Research to Determine Causes of Aortic Injury in Near-Side Crashes

The George Washington University
and
The William Lehman Injury Research Center (WLIRC)

Research Objectives

- Define Crash Characteristics Causing Aortic Injury
- Determine Aortic Injury Mechanisms
- Recommend Injury Criteria
- Recommend Critical Test Procedures and Test Dummies

Outline

1. Why Did We Study Aortic Injuries?
2. Approach to the Study
3. Selected Results to Date
4. Continuing Aortic Injury Research
5. Findings & Recommendations for Future Research

Typical Cases with Aortic Injuries

Cases from the William Lehman Injury Research Center (WLIRC)

14 MPH - FATALITY

- Driver, 62 Y/O Male
- 68” Tall; 174 Lbs
- 10 O’clock
- 13” Max Crush
- Injuries:
  AIS-6 Aorta
  AIS-5 Rib/Lung
  AIS-4 Lower X
- Alert on Scene

Case Vehicle - 1990 Lexus 250
Bullet Vehicle - 1983 Olds Cutlass

Case 96-008S

19 MPH - NON FATAL

- Driver 49 Y/O Female
- 67” Tall; 240 Lbs.
- 10 O’clock
- 20” Max Crush
- Injuries:

    AIS-5 Aorta

    AIS-4 Rib
- Alert on Scene

Case Vehicle -1987 Buick Park Ave.
Bullet Vehicle-1992 Lincoln Continental

Case 97-003S

21 MPH CRASH - FATALITY

- Driver
- 27 Y/O Male
- 69” Tall; 164 Lbs
- 11 O’clock
- 19” Max Crush
- Injuries:

  AIS-6 Aorta

  No Serious Rib Fx

Case Vehicle - 1985 Nissan Sentra
Bullet Vehicle- 1987 Dodge Caravan

Case 97-024S

Significance of AIS 4+ Aortic Injury

- Occur in low severity near-side crashes
- Frequently occult (no physiological cues)
- Frequently fatal
- Usually complete recovery when successfully treated

Significance of AIS 4+ Aortic Injury

- NASS
  - 2964 per year
  - 26% in near-side crashes
  - Most frequent AIS 6
  - 88% Fatal
- WLIRC
  - 12 Cases per year
  - 85% Fatal in near-side
  - 50% Alive on-scene - potentially survivable

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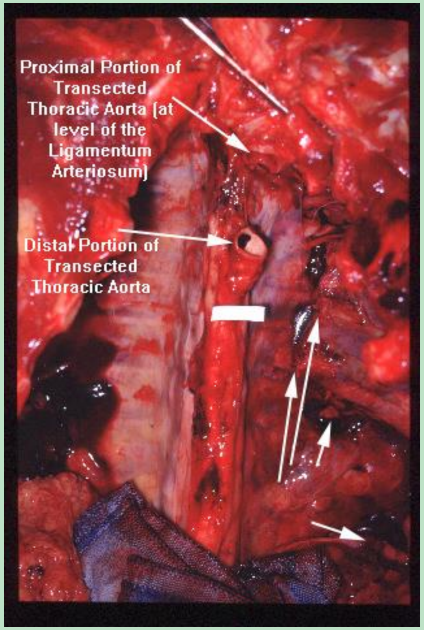
WLIRC/GW Aortic Injury Research

Individual CIREN Cases → Documented Crashes & Injuries → **Studies of Aortic Injuries**

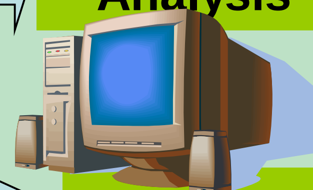


WLIRC/GW Aortic Injury Research

Individual CIREN Cases → Documented Crashes & Injuries → **Studies of Aortic Injuries**

CIREN + NASS Data

Cadaver Tests → Regression Variables → **Regression Analysis** ← Regression Variables ← **Injury Patterns Crash Patterns**



