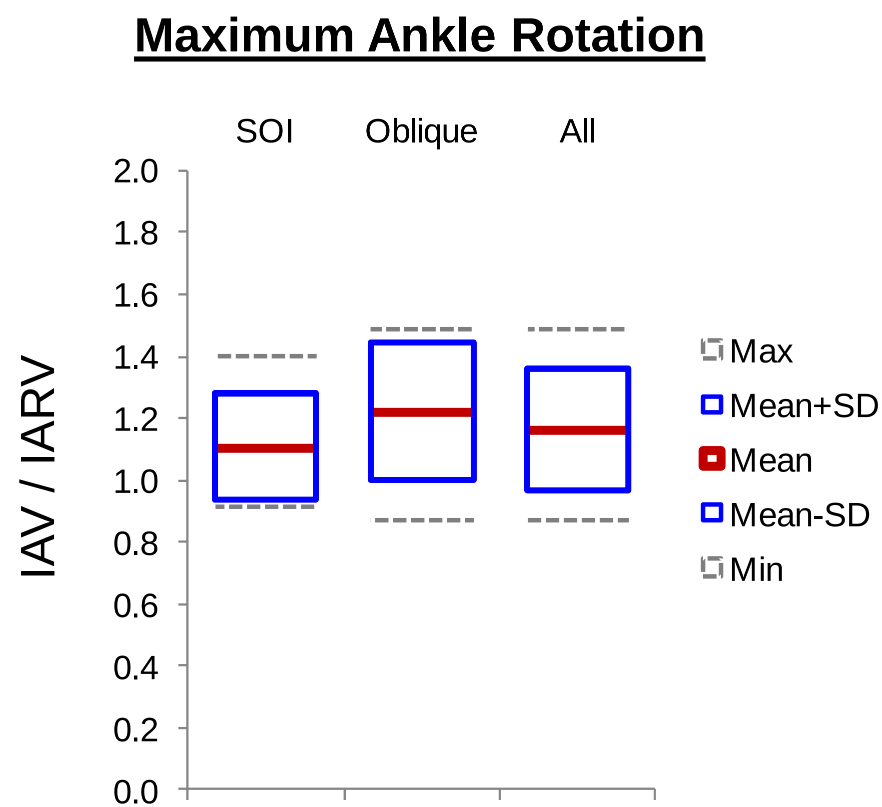
Oblique vs. SOI: Knee-Thigh-Hip



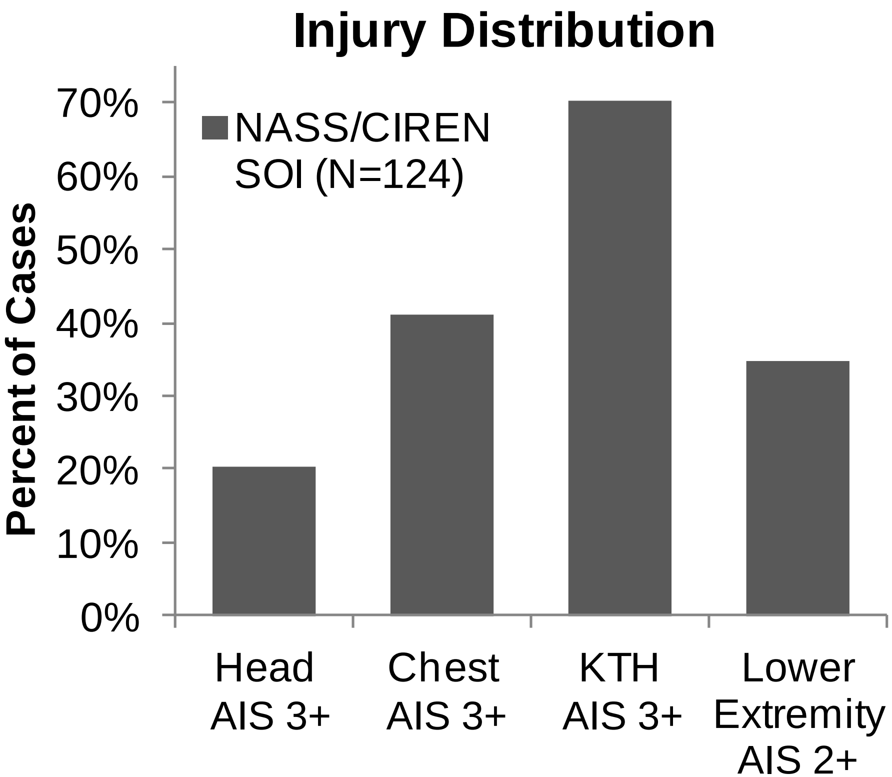


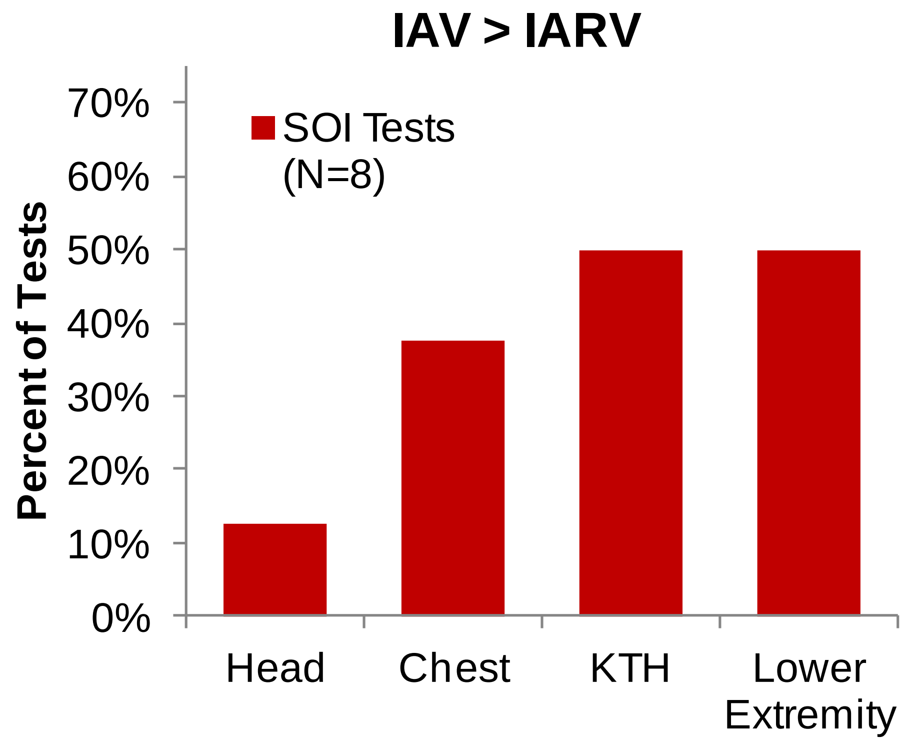
Oblique vs. SOI: Lower Extremity





SOI Test vs. Real World





- NASS/CIREN data from case study of MY 1998 to 2009 with AIS3+ head, chest, and/or KTH
  - NASS/CIREN data represents older vehicle designs

