AMERICAN COLLEGE OF EMERGENCY PHYSICIANS
SCIENTIFIC ASSEMBLY
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# Injury Mechanism Workshop

Every emergency physician knows that there is a correlation between mechanism of injury and trauma morbidity and mortality rates. This multimedia course will describe examples from current research and government attempts to reduce injury in the United States. Examples will include how mechanism predicts the extent of injury and proper emergency department management. The lecturer will also discuss what can be done to prevent injury.

- Describe the impact of mechanism of injury on trauma.
- Describe how design, such as automobile and road designs, can be changed to minimize injury.
- Cite examples of recent safety advances.
- Describe how mechanism predicts injury and how it can guide emergency department clinical management.

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**FACULTY**

Ricardo Martinez, MD

Administrator, National Highway Traffic Safety Administration, Washington, DC

Jeffrey W Runge, MD, FACEP

Assistant Chairman and Clinical Research Director, Carolinas Medical Center, Charlotte, North Carolina

# Injury Biomechanics Workshop
## 1999 ACEP Scientific Assembly
## Las Vegas, NV

**Jeffrey W. Runge, MD**
**Carolinas Medical Center**
**Ricardo Martinez, MD**
**National Highway Traffic Safety Administration**

1. Mission
   - For physicians to recognize injury as a disease, with similar strategies for disease control as any other disease
   - For physicians to care for MVC patients with attention to biomechanical risk factors
2. Permissions
   - Still pictures, video, audio and syllabus are not under copyright by ACEP.
   - ACEP has our permission to use tapes of this presentation and our syllabus for educational purposes.
3. Acknowledgements
   - National Highway Traffic Safety Administration - Still images, video, case studies
   - Insurance Institute for Highway Safety - Still crash images, video
   - Association for the Advancement of Automotive Medicine -Video
4. Course Outline
   - Module 1 -- Biomechanics and Injury Control
     * Understand the principles of Injury Control
     * Biomechanics as a segment of Injury Control
   - Module 2 -- Crash physics
     * How crash forces induce injury
     * Physical models of crash injury
     * Physical parameters that determine injury
     * Characteristics of crashes that help clinical decision making
   - Module 3 --Vector and environment design modifications
     * Changes in motor vehicle design
     * Seat belts and child safety restraints
     * Air bags

* Environment (roadway engineering)

- Module 4 -- Case studies in biomechanics

5. Definitions
   - AIS Abbreviated Injury Scale -- Scored 1 – 6
   - MAIS - Maximum AIS of a patient
   - Effectiveness Injuries Prevented/Base Injuries
   - Delta V - Crash Severity (mph) change in velocity as index of energy of crash
6. Definitions
   - Harm - Index of total injuries using cost
   - NASS - National Automotive Sampling System
   - GES General Estimates System
   - CDS - Crashworthiness Data System

**Module 1 – Biomechanics and Injury Control**

7. What is an <u>INJURY</u>?
8. Biomechanical definition: A harmful event resulting from an inappropriate exposure to *energy*
9. Energy exposure:
   - Kinetic
   - Thermal
   - Electrical
   - Radiation
10. Types of energy transfers
    - Scald/burn
    - Motor vehicle crash
    - Fall
    - Gunshot
    - Lightning
11. Essential Principles:
    - Injuries are *NOT accidents*
    - Injuries are NOT *acts of* fate
    - Injuries *<u>ARE predictable</u>*

- Injuries *ARE preventable*

12. Years of life lost by disease
    - Injuries 40.8%
    - Cancer 18%
    - Heart disease 16.4%
    - All others 24.8%
13. Injury triangle: For an injury to occur, there must be an interaction between host (human), agent (energy), and environment.
14. Haddon's Matrix: 3x3 table, showing that there are 3 phases to the host, agent, and environment interaction, pre-event, event, and post-event. All are amenable to injury control strategies.
15. "Injury Control" is comprised of the continuum of Prevention, Acute Care, and Rehabilitation.
16. Prevention
    - Understanding the epidemiology of injury
    - Understanding and applying technological advances to biomechanics of injury
    - Intervening in the interaction of host, agent and environment
17. Injury pyramid
    - 0.1% deaths
    - 10% Admitted to hospitals
    - 90% Treated in ED and discharged
    - Unknown number treated elsewhere or not treated
18. Injury Prevention Strategies
    - Education of the public
    - Enforcement of laws and regulations
    - Engineering of vector and environment
    - Economic incentives
19. Public Education
    - Costly
    - Labor intensive
    - May fail to reach target populations
    - *Absolutely necessary adjunct to other strategies*
20. Enforcement of Law and Regulations

