INVESTIGATION OF LOWER SPINE COMPRESSION FRACTURES IN FRONTAL CRASHES

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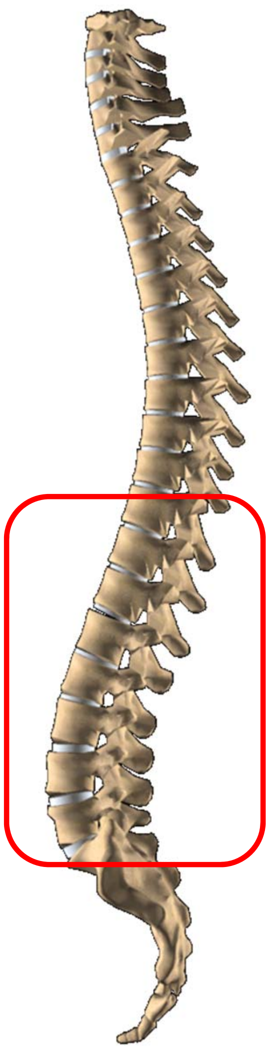
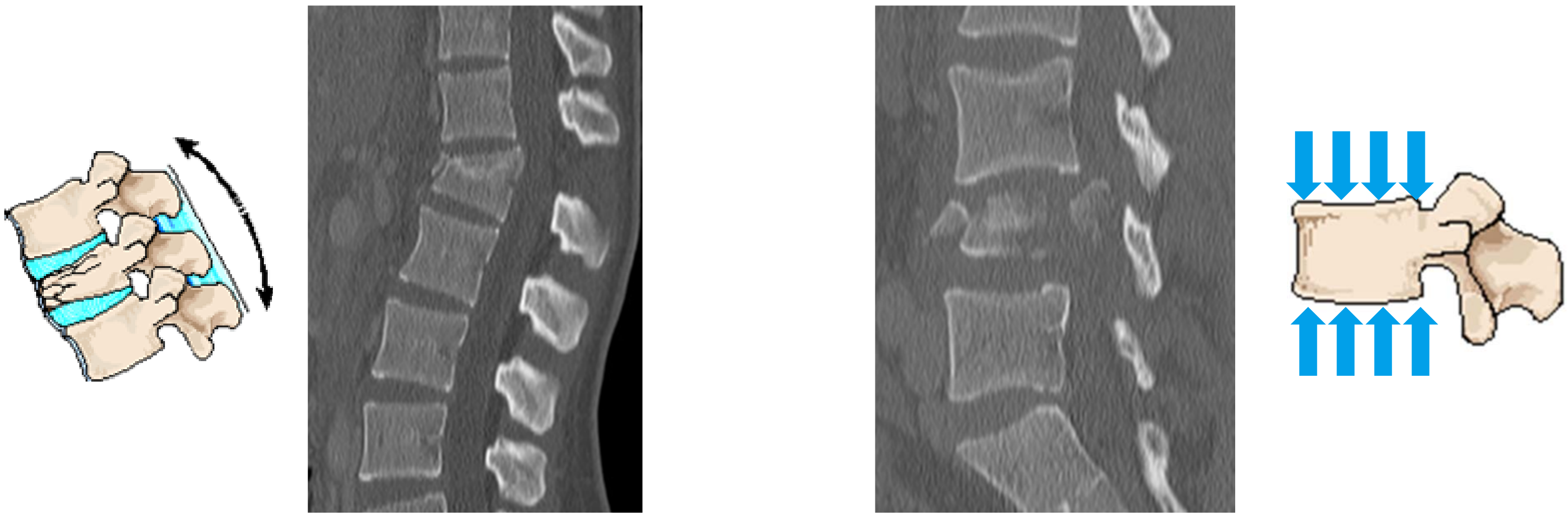
Overview

- Lower spine includes:
  - 10^{th} through 12^{th} thoracic vertebrae
  - 1^{st} through 5^{th} lumbar vertebrae
- Focus is on planar frontal crashes
  - Crashes without major vertical loading to undercarriage
  - No rollovers
- Trends in data
- Development of research
- Current research



Observations in Field Crashes

- Crash Injury Research and Engineering Network (CIREN) as sentinel
  - More frequent observation of lumbar and lower thoracic fractures
    - Frontal crashes (planar)
    - Newer vehicles
    - Belted occupants
    - More compressive in nature