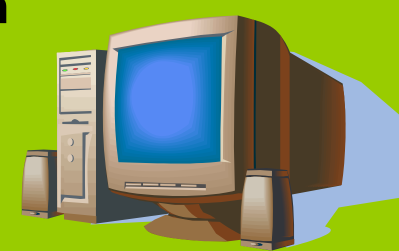
Simulation Conditions

Cadaver Tests →

Model Validation and Assessment

Vehicle Crash Tests →

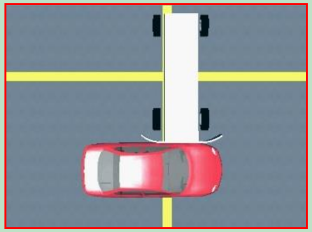
Computer Reconstruction
- **Vehicle Dynamic Model**
- **Vehicle FEM Model**
- **Occupant Model**
- **Human Aorta Model**



Critical Crash Conditions
Injury Mechanisms & Criteria
Test Conditions & Countermeasures

Computer Modeling

Typical Crashes with Aortic Injury

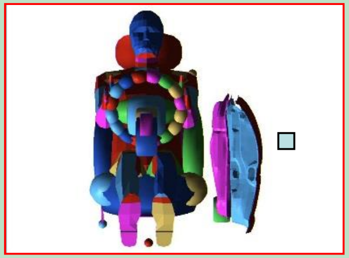


Crash Reconstruction - Vehicle Dynamics Model (HVE)

Crash Direction & Pulse

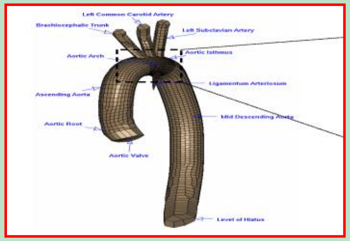
Vehicle Structural Model (Neon FEM)

Intrusion and Acceleration Environment



Occupant Model (MADYMO)

Occupant Response & Injury Measures



Human Organ Model – (Chest/Aorta FEM)

Injury Measures vs. Critical Strain

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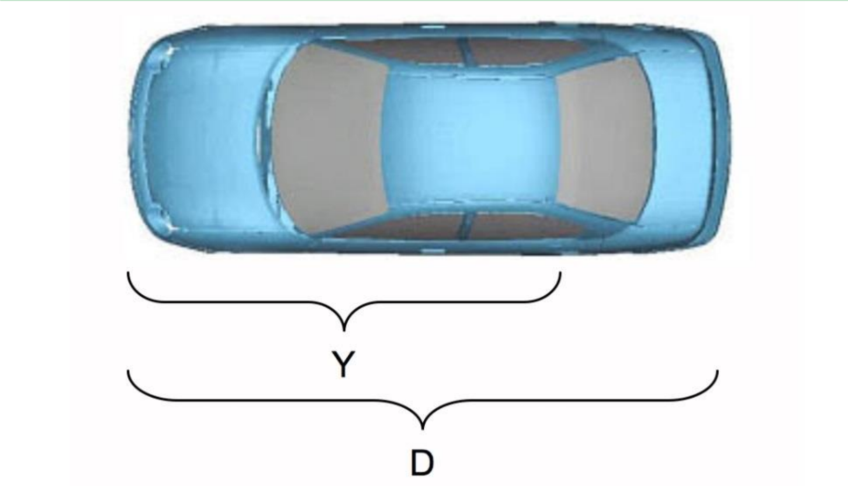
Results of CIREN Case Analysis

Significant Variables in Near Side Crashes:

- **Intrusion**
- **Age**
- **Y Damage Pattern**

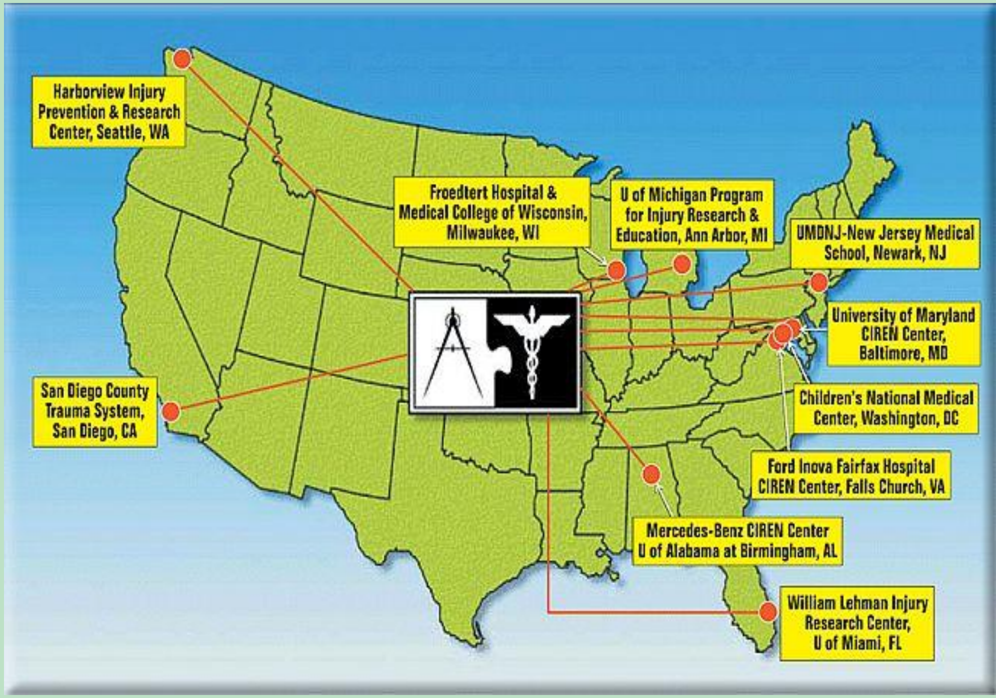
Typical Vehicle Damage



Y Damage Location

Data for Regression Analysis

- WLIRC + CIREN + NASS-CDS 1997-2000
- Front seat occupants only
- Case occupant sitting on the struck side of the vehicle
- Vehicle was struck by another vehicle, not a fixed object

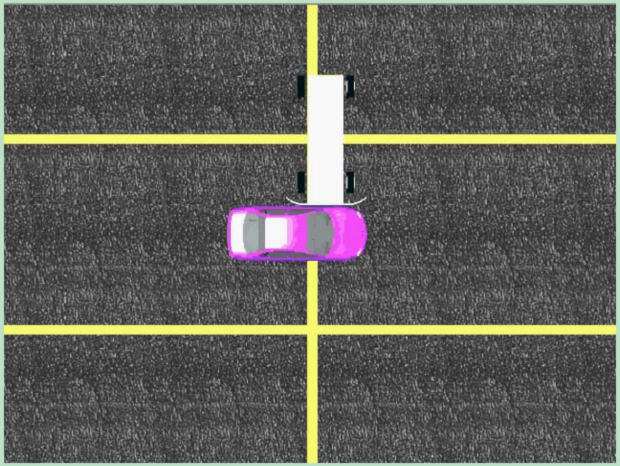


- 679 total occupants
- 58 occupants with aortic injury

Results of Regression Analysis

Parameter	**Odds Ratio**	**P value**
Age	1.036	≤0.01
Delta-v	1.079	0.05
Intrusion	1.069	≤ 0.01
Y Damage Location	2.352	0.04

Results of Crash Reconstruction HVE Model



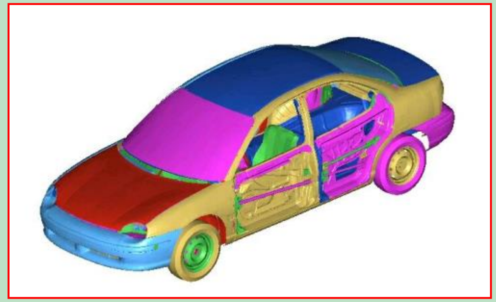
HVE – Both Vehicles Moving

- Determined Crash Pulse & Direction for Y-damage
- Velocity of Struck Vehicle Not a Predominate Factor
- Simulation of Stationary Struck Vehicle is OK