- Effective if consistent
- Subject to public opinion
- Often not based on scientific evidence

21. Engineering Enhancements
    - Most effective
    - Not dependent on subject's cooperation
    - Most costly
    - Not dependent on enforcement
    - Based on scientific evidence
22. Economic Incentives
    - Insurance reductions or surcharges
    - Fines and penalties
23. Acute Care in Injury Control
    - Trauma system design and implementation
    - Prehospital response and care
    - Pre-hospital triage and in-hospital triage
    - Acute injury management
    - Definitive care
24. Rehabilitation
    - Short term restorative care
    - Home restorative services
    - Return to pre-morbid condition
    - Prevention of future injury
25. Haddon method for injury control interventions
    * Prevent creation of the hazard
    * Reduce the amount of the hazard
    * Prevent inappropriate release of the hazard
    * Modify rate or spatial distribution
    * Release of the hazard in time or space
    * Put a barrier between the hazard and the host
    * Change the basic nature of the hazard
    * Increase resistance of people t the hazard
    * Counter damage already done

* Stabilize, bring to definitive care
* Rehabilitate

## Module 2 -Crash Physics

26. MVC pyramid (1998)
    - 41,471 fatalities
    - 2,250,000 injury crashes
    - 4,269,000 property damage only
    - 6,334,000 police reports
    - > 10,000,000 crashes
27. Fatalities decreasing
    - Over 50,000 in 1960s
    - Rate of decrease greater when vehicle miles traveled (VMT) used to calculate rate
28. How Crash Fatalities Occur (FARS)
    - Multi vehicle 45%
        * Frontal 25%
        * Side 17%
        * Rear 3%
    - Single vehicle 40%
        * Frontal 13%
        * Side 5%
        * Other 2%
        * Rollover 20%
            - Passenger car 10%
            - Light truck 9%
            - Heavy truck 1%
    - Non-occupant
        * Pedestrian 13%
        * Bicycle 2%
29. How Crash Injuries Occur (NASS GES)
    - Multi-vehicle 77%

* Front 31%
* Side 25%
* Rear 21%

- Single vehicle 19%
  * Front 9%
  * Side 3%
  * Other 1%
  * Rollover 6%
    - 0 Passenger car 3%
    - V Light truck 2%
    - V Heavy truck 1%
- Non-occupant
  * Pedestrian 2%
  * Bicycle 2%

30. Harm by crash direction
    - Frontal 47%
    - Side 34%
    - Rollover 16%
    - Rear 3%
31. Severity of crashes by A V
    - All crashes AV ≈ 5 mph
    - Police involved AV ≈ 10 mph
    - Injury crashes AV ≈ 19 mph
32. Harm by crash severity ($\Delta V$)
    - O-15 mph 23%
    - 16-30 mph 54%
    - > 30 mph 23%
33. Injury Weighted Harm by body region
    - Severe frontal crash
      * Head predominates, followed by torso and lower extremities
      * Unrestrained occupants lead
      * Note higher torso injuries for lap belt only, and LE similar to head for belt + bag

- Moderate frontal crash
  - * Torso and lower extremities
  - * Mostly in unrestrained
- Low severity
  - * Head and integument
  - * Virtually all in unrestrained-belt completely protective

34. Head Injury Criterion
- Impact tolerance for human brain'in forehead impacts against a plane
- Function of G Forces and time of deceleration
- Highly reproducible
- Used to compare crash performance and regulate vehicles

35. Effect of age on crash injury
- Fatalities bimodal. worse in males
- Injuries bell curve, peak 16 – 24 years.
- Consider differences in exposure (VMT)
- Chest injury tolerance is example of differences in host resistance by age

36. G Force = AV I(32 • stopping distance)
- Increasing stopping distance is a major goal of safety engineering
- AV can be + or – (acceleration or deceleration) and can be additive

**Module 3 -Vector and Environment design modifications**

37. Vehicle design examples
- Passenger "cage"
- Crumple zones
- Plastic v. steel and chrome
- Smooth interior surfaces
- A-pillar and B-pillar strength
- Toe pan modifications
- Automatic (passive) seat belts
- Child safety restraints
- Seat belt pretensioners

38. Air Bag Statistics

- 200 million cars on US roads
  * 34% have driver air bag
  * 20% have passenger air bag
  * 84% of 1995 models have dual bags
  * 1 million new cars sold each month
  * 2 million deployments as of 10197

