Differences Between Crash Dummy Responses and Real-World Injury

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MEDICAL COLLEGE OF WISCONSIN

Introduction

MEDICAL COLLEGE OF WISCONSIN

- Anthropomorphic Test Devices (ATD)
  - a. k. a. crash test dummies
  - Used to design modern safety systems
  - Used to evaluate modern safety systems
    - NHTSA Regulatory testing
    - NHTSA NCAP star rating
    - IIHS ratings
    - Euro-NCAP, Japan-NCAP, etc
  - Designed to represent the living human
  - Assess injury potential without getting injured
    - Non-frangible

How human-like is an ATD?

Biofidelity

Purpose

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- Crash test dummy characteristics
  - Biofidelity
  - Injury criteria
- US-DOT-NHTSA Regulations
- Vehicle-related injuries in the real-world
  - CIREN identifies emerging trends
- Discuss areas of development

Dummy Characteristics - Biofidelity

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Hybrid-III
Frontal Impact Dummy
GM-designed 1970's

Dummy Characteristics - Biofidelity

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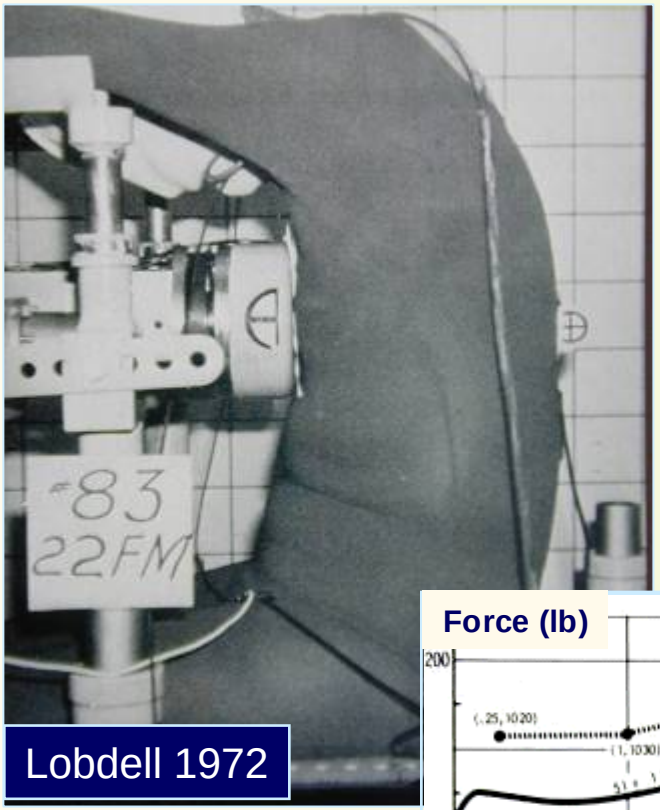
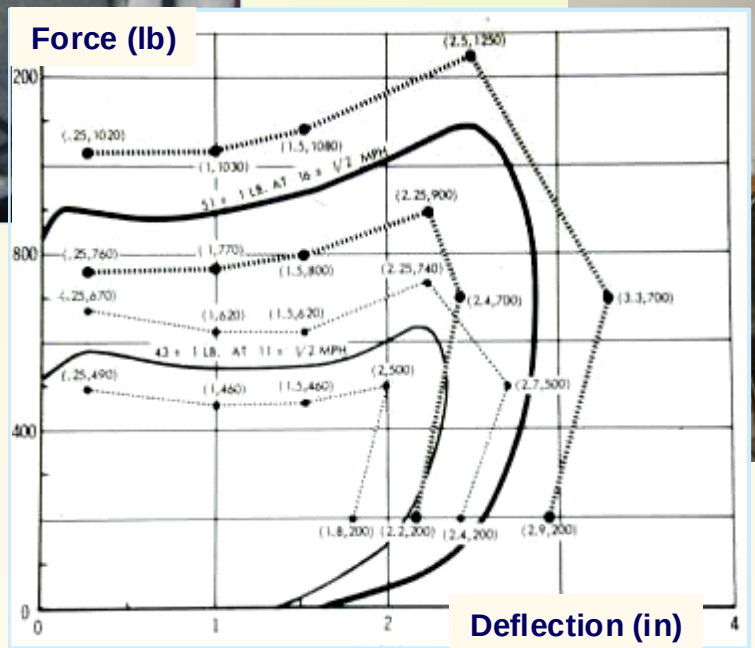
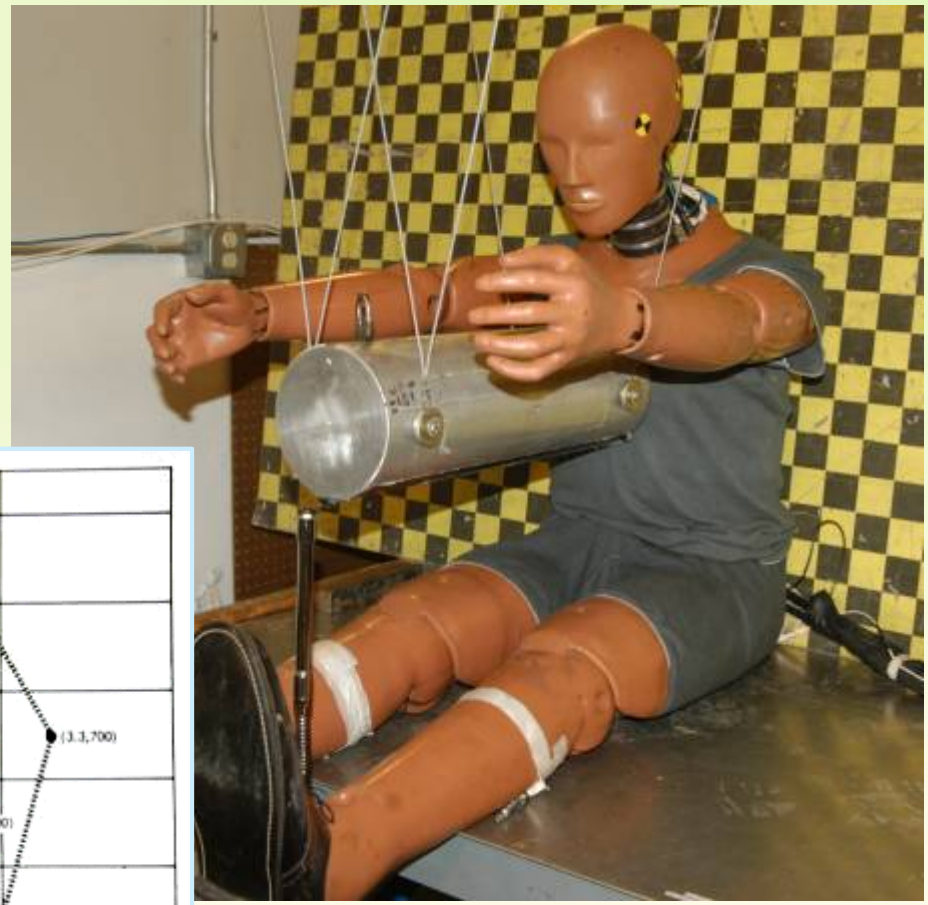