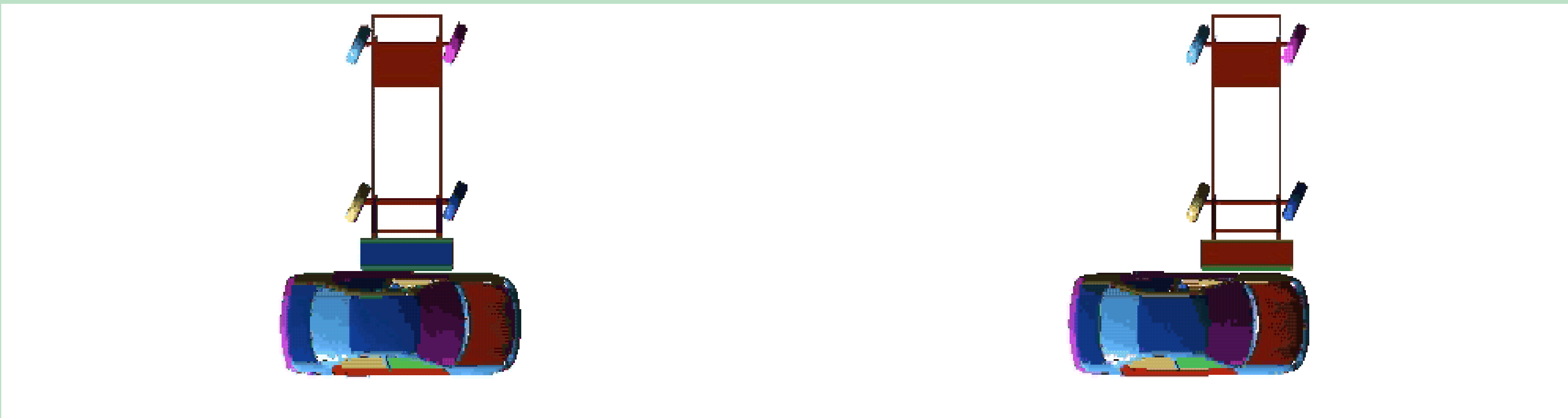
The Next Step:

- Compare 214 (or SNCAP) Test with Y-damage Crash

Crash Reconstruction



Neon FEM Model



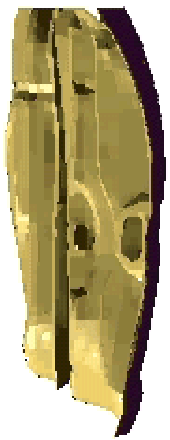
214/SINCAP

Y-Damage

Purpose: Determine Differences in
Acceleration and Intrusion Time History

Door Intrusion from FEM Model

Front View



214/SINCAP

Y-Damage

Door Intrusion from FEM Model
Front View

214/SINCAP

Y-Damage

For Y-damage:

- Intrusion starts in the front part of the door
- Intrusion is more uniform along the height of the door

MADYMO Human Model Response
Y-Damage Pattern

- **Thorax is impacted by a force component from the front**
- **Head z acceleration increased – more spinal stretching**

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Y-Damage Crash Test

Conducted May 8, 2003
By GW University, NCAC
At FHWA Test Facility
McLean Va.

