TRAUMATIC BRAIN INJURY
A NEUROPSYCHIATRIC PERSPECTIVE

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Disclosures

“Neither I nor my spouse/partner has a relevant financial relationship with a commercial interest to disclose.”
PREVALENCE

• TBI is common
  – Annual incidence 1.7 million in the US
  – 2.5-6 million live with chronic consequences of TBI
  – In 2013, there were about 2.8 million TBI-related emergency department (ED) visits, hospitalizations, and deaths in the United States
    • 56,000 TBI-related deaths
    • TBI was diagnosed in 2.5 million ED visits and 282,000 hospitalizations

• TBI leads to frequent long-term disability
  – 10-20% of mild TBI
  – 66% of moderate TBI
  – 100% of severe TBI

Faul M, 2010; Taylor CA, 2017; Kraus JF, Sorenson, 1994
PREVALENCE

• **Method:**
  – Meta-analysis of studies before May 2011 estimating prevalence of TBI with loss of consciousness (LOC) in adult general population
    • 15 studies, all in developed countries
    • 25,134 adults

• **Results:**
  – 12.1% had history of TBI
    • Men: 17%
    • Women: 9%
  – Odds of history of TBI with LOC are 2.2x higher for men than women (CI = 1.9982.468, p < 0.001).
    • This could be because males engage in more risk-taking behavior, contact sports and alcohol consumption

• **Discussion:**
  – US prevalence of TBI-related disability after hospitalization is 3.2 million individuals
  – 43% of hospitalized TBI survivors will have long-term disability
  – Individuals who sustain one TBI are at an increased risk of sustaining additional TBIs
  – Approximately 80% of all TBIs are mild and often do not result in LOC- they are be included in this analysis

RISK FACTORS

• Highest risk for TBI in 15-24 y/o
• Alcohol abuse
• Motor vehicle accidents – half of TBI
• Falls – 21% - highest among 0-4 y/o and >75 y/o
• Assaults and violence – 20%
• Sports and recreation – 3%

NIH Consensus Development Panel 1999; Faul M, Coronado V, 2015
RISK FACTORS

• Among TBI-related deaths in 2013:
  – Highest risk for TBI in 75+ y/o
  – Leading cause of TBI-related deaths by age:
    • 65+: Falls
    • 25-64: Intentional self-harm
    • 5-24: Motor vehicle crashes
    • 0-4: Assaults

• Among non-fatal TBI injuries in 2013:
  – Hospitalization rates highest in 75+ y/o
  – ED visits highest in 75+ y/o and 0-4 y/o
  – Falls are leading cause of TBI-related ED visits in all groups except
  – In 15-24 year olds, being struck by or against an object is leading cause
  – Leading cause of TBI-related hospitalizations by age:
    • 0-14 and 45+: Falls
    • 15-44: Motor vehicle crashes

Center for Disease Control (2017, April 27). “TBI: Get the Facts.”
CONSEQUENCES

- Risk of death
  - Seven times that of the general population in the first year after injury
  - 5.3 times that of the general population over the first 7 years after injury

- Conditions that promote a shorter lifespan
  - Seizures
  - Sepsis
  - Digestive conditions
  - Pneumonia
  - Other respiratory conditions
  - External causes and unintentional injury

Faul M, Coronado V, 2015
CONSEQUENCES

• Moderate TBI patients interviewed 3-5 years post injury (n=79)
  – 74% of patients worked full time
  – The majority struggled with cognitive and functional limitations (1)

• Moderate-severe TBI patients interviewed up to 10 years post injury (n=141)
  – 70% returned to driving
  – 60% reported changes in cognitive, communication, behavioral, and emotional functions
  – 30% reported difficulties in personal relationships
  – 40% required more support than before injury
  – Of those studying or employed prior to injury
    • 53% studying or employed at 2 years
    • 50% at 5 years
    • 50% at 10 years
  – Overall, problems evident at 2 years post injury persisted until 10 years post injury (3)

• Moderate-severe TBI patients interviewed up to 24 years post injury (n=306)
  – 29% of them had returned to full time employment
  – Patients continued to experience limitations in activities such as managing money and shopping (3)

(1) Vitaz TW, 2003; (2) Ponsford A, 2014; (3) Colantonio A, 2004
PATHOPHYSIOLOGY

• Primary mechanisms
  – Contusions
  – Diffuse axonal injury
  – Hematomas
    • Epidural
    • Subdural
    • Intracerebral

