Pediatric Concussion

Top 10 reasons why are children predisposed to **concussion**

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About TBI

In the United States
one person incurs a traumatic brain injury
every 21 seconds.

Every 5 minutes
one person will die and another will become permanently disabled due to a brain injury.

About TBI

- TBI accounts for 1/3 of all injury-related deaths in the United States.
- About 75% of TBI's that occur each year are concussions or other forms of mild TBI.
- The number of people with TBI who are not seen in an emergency department or who receive no care is unknown.

About TBI

- TBI can be categorized by severity
  - Mild – *concussion*, confused
  - Moderate – consciousness is more impaired
  - Severe – patient is in a coma

Kids are not little adults

Case:
14 Male
Jumped off the back of
a moving school bus…

Brought to Peds ED.
GCS3

Pupils 6mm, Non-reactive.
No movement to stim.

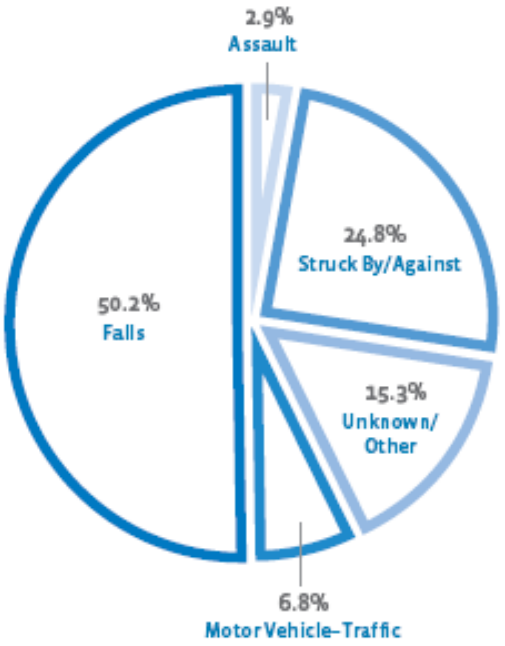
CT Severe sulcal effacement
No mass lesions.

EVD placed. ICP 40. Brought to PICU.
Cooled, Licox placed Brain O2 optimized.
Day 4 emergence with movement, EVD
Removed Day 7 when extubated and rewarmed.

Pediatric Head Injury Background

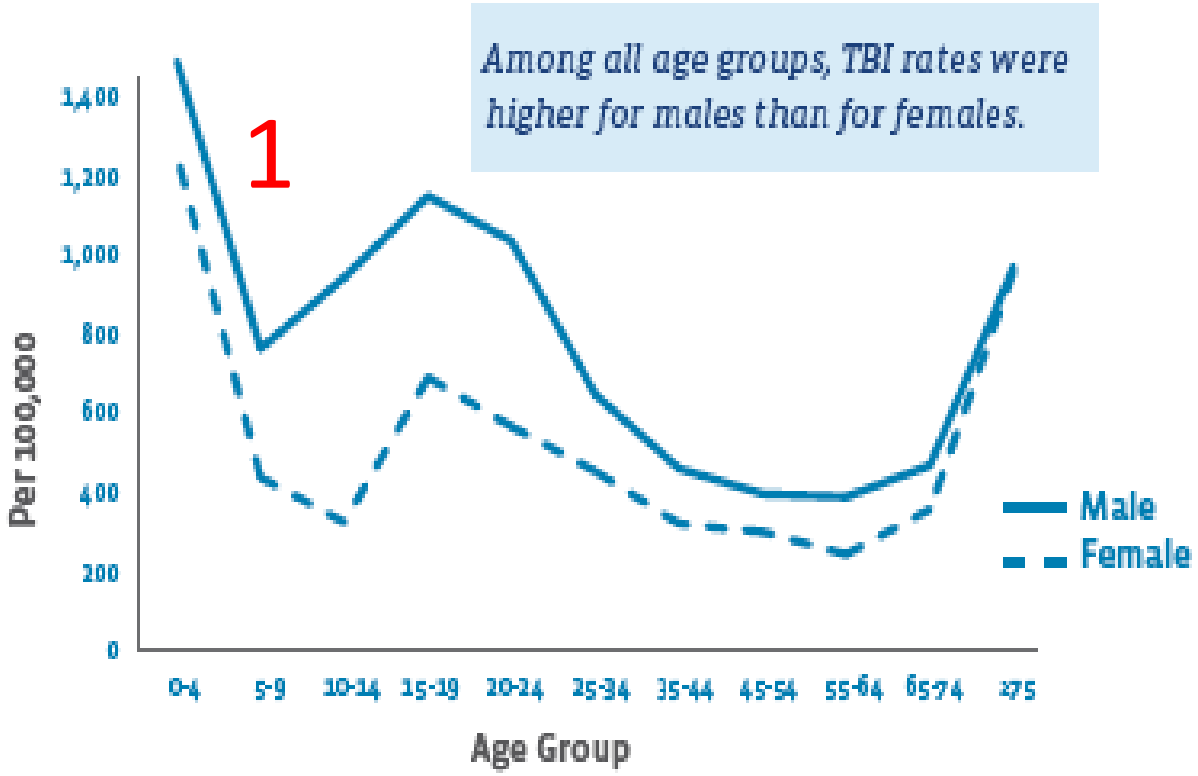
- Most common cause of death and disability in the young is head injury:
  - 1.7 million injuries, 52k deaths, 1.4 million ER visits
  - 30% of all injury-related deaths
  - 80k severe disabilities from sTBI
- Damage from combination of direct impact and rotational forces on axons
- Secondary injuries due to brain swelling and ischemia
- Incidence of concussion thought to be vastly underestimated
  - ~300k sports-related concussion with LOC annually
  - Represents only 8-19.2% of all sports-related concussion