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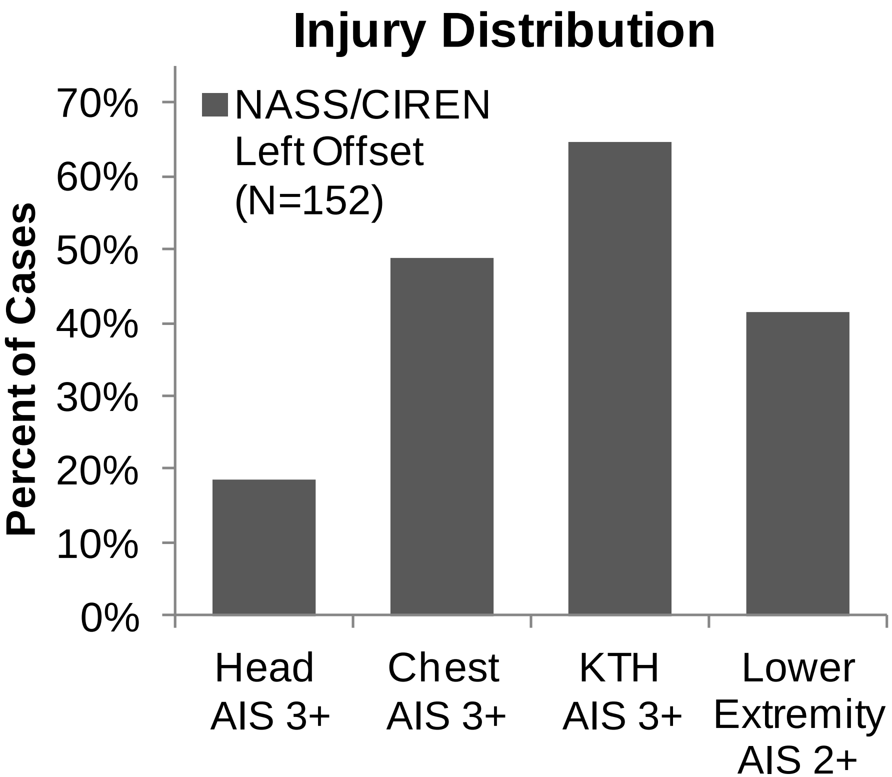
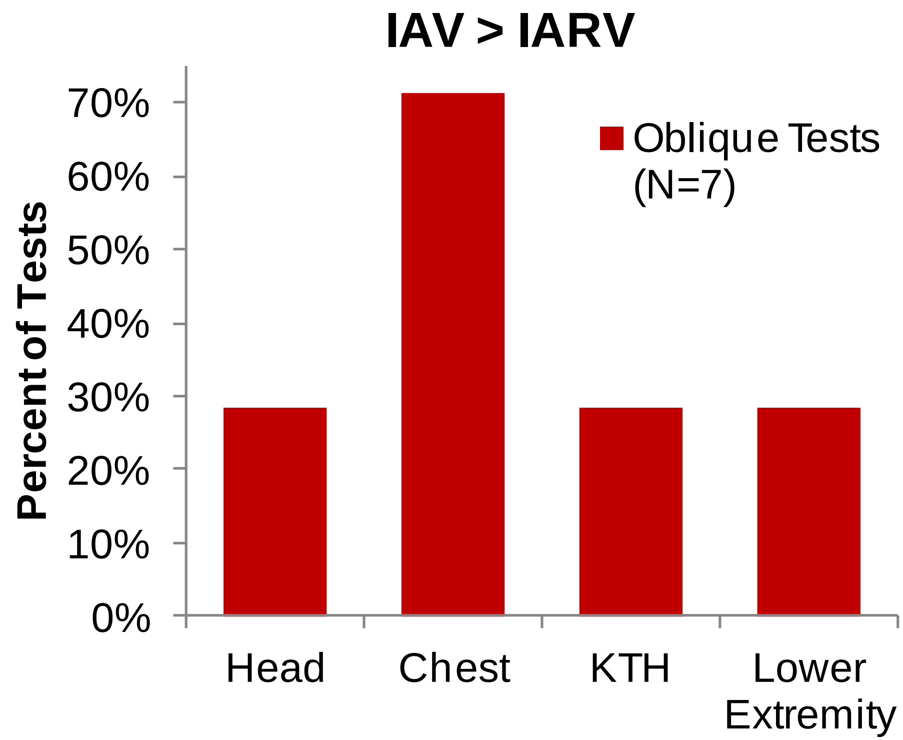
Oblique Test vs. Real World





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4/25/2012

Summary

- RMDB test shows similar occupant kinematics to Vehicle-to-vehicle test
- SOI and Oblique test conditions show similar kinematics but different injury risk
  - Head, chest higher risk in Oblique
  - Knee-thigh-hip higher risk in SOI
  - Lower extremity similar risk in Oblique and SOI
- SOI and Oblique conditions demonstrate field injury risk
- SOI and Oblique test conditions demonstrated usability, durability, and utility of Mod Kit THOR ATD