• Some mechanisms of secondary injury
  – Cerebral edema
  – Hydrocephalus
  – Increased intracranial pressure
  – Infection
  – Hypoxia
  – Neurotoxicity
  – Inflammatory response
  – Protease activation
  – Caspase activation - apoptosis
  – Calcium influx
  – Excitotoxins
  – Free radical release
  – Nitric oxide
TBI PRIMARY MECHANISMS

• Sudden acceleration of the head creates physical forces acting on the brain within the enclosed and rigid space of the skull
• Compressive strain – when the brain is compressed against the skull close to the impact (coup)
• Tensile strain – when brain tissue is stretched on the side opposite to the impact (contre-coup)
• Shearing strain – when brain tissues slide against one another (e.g., gray against white matter)
TBI PRIMARY MECHANISMS

- Diffuse axonal injury
  - In accidents when there is twisting and turning of the brain around the brain stem
  - Most vulnerable sites
    - Reticular formation
    - Superior cerebellar peduncles
    - Basal ganglia
    - Hypothalamus
    - Limbic fornices
    - Corpus callosum

- Contusions and hematomas
  - From the movement of the brain against the hard and ridged internal bony surfaces
  - External or internal to the brain surface
  - Bony prominences along the base of the skull – orbital, frontal, temporal

- Thinning of the corpus callosum in TBI (top left)
- Healthy Control (top right)
- 3D reconstruction of the CC in TBI (bottom left) showing fewer fiber bundles
- Healthy Control (bottom right)
MECHANISMS OF SECONDARY INJURY

• Biochemical injury
  – Disruption of the blood brain barrier and disruption of nerve cells => massive releases of neurotransmitters and free radicals
  – Glutamate, aspartate and other excitatory amino acids are released from injured cells
  – Excitatory amino acids act as cytotoxins => thousands of nearby cells depolarize, swell, lyse and die
  – Lysed cells release more cytotoxins => cascade of auto destructive events => progressive cell death for hours or days after the original injury
  – Glutamate has been implicated based on animal model of brain injury – glutamatergic hypothesis of neuronal death
  – NMDA receptors play a major role in glutamate-mediated neurotoxicity
  – Hippocampal formation especially vulnerable to injury with or without actual neuronal death
MECHANISMS OF SECONDARY INJURY

• Inflammatory mechanisms may contribute to the enlargement of the initial injury over days to weeks since the initial physical trauma
  – Cellular cultures and in vivo rat brain experiments – activated macrophages and microglia in evolving brain injury

• Nitric oxide
  – Dilates blood vessels
  – Acts as chemototoxin in inflammatory processes
  – Damages DNA directly
  – Inhibits DNA synthesis
  – Inhibits mitochondrial respiration

• Mitochondrial dysfunction
  – Decreased ATP production
  – Mitochondrial swelling and membrane rupture => cell death
MECHANISMS IN BLAST INJURIES

• Shock waves cause greatest injury at air-tissue interface such as
  – Lungs (alveolae)
  – Intestines
  – Tympanic membrane

• Brain effects of blast injuries
  – Purkinje neurons of the cerebellum
  – Pyramidal neurons of the hippocampus

Courtney et al, 2011; Courtney and Courtney, 2015; McAllister TW, 2011
MECHANISMS IN BLAST INJURIES

• Primary and secondary mechanisms
  – Primary – injury caused by blast wave itself
  – Secondary – injury by flying objects or the body striking objects

• Brain – 3 possible mechanisms
  – Acceleration mechanism - Translational and/or rotational accelerations of the brain caused by exposure to a blast wave
  – Direct cranial entry - A pressure transient traverses the skull and directly injures brain tissue.
  – Thoracic mechanism - Some combination of a pressure transient reaching the brain via the thorax and a vagally mediated reflex result in bTBI
    • Hypothesis: blast wave => pressure on thorax => volumetric blood surge => increase in intracranial pressure => damage to BBB and capillaries in the brain
    • Hypothesis: Propagation of pressure waves from thorax to brain, perhaps via the soft tissues or vasculature more specifically. Pressure waves travel near the speed of sound.
DEFINITIONS OF MTBI