FIGURE 6: Estimated Average Percentage of Annual Traumatic Brain Injury-Combined Emergency Department Visits, Hospitalizations, and Deaths Among Children 0 to 14 Years, by External Cause, United States, 2002–2006



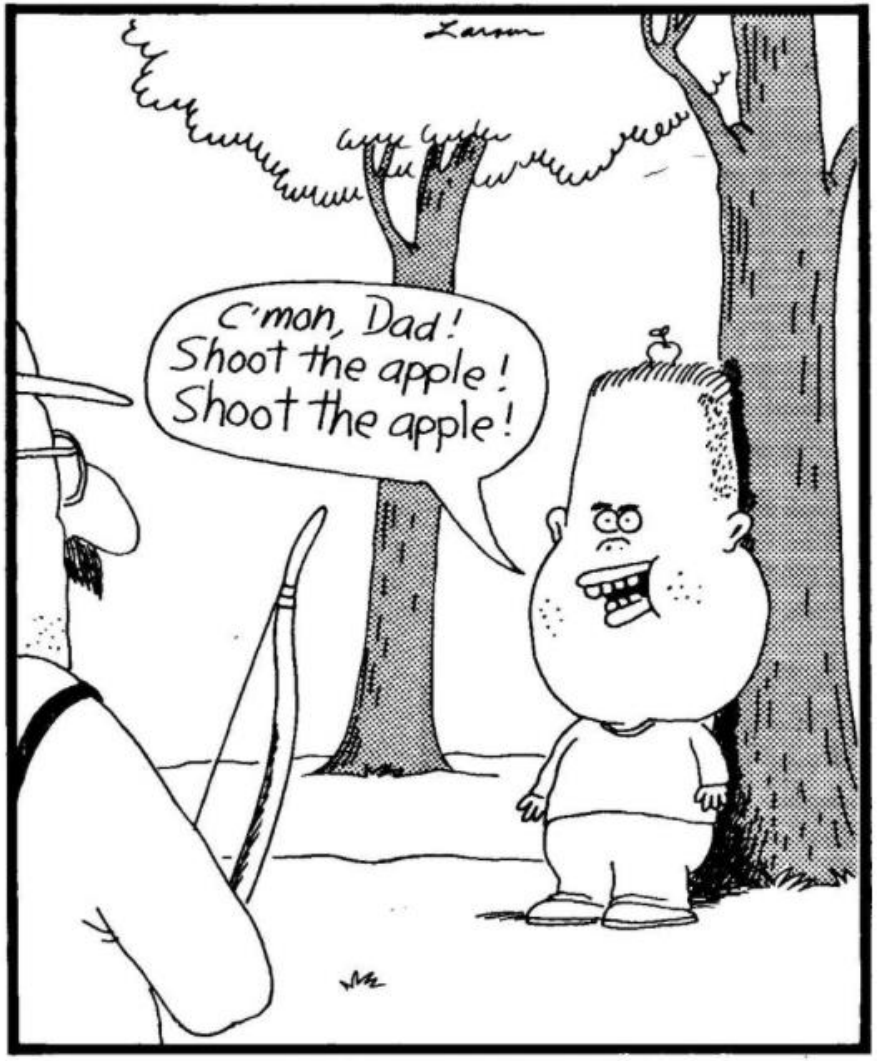
Faul M, Xu L, Wald MM, Coronado VG. *Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002–2006.* Atlanta (GA): CDCP, NCIPC; 2010.

Age and TBI



"Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002-2006"
www.cdc.gov/TraumaticBrainInjury

Anatomical differences in children



Unknown to most historians, William Tell had an older and less fortunate son named Warren.

Pediatric brain has a higher water content, 88% versus 77% in adult, which makes the brain softer and more prone to acceleration-deceleration injury.

