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# TBI: The Silent Epidemic

According to the Centers for Disease Control (CDC) traumatic brain injury (TBI) is an important public health problem in the United States. TBI is frequently referred to as the “silent epidemic” because the complications from TBI, such as changes affecting thinking, sensation, language, or emotions, may not be readily apparent. The most recent CDC report (Frieden et. al, 2010) estimates 1.7 million people sustain a TBI annually, of them 52,000 die.

The report finds that among all age groups, motor vehicle traffic (MVT) was the second leading cause of TBI (17.3%) and resulted in the largest percentage of TBI-related deaths (31.8%). Based on NASS-CDS analyses of frontal crashes (Eigen and Martin, 2005) fatalities attributable to head injuries are second only to fatalities attributable with societal costs exceeding $6 Billion.

Head rotation as a mechanism for brain injury was proposed back in the 1940s. Since then a multitude of research studies by various institutions were conducted to confirm/reject this hypothesis. Most of the studies were conducted on animals and concluded that rotational acceleration sustained by the animal’s head may cause axonal deformations large enough to induce their functional disruption.

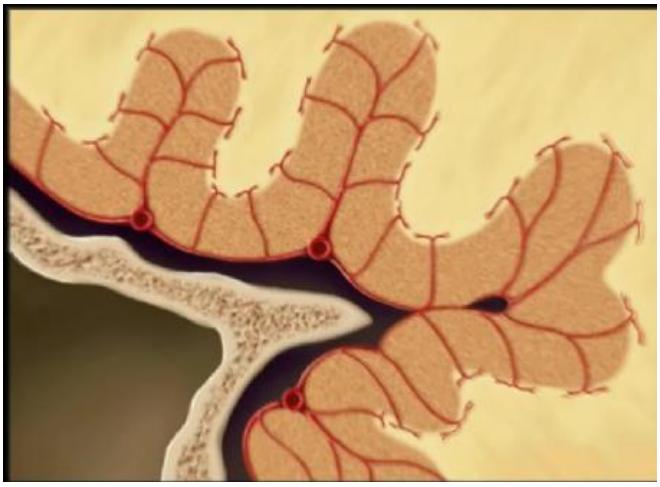


Figure A. Before the collision

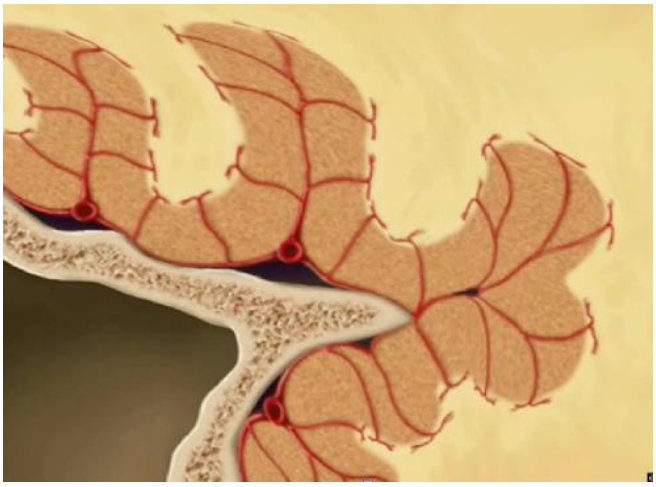


Figure B. After the collision

Other studies utilized mathematical models of human and animal heads to derive brain injury criteria based on deformation/pressure histories computed from the models. This study differs from the previous research in the following ways: first, it uses a detailed mathematical model of human head validated against various human brain response datasets; then establishes physical (strain and stress based) injury criteria for various types of brain injury based on scaled animal injury data; and finally, uses dummy (Hybrid III, ES-2re, WorldSID; all 50th percentile male) test data to establish kinematically (rotational accelerations and velocities) based brain injury criterion (BRIC) for each dummy.