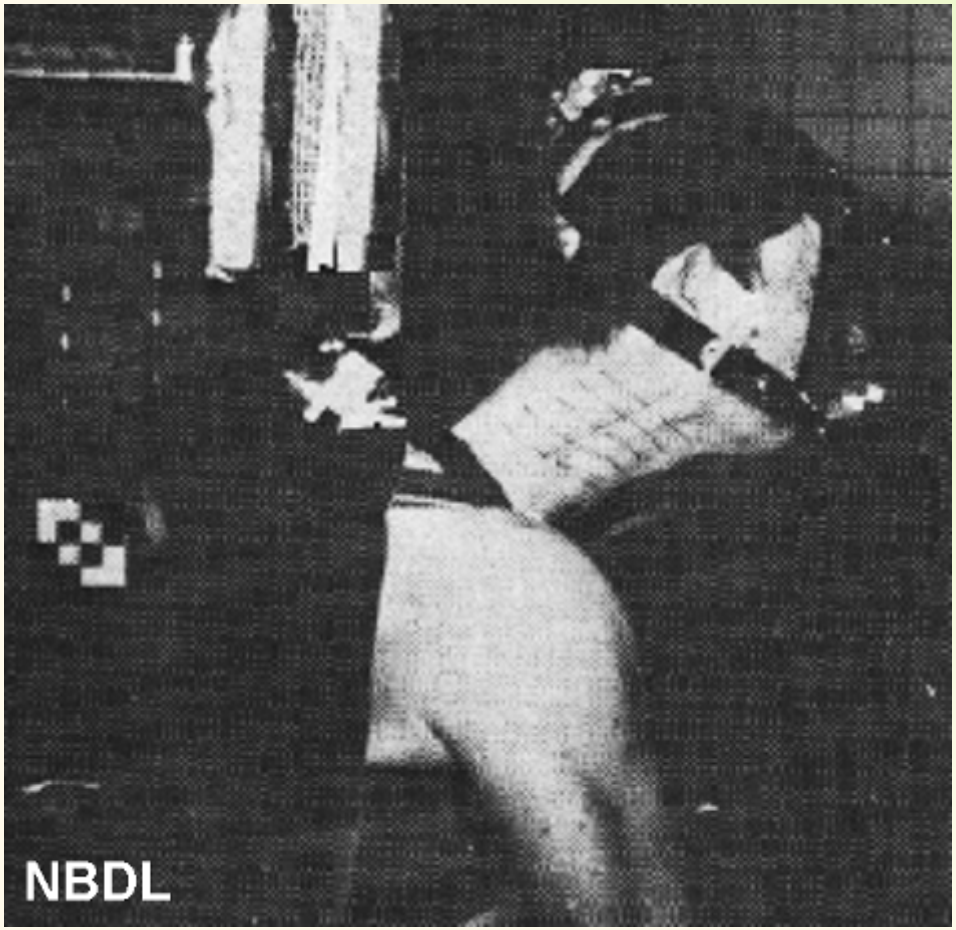
Lobdell 1972



Hybrid-III Frontal Impact Dummy Chest Compliance

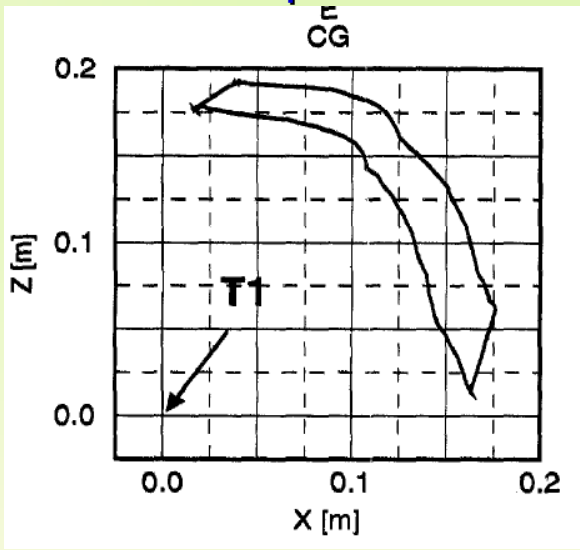


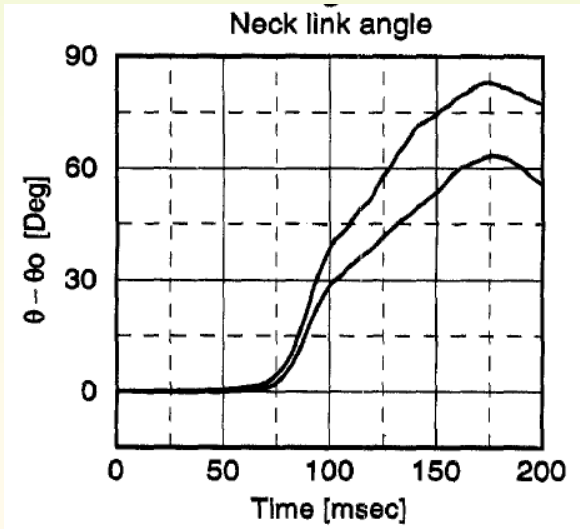
Dummy Characteristics - Biofidelity



Military personnel volunteers

Hybrid-III Frontal Impact Dummy Neck Compliance





Dummy Characteristics – Injury Criteria

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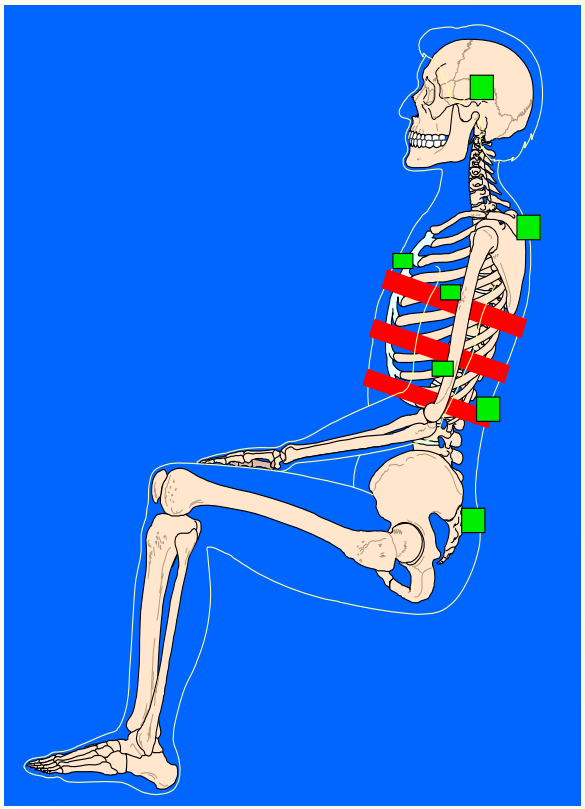
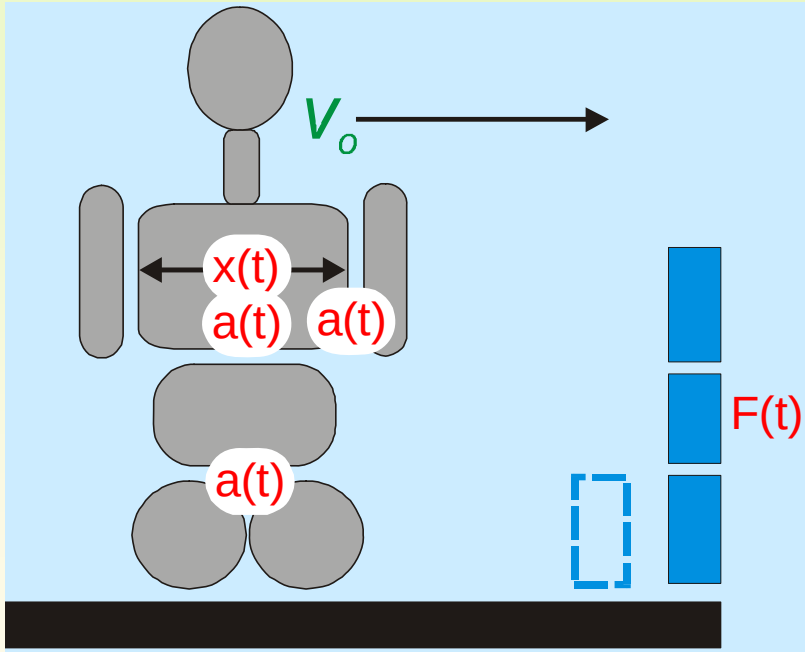