The unmyelinated brain is more susceptible to shear injuries

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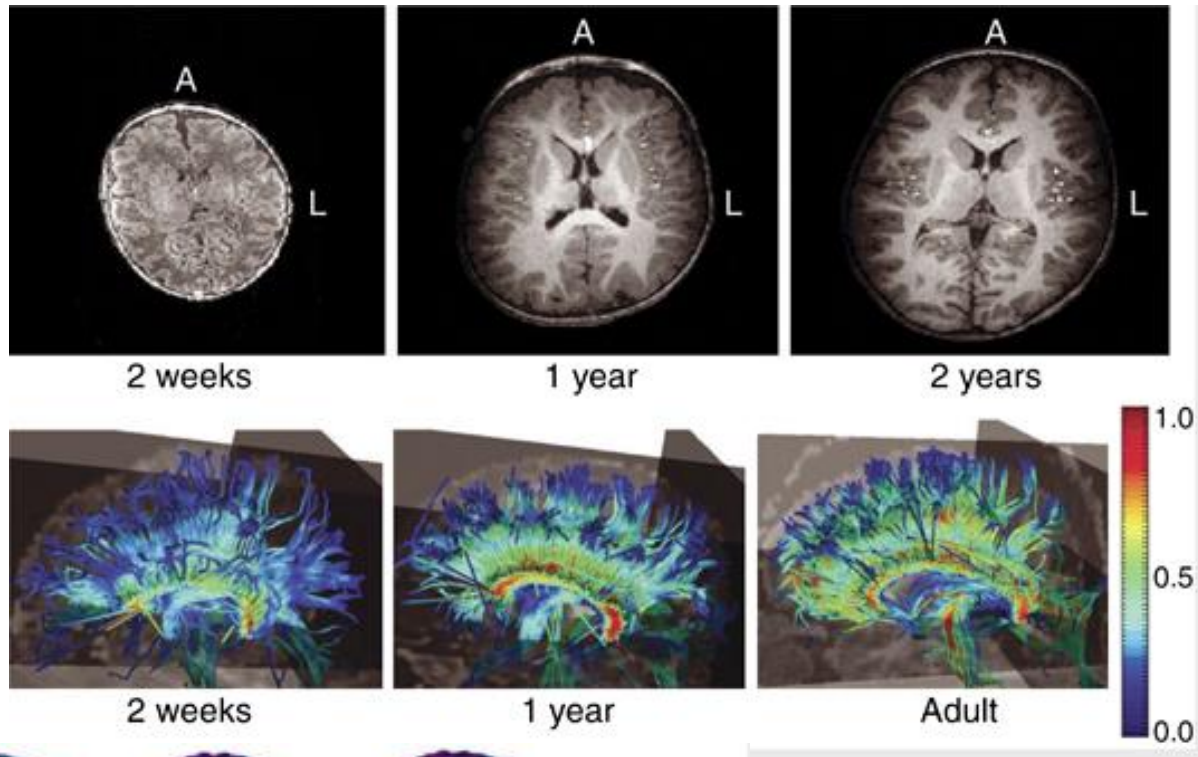
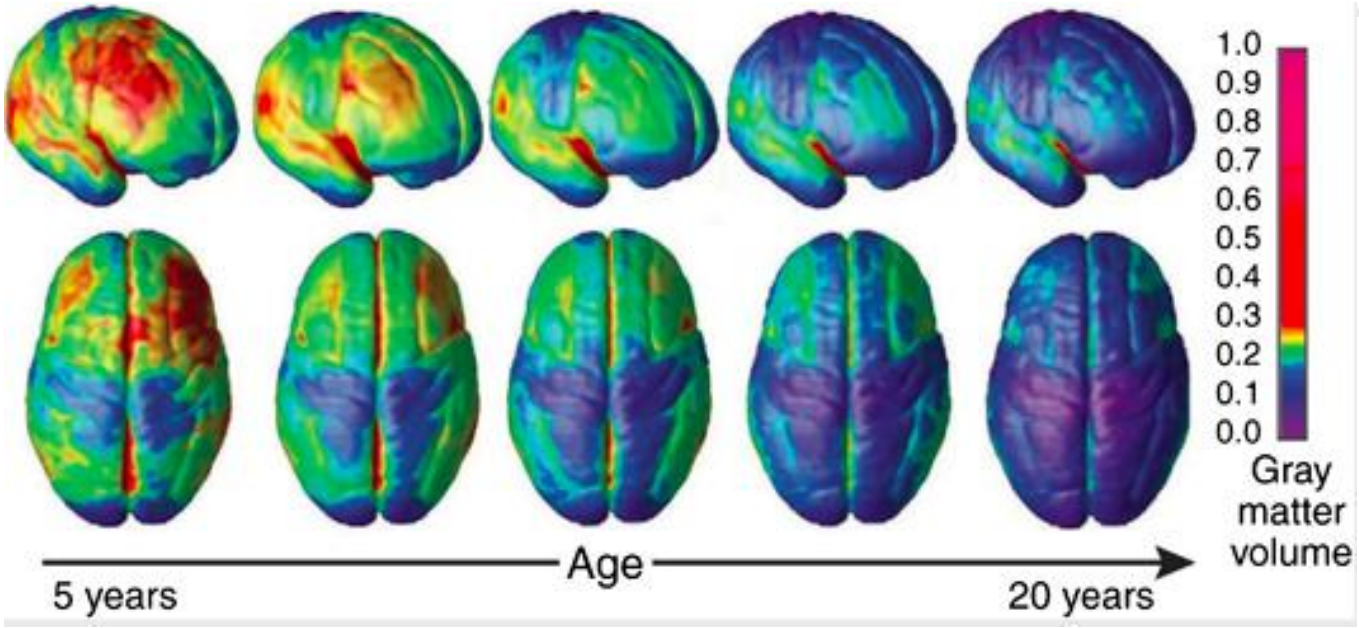
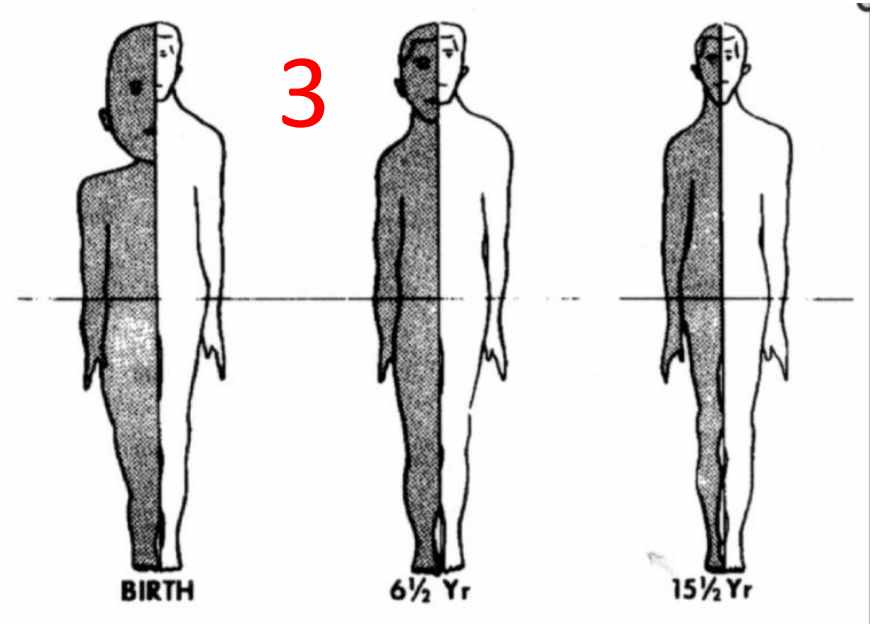