39. How Air Bags Work
- Three components
  * Air bag module
  * Crash sensor
  * Diagnostic unit

40. Air bag module
- Inflator
- Porous vented bag
- Dry lubricant

41. Crash sensor
- Detects change in velocity
  * Should deploy at delta V = 9-13 mph
- Tolerances and designs vary
- Electronic signal deploys the bag

42. Diagnostic unit
- Monitors operational readiness when ignition switch is on
- Activates warning light

43. Air Bag Inflation
- Regulations required bags to protect unbelted occupants (until 1999)
- Requires very aggressive air bag
- Must deploy before "2nd collision"
- Less than 200 msec

44. Injury weighted Harm in frontal crashes -- Head and Torso
- Head
  * AIS 2+ ⇒ Belt + bag protective > Belt only > Bag only > unrestrained
- Chest
  * AIS 3+ ⇒ Belt + bag protective > Belt only > Bag only > unrestrained

- Lower extremity
  - * AIS 3+ ⇒ Bag only highest rate; seat belts protective
  - * AIS 2+ ⇒ Slightly higher rate with belt + bag; rate with bag only > unrestrained
- Upper extremity fx
  - * AIS 3+ ⇒ Belt + bag protective > Belt only > Bag only > unrestrained
  - * AIS 2+ ⇒ Bag increases risk
- Eye injuries
  - * AIS 1 injuries occur, but bag does not increase risk; bag may change pattern
  - * AIS 2 not increased by bag; belt protective
  - * Case reports in literature include injuries with eye glasses and corneal burns
  - * Dummies with glasses: less globe contact with bag than no bag
  - * Special Crash Investigation: 45 cases since 1984
  - * NASS analysis
    - Fewer AIS 1 and 2 injuries
    - Less contact with windshield and interior components

45. Seating Position
    - Risk zone: first 2-3 inches of inflation
    - Safety zone: >10 inches from wheel
    - Raise and recline seat
    - Tilt wheel downward
46. Ongoing Problems
    - Air bags designed to protect unbelted 155 lb adult
    - Low belt usage
    - Improperly installed infant seats
    - Seat belts for children < 90 lbs, 55”
47. The Future
48. Sensors to detect
    - Seating position
    - Infant seat
    - Belt users
    - Non-belt users
    - Programmable for pregnancy

- Speed of inflation relative to Delta V

49. Air Bag Disconnection
    - Panel of 17 physicians
    - From 17 organizations
    - Review of medical and engineering literature on air bags
    - Handled specific queries to NHTSA
        * Pacemakers
        * Supplemental oxygen
        * Eyeglasses
        * Median sternotomy
        * Angina
        * COPD/Emphysema/Asthma
        * Breast reconstruction
        * Scoliosis
        * Prior back/neck surgery
        * Prior facial reconstruction
        * Hyperacusis or tinnitus
        * Advanced age
        * Osteogenesis imperfecta
        * Wheelchairs
        * Achondroplasia
        * Prior eye surgery
        * Down's syndrome with atlanto-axial instability
        * Monitoring of CWSN
        * Pregnancy
        * Short stature

50. Indications for on/off switch
    - Rear facing infant seats that must be in the front seat
    - Children who must be seated in front seat
    - Drivers who must sit closer than 10" from wheel
    - MD says the risks of a condition outweigh advantages of air bag
    - Physical condition that prevents proper seating away from AB
        * Kyphosis/scoliosis
        * Achondroplastic dwarfism
        * Atlanto-axial instability
    - Monitoring of CWSN

51. More data needed
    - Late pregnancy
    - Elderly patients' interaction with seat belts + air bag
    - Short stature

52. Minimizing risk – <u>Golden opportunity for EPs to practice prevention!</u>
    - ALWAYS put rear-facing infant seats in the back

- Always seat children 1-12 in the back seat in age-appropriate restraints
- Wear your seat belt
- Keep 10 inches away from the AB

53. Air Bag Performance Summary
    - Highly Effective in Preventing Deaths
    - Highly Effective in Preventing Head Injuries
    - Belts are Needed with Air Bags
    - Occupant Positioning is Important.
    - Close Positioned Occupants Can be Injured by the Deploying Air Bag
    - Injury Risk for Belt Restrained Occupants is Small-Based on NASS Data
54. New technologies
    - Side air bags
        * Seat mounted
        * Door mounted
        * Inflatable head protection
    - Knee bolster air bags
    - Toe pan air bags
55. Causal factors requiring research
    - Driving task error – 75%
        * NADS
    - Driver physiologic state – 14%
    - Road surface – 8%
    - Vehicle defects – 3%
        * Material flammability
        * Fuel systems
    - Delayed EMS response
        * ACN

Module 4 - CIREN **case studies**