THE ESSENTIAL BRAIN INJURY GUIDE

Neuroanatomy & Neuroplasticity
Section 2

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Certified Brain Injury Specialist Training – October 26 & 27, 2017

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&
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This training is being offered as part of the Brain Injury Alliance of Connecticut’s ongoing commitment to provide education and outreach about brain injury in an effort to improve services and supports for those affected by brain injury.
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Neuroanatomy and Neuroimaging
Learning Objectives

Understand the anatomy of the brain, spine, and spinal cord;

Distinguish between symptom patterns due to brain injury and syndromes in spinal cord injury

Compare the incidence of spinal cord injury to TBI

Articulate the methods of neuroimaging which support diagnostic and treatment decisions when a patient has sustained either a brain injury or spinal cord injury.
NEUROANATOMY
Skull Anatomy

- The skull is a rounded layer of bone designed to protect the brain from penetrating injuries.
- The inside of the skull is rough with many bony protuberances.
- These ridges can result in injury to the brain during rapid acceleration.
Cerebrospinal Fluid

3rd & 4th Ventricles

Lateral Ventricles
The Meninges

- The meninges are layers of tissue that separate the skull and the brain
- There are 3 layers
  - Pia Mater
  - Arachnoid
  - Dura Mater

Essential TIP!

The Meninges P-A-D the Brain

Pia Mater  Arachnoid  Dura Mater

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Brain Cells

- Neurons
  - Axon
  - Cell Body
  - Dendrites
  - Dendritic Spines
  - Synapse

- Glial Cells
  - Oligodendrocytes
  - Ependymal cells
  - Astrocytes
  - Schwann cells

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Neurons Communicate via Synapses
Step 1
Synaptic stimulation with release of glutamate.

Step 2
Glutamate binds to AMPA and NMDA receptors.

Step 3
Influx of Na$^+$ and Ca$^{2+}$ into the post-synaptic neuron.

End Result
Stronger link between the synapsed neurons.

A synapse is stimulated.
This results in the release of the neurotransmitter glutamate from the axon terminal into the synaptic cleft.

Glutamate binds to the AMPA receptors.
With weak levels of stimulation AMPA receptors open, allowing Na$^+$ into the post-synaptic cell.
For NMDA receptors to allow Na$^+$ and Ca$^{2+}$ into the post-synaptic cell there must be higher rates of stimulation.

With higher rates of stimulation both AMPA and NMDA receptors allow Na$^+$ and Ca$^{2+}$ into the post-synaptic neuron.
The influx of Ca$^{2+}$ begins a cascade of biological reactions.

Increased neurotransmitters.
Increased AMPA & NMDA receptors.
Increased response to a given stimulus.
Brain Stem Anatomy

Midbrain

Pons

Medulla
Reticular Activating System

- Arousal
- Alertness
- Concentration
- Basic biological rhythms
Diencephalon
Thalamus and Hypothalamus
LIMBIC SYSTEM
Limbic System

Hippocampus

Amygdala

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Basal Ganglia and Cerebellum

Basal Ganglia

Cerebellum
- Two Hemispheres
- Four Lobes
- Interconnected
# Information Processing

<table>
<thead>
<tr>
<th>Right Hemisphere</th>
<th>Left hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holistic</td>
<td>Linear</td>
</tr>
<tr>
<td>Visual Spatial</td>
<td>Verbal-analytic</td>
</tr>
<tr>
<td>Intuitive</td>
<td>Logical</td>
</tr>
<tr>
<td>Controls left side of body</td>
<td>Controls right side of body</td>
</tr>
<tr>
<td>Music, art, shapes</td>
<td>Speaking, reading, writing</td>
</tr>
</tbody>
</table>
Cerebral Features

- **Gyri** - Elevated ridges that wind around the brain
- **Sulci** - Small grooves dividing the gyri
- **Fissures** - Deep grooves, usually dividing large regions/lobes of the brain
Frontal Lobe Functions

- Planning
- Organizing
- Problem Solving
- Judgment
- Impulse Control
- Decision Making
- Working Memory
Expressive and Receptive Speech