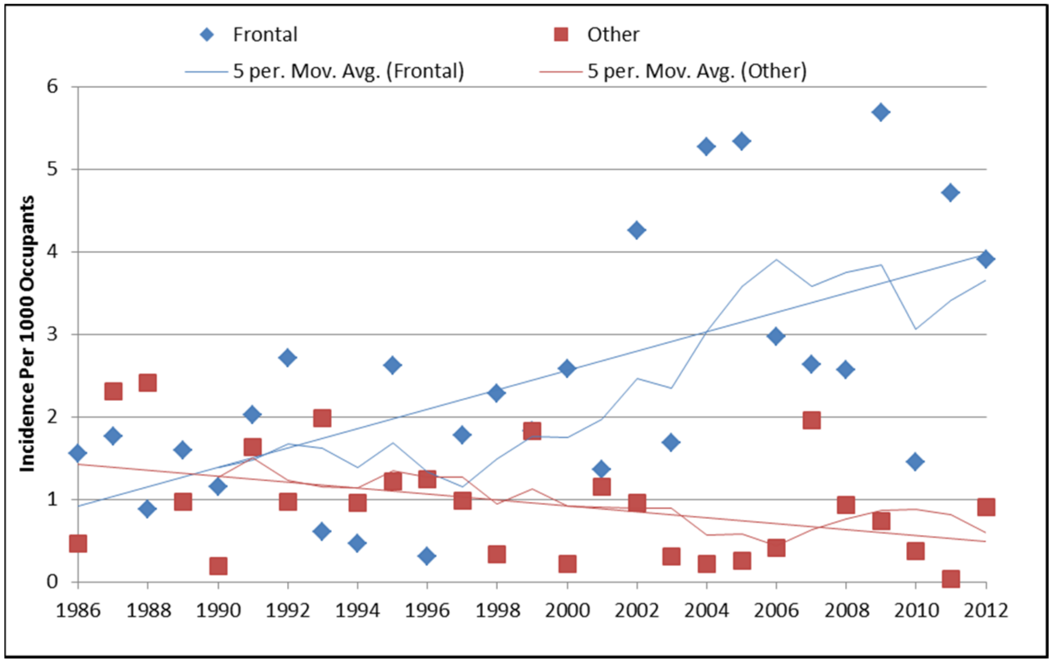


  - Catalyst role of CIREN spawned a research project

Field Incidence – Nationally-Representative Crash Data

Pintar, *et al*. [2012]

- NASS-CDS
  - Looked at specific injury codes (AIS) for vertebral body fractures T10-L5
  - Identified trend of increasing incidence with newer model year vehicles in frontal crashes compared to other crash modes
- Updated analysis in 2014
  - Model year trend continued with additional data years
  - Exemplar odds ratios:
    - Object struck
      - Object vs. other vehicle 4.51 (4.35, 4.60)
    - Restraint
      - Belted vs. unbelted 2.06 (1.96, 2.16)



Pintar, F.A., *et al.* (2012) "Thoracolumbar Spine Fractures in Frontal Impact Crashes" Annals of Advances in Automotive Medicine, vol. 56, pp. 277-283.

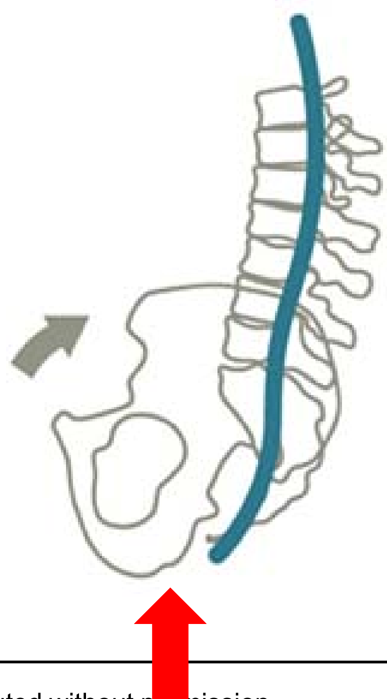
Field Incidence – Nationally-Representative Trauma Data