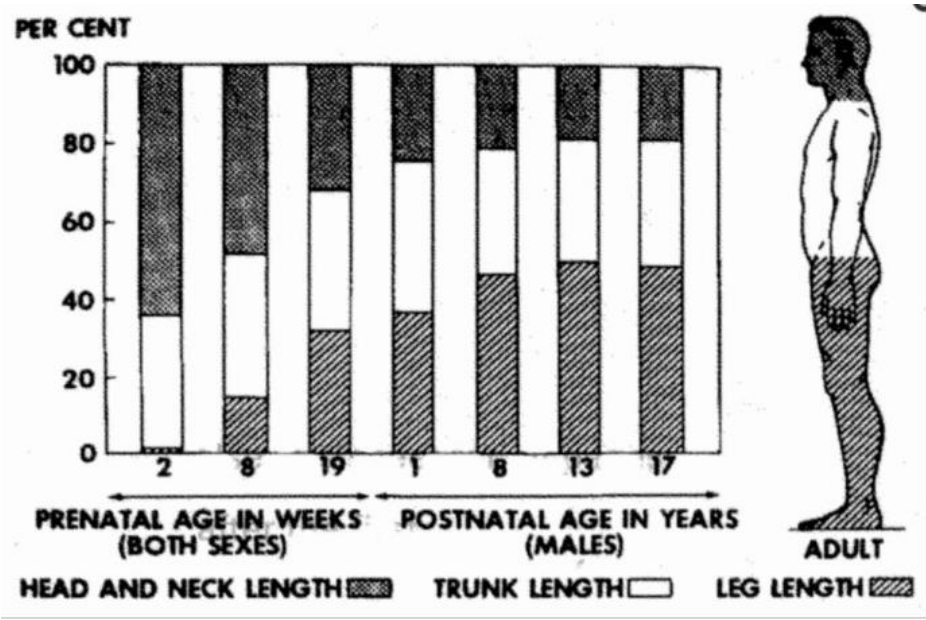


The child's head is proportionately larger than in the adult



- The important relation of brain size and cranium size can be demonstrated on a percentage basis, which shows that 70% of the adult brain weight is achieved at 18 months, 80% at 3 years, 90% at 5–8 years and approximately 95% at the 10th year.