WHO definition (2004) of mTBI and operational criteria

- Acute brain injury resulting from mechanical energy to the head from external physical forces.
- One or more of the following:
  - Confusion or disorientation
  - Loss of consciousness for 30 minutes or less
  - Post-traumatic amnesia for less than 24 hours, and/or
  - Other transient neurological abnormalities such as focal signs, seizure, and intracranial lesion not requiring surgery
  - Glasgow Coma Scale score of 13–15 after 30 minutes post-injury or later upon presentation for healthcare

- These manifestations of mTBI must not be due to drugs, alcohol, medications, caused by other injuries or treatment for other injuries (e.g. systemic injuries, facial injuries or intubation), caused by other problems (e.g. psychological trauma, language barrier or coexisting medical conditions) or caused by penetrating craniocerebral injury

Adapted from Ruff R, 2008
DETERMINING TBI SEVERITY

- **Mild** – at least one of the following:
  - GCS 13-15
  - LOC 0-30 min
  - AOC momentary up to 24 hours
  - PTA 0-1 day
  - Normal imaging

- **Moderate**
  - GCS 9-12
  - LOC > 30 min and ≤ 24 hours
  - AOC > 24 hours (severity based on other factors)
  - PTA >1 and <7 days
  - Normal or abnormal imaging

- **Severe**
  - GCS < 9
  - LOC or PTA for 1 week or longer
  - LOC > 24 hours
  - AOC > 24 hours (severity based on other factors)
  - PTA >7 days
  - Normal or abnormal imaging

Veterans Health Initiative, Employee Education System, Department of Veterans Affairs.
DoD/VA Definition and Symptomatic Taxonomy Working Group Definition
GLASGOW COMA SCALE (GCS)

• Eye opening
  – None – 1
  – To pain – 2
  – To speech – 3
  – Spontaneous – 4

• Motor response
  – No response - 1
  – Extension – 2
  – Abnormal flexion – 3
  – Withdrawal – 4
  – Localizes pain – 5
  – Obeys commands – 6

• Verbal response
  – No response - 1
  – Incomprehensible – 2
  – Inappropriate - 3
  – Confused – 4
  – Oriented - 5

Teasdale G, Jennett B, 1974
POSTCONCUSSIVE SYNDROME

• Term usually used after mild TBI
• Clinical symptoms
  – Somatic symptoms
    • Headache
    • Dizziness
    • Fatigue
    • Insomnia
  – Cognitive symptoms
    • Memory difficulties
    • Impaired concentration
  – Perceptual symptoms
    • Tinnitus
    • Sensitivity to noise
    • Sensitivity to light
  – Emotional symptoms
    • Depression
    • Anxiety
    • Irritability

(1) Bohnen et al, 1992; (2) Wade et al, 1998
POSTCONCUSSIVE SYNDROME

• Time course
  – Most patients recover at 1-6 months post-injury
  – However, up to 44% of individuals report three or more symptoms 1 year following injury (2)
  – Some continue with significant complaints (1)
    • 16-49% with persistent symptoms at 6 months
    • 1-50% with persistent symptoms at 1 year
  – Professional athletes have the same symptoms as work-injured individuals

(1) Bohnen N, 1992; (2) Zgaljardic DJ, 2014
POSTCONCUSSIVE SYNDROME

• Low specificity – PCS happens in:
  – Healthy adults
  – Chronic pain patients
  – Spinal cord injury patients
  – Non-TBI trauma patients
  – Psychological distress patients
  – Orthopedic injury patients

• Low specificity makes misdiagnosis possible

• Attribution of PCS to TBI is difficult
POSTCONCUSSIVE SYNDROME

• Predictors of PCS symptoms > 3 months post-mTBI
  – mTBI does not predict PCS
  – Emotion-focused coping ⇔ increased symptom reporting
  – Problem-focused coping ⇔ decreased symptom reporting
  – Premorbid psychiatric history
  – Pre-injury neuroticism, depression, anxiety
  – Pain
  – Anxiety sensitivity - belief that sensations are signs of impending harmful consequences
  – Cognitive misattribution and “the good old times” effect
    • Individuals who had TBI reported 60% fewer symptoms pre-injury compared to healthy controls
    • Athletes underestimated their per-concussion symptoms by 97% compared to healthy controls
      – Of 30 symptoms in survey, only headache was reported more frequently by concussed athletes
POSTCONCUSSIVE SYNDROME