PMHS tests – full Instrumentation

Various boundary conditions:
Rigid wall
Padded wall
Offset wall

Matched-pair testing with
EuroSID-2re Side Impact Dummy



Dummy Characteristics – Injury Criteria

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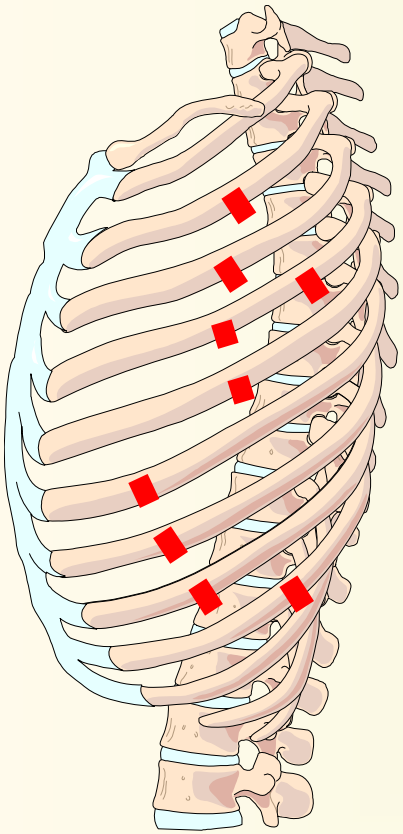
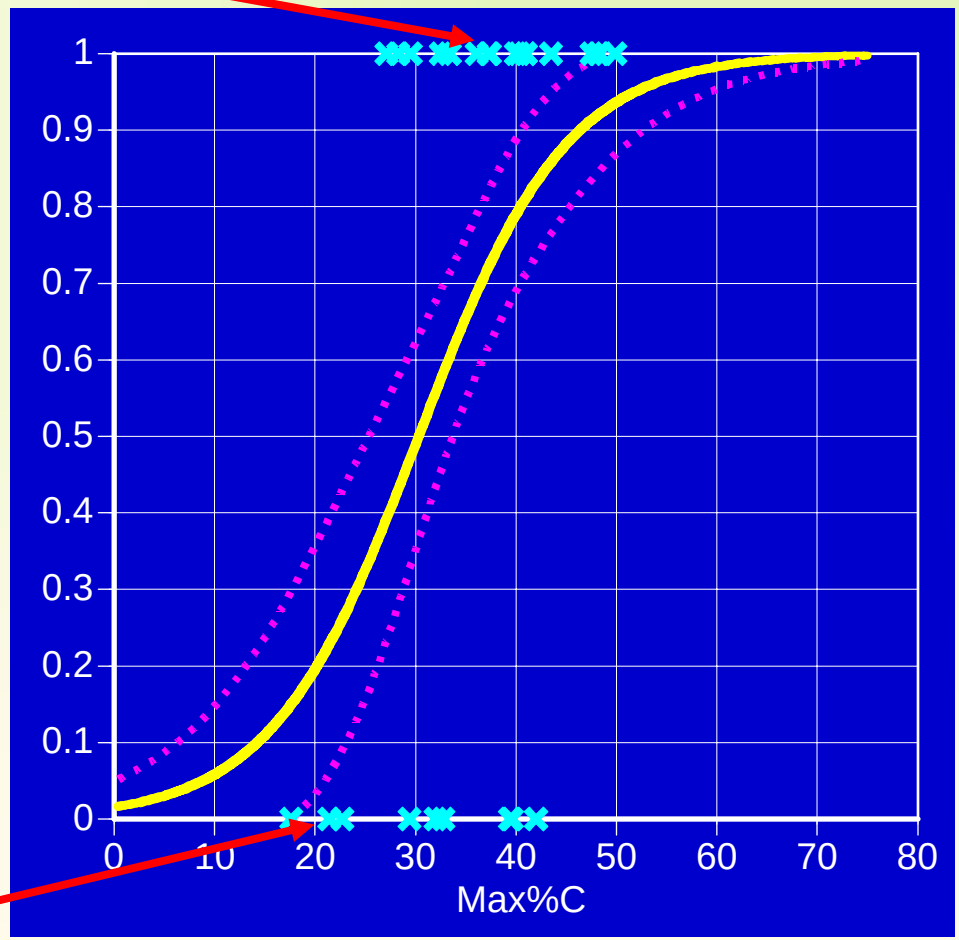
Derive Probability of Injury



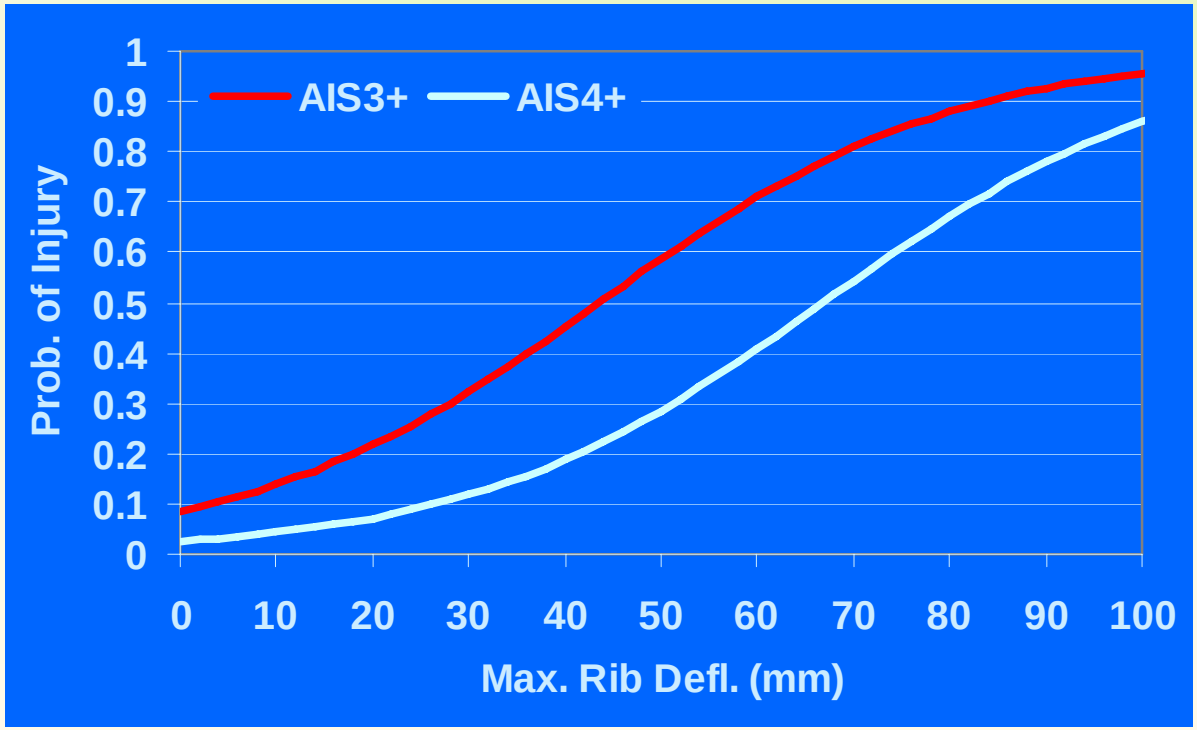
Tests with Injuries



Tests without Injuries

Dummy Characteristics – Injury Criteria

Probability of Serious Chest Injury for
EuroSID-2re Side Impact Dummy
Normalized to 45 year old