Developmental changes in body proportions as seen in direct comparison between the adult and the newborn, child and adolescent.



COGNITIVE AND NEUROBIOLOGICAL RESEARCH CONSORTIUM IN TRAUMATIC BRAIN INJURY (CNRC-TBI)

Weill Medical College of Cornell University – New York Presbyterian Hospital,
University of California at Berkeley, University of California at San Francisco

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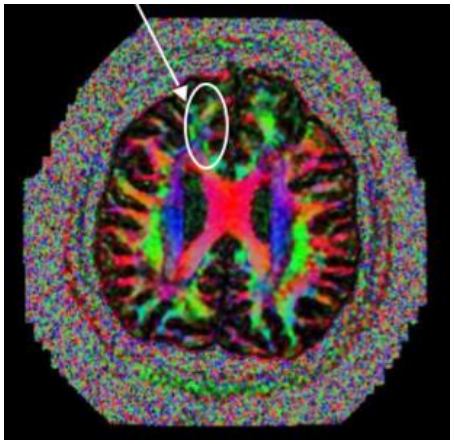
Steven Weinstein – Pediatric Neurology
Jeffrey Greenfield – Pediatric Neurosurgery
Ken Perrine –Neuropsychology

UC-Berkeley
Mark D' Esposito – Neuroimaging/Neuroscience
Richard Ivry – Cerebellar Function/Neuroscience
Robert Knight – Frontal Lobe/Attentional Function/Neuroscience

UC-San Francisco*
Geoffrey Manley – TBI expert/Neurosurgery
Pratik Mukherjee – DTI expert/Radiology



We hypothesize long white matter tract injury from mild and moderate TBI, visualized by MRI diffusion tensor imaging, causes cognitive deficits.

Anterior white matter tracts subserving anticipatory timing and attention are preferentially damaged and the locus and severity of tract injury accounts for persistent symptoms.

Prefrontal cortex is still developing in most patients with concussion!

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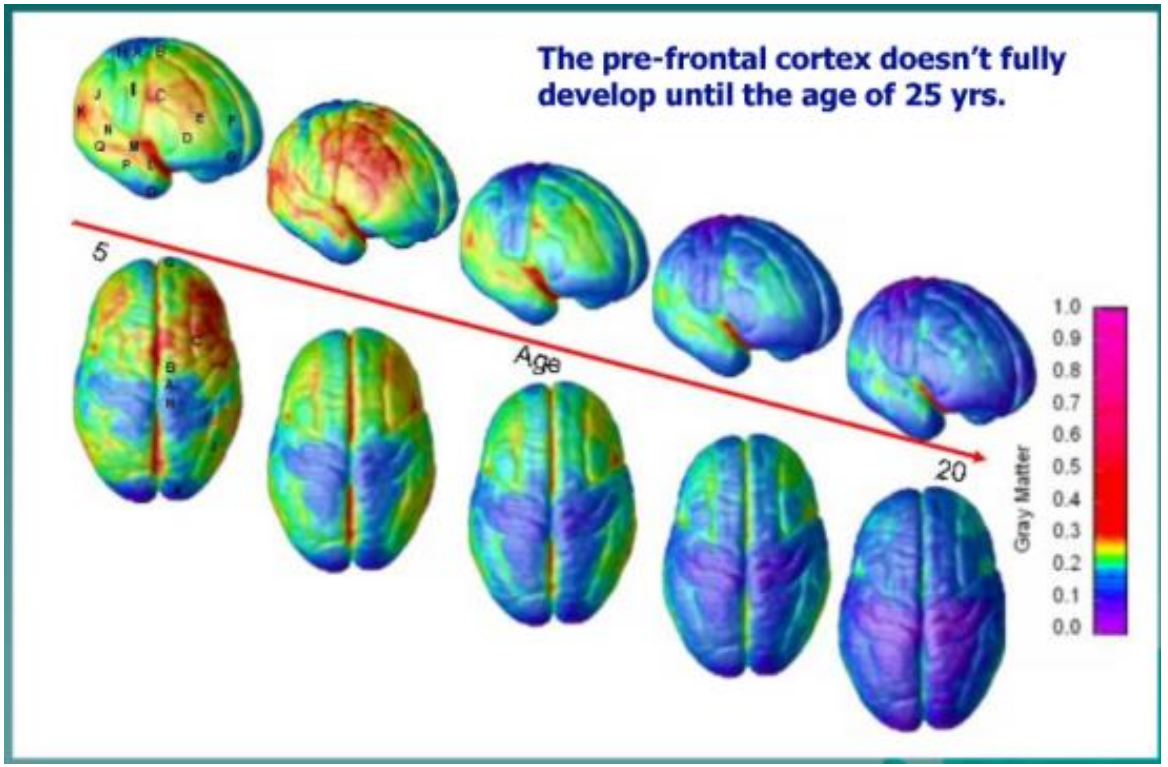