• Treatment principles
  – Education and reassurance
  – Exercise and return to activities
    • Rest may not be “the best medicine” after a concussion
    • Regular exercise may be protective against anxiety and depression
    • Graded exercise protocols under the supervision of an athletic trainer or other healthcare provider may also provide an in vivo method for anxiety desensitization
    • Vigorous exercise within 2 weeks may result in additional symptoms
    • Return to competitive sports within 1 week after concussion may result in additional concussions

Broshek D, 2015; Silverberg ND, Iverson GL, 2013
FIGURE 9.1 Anatomy of three prefrontal regions corresponding to orbitofrontal (green), dorsolateral (blue), and medial frontal (pink) syndromes.
FRONTAL LOBE DAMAGE

- Abulia
  - Decrease in initiation and maintenance of actions
- Apathy
  - Absence or reduction of affect
- Disinhibition
- Working memory difficulties
  - Attentional on-line maintenance
    - PFC and Posterior Parietal Cortex
  - Volitional manipulation

Cummings JL, Mega MS, Neuropsychiatry and Behavioral Neuroscience, 2003
PREFRONTAL SYNDROMES

• Orbitofrontal syndrome
  – Clinical features
    • Disinhibition, impulsiveness
    • Poor social judgment
    • Lack of interpersonal sensitivity or empathy
    • Limited insight
    • Irritability, mood lability
    • Hypomania, depression
    • Poor hygiene, neglect of personal care
    • Utilization behavior and imitation behavior

Cummings JL, Mega MS, Neuropsychiatry and Behavioral Neuroscience, 2003
PREFRONTAL SYNDROMES

• Dorsolateral convexity syndrome
  – Executive dysfunction
  – Impaired strategy generation for problem solving
  – Impaired abstract ability
  – Impaired manipulation
  – Depression

Cummings JL, Mega MS, Neuropsychiatry and Behavioral Neuroscience, 2003
Medial frontal syndrome
- Reduced interest and emotional responsiveness to events
- Reduced curiosity, engagement in usual activities
- Lack of concern for health, family, future
- Impaired initiation of new activities, lack of effort
- Reduced activity, effort

Cummings JL, Mega MS, Neuropsychiatry and Behavioral Neuroscience, 2003
# NEUROPSYCHIATRIC SYMPTOMS AFTER TBI

## Early Trajectory of Psychiatric Symptoms after Traumatic Brain Injury: Relationship to Patient and Injury Characteristics

Tessa Hart, Emma K.T. Berrin, Emilia Bagileva, Patricia Arenth, Sureyya Dikmen, Dale C. Hesdorffer, Thomas A. Novick, Joseph H. Ricker, and Ross Zafonte

### Table 2. Summary Statistics for T Scores and Proportions Meeting Casename Criteria for Each BSI Clinical Scale and GSI at 30, 90, and 180 Days

<table>
<thead>
<tr>
<th>Scale</th>
<th>30 days (n=713)</th>
<th>90 days (n=780)</th>
<th>180 days (n=711)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Proportion ≥63 (%)</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Somatization</td>
<td>59.9 ± 10.9</td>
<td>41.9</td>
<td>56.3 ± 10.8</td>
</tr>
<tr>
<td>Obsessive-compulsive</td>
<td>59.9 ± 11.6</td>
<td>42.6</td>
<td>59.1 ± 11.6</td>
</tr>
<tr>
<td>Interpersonal Sensitivity</td>
<td>52.4 ± 10.4</td>
<td>22.0</td>
<td>52.3 ± 10.4</td>
</tr>
<tr>
<td>Depression</td>
<td>55.5 ± 10.7</td>
<td>25.1</td>
<td>54.6 ± 10.9</td>
</tr>
<tr>
<td>Anxiety</td>
<td>54.3 ± 12.0</td>
<td>26.9</td>
<td>52.8 ± 12.3</td>
</tr>
<tr>
<td>Hostility</td>
<td>53.5 ± 10.9</td>
<td>16.6</td>
<td>52.4 ± 11.0</td>
</tr>
<tr>
<td>Phobic anxiety</td>
<td>55.8 ± 10.7</td>
<td>30.9</td>
<td>53.9 ± 10.0</td>
</tr>
<tr>
<td>Paranoid ideation</td>
<td>53.1 ± 11.1</td>
<td>23.7</td>
<td>53.5 ± 10.7</td>
</tr>
<tr>
<td>Psychoticism</td>
<td>57.4 ± 11.0</td>
<td>30.2</td>
<td>57.0 ± 11.4</td>
</tr>
<tr>
<td>GSI</td>
<td>58.3 ± 11.2</td>
<td>33.4</td>
<td>56.4 ± 11.9</td>
</tr>
</tbody>
</table>