- Doud, *et al.* [2015] reviewed multiple trauma databases
  - Trauma databases
    - National Trauma Databank® (NTDB®) 2002-2006
    - National Inpatient Sample 1998-2007
  - Crash database
    - NASS-CDS 2000-2011
  - All three databases showed increases in crash-related thoracolumbar spine injuries despite decreasing rates of crash-related injuries overall – 8-10% per year
  - More sensitive screening tools likely not the main driver of increased incidence
  - No consistent compensatory decreasing trends in sacropelvic injuries (trade-off)

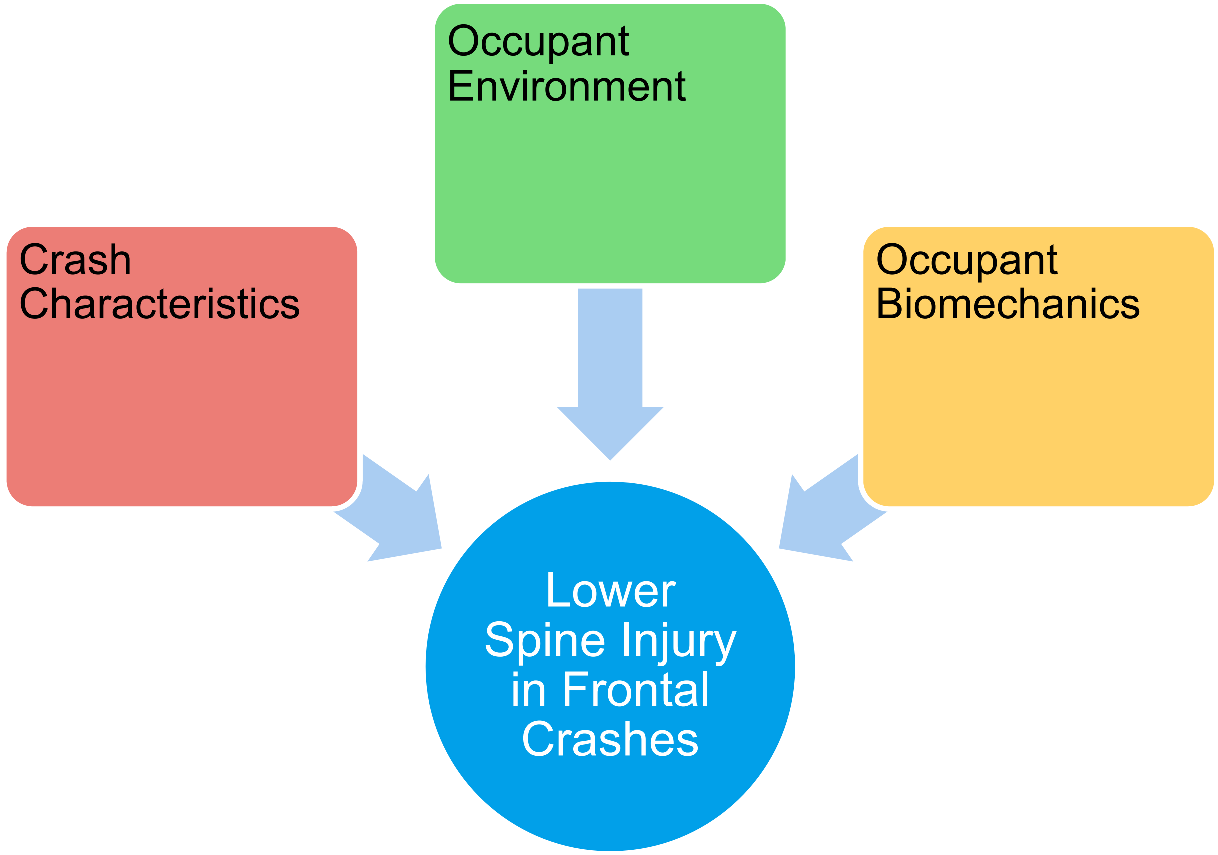
Doud, A.N., *et al.* (2015) "Has the Incidence of Thoracolumbar Spine Injuries Increased in the United States From 1998-2011?" Clinical Orthopaedics and Related Research, v. 473, no. 1.

