INVESTIGATION OF LOWER SPINE COMPRESSION FRACTURES IN FRONTAL CRASHES

Rodney W. Rudd, National Highway Traffic Safety Administration
Overview

- Lower spine includes:
  - 10th through 12th thoracic vertebrae
  - 1st through 5th 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
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)

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

- Crash Characteristics
- Occupant Environment
- Occupant Biomechanics

Lower Spine Injury in Frontal Crashes
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
• Examined crash, vehicle, restraint, and occupant-related factors
• For example, of 64 cases with BES $\leq 56$ 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
Compression/burst more common than wedge fractures, suggesting a more pure compressive loading with adjacent endplates being nearly parallel.
Seat Characterization

- 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

Seat Characterization

• 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

- 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

Occupant Biomechanics
- Positioning
- Spinal alignment

Occupant Environment
- Restraints
- Knee bolster
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