Similar procedures were applied to the college football data where thousands of head impacts were recorded using six degrees of freedom (6 DOF) instrumented helmet system. Since animal injury data used in derivation of BRIC were predominantly for diffuse axonal injury (DAI) which is an AIS 4+ injury, cumulative strain damage measure (CSDM) was used to derive BRIC risk curve for AIS 4+ brain injuries.

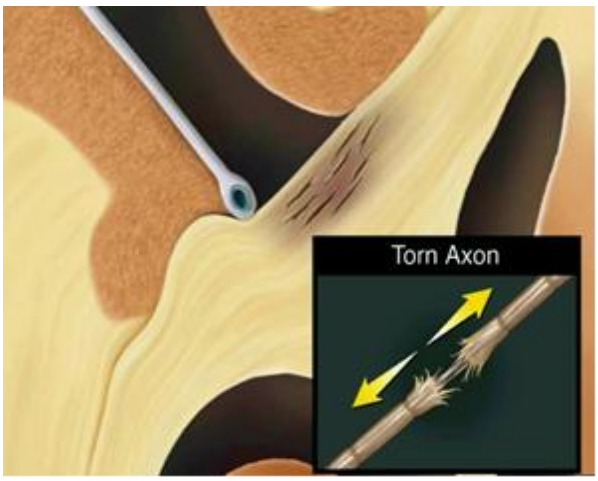



Figure A. Diffuse Axonal Injury (Intact)

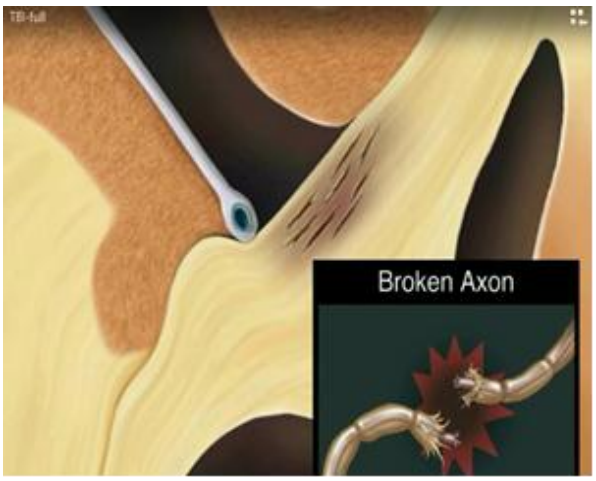
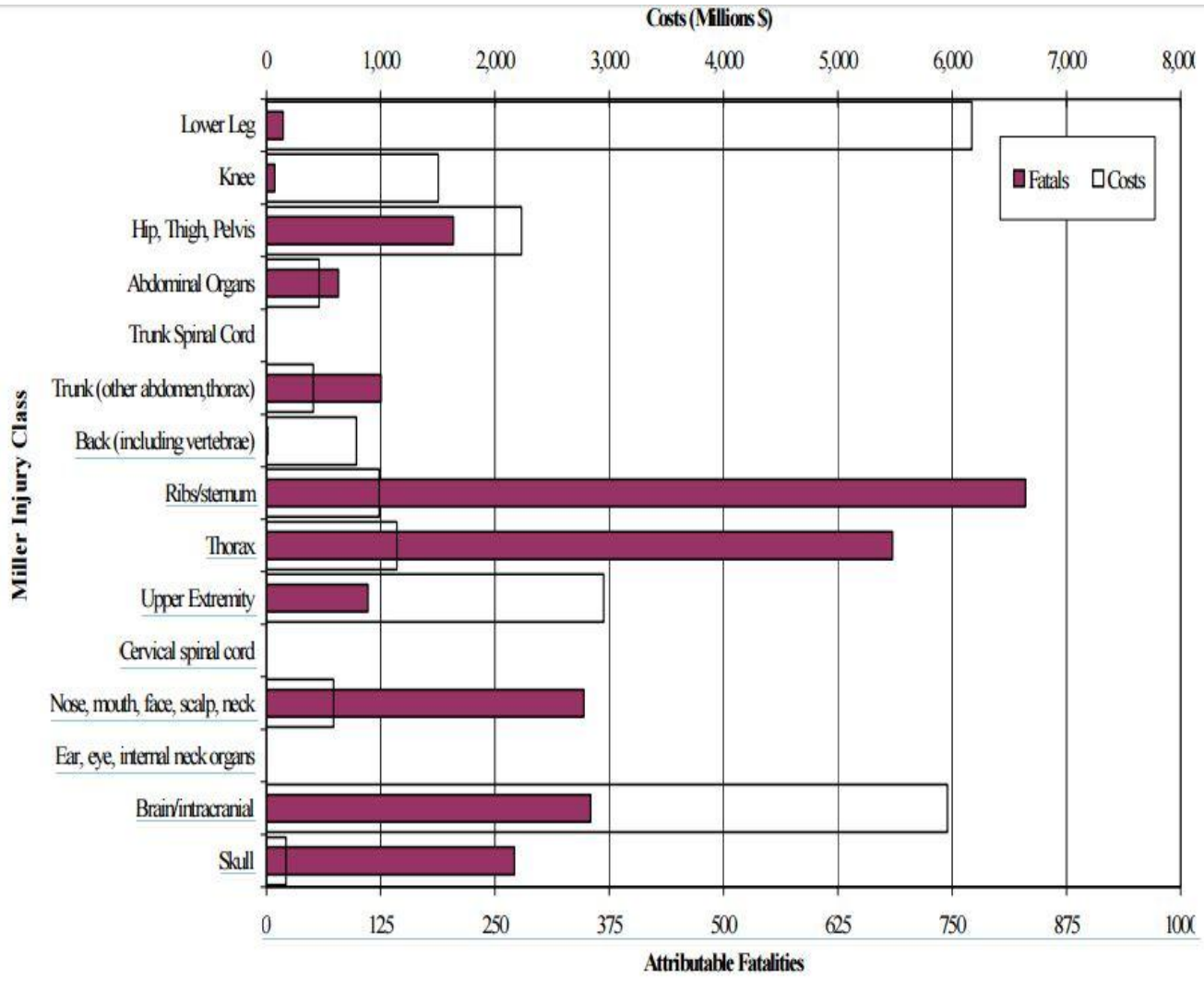