Dummy Characteristics – Injury Criteria

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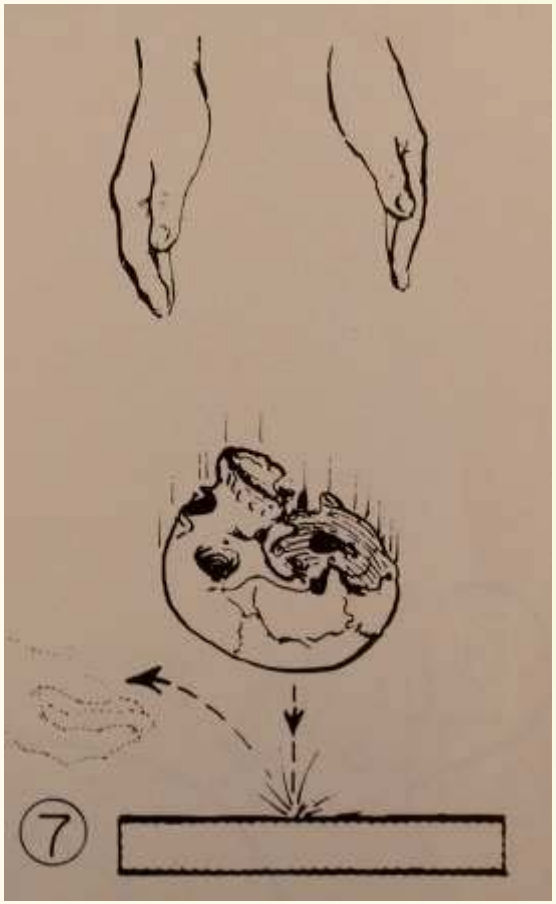
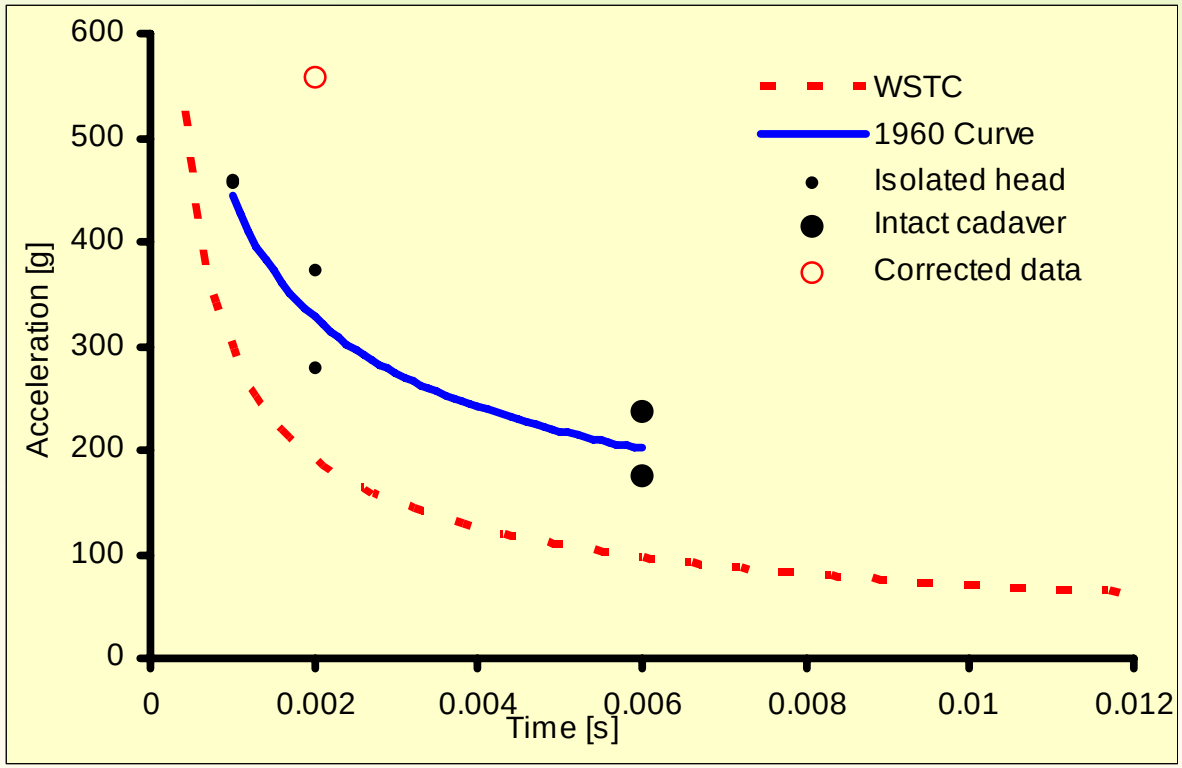
Head Injury Criteria

$$HIC_{15} = [1/(t_2-t_1) \int a\, dt]^{2.5} (t_2-t_1)$$

where t_2-t_1 is chosen to maximize HIC, t_2-$t_1 \leq 15$ ms
a is resultant acceleration measured at head center of gravity



Gurdjian, 1960s PMHS
"hand dropping" technique



Dummy Characteristics – Injury Criteria

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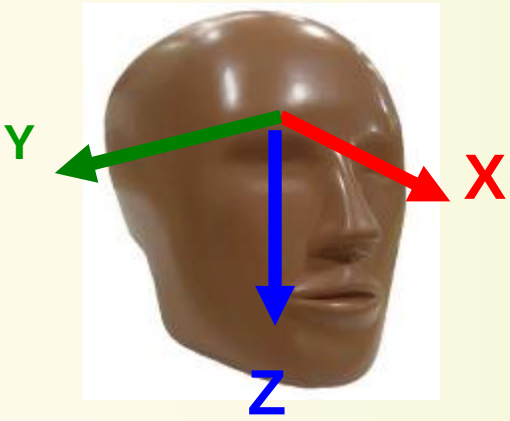
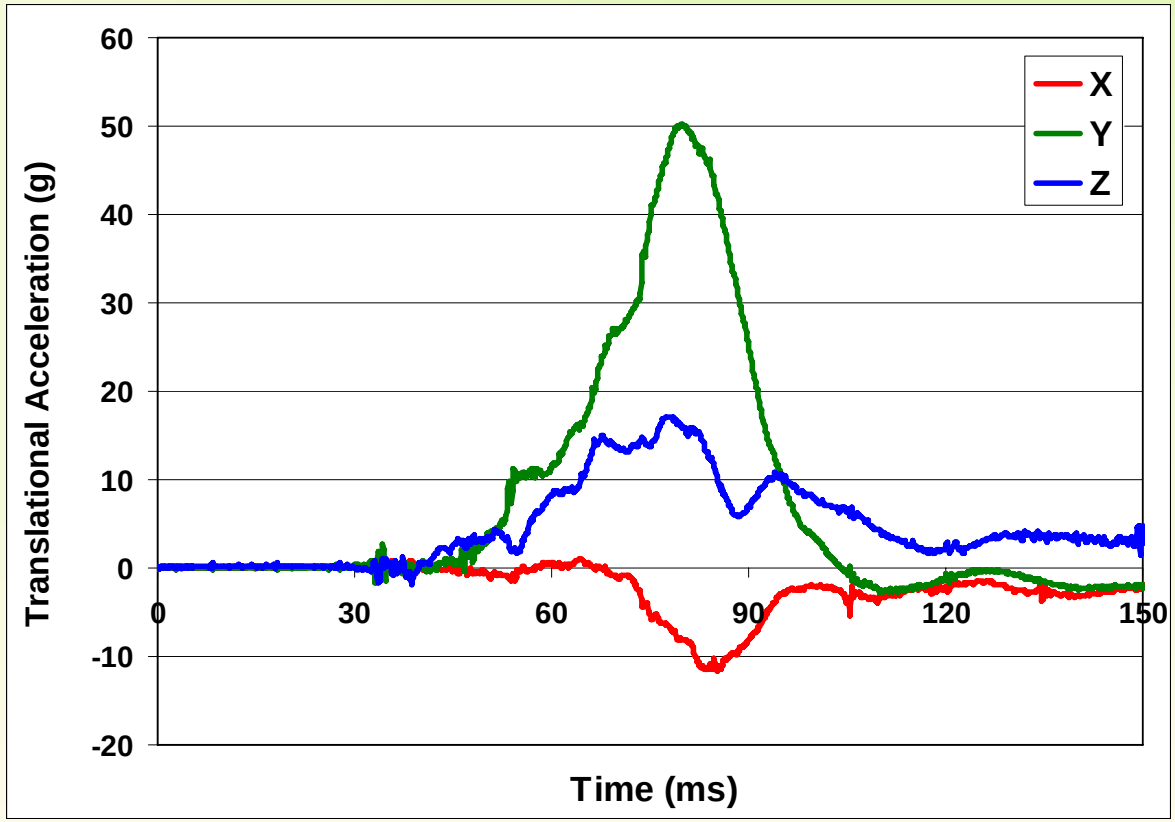
Head Injury Criteria