BSI, Brief Symptom Inventory; GSI, General Severity Index; SD, standard deviation.
AGGRESSION AFTER TBI

• Prevalence
  – 35-96% in the acute recovery period
  – In rehabilitation
    • 11-70% with agitation (7)
    • 25-39% with aggression (7)
  – Years post-injury (2,3)
    • 5-70% after mild TBI
    • 31-71% after severe TBI

• Associations
  – Depression (4, 5,7)
  – H/o substance abuse (6)
  – Orbito-frontal lesions (6,7)
  – Older males (7)
  – Poor premorbid functioning (6)
  – Language Disorders (7)
  – In noisy environments (7)
  – Within 24 hours following a seizure (7)

• Characteristics of violence after TBI
  – Reactive
  – Nonreflective
  – Nonpurposeful
  – Periodic – brief outbursts of aggression
  – Ego-dystonic
  – Explosive, without buildup

AGGRESSION AFTER TBI

• Pharmacotherapy of acute aggression
  – Antipsychotics
    • Short term
    • Likely act through sedative effect
    • Possible negative effects on TBI
  – Benzodiazepines
    • Lorazepam 1-2mg PO/IM q 1 hour

• Pharmacotherapy of chronic aggression
  – Antipsychotics – some evidence that they may impede recovery. Newer antipsychotics preferred (1)
  – Anticonvulsants – Valproate and Carbamazepine (1,2,4)
  – Lithium – could be effective but possible neurotoxicity in TBI (1)
  – Buspirone may be effective (1)
  – Antidepressants – mixed results. Possible seizures with TCA’s (1)
  – Beta-blockers (1)
    • Propranolol – lipid soluble, nonselective – up to 520mg/day
    • Pindolol – lipid soluble, nonselective, with partial sympathomimetic activity – up to 100mg/day
      – Good when bradycardia is an issue
  – Amantadine (1, 3)
  – Methylphenidate (1)

PERSONALITY CHANGE IN TBI

• 50-80% prevalence
• Abrupt onset, lasting for years
• Personality change due to TBI
  – Labile type
  – Disinhibited type
  – Aggressive type
  – Apathetic type
  – Paranoid type
  – Other type
  – Combined type
  – Unspecified type

DSM-5, 2013
MOOD DISORDERS

- **MDD**
  - Incidence 15.3-33% (1)
  - Prevalence 11.1-61% (2, 3, 4)
- **Dysthymia** – prevalence 5.5-14% (5)
- **Minor depression** (2-4 symptoms X 2 weeks) – 22% (7)
- **Mania**
  - Incidence 9.1%
  - Prevalence 0.83-22.2% (1)
- **Depression associated with** (6, 8)
  - Anxiety (77%)
  - Aggressive behavior (57%)
  - Fatigue (29%)
  - Distractibility (28%)
  - Anger or irritability (28%)
  - Rumination (25%)

MOOD DISORDERS

• High rate of SI and SA (1)
  – 10% with SI 1 year post-TBI
  – 2% with SA 1 year post-TBI
  – 15% with SA 5 years post-TBI
  – High SA rate may be due to high MDD rate + disinhibition

• Simpson, Tate review, 2007
  – Relative risk for suicide after TBI is 3-4 times that of the general population
  – Cumulative suicide rate is 1% over the first 15 years post-TBI
  – Clinically significant SI in 21-22% of people with TBI
  – Rate of post-TBI suicide attempts among severe TBI people is as high as 18%

• Observational study of 559 adults with mild complicated through severe TBI for 1 year after TBI (3)
  – 25% reported SI at one or more points during assessments
  – 7-10% reported SI at each assessment point
  – SI highest during months 2 and 8 post-TBI
  – 53% of those with SI have probable depression at the first assessment post-TBI