Y- Damage Test

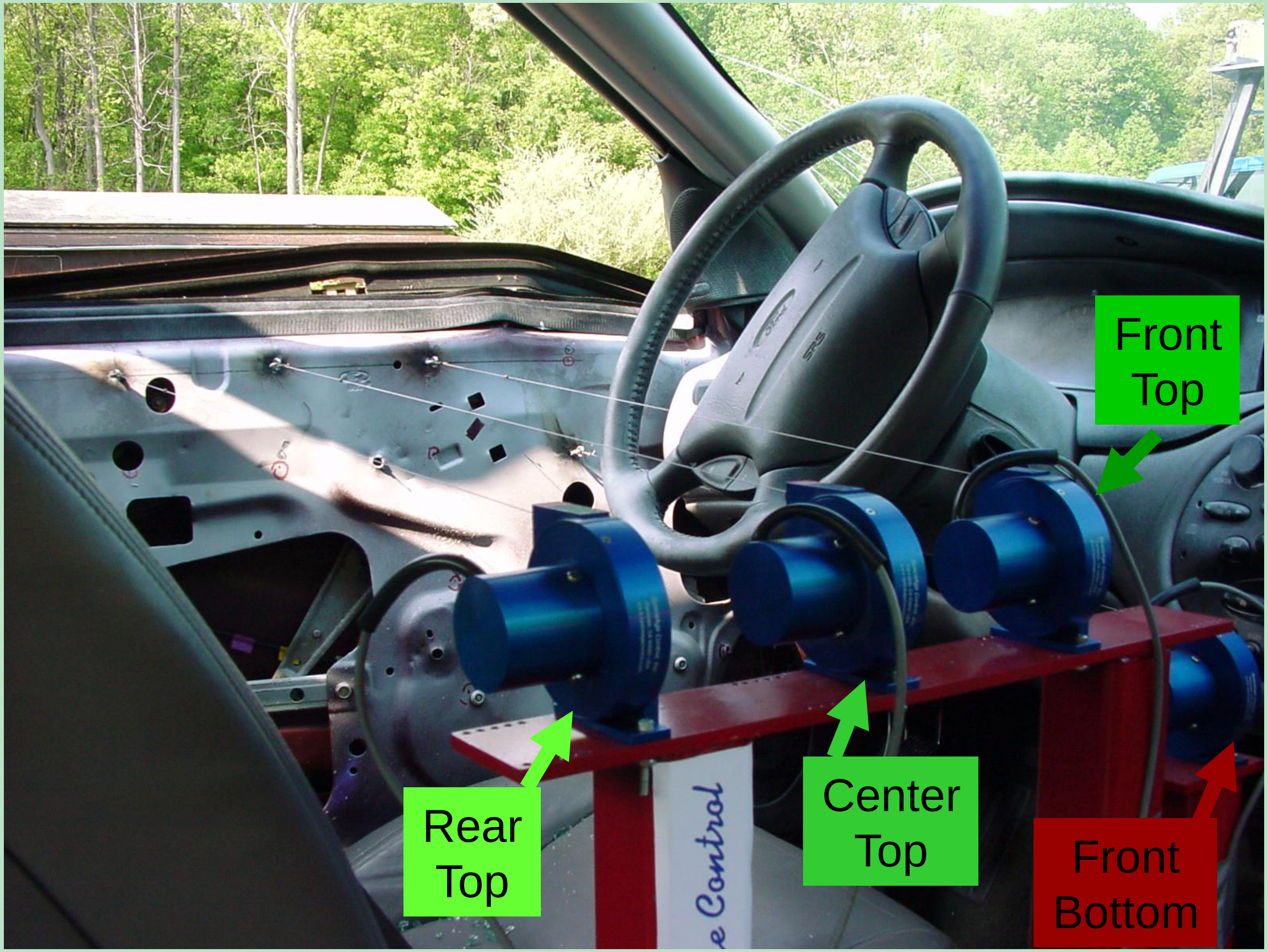
Chevy S-10 Pickup into Ford Taurus at 30 mph