Accelerometers in the dummy head record translational acceleration



Federal Motor Vehicle Safety Standards

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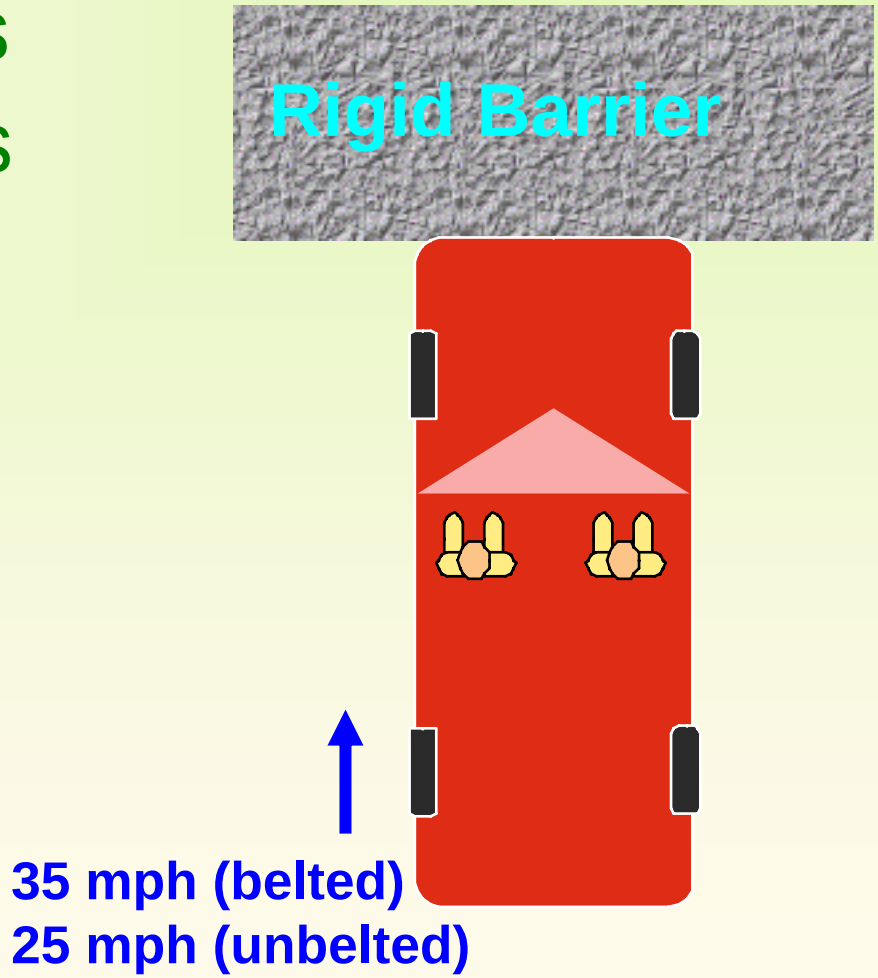
- Part 571: Includes Crashworthiness Standards
  - 571.208 – Frontal Impact Occupant Protection
  - 571.213 – Child Restraint Systems
  - 571.214 – Side Impact Occupant Protection
- Part 572: Anthropomorphic Test Devices used in 200-series of part 571

US DOT-NHTSA Regulations

Frontal Impact Crashworthiness FMVSS 208

- Front outboard seats
- Two belted dummies
- Stationary barrier
- Moving vehicle
- Trauma to
  - Head
  - Neck
  - Chest
  - Thigh



US DOT-NHTSA Regulations

Frontal Impact Crashworthiness

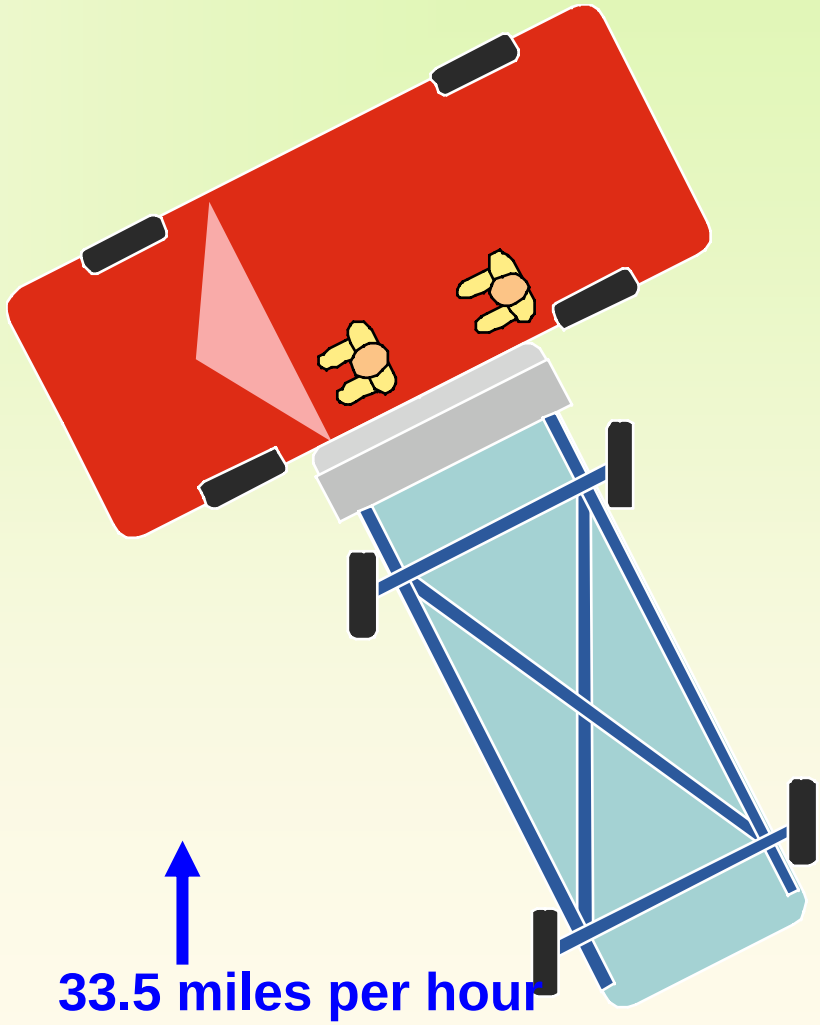
Hybrid-III 50th Male Dummy Injury Criteria

- Head Injury Criteria (HIC15) – 700 (15 ms)
- Chest Acceleration – 60 g
- Chest Deflection – 63 mm
- Neck Injury Criteria Nij < 1.0
- Femur Criteria – 10 kN

US DOT-NHTSA Regulations

Side Impact Crashworthiness FMVSS 214

- Two Belted dummies
- Left side seating
- Stationary vehicle
- Moving deformable barrier “crabbed”
- NHTSA-SID Trauma to
  - Chest
  - Pelvis



US DOT-NHTSA Regulations

Side Impact FMVSS 214 UPGRADE

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Test Configurations

Oblique vehicle to pole impact

MDB--to-vehicle side impact

Dummies

BOTH mid-size male & small female

ES-2re

SIDIIs

US DOT-NHTSA Regulations

Side Impact Crashworthiness

ES-2re 50th Male Dummy Injury Criteria

- Head Injury Criteria (HIC36) – 1000 (36 ms)
- Lower Spine Acceleration – 82 g
- Rib Deflection – 40 mm
- Abdomen Force – 2500 N
- Pubic Force – 6000 N

US DOT-NHTSA Regulations

Child Restraint Systems FMVSS 213

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- Newborn, 12-mo, 3-yo, 6-yo
- Head Injury Criteria (HIC36) – 1000 (36 ms)
- Chest Acceleration – 60 g
- Head Excursion Limit
- Knee Excursion Limit