• Predictors of suicidal ideation (3)
  – Having Medicaid insurance (relative to commercial or private)
  – Having a higher score on the first PHQ-8 after injury
  – A history of depression, bipolar disorder, or other anxiety disorder
  – Prior suicide attempt(s) or psychiatric hospitalization
  – Having less than high school education

(1) Silver JM, 2002; (2) Simpson G, Tate R, 2007; (3) Mackelprang JL, 2014
MOOD DISORDERS

• Associations with brain regions
  – Depression associated with lesions in the
    • Left DLPFC
    • Left basal ganglia
    • Right orbitofrontal cortex
    • Parieto-occipital lesions
  – Mania associated with damage of
    • The ventral and anterior aspects of the temporal lobe
    • The orbitofrontal cortex
    • The thalamus
  – Laterality of lesions
    • The association between left vs. right lesions and type of affective presentation has not been well established

Jorge RE, Robinson RG, 2003; Jorge RE, Robinson RG, 1993
MOOD DISORDERS TREATMENT

• Antidepressants
  – Choice based on SE profile
    • SSRI’s first line
    • Caution for anticholinergic SE
    • Caution for apathy in SSRI’s
    • Bupropion – seizures, dysphoria
    • TCA’s – seizures up to 19%

• ECT can be effective (1,2)

(1) Kant R, 1999; (2) Ruedrich SL, 1983
MOOD DISORDERS TREATMENT

- Antimanic agents
  - Lithium associated with
    - Confusion
    - Nausea
    - Tremor
    - Ataxia
    - Lethargy (1)
    - May lower seizure threshold (2)
  - Some experimental TBI paradigms using Lithium (3)
    - Lithium reduces neuronal death, microglial activation
    - Preserves blood-brain barrier integrity
    - Mitigates neurological deficits
    - Improves learning and memory outcome
  - VPA, CBZ – most common SE
    - Lethargy
    - Confusion
    - Drowsiness
    - Ataxia
    - Nystagmus

(1) Schiff HB, 1982; (2) Massey and Folger, 1984 (3) Leeds PR, 2014
MOOD DISORDERS PSYCHOSOCIAL TREATMENTS

• Hopelessness RCT after mod-severe TBI (2)
  – 20 hour CBT vs. wait-list
  – Significant group by time interaction pre to post-tx favoring the intervention group
  – SI, depression, social problem solving, self-esteem, hopefulness displayed no significant group-by-time interactions or main effects.

• Home based walking study (3)
  – Assigned daily coaching to encourage walking vs. same frequency nutrition coaching
  – Pedometers used to document steps per day
  – 24 weeks, with a cross-over at 12 weeks
  – Perceived stress and depression improved after walking intervention

• CBT by telephone or in-person can be helpful for depression after TBI compared to usual care (4)

(1) Silver JM, 2002; (2) Simpson GK, 2011; (3) Bellon K, 2014; (4) Fann JR, 2015
MOOD DISORDERS MEDICATION TREATMENTS

• Randomized controlled trials (RCT)
  – Small double blind RCT with cross over from placebo to active medication at 1 month
    • Desipramine effective in post-TBI depression (n=10, with 6 of 7 completers achieving resolution of their depression on desipramine) (1)
  – Double blind RCT comparing sertraline to placebo
    • 52 subjects with mild, moderate or severe TBI at an average of 17+/-14 years after their injury
    • Significant pre to post treatment changes in mood, anxiety and quality of life measures in both groups
    • No significant differences between the sertraline and placebo groups post treatment (2)

(1) Wroblewski BA, 1996; (2) Ashman TA, 2009
Most data come from open label studies and case series.

- Single-blind placebo run-in design of Sertraline in 15 patients with MDD after TBI (1)
  - Remission (HAM-D) in 2/3 of patients
  - Cognitive improvement observed
- Fluoxetine and sertraline, in addition to their antidepressant effects, led to improvements in attention, psychomotor speed, memory and other neuropsychological functions (3, 4)
- Tricyclic antidepressants, sertraline, citalopram and milnacipran (a serotonin-noradrenalin reuptake inhibitor) were effective in post-TBI depression (5-7)
- Carbamazepine beneficial for depression, inattention and confusion in a subpopulation of TBI (2)
- Carbamazepine and valproic acid were helpful in post-TBI aggression (8, 9)
- Antipsychotics associated with decreased cognition in animal models and human subjects (10)