Y Damage Crash and Test

Real Crash With Aortic Injury

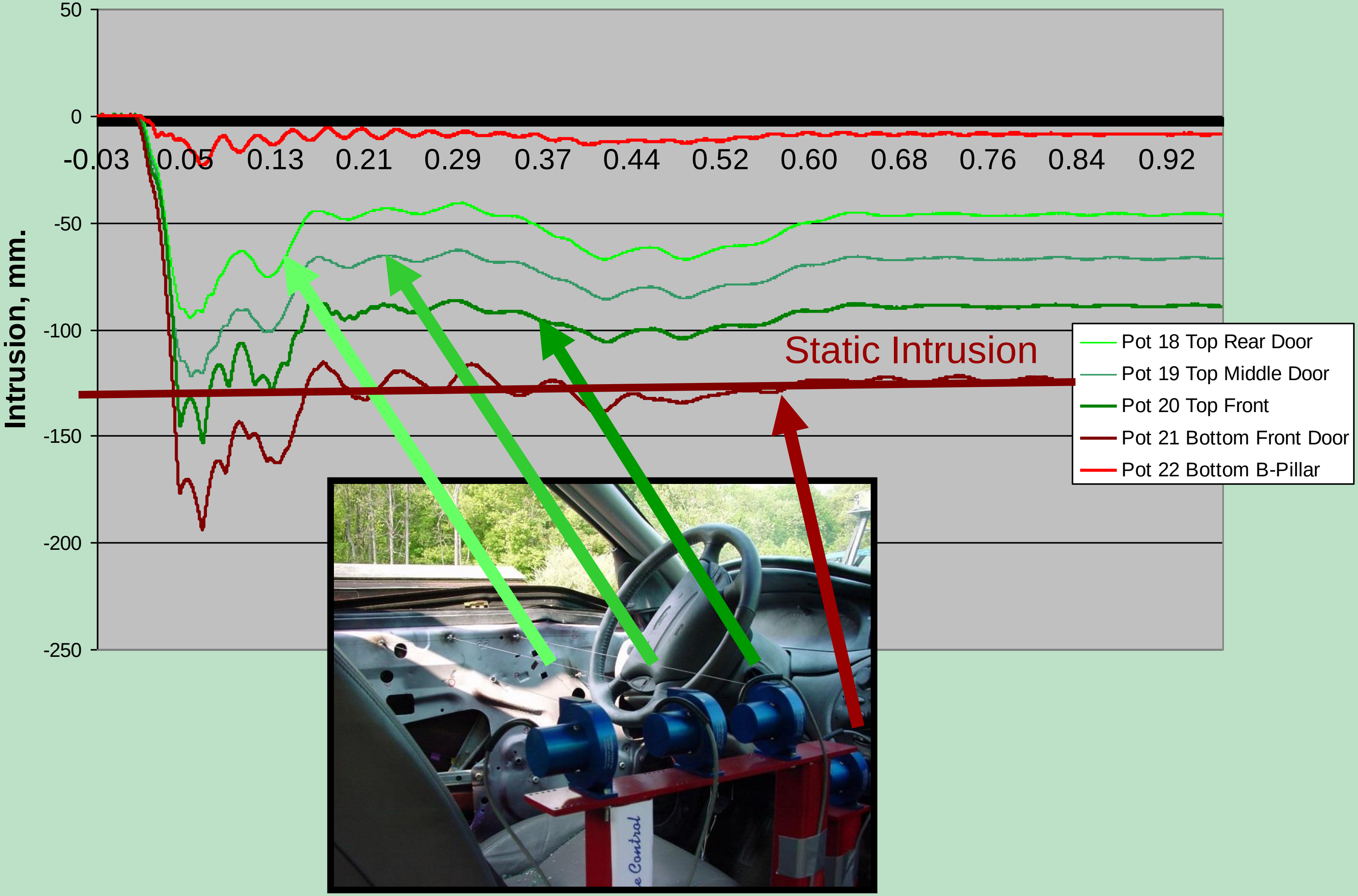
Y- Damage Crash Test

Door Intrsion Measuements by String Pots



Door Intrusion vs. Time

Door Intrusion vs. Time



Test Results – Y Damage Crash

- Static and dynamic displacement determined
- Time history of door displacement available for model validation
- Model predictions of door displacement confirmed

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Summary of Findings - Triage

- Predictors of aortic injury in all near-side crashes include
  - age,
  - delta-v
  - greater than 6” of door intrusion
- For non-catastrophic crashes:
  - damage beginning forward of the A-pillar and extending into the occupant compartment
  - 2.4 times more likely to result in aortic tear

Summary of Findings - Critical Test Conditions

- Y-damage most likely to produce injury
- Loading of the thorax that produces longitudinal components in addition to lateral may contribute to aortic injury
- Y-Damage results in higher axial head acceleration indicating higher spinal stretching
- Intrusion timing is later than in SINCAP