Real-World Trauma

Injuries that dummies don't tell you about

Types of Abdominal Trauma

Upper Extremity Trauma

Real-World Trauma

Injuries that dummies don't tell you about

Types of lower extremity trauma

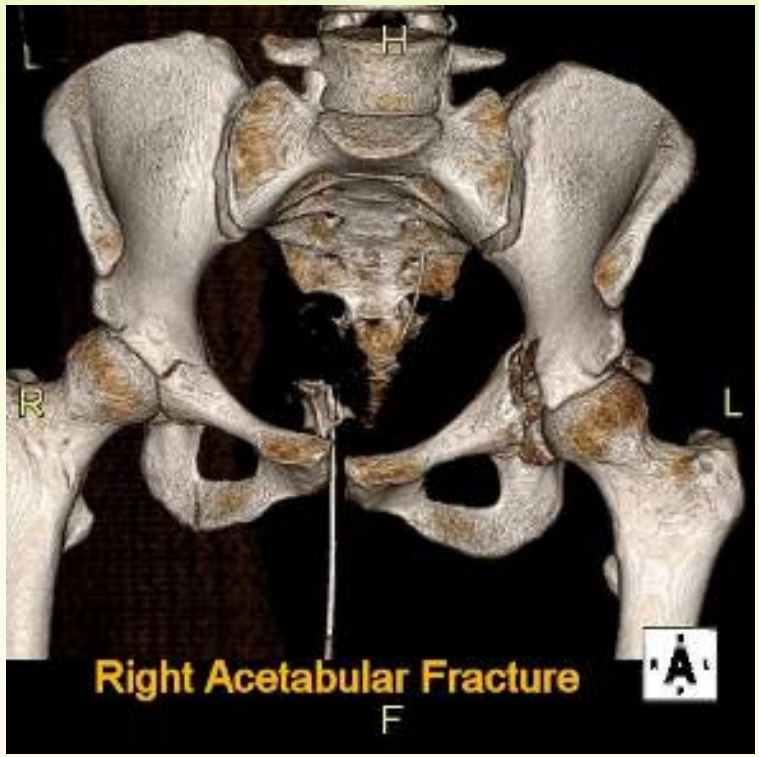
Some spine trauma

Vascular trauma

Real-World Trauma

Pelvic Fractures

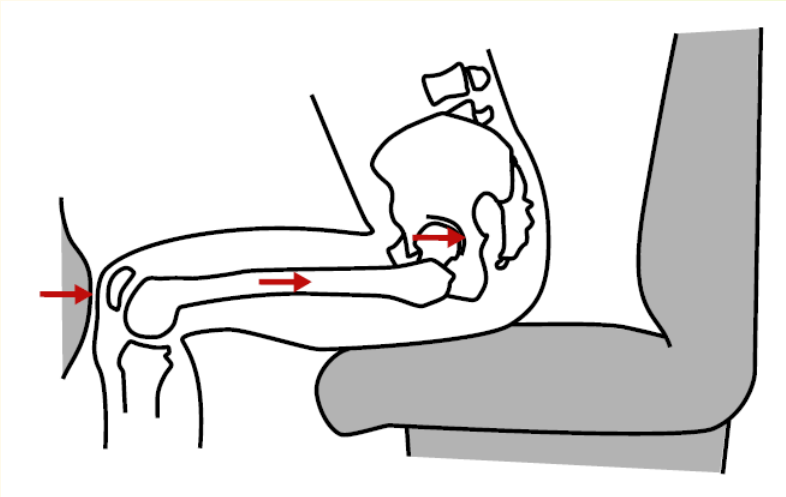
Frontal impact of
1999 Jeep Cherokee
Rt acetabular Fx induced by
knee contact with knee bolster



Frontal impact of
1997 Lexus LX450
Acetabular Fxs induced by
knee contact with knee bolster

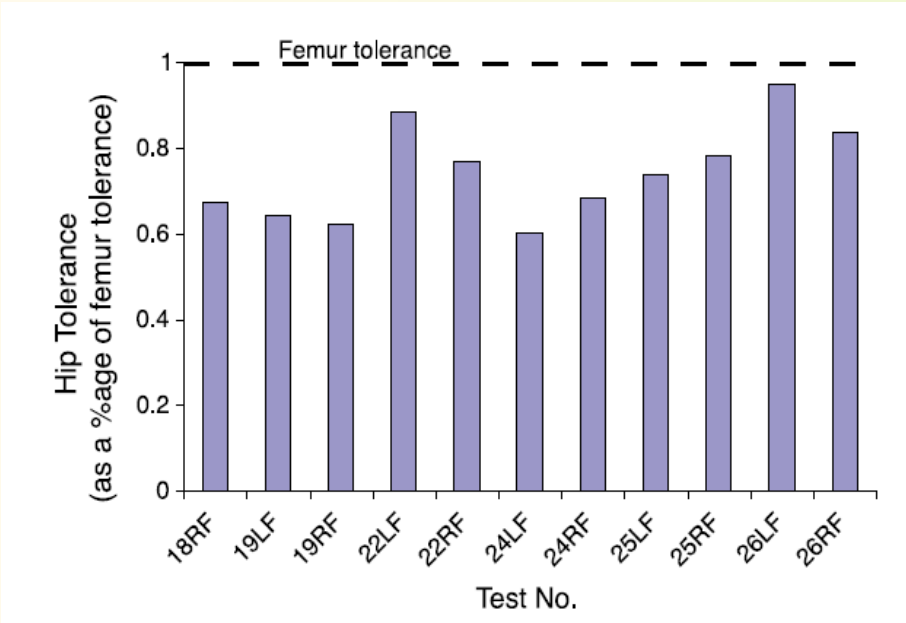
Developments in Understanding

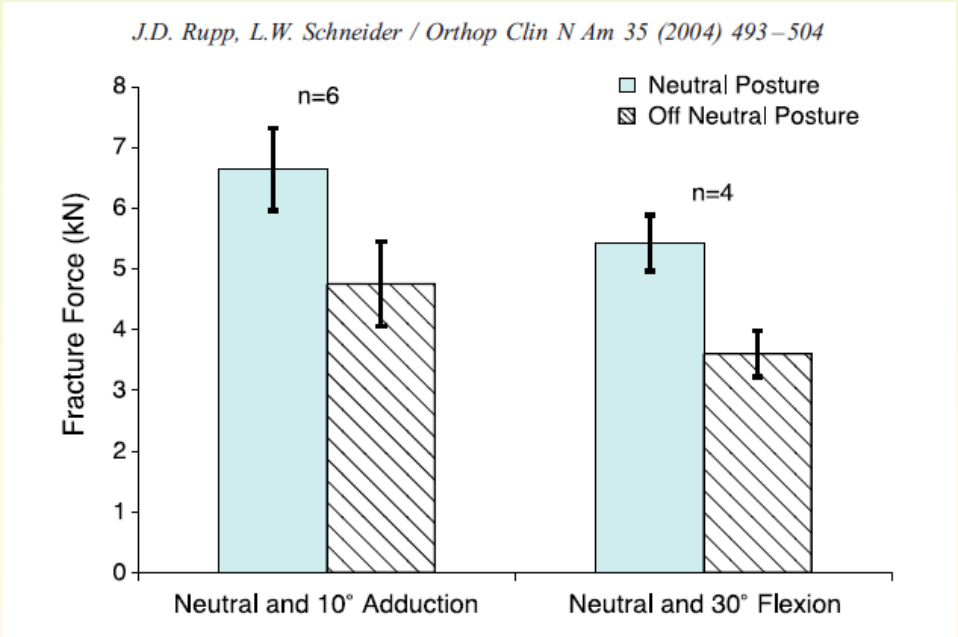
Pelvic Fractures



- Knee-Thigh-Hip trauma
- Knee contact – knee bolster
- Effect of loading rate
- Effect of position