Motivation

- Incidence is low, but increasing
  - What are the mechanisms?
  - Are these trade-off injuries?
  - Are vehicle design changes responsible?
- Hypothesized mechanisms under consideration
  - Combination of lap belt and seat bottom interacting with pelvis
  - Straightening of lower spine curvature
  - Downward motion into seat structure

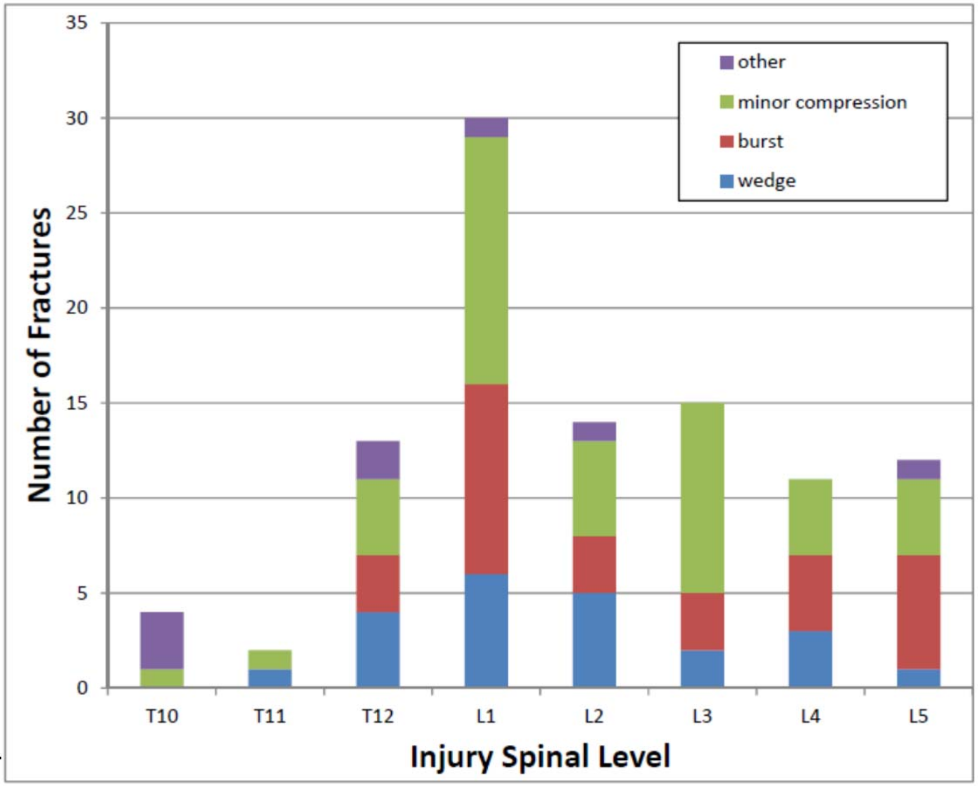


Research Approach – Identify Relevant Factors



In-Depth Review of CIREN Cases

- In-depth case review to better understand variables and factors
  - Model year 2000 and newer
  - Row 1 occupants 16 years or older
  - Frontal impacts, primarily x-axis loading, no rollovers
- 82 case occupants with 102 spinal fractures
  - 96.3% belted
  - 58% female
  - L1 most common vertebra
  - Minor compression and burst fractures most common



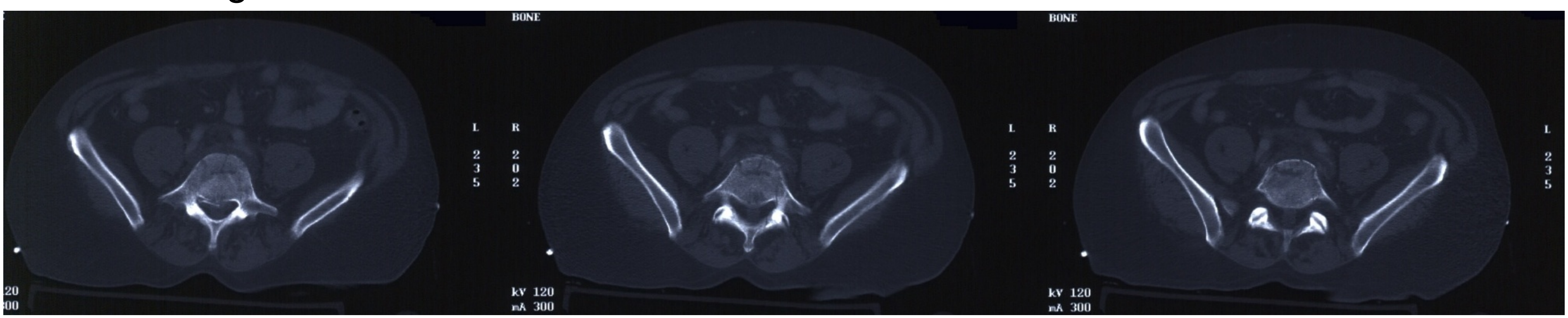
In-Depth Review of CIREN Cases - Example

