Traumatic Brain Injury Update 2010

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Learning Objectives

• Describe the clinical presentation of TBI in relationship to the cognitive, affective, behavioral and somatic spectrum of problems.

• Evaluate current technologies used to evaluate brain function including MRI, DTI, SPECT, EEG, QEEG, Evoked Potentials, and MEG.

• Explain treatment options for TBI patients.
Lecture Themes

• A rational approach to treatment rests on substantiating that a brain injury has occurred.

What is a TBI and how do you diagnose it?

• A rational approach to treatment includes a combination of pharmacotherapy, neurotherapy, cognitive rehabilitation, case management and system therapy-education for family.

Creating a Treatment Plan.
Overview TBI

- Four Case Presentations
- Epidemiology
- Neuropathology
- Neuroanatomy- from autoradiography to nuclear imaging fiber tracts
- Imaging tools for brain structure and function
- Clinical Spectrum of TBI
- Treatment integrating rational pharmacotherapy with various treatments
Bicycle Fall Head Injury

“...a Traumatic Brain Injury occurs when the brain is injured singly or in combination...”

Gennarelli, T, Graham D
Body in Motion

Courtesy of Thomas P Routh, Esq.
Nolan Law Group
Internal Impact of Brain

Courtesy of Thomas P Routh, Esq.
Nolan Law Group
Cavitation

Courtesy of Thomas P Routh, Esq.
Nolan Law Group
MRI Coronal Reconstruction

Courtesy of Thomas P Routh, Esq.
Nolan Law Group
**Epidemiology**

*Prevalence in total US Population*

1.4 million people sustain a TBI each year

Distribution of Average incidence of hospitalizations, emergency department visits, and deaths between 1995-2001

As a cumulative result of TBI, an estimated 5.3 million Americans are living with a permanent disability
TBI
Mild - Moderate - Severe

- **Mild** TBI - 131 cases/100,000 people (397,700)
- **Moderate** TBI - 15 cases/100,000 people (45,540)
- **Severe** TBI - 14 cases/100,000 people (42,500)

Mortality rates:
- severe TBI 33%
- moderate TBI 2.5%
Incidence by External Cause in total US Population

Percentage of Average Annual Traumatic Brain Injury-Related Emergency Department Visits, Hospitalizations, and Deaths, by External Cause, United States, 1995–2001

- Falls: 28%
- Motor Vehicle Traffic: 20%
- Struck By/Against: 19%
- Assault: 11%
- Pedal Cycle (non MV): 3%
- Other Transport: 2%
- Suicide: 1%
- Unknown: 9%
Neuropathology
Cortex, White Matter Tracts

- **Focal Injury - Cortex** expansion of tissue creates initial increase in rCBF with secondary ischemia and subsequent decrease in rCBF. Ischemia leads to altered cellular metabolism of glucose, Ca influx, membrane destabilization, apoptosis cascade with cytokines released.

- **Diffuse Axonal Injury - White Matter** stretch and twisting of axons results in de-afferentation or loss of axons and synaptic bulb from the cell body in myelinated and unmyelinated neurons; Wallerian degeneration occurs.
Focal Injury
Skull Fx, EDH, SDH, Periventricular H, Frontal-TP Contusion
Diffuse Axonal Injury

Forces – Axonal Shearing-Tearing - Electron Micro View Axonal Bulb Formation

- Normal Axon
- Shearing of the Axon
- Post-trauma Condition

A. Trauma causes the axon to twist and tear
B. The result is permanent death of the brain cell
White Matter Fiber

- Long association fibers
- Short association fibers (U-fibers)
- Neighborhood association fibers
- Commissural fibers
- Striatal fibers
- Thalamic fibers
- Cord fibers
Diffusion Spectrum Imaging

10% White Matter Fibers, colors rep. xyz vectors

Clinical Spectrum

- Patient lost her job when the attention to her injury was peripheral and did not determine her Cognitive problems.
- Her Neuropsych testing showed:
  - Working memory - moderate to severely impaired new learning
  - Processing speed - mild to moderate impaired auditory
  - Sustained Attention - mildly impaired
  - Expressive Language - mild impaired confrontation naming, phonological fluency and moderate impaired abstract reasoning
  - Executive Function - impulsive, difficulty modulating emotions and monitoring social behavior, variable moderate impaired
MRI Frontal Contusions
MRI Tractography
Clinical Spectrum

Patient was unable to return to work for more than a year undergoing extensive physical rehabilitation. Marital problems worsened, his self image as a confident, athletic, helpful professional dwindled. He experienced fatigue and withdrew from his family.

LM
MRI Tractography
(Normal)
He returned home to find his wife separated from him, filing for divorce, claiming full custody of their children. He was unemployed and very depressed.