Rupp & Schneider, Orthop Clin N Am, 2004

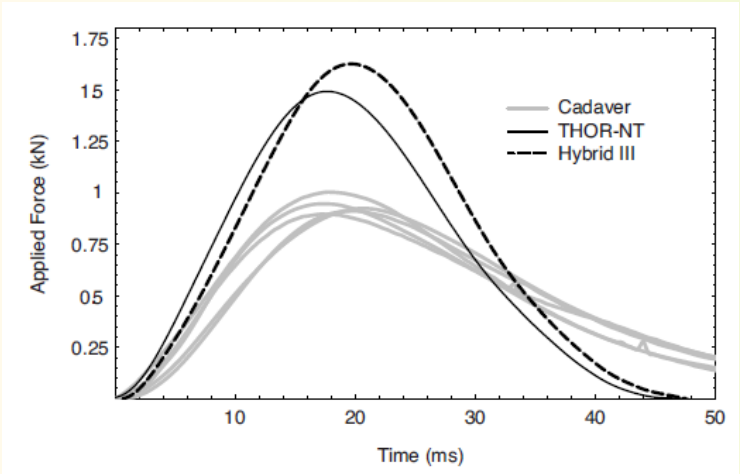




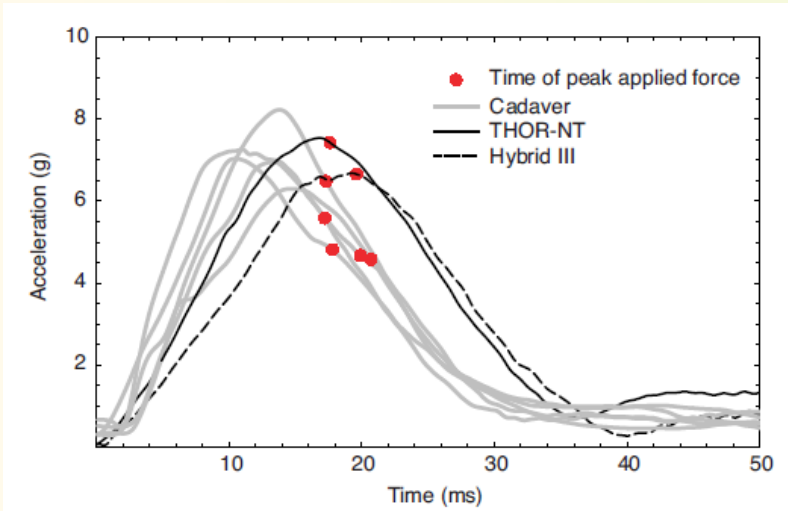
Developments in Understanding
Pelvic Fractures

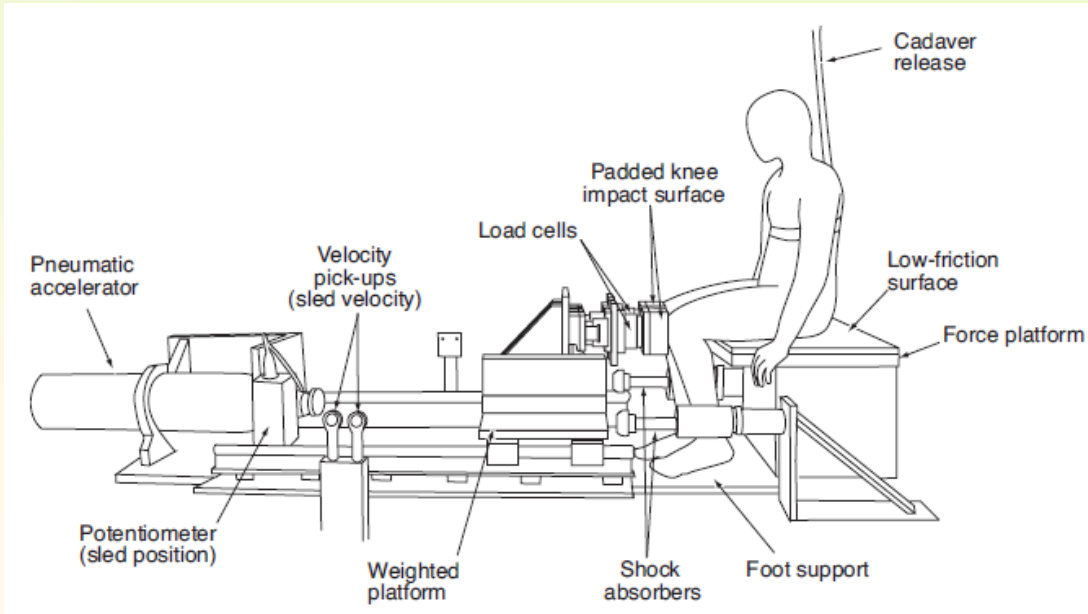
MEDICAL COLLEGE OF WISCONSIN

- Translate PMHS response data to dummy response
- Translate PMHS injury criteria to dummy criteria



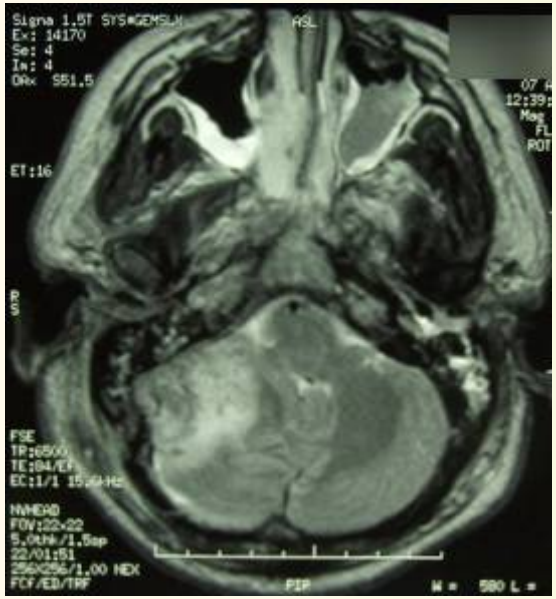
Rupp, et al, ESV 2005





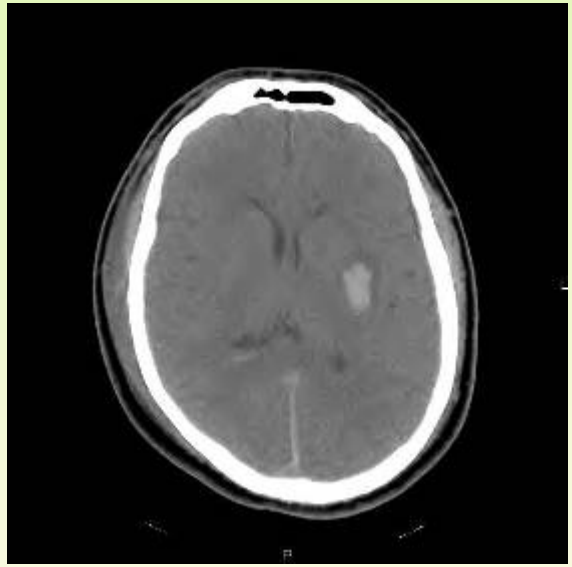
Real-World Trauma

Brain Injuries

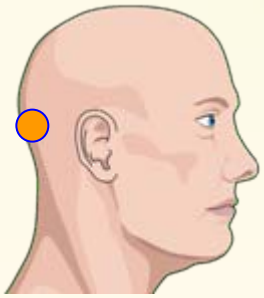


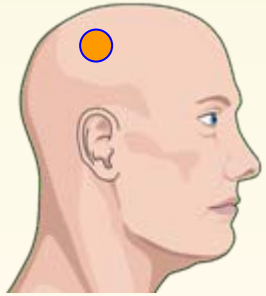
Right Occipital Skull Fx
Cerebellar contusion