- 45 yo female driver
  - Belted
  - SW bag deployed
- 2001 Nissan Sentra
  - 12FDEW2, 41 km/h
  - V2: 1994 Camry
- L1 burst fracture
  - AIS 3
  - Unstable
  - Retropulsion of fragments
- Only other injury was T12 spinous process fracture

In-Depth Review of CIREN Cases - Example

- 57 yo male driver
  - Belted
  - SW bag deployed
- 2004 Toyota Tacoma
  - 12FCEN3, 45 km/h BES
  - Struck utility pole
- L5 minor comp fracture
  - AIS 2
  - Retropulsion of fragments

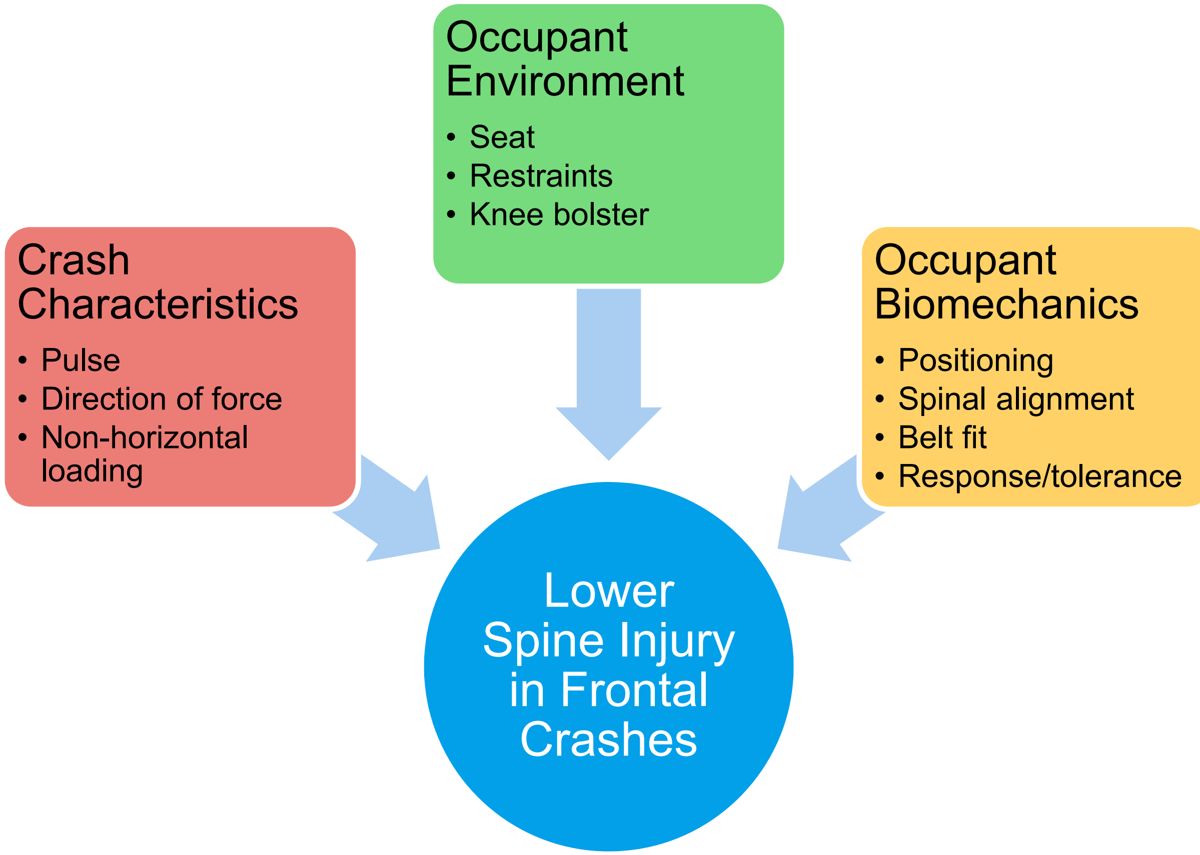
- Also sustained thoracic and below-knee lower extremity fractures