Figure B. Diffuse Axonal Injury (Broken)

The AIS 1+, 2+, 3+, and 5+ risk curves for CSDM were then computed using the ratios between corresponding risk curves for head injury criterion ( HIC) at a 50% risk. The risk curves for BRIC were then obtained by setting its value to 1 such that it corresponds to 30% probability of DAI (AIS4+). The newly developed brain injury criterion is a complement to the existing HIC which is based on translational accelerations.

Conclusion:

Together, the two criteria may be able to capture most brain injuries and skull fractures occurring in automotive or any other impact environment. One of the main limitations for any brain injury criteria, including BRIC, is the lack of human injury data to validate the criteria against, although some approximation for AIS 2+ injury is given based on the estimate of average injurious (concussion) angular velocities and accelerations for the college football players instrumented with 5 DOF helmet system. Despite the limitations, a new kinematic rotational brain injury criterion – BRIC – may offer additional protection to an automotive occupant in situations when using translational accelerations based HIC alone may not be sufficient.


Costs (Millions $)
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Lower Leg
Knee
Hip, Thigh, Pelvis
Abdominal Organs
Trunk Spinal Cord
Trunk (other abdomen,thorax)
Back (including vertebrae)
Ribs/sternum
Thorax
Upper Extremity
Cervical spinal cord
Nose, mouth, face, scalp, neck
Ear, eye, internal neck organs
Brain/intracranial
Skull
Fatals
Costs
Miller Injury Class
0
125
250
375
500
625
750
875
1000
Attributable Fatalities