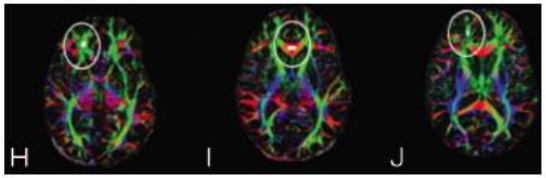

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ORIGINAL RESEARCH

Extent of Microstructural White Matter Injury in Postconcussive Syndrome Correlates with Impaired Cognitive Reaction Time: A 3T Diffusion Tensor Imaging Study of Mild Traumatic Brain Injury

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BACKGROUND AND PURPOSE: Diffusion tensor imaging (DTI) may be a useful index of microstructural changes implicated in diffuse axonal injury (DAI) linked to persistent postconcussive symptoms, especially in mild traumatic brain injury (TBI), for which conventional MR imaging techniques may lack sensitivity. We hypothesized that for mild TBI, DTI measures of DAI would correlate with impairments in reaction time, whereas the number of focal lesions on conventional 3T MR imaging would not.

MATERIALS AND METHODS: Thirty-four adult patients with mild TBI with persistent symptoms were assessed for DAI by quantifying traumatic microhemorrhages detected on a conventional set of T2*-weighted gradient-echo images and by DTI measures of fractional anisotropy (FA) within a set of a priori regions of interest. FA values 2.5 SDs below the region average, based on a group of 26 healthy control adults, were coded as exhibiting DAI.

RESULTS: DTI measures revealed several predominant regions of damage including the anterior corona radiata (41% of the patients), uncinate fasciculus (29%), genu of the corpus callosum (21%), inferior longitudinal fasciculus (21%), and cingulum bundle (18%). The number of damaged white matter structures as quantified by DTI was significantly correlated with mean reaction time on a simple cognitive task ($r = 0.49$, $P = .012$). In contradistinction, the number of traumatic microhemorrhages was uncorrelated with reaction time ($r = -0.08$, $P = .71$).

CONCLUSION: Microstructural white matter lesions detected by DTI correlate with persistent cognitive deficits in mild TBI, even in populations in which conventional measures do not. DTI measures may thus contribute additional diagnostic information related to DAI.

This work was supported by a collaborative grant from the James S. McDonnell Foundation to the Brain Trauma Foundation

Association for the Advancement of Automotive Medicine

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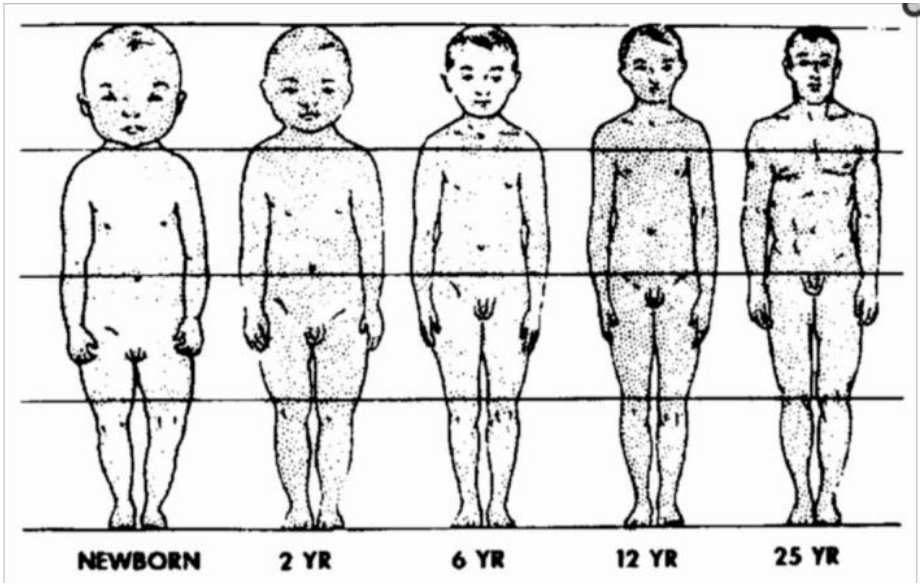
- In automotive collisions, the child's head is the body area most frequently and most seriously involved. It *was found that children (birth through 11 years) had a frequency of 77% head injuries* (Moore et al, 1959).