In-Depth Review of CIREN Cases

- Examined crash, vehicle, restraint, and occupant-related factors
- For example, of 64 cases with BES ≤ 56 km/h:
  - 57 cases demonstrated burst, minor compression, or wedge fractures
  - Only 5/57 were similar to NCAP full overlap crashes with engagement of both longitudinal rails
  - 44/57 cases involved engagement of 0 or 1 longitudinal rails
  - Crash pulse differences may be crucial to generating injurious loading conditions

Research Approach – Relevant Factors



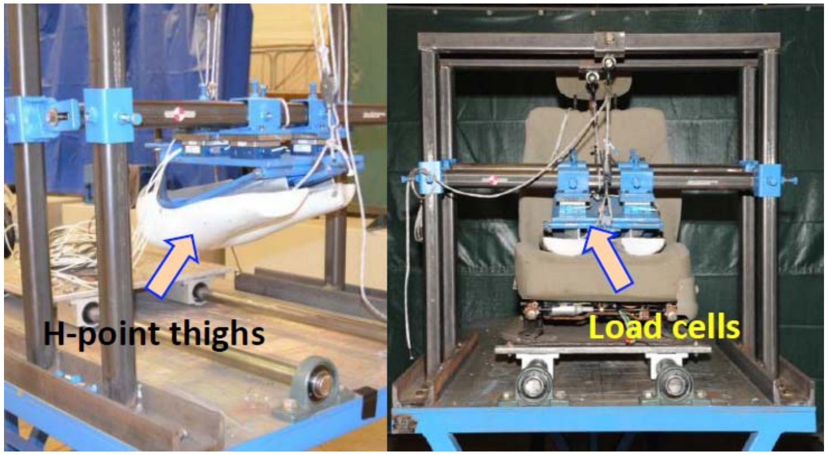
Compression/burst more common than wedge fractures, suggesting a more pure compressive loading with adjacent endplates being nearly parallel

Seat Characterization

Occupant Environment
- Seat
- Restraints
- Knee bolster

Crash Characteristics
- Pulse

- Seat bottom was considered a relevant component for causation
- Commenced CIREN research project to better understand seat characteristics
  - Quasi-static response characterization DeRosia, *et al.* 2013 (ESV)
    - Response of forward translation of pelvis/thighs
    - Examination of bottom structure
  - Dynamic evaluation on sled
    - Restraint factors
    - Pulse effects – full-frontal vs. pole impact
    - Dummy sensitivity to stiff vs. soft seats from quasi-static evaluation

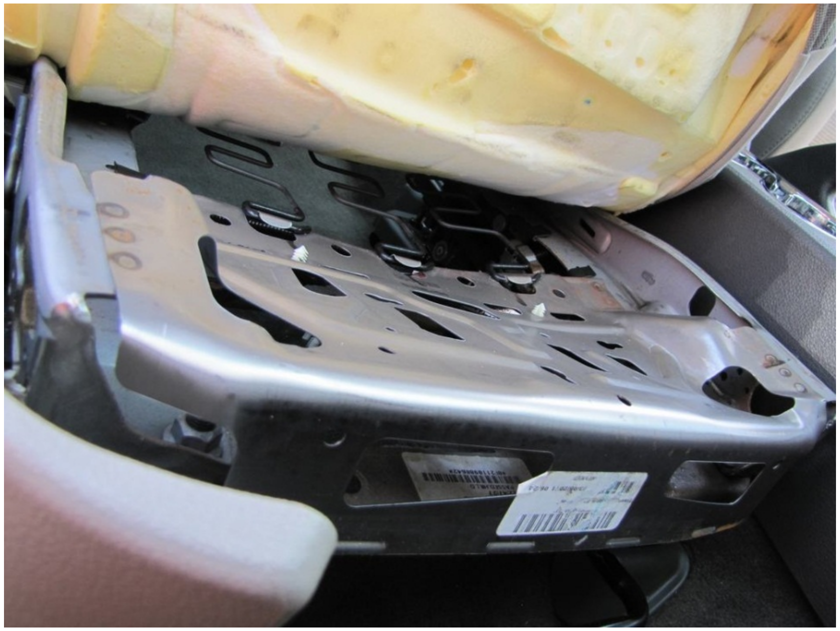


DeRosia, J.J., Pintar, F.A., Halloway, D.E., Meyer, M.A., and Yoganandan, N. (2013) “Seat Pan Loading Differences Using a New Test Apparatus.” International Technical Conference on the Enhanced Safety of Vehicles, Paper number 13-0102.