Broca’s Area

Wernicke’s Area
Occipital Lobe

Primary Visual Cortex
Visual Pathway

Left Visual Field

Right Visual Field
Spinal Column Divisions

Cervical Spine showing Lateral, Anterior, and Posterior view

Thoracic Vertebrae showing Lateral, Anterior, and Posterior views

Lumbar Vertebrae showing Lateral, Anterior, and Posterior views
Vertebral Bodies

- Vertebral Bodies
- Spinal Cord
- Disk
- Meninges
- Nerve Root
- Vertebra
Spinal Cord

Afferent Sensory Information

Efferent Signals

Essential TIP!
Afferent Nerves Ascend upward

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Spinal Cord Syndromes

Central Cord Syndrome

Brown-Sequard Syndrome

Anterior Cord Syndrome

Posterior Cord Syndrome
Computed Tomography (CT)
Magnetic Resonance Imaging (MRI)

Diffusion Tensor Imaging (DTI)

Functional MRI (fMRI)
Brain Symmetry & Imaging

T1

T2

FLAIR
Mechanisms of Traumatic Injury

Categories of Brain Injury

Focal
- Contusions
- Lesions
- Hematomas

Diffuse
- Diffuse Axonal Injury
- Hemorrhage

TRAUMATIC IMPACT
Contact Injury
Head struck by or against an object

- CLOSED
  (Non-Penetrating)
  Skull Fracture
  Meninges Breach

- OPEN
  (Penetrating)
  Brain moves within skull

TRAUMATIC INERTIAL
Non-Contact Injury
Brain moves within skull

Rotational/Angular Forces
Non-Contact Injury
Brain moves within skull

Primarily Diffuse (Multifocal)

- Epidural Hematomas
- Subdural Hematomas
- Intracerebral Hemorrhage
- Infections

Primarily Focal

- Diffuse Axonal Injury
- White Matter Lesion
- Hemorrhage

Categories of Brain Injury

Focal
- Contusions
- Lesions
- Hematomas

Diffuse
- Diffuse Axonal Injury
- Hemorrhage

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Mechanism of Injury
Acceleration-Deceleration (Traumatic Inertial)

Mechanism of Injury

Coup Contrecoup

- The bouncing of the brain in the skull can result in injury in two sites:

  The initial site of injury (coup)

  The contrecoup injury
Mechanism of Injury:
Intracranial Pressure
Neuroprotection and Neuroplasticity
Learning Objectives

- Understand the conceptions of neuroprotection, neuroplasticity, and neurodegeneration
- Be able to explain factors leading to neurodegeneration following TBI
- Be able to articulate the effects of brain injury and injury severity
- Be able to articulate the two main areas of the brain known to be sites of neurogenesis
- Be able to distinguish between rehabilitative training models appropriate for TBI and those for stroke
NEUROPLASTICITY
Synaptogenesis

**Definition:** the formation of synapses between neurons

The greater the numbers of synapses within a grouping of neurons, the greater the speed and efficiency with which those neurons communicate.

Dendritic spines have the ability to change in response to experience.
Neuroplasticity Post-TBI

- Plasticity: the ability of the nervous system to change, grow or compensate for injury.
Neuroplasticity: TBI Research
NEUROPROTECTION
Biological Cascade Following TBI

- **Primary Injury** - direct damage to the brain
- **Secondary Injury** - causes additional damage
  - Excitotoxicity
  - Edema
  - Apoptosis
Potential Neuroprotective Agents for TBI

- Neuroprotective agents limit neuronal death following injury and/or enhance recovery

<table>
<thead>
<tr>
<th>Neuroprotective Agent</th>
<th>Intervention Target</th>
<th>Animal Models Showing Efficacy (Stroke)</th>
<th>Human Studies Showing Efficacy (TBI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>Increase Mg2 (decreased Mg2 results in excessive production of free radical and mild inflammation)</td>
<td>✓</td>
<td>Failed</td>
</tr>
<tr>
<td>Progesterone</td>
<td>Decrease cerebral edema</td>
<td>✓</td>
<td>Initial Efficacy; Follow Up Trial</td>
</tr>
<tr>
<td>Nicotinimide</td>
<td>Reduce injury volume; decrease glial activation; reduce BBB breaches; reduce edema</td>
<td>✓</td>
<td>Unknown</td>
</tr>
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Thank You!

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