- "*In a collision, for example, the unrestrained child, because of his large head and high CG, would 'lead with his head*'. Crash data covering infants and children up to 4 years of age indicate that 77% of those who were injured in automobile accidents had head injuries (Kihlberg and Gensler, 1967)

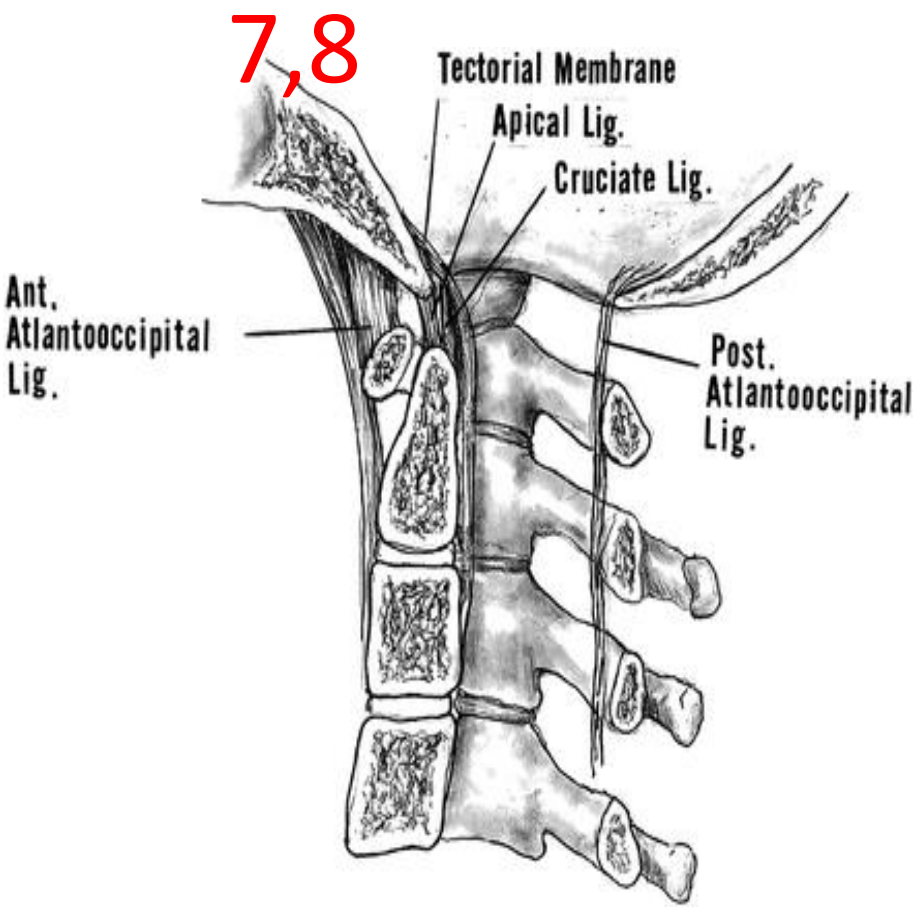
- The reasons for this greater frequency of head injury in children can be demonstrated both anatomically and biomechanically. The child's head is proportionately larger than in the adult (Young, 1966).

- *Heavier head mass, higher center of gravity may in part be the basis for higher frequency of head injury in children.*



There are several unique aspects of the anatomy of the child's neck. Neck muscle strength increases with age yet, with the greater head mass perched on a slender neck, the neck muscles generally are not developed sufficiently to dampen violent head movement, especially in children.

The neck vertebrae of children are immature models of the adult. These cervical vertebrae are mainly *cartilaginous in the infant*, with complete replacement of this cartilage by bone occurring slowly. *Articular facets, the contact areas between the vertebrae, are shallow*; *neck ligaments, as elsewhere in the body, are weaker than in adults*. The disproportionately large head, the weak cervical spine musculature, and laxity, can subject the children to *uncontrolled and passive cervical spine movements* and possibly to compressive or distraction forces in certain impact deceleration environments.



Effect of neck muscle strength and anticipatory cervical muscle activation on the kinematic response of the head to impulsive loads

The American Journal of Sports Medicine, 03/06/2014 **Evidence Based Medicine**

Pediatric Sports-Related Concussion Produces Cerebral Blood Flow Alterations

WHAT'S KNOWN ON THIS SUBJECT: The pathophysiology of pediatric sports-related concussion (SRC) is largely unknown. Studies of concussed adults have identified neuronal and axonal injury and time-limited metabolic disruptions. An experimental animal model has also demonstrated physiologic perturbations, including reduced cerebral blood flow (CBF).

WHAT THIS STUDY ADDS: Using MRI techniques, we found no evidence of neuronal, axonal, or metabolic disruptions in 12 children with SRC. However, when compared with controls, statistically significant alterations in CBF were defined and frequently persisted beyond 30 days after injury.