Seat Characterization

Occupant Environment
- Seat

- Enhanced CIREN seat inspection
  - New photography and variables for structural components
    - Pelvis support type (e.g. pan, spring basket)
    - Thigh support type (e.g. pan, bar)
    - Seat movement (e.g. manual, power)
  - Identification of damage to seat bottom

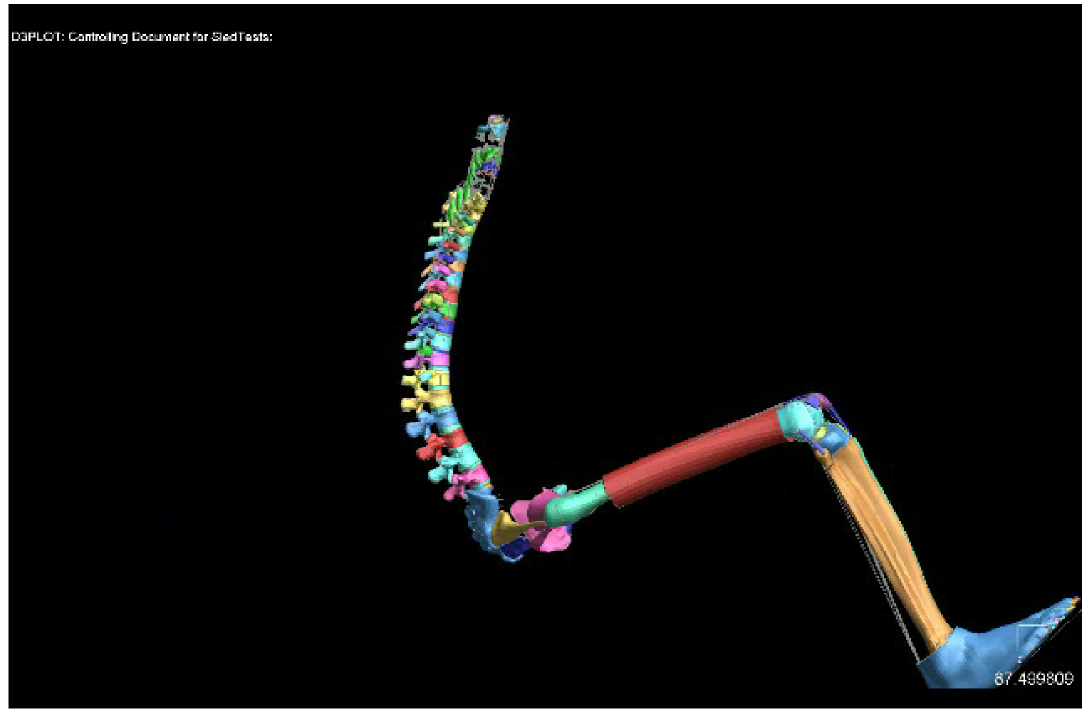


Computational Modeling

Occupant Biomechanics
- Positioning
- Spinal alignment

Occupant Environment
- Restraints
- Knee bolster

- GHBMC modeling efforts
  - Basic configuration
    - Rigid seat
    - Simulated knee bolster
    - Belt pretensioner
  - Validation against PMHS sled tests
  - Limitations in model detail for lumbar spine
    - Focus on kinematics



Summary

- Increasing incidence of lower spine fracture in frontal crashes of restrained occupants
- CIREN case review identified crash, vehicle, occupant, and restraint factors
- Research underway
  - Laboratory and field investigation of seats
    - Effects of structural differences on occupant response
  - Parametric studies on sled and with computational modeling
    - Restraint and crash pulse factors
  - ATD response
  - Continued field data review