His neuropsych testing revealed:

- Attention- severely impaired
- Working memory- severely impaired
- Processing speed and concentration-severely impaired
- Expressive language-severely impaired
- Executive function-severely impaired
MRI
Sagittal, Coronal, Transverse views
Encephalomalacia secondary to cortical atrophy from contusions
Clinical Spectrum

Patient underwent neuropsych testing which confirmed mild impairment with visual recall, moderately impaired visual spatial ability with poor planning and organization. Her attention, expressive language and processing speed was average to superior.
MRI w Tractography (Normal)
TBI Evaluation Tools

- **CT** - fracture, hemorrhage
- **MRI** - cortical - subcortical visualization of tissue structure
- **Diffusion Tensor Imaging** - white matter tracts, diffuse axonal injury pattern, tractography
- **SPECT** - regional blood flow is a function of metabolism
- **EEG** - sharp waves, spikes, rhythmic discharges
- **QEEG** - power spectrum of frequencies, excess delta, decreased alpha, increased Theta-Beta ratio
- **EP’s** - delay with P50 and P300 seen on odd ball paradigm
- **MEG** - Magnetoencephalography slow waves-delta superimposed on MRI or MRI + DTI imaging
Traumatic Brain Injury: A Review and High-Field MRI Findings in 100 unarmed combatants Using a Literature-Based Checklist Approach

Hippocampal Atrophy 76%  
Cavum Septum Pellucidum 43%  
Dilated Perivascular Space 32%  
Diffuse Axonal Injury 29%  
Cerebral Atrophy 24%  
Increase Lat Ventricle size 19%  
Pituitary Gland Atrophy 14%  
Arachnoid Cysts 5%  
Contusions 2%  

Diffuse Axonal Injury
Lateral Ventricle normal, mild large
FLAIR Cortical Contusion
SPECT Scales

Hot

Warm

Gray

Step-10

Cool

Geographic
Nuclear Medicine Flow Study
SPECT vs MRI

Transverse view of Inferior Frontal lobe absent rCBF vs Encephalomalacia
SPECT vs MRI

absent  rCBF Frontal lobe secondary to Encephalomalacia inferior Frontal lobe
Post Concussion Syndrome (Left)

Less rCBF w PCS

Anxiety (nl rCBF)
Cortex and Limbic System
Brain Networks Cortical Function

• Frontal lobe "Desktop"
  - dPFC - central executive function
  - OFC - stimulus-reinforcer association learning with visual, taste, olfactory, somatosensory connections

• Temporal lobe "Lexicon"
  - dominant lobe for language,
  - non-dominant for prosody-emotional components
  - Lateral, the "What" system for attention
  - Medial, for memory; declarative-Hippocampus. emotional- Amygdala, i.e. facial expression, fear
Brain Networks  Cortical Function

• Parietal lobe
  - Visual spatial processing
  - "Where" system of attention
  - somatosensory representation
  - procedural scripts - praxis.

• Occipital lobe
  - hierarchy of visual processing of shape, size, contour, motion, facial expression with connections to the "What and Where" attention systems of the Temporal and Parietal lobe respectively.
Brain networks

• **Cerebellum** - motor coordination, cognitive-affective coordination (CCAS)

• **Brain stem** - DRN and 5HT, LC and NE, VTG and DA neurotransmitter production

• **Limbic** – Intrapersonal Space
  Basal Ganglia, Thalamus, medial Temporal-Amygdala, Hippocampus, OrbitoFrontal, Cingulate - attaches valence to internal maps for motivation, affect, drive, homeostasis
Spectrum of Symptoms of TBI
Clinical Spectrum
C-A-B-S

**Cognitive** - Executive Dysfunction implies disconnection-disruption of Frontal lobe - dPFC, OFC along with limbic connections in the medial Temporal lobe, Parietal lobe.

- **Deficits** - Attention speed, stamina, distractibility, vigilance, Decision making strategies, Judgment, Language, Memory-Short Term and Procedural, Planning, broad Reasoning skills, Time Management

**Affective** - Dysregulation of mood state, Anxiety, Anger, Irritability, Mania and PTSD
Clinical Spectrum
C-A-B-S

**Behavioral** - amotivation, lack of drive, inhibition dysregulation leads to Impulsivity, aggression. The reward systems supervising behavior, Ventral Frontal connections to Limbic system, dysfunctional.

**Somatic** - multiple components of pain such as post traumatic headache, neck, back, limb pain, fatigue, dizziness, insomnia.
Electrophysiological Evaluations
EEG

Post Traumatic Epilepsy; sharp waves, spike and wave, rhythmic theta

QEEG

Digital analysis of frequencies 1-30 Hz compares to standard data base to create Brain Map. Findings suggest a new steady state of decreased magnitude of differentiation of frequencies, coherence, phase changes.


Evoked Potentials

Wave forms following induced auditory, visual stimulation; P50, N100, P300. Decreased Amplitude, delayed timing in TBI
Normal Awake EEG
Post Traumatic Epilepsy
P300 Evoked Response Potential
Wave form occurs 300 msec after stimulus. Latency represents speed of processing, Amplitude # neurons recruited.
QEEG Comparison power spectra
EO condition - Excess Occipital Delta & Midline Theta
Focal Cortical Dysfunction and Blood-Brain Barrier Disruption in Patients with Postconcussion Syndrome

- 17 pts w PCS 1 mo to 7 yrs post injury
- Studied digitalized EEG w SPECT and low-resolution brain electromagnetic tomography - LORETA
- 7mm resolution LORETA, SPECT correlate w 8 of 17 pts
- Decrease in Alpha band
- Increase in Delta, Theta and some with Beta band
- Abnormal rhythms originate in peripheral cortex v controls w midline restricted symmetry source
LORETA voxels representing Delta Activity
2394 voxels

T-test, p < 0.01
Significant Excess **Delta** activity in periphery (**Red**) and decreased activity central (**Blue**) statistical
LORETA and ECD - SPECT
co-localization of abnormal cortical activity w BBB disruption, rCBF deficit

C. PATIENT 2
Abnormal MEG delta waves
generated from left LPFC, OFC, ACC, and parietal-temporal junction regions in the left hemisphere (left column) and the LPFC in the right hemisphere

Ming-Xing Huang, JI Neurotrauma (2008) 26:1-14