Mechanisms of coup and contrecoup injury during trauma to the brain

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Whiplash

- [https://www.youtube.com/watch?v=Vqlkpt9d89g](https://www.youtube.com/watch?v=Vqlkpt9d89g)
- Brain is seen to make contact with skull, leading to injury
- Sudden acceleration or deceleration responsible
- Different than if skull contacts an object
Definition of Terms

Coup Injury
- Occurs during blow to the head
- Site of initial impact
- Likely caused by skull inbending or fracture

Contrecoup Injury
- Occurs during blow to the head
- Site opposite the initial impact
- Many theories for mechanism
Review of Skull/Brain Interface

- Skull is a relatively hard, bony interface
- Meninges protect the brain from direct contact
  - Dura Mater
  - Arachnoid – subarachnoid space contains CSF, blood vessels
  - Pia Mater
Coup Injury

• Depression of the skull impacts brain (clear mechanism)

• Typically seen when stationary skull is struck by a moving object

• Focal injuries usually resulting in cerebral contusion/hemorrhage
Contrecoup Injury

• Mechanism is far less easily understood

• Widely recognized as having greater severity

• Often seen when moving skull impacts an immovable/external object

• Similarly results in focal injury and cerebral contusion/hemorrhage
Theories for Contrecoup Injury

- Positive Pressure Theory
- Rotational Shear Stress Theory
- Angular Acceleration Theory
- CSF Displacement Theory
- Negative Pressure (Cavitation) Theory
Positive Pressure Theory

• During movement, the brain lags at the back of the skull while the CSF pools near the front (lessening coup injury)

• Upon impact, compressive waves transmit across the brain and cause it to press against the back of the skull

• Problems: CSF is more dense than brain, meninges would stop brain from migrating towards the back
Rotational Shear Stress Theory

• Takes into account non-linear forces, significant rotational movement during traumatic injury

• Combination of rotational and linear movements cause stress to tear wherever it is greatest

• Problems: does not explain contrecoup, injuries likely from irregular bone
Angular Acceleration Theory

• During angular acceleration, objects attached to another accelerate more slowly

• Similar to positive pressure theory, specifically explains injury to frontal lobe when falling backwards

• Brain accelerates more slowly than skull and is pushed up against frontal portion

• Problems: does not explain linear contrecoup injuries, meninges would counter most differences in acceleration, CSF is more dense
CSF Displacement Theory

- One of the most recent theories, based on fact that CSF is more dense than the brain

- Upon sudden deceleration, the CSF displaces the brain backwards so initial contact will be with contrecoup surface

- In falling backwards, the initial contact will be with narrow, irregular surface and involve a small surface area of the brain

- Problems: CSF composes only 150mL of volume, does not take lateral/angular movement into account
2004 CSF Displacement

- Paper by Drew and Drew, *Neurocritical Care*
- Modeled brain and CSF off balloon in water
- First picture immediately before impact, second 1 sec. after
- Shows initial movement is in the backwards direction
Negative Pressure Theory

• Also known as the cavitation theory, generally most popular in nature

• Upon sudden deceleration, the brain moves forward creating tensile stress through negative pressure at the contrecoup site

• The cavitation of the brain pulls apart the contrecoup area

• Problems: CSF is more dense and would move forwards first
2012 Cavitation Study

- Goeller et al, *Journal of Neurotrauma*
- Modeled brain using sophisticated polycarbonate ellipsoid
- Filled ellipsoid with degassed water for CSF and Sylard gel for brain tissue
- Recorded pressure in the CSF and skull deformation
- Results indicated cavitation as a likely cause of damage
Best Candidate?

- Positive pressure, rotational shear stress, and angular acceleration theories seem either inaccurate or incomplete

- 2004 study suggests rudimentary evidence for CSF displacement theory

- 2012 study implies cavitation theory most likely
Occurrence of Contrecoup Injury

- 2012 study used as a model of the effect of a blast wave from an improvised explosive device (IED)
- 2014 Case Study (Sato et al., *Legal Medicine*)
  - 54 y.o. alcoholic woman found dead from traumatic basal subarachnoid hemorrhage (TBSAH)
  - Fell and bruised left posterior parietal region, but the hemorrhage appears to have been most serious in right cerebellum
  - Cerebellum usually tightly packed into posterior fossa, alcoholism led to atrophy (assessed by Purkinje cell loss and stumbling gait) allowing for increased movement and resulting contrecoup injury
  - Proposed as the first recorded instance of contrecoup TBSAH
Subarachnoid Hematoma (notice arteries still intact)

(A) Right cerebellar contusion (arrows) (B) Histological exam shows tissue damage
References

• Images
  • Types of Neurologic Damage
  • Meninges Catalog

• Journal Articles
Questions? Comments?