Measurement of Aortic Injuries In Lower Severity Near-side Impacts

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Bottom Line

- Aortic injuries in lower severity near-side crashes are a serious problem not recognized by NASS or by cadaver tests
  - Field detection of aortic injuries is difficult
  - High fatality rate when present
- Existing IIHS side impact test is good for evaluating aortic injury risk
- Best Injury measures – (T12Z and V*Cmax)
- Testing for aortic injury may require
  - a better side impact dummy
  - different injury criteria
Doctorial Dissertations and Master’s Theses


Hardy, WN; Shah, CS; Mason, MJ; Kopacz, JM; Yang, KH; King, AI; Van Ee, CA; Bishop, JL; Banglmaier, RF; Bey, MJ; Morgan, RM; Digges, KH (2008) Mechanisms of Traumatic Rupture of the Aorta and Associated Peri-isthmic Motion and Deformation. Stapp Car Crash Journal, 52:233-265.
Other Publications


Other Publications


Other Publications


Research Objectives

• Define Crash Characteristics Causing Aortic Injury
• Determine Aortic Injury Mechanisms
• Recommend Injury Criteria
• Recommend Critical Test Procedures and Test Dummies
Research Objectives

• Define Crash Characteristics Causing Aortic Injury
  – Data Sources:
    • NASS
    • William Lehman Injury Research Center (WLIRC)
      (A CIREN Center during the initial research period)
Aortic Injury Rates in Near-side Crashes

Steps Dissertation, 2003
Aortic Injury Rates in Near-side Crashes

Frequency of Aortic Injury vs % at Lower Speed

- NASS
- WLIRC

Steps Dissertation, 2003
Fatality Rate for Aortic Injuries in Near-side Crashes

Steps Dissertation, 2003
Why Study Aortic Injuries?

Observations:
- NASS is missing the aortic injuries in lower severity crashes
- Incorrect assessment of aortic injuries may result
- Aortic injuries carry a very high fatality rate
WLIRC Observations
Aortic Injuries

- 49% did not die at the scene
- Of the 51% transported to the medical centers 70% survived for over 1hr.
- More than 50% of those transported, died
- Survivors suffered no long term impairment
- Normal physiological indicators frequently give no indication of potentially fatal aortic injuries
Constraints on the Aorta

Heart Mass
Relatively Free

Injury Location

Spine Attachment
Composition of the Aorta

Diagram showing the layers of the aorta: Intima, Media, and Adventitia.
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
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
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
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
Results of CIREN Case Analysis

Significant Variables in Near Side Crashes:
1. Intrusion
2. Age
3. Y and D Damage Pattern

Typical Vehicle Damage

Y Damage Location
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
Crash Reconstruction

Steps Dissertation, 2003

FEM Vehicle Model

214/SINCAP

Y-Damage

Purpose: Determine Differences in Acceleration and Intrusion Time History
Model Response to Y-Damage Pattern

- Thorax is impacted by a force component from the front
- Head z acceleration increased – more spinal stretching
MADYMO Human Facet Model Response

Y-Damage has:
Greater head excursion and z spinal acceleration;
Chest compressed in both the x and y direction

SINCAP
Y-Damage

Unable to observe a difference using MADYMO dummy models!
An improved spine is needed in the model
Aortic Injury in Cadaver Tests

- NHTSA database of cadavers in side impacts
  - 137 tests
  - 5 with aortic injuries
  - All 5 were at WSU in Cavanaugh’s project for CDC to evaluate padding stiffness and door offset at the hip region.
Wayne State University
Cavanaugh CDC Cadaver Tests

- 17 Tests Conducted with and without pelvis offset
- 5 Produced Aortic Tears
- Heidelberg-type sled
- Pressurized aorta
Aortic Injury Predictors – Cavanaugh Analysis of Cadaver Tests

ASA – Average Spinal Acceleration
Cmax – Max Chest Compression
VCmax – Max Viscous Criteria
T12Z – Max Spinal Vertical Acceleration at T12
UpsX – Max Upper Sternum X Displacement

(T12Z, V*C) combination are best predictors

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<th>Variable or Combination</th>
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<th>k2</th>
<th>k3</th>
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Echemendia’s Spring Mass Model

- Spring Mass Model was added to represent the heart-aorta in TNO’s Human Facet Model.
- The spring with the mechanical properties of the aorta
Human Model Simulations of Cavanaugh’s of Cadaver Tests

FEM Crash Simulations and Human Model Simulations

Loadcase 1 : Time = 0.060000 Frame 7
Loadcase 1 : Time = 0.060000 Frame 13
Loadcase 1 : Time = 0.060000 Frame 13

NCAP
Y-NCAP
IIHS
Human Model Simulations of Alternative Crash Tests

Wayne State Studies Supported by GW

Shah (2007) – High speed biaxial tissue testing machine
  o Mechanical Properties of Aorta - Stress-Strain response

• Hardy (2007) – Inverted cadaver impacted
  o 8 cadavers, 7 with aortic injuries.
  o 3 side impact tests – all with aortic injuries
  o Position of the heart controlled by inverting the cadaver
  o High speed X-ray captured motion
Conclusions – Hardy and Shah

- Longitudinal stretch of the aorta is central to aortic injury
- Spinal Z-acceleration may cause longitudinal stretch of the aorta
- Anterior sternum displacement may be important to aortic injury
  - sternum displacement causes the aorta to move away from the spine during side impacts
Implications of Injury Measures

• A dummy may need a more biofidelic chest to measure sternum displacement
• Spinal biofidelity is needed to accurately reproduce the spinal z acceleration
Observations

• Pelvic offset loading increased the risk of aortic injury in cadaver tests
• The flexibility of the dummy spine is an important factor in accurately detecting crash environments that produce aortic injury
• The IIHS test with an improved side impact dummy should predict aortic injuries
Acknowledgements

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