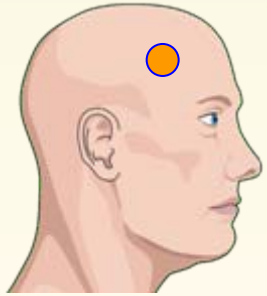
DAI, IVH, SAH



IVH, SAH







Developments in Understanding

Brain Injuries

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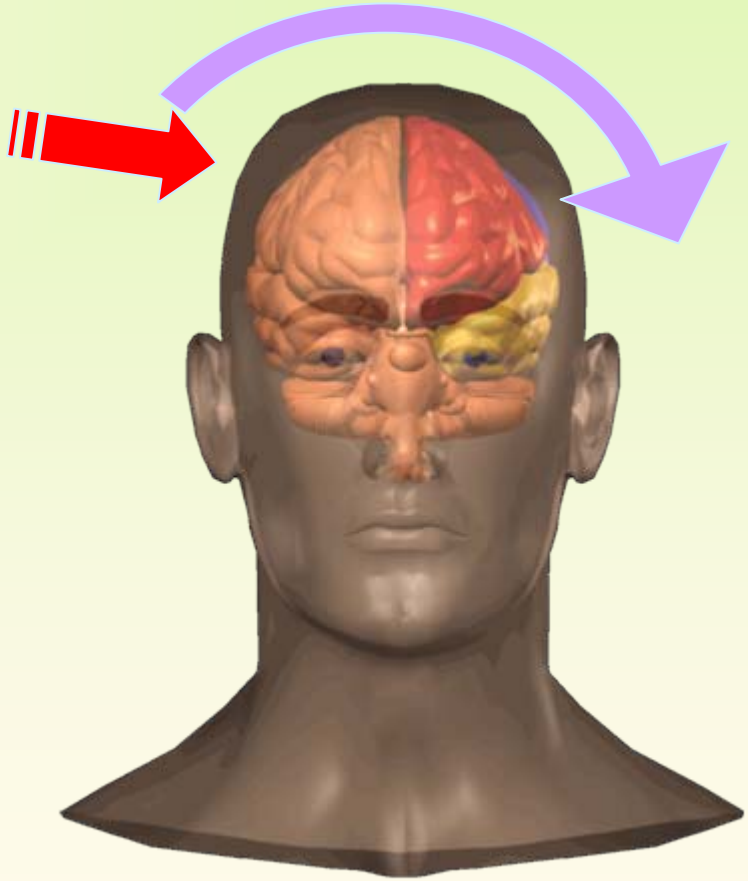
Focal

Translational Acceleration

Motion



Rotational Acceleration

Developments in Understanding
Brain Injuries

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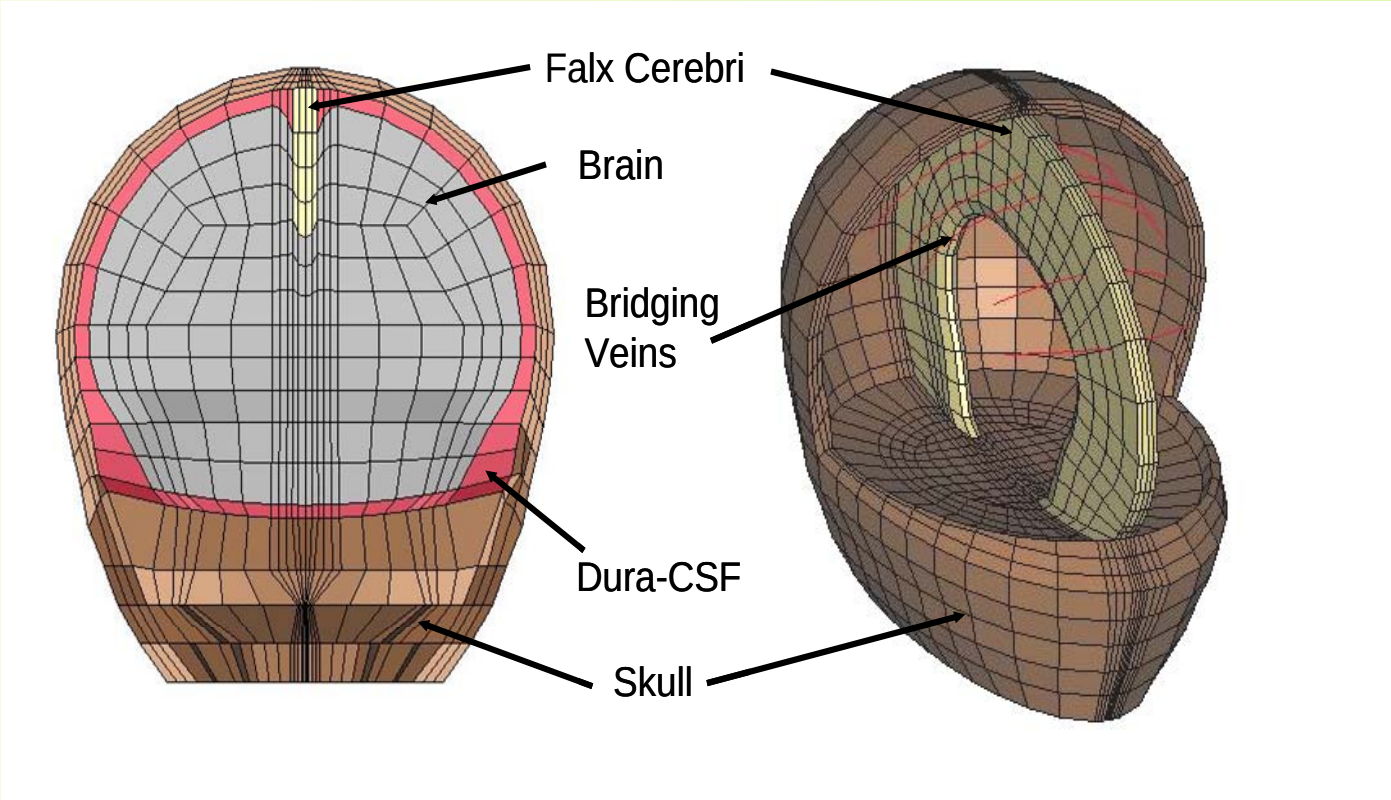
SIMon Computation Model



Rotational motion induces deep brain trauma

Developments in Advanced Dummies

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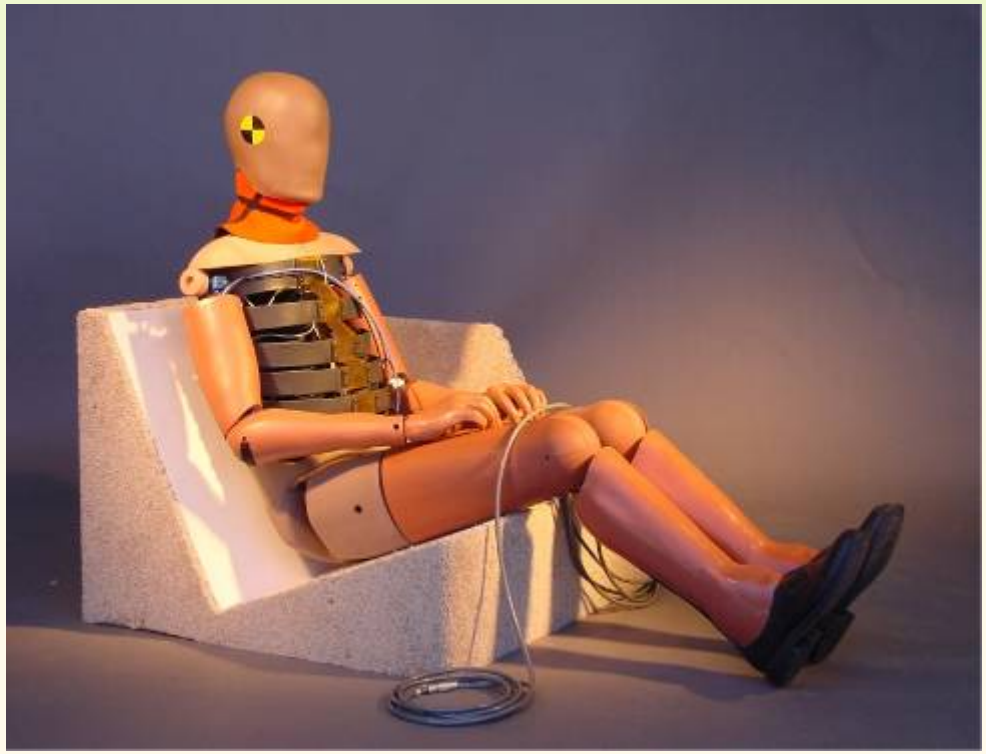
THOR
Frontal Impact Dummy

~150 sensors
3X-4X biofidelity
Injury Criteria ?

WorldSID
Side Impact Dummy



Summary

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- Dummies are valuable tools
- Great improvements to human safety
- Dummy biofidelity is advancing
- Dummy-based injury criteria needed
- Dummies don’t measure every type of injury
- Development of dummy with computer models

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