Summary of Findings - Critical Test Conditions

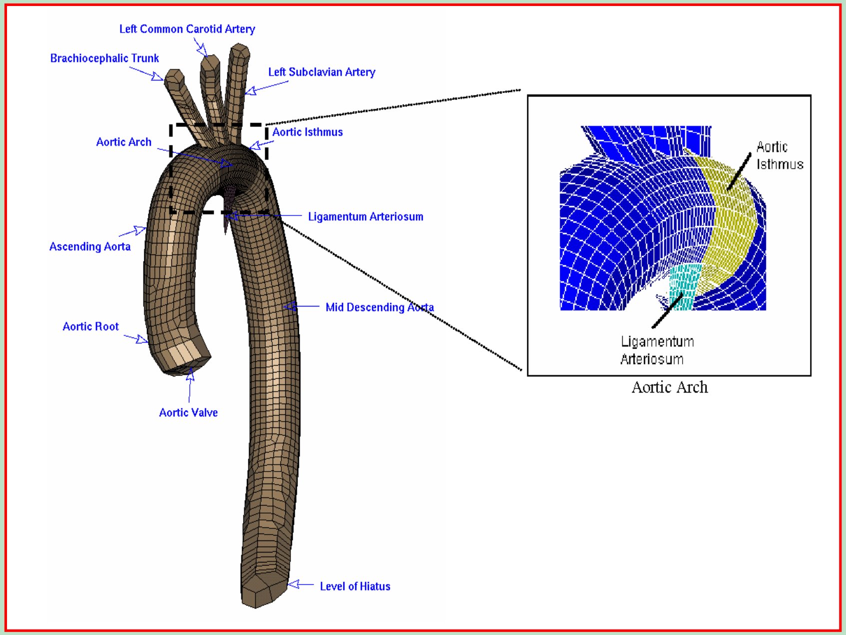
NHTSA's current side impact regulation and testing program may not address the issue of aortic injury

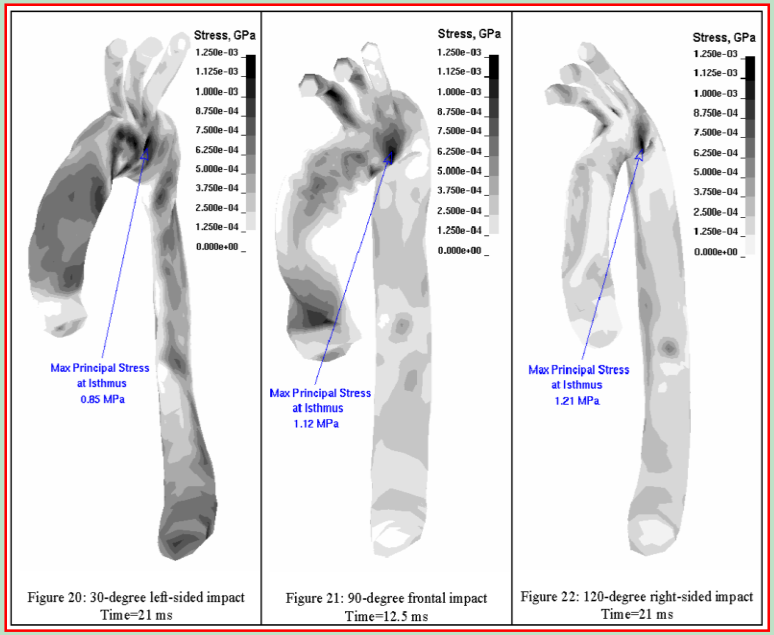
- 214 crash configuration produces less lateral and longitudinal loading to the chest than Y-damage crash
- Current side impact dummies unable to measure multidirectional chest compression

Summary of Findings –Injury Criteria

- Based on limited cadaver tests, V*C was best injury criteria
- Conditions that produced aortic injury in cadavers unclear
- Injury criteria needs to be verified by FEM modeling

Future Work – Wayne State Model of Aorta





- Examine effects of near-side crash characteristics on loading locally at the aorta

The Next Steps

- Validate Wayne State aortic model
- Validate FEM & MADYMO Models for Y-damage
- Apply above to reconstruct crashes with aortic injuries
- Compare critical aorta stress with dummy injury measures
- Recommend critical tests and injury criteria