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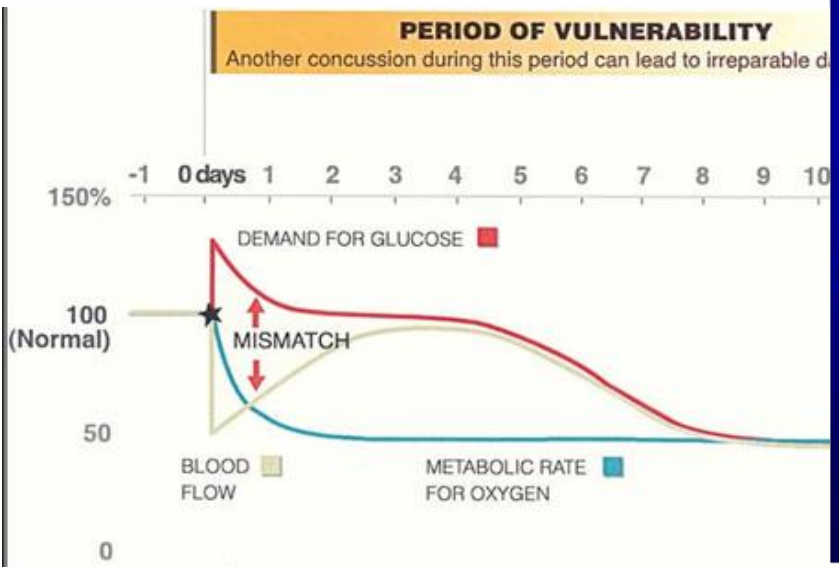
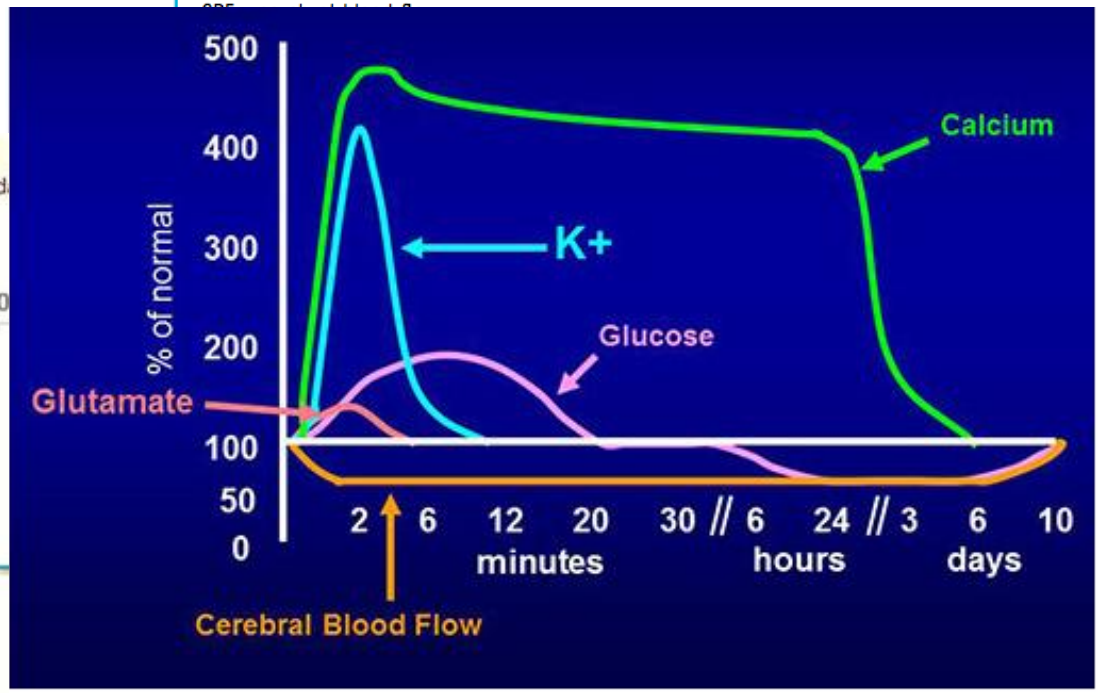
KEY WORDS

concussion, pediatrics, MRI, cerebral blood flow, magnetic resonance spectroscopy

ABBREVIATIONS





10 reasons why children are predisposed to concussion

- (1) Children make up the largest demographic of traumatic brain injury in the world
- (2) Pediatric brain has a higher water content, 88% versus 77% in adult, which makes the brain softer and more prone to acceleration-deceleration injury. The unmyelinated brain is more susceptible to shear injuries
- (3) The child's head is proportionately larger than in the adult
- (4) Anterior white matter tracts subserving anticipatory timing and attention are preferentially damaged and the locus and severity of tract injury accounts for persistent symptoms.
- (5) Pre-frontal cortex dosesn't develop fully until approximately age 25
- (6) The fulcrum of cervical movement is located higher in young children (C2-3 level than in adults (C5-6). A heavy head on a small body results in high torques being applied to the neck and consequently, high susceptibility to flexion-extension injuries,
- (7) The lax ligaments that allows a significant degree of spinal mobility
- (8) The cervical musculature is not fully developed in the infant and children allowing for unchecked distracting and displacement forces
- (9) Anticipatory muscle activation is poorly developed in children
- (10 Cerebral vasoreactvity/CBF is poorly regulated in children.

Food for thought