Pathophysiology of traumatic brain injury

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OSU CBI Neuro-Nights
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Disclosures

- Neurologist and physician scientist at Ohio State Medical Center

- I split my time between clinical care of patients with traumatic brain injuries (TBI) and research in a lab and clinic exploring the immune response to TBI and long term effects of TBI.

- I have no financial relationships or conflicts of interest

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Traumatic Brain Injury (TBI)

- TBI accounts for approximately 2.5 million emergency department visits in the United States
- Approximately 2.2 million were treated in and released from EDs, 300,000 admissions, and 50,000 deaths
- Children and young adults ages 0 to 19 years are at the highest risk for TBIs.
- Elderly over the age of 70 are at highest risk of death from TBI.
- Most common causes of TBI
  - Falls: 40-50%
  - MVA: 20-25%
  - Blunt Trauma: 10-15%
- 3.2 million–5.3 million persons in the United States are living with a TBI-related disability
Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Eye opening</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>To loud voice</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To pain</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal response</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oriented</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Confused, disoriented</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inappropriate words</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incomprehensible sounds</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Best motor response</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obeys</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Localizes</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Withdraws (flexion)</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal flexion posturing</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extension posturing</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Grading TBI severity

<table>
<thead>
<tr>
<th>Glasgow Coma Scale</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>9-12</td>
<td>3-8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Structural Imaging</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal or abnormal</td>
<td>Normal or abnormal</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Loss of Consciousness</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;30 min</td>
<td>30 min – 24 h</td>
<td>&gt;24 h</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Post Traumatic Amnesia</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3 day</td>
<td>1-7 days</td>
<td>&gt;7 days</td>
<td></td>
</tr>
</tbody>
</table>

Mena et al. J Trauma: 2011
Pathologic injuries of TBI

Coup-countercoup injury

Axon shearing

Knipe et al. Radiopedia.org
Pathophysiology

- Metabolic cascade that starts with electrolyte abnormalities (K+ and Ca2+).

- Depletion of glucose in an attempt to re-establish cell homeostasis.

- The rapid use of glucose leads to a prolonged hypo-metabolic state.

- Prolonged hypoperfusion, excitotoxicity, and axonal injury.

TBI leads to a network injury

- 100 billion+ neurons in the central nervous system (CNS)

- Each region must communicate efficiently and synchronously

- Metabolic disequilibrium leads to dys-synchronous neuronal communication
Common TBI Symptoms

**Somatic:**
- Headache
- Dizziness
- Balance problems
- Visual disturbances
- Photo/Phonophobia

**Cognitive:**
- Confusion/Disorientation
- Retro/anterograde Amnesia
- Foggy thinking
- Inattention
- Delayed verbal response
- Slurred speech
- LOC

**Sleep:**
- Trouble falling asleep
- Sleeping more
- Sleeping less

**Affective:**
- Emotional Lability
- Anxiety
- Fatigue
- Irritability
- Sadness

**Moderate/Severe:**
- Seizure
- Weakness
- Loss of sensation

http://www.cdc.gov/TraumaticBrainInjury/
Mild TBI Normal Recovery

Conceptually can be applied to moderate and severe injury

- Phase I: Acute Rest
- Phase II: Relative Return to life
- Phase III: Return to life/Graduated exertion

Adapted from: Giza CC and Kutcher JS. Sports Concussion Diagnosis and Management
Chronic brain injury symptoms are associated with changes in brain connectivity

- Research studies show that chronic TBI patients have changes in regions of their brain after mTBI.

- The brain is constantly changing. Memories, growth, maturity, age, and injuries.

- The brain is plastic, in TBI connectivity changes do not have to be permanent

Khong et al. 2016
Long term TBI symptoms are treatable

• Therapies
  • Physical therapy
  • Vestibular therapy
  • Vision therapy

• Symptomatic medications
  • Mood changes
  • Headache
  • Foggy thinking
  • Poor sleep

• Neuropsychology evaluation
  • Cognitive behavioral therapy

• Exercise and Sleep

The brain is trainable, teachable, and can learn again. Symptoms and deficits can improve with time.

Grool et al 2017
Seifert 2016
Ellis et al 2015
Conclusions

**What we do know**

- TBI causes direct injury to brain at the time of injury

- Your brain can also suffer for long term signaling changes in the ways your neurons talk to each other

- Your brain is plastic: It has the ability to be trained to be better or worse depending on the situation

- You should talk with your physician about if you are getting the right types of therapy to help your recovery

**What can you do at home:**

- How is your sleep?
  - Do you have a calm environment, TV off and phone away? Do you sleep through the night? Do you feel rested when you get up in the morning?

- Sleep is when you body restores your neuron energy supply

- Do you exercise?

- Exercise produces growth factors that are good for your brain and stimulates new neuron connections

- Do you use your phone too much?
  - Phones are great to stay connected, keep calendars, schedules and information stored
  - They are also distractors

- Put your phone away when need to focus and turn off the reminders so it does not ping you. Microdistractions can make people feel like their focus is worse than it actually is
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