MOOD DISORDERS MEDICATION TREATMENTS

- Meta-analysis of depression post mTBI
  - 13 studies included
    - Pre to post-treatment (no control group)
    - Control group
    - Medications – SSRI’s, stimulants, TCA’s, non-medication
  - Main results
    - Pre–post design studies produced an effect size of 1.89 (95% CI=1.20–2.58) => treatments effective
    - Controlled trials produced an effect size of 0.46 (95% CI=0.44–1.36) => controls did better than treatment groups
    - Controlled trial of methylphenidate produced an effect size > 0
    - Amitriptyline produced effect size < 0 => less effective than Placebo
    - Sertraline – mixed results

Barker-Collo S, 2013
MOOD DISORDER PREVENTION?

- **Subjects:**
  - Moderate-severe TBI subjects not depressed at study initiation

- **Methods:**
  - Double-blind RCT of sertraline (n=49) vs. Placebo (n=50)
  - Treatment X 3 months started at an average of 21 days after injury (none >8 weeks)
  - Outcome measures
    - the Hamilton Depression Rating Scale (HDRS)
    - the Depression Scale of the Neurobehavioral Functioning Inventory (NFI)

- **Results**
  - Greater depressive symptoms in placebo vs. sertraline group during treatment (HDRS > 6 in 10% vs. 0%; p < 0.023.)
  - No significant difference during the remainder of the year between groups

- **Conclusions:**
  - Sertraline is effective in diminishing depressive symptoms even among those not clinically depressed while the medication is being taken
  - Administration early in recovery does not prevent depression after the drug is stopped

Novack TA, 2009
PSYCHOSIS

• DSM-5 - Psychotic disorder caused by another medical condition (TBI)
• Prevalence
  – 3.4% 1-10 years post-injury (among 530 TBI patients) (1)
  – 0.9-8.5% (2)
• Symptoms (2)
  – Delusional disorder
    • Capgras syndrome (loved ones are replaced by identical impostors) (32%)
    • Reduplicative paramnesia (familiar place is duplicated in another location) (32%)
    • Delusional jealousy (16%)
    • Cotard syndrome (being dead or dying) (16%)
    • Somatic delusions (11%)
    • Fregoli (different people are a single person who changes in appearance) (5%).
    • Negative symptoms are uncommon (25%)
  – Schizophrenia-like psychosis – both hallucinations and delusions
    • Hallucinations (97%): auditory hallucinations (88%) and visual hallucinations (22%)
    • Delusions (85%): persecutory (65%); bizarre delusions (20%), ideas of reference (18%), and
      grandiose delusions (16%).
    • Negative symptoms (43%): blunted affect (70%), social withdrawal (49%), and poor hygiene
      (40%).

(1) Violon and De Mol, 1987; (2) Fuji DE, 2014
PSYCHOSIS

• Etiology (1)
  – Multifactorial – mania, depression, epilepsy, impaired reality testing from FL dysfunction
  – Strongest evidence for TBI as etiology of psychosis is the absence of psychotic symptoms or prodromal symptoms before the onset of TBI combined with the abrupt onset of psychotic symptoms within months after the TBI
  – However, there is frequently a delayed onset of psychosis after sustaining a TBI up to 4-5 years

• Risk factors (1)
  – For Delusional disorder
    • 44% with seizure disorder
    • 25% with a family history of mental illness
  – For Schizophrenia-Like Psychosis
    • 38% with seizure disorder
    • 38% with a family history of mental illness

(1) Fuji DE, 2014
## Laboratory findings associated with Delusional Disorder and Schizophrenia-Like Psychosis caused by TBI

<table>
<thead>
<tr>
<th>Test Type</th>
<th>Delusional Disorder</th>
<th>Schizophrenia-Like Psychosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI/CT: positive findings (%)</td>
<td>94</td>
<td>55</td>
</tr>
<tr>
<td>Most common finding (%)</td>
<td>75 frontal</td>
<td>34 frontal</td>
</tr>
<tr>
<td></td>
<td>56 temporal</td>
<td>19 temporal</td>
</tr>
<tr>
<td></td>
<td>38 enlarged ventricles</td>
<td>19 enlarged ventricles</td>
</tr>
<tr>
<td>SPECT/PET: positive findings (%)</td>
<td>—</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>86 temporal</td>
</tr>
<tr>
<td></td>
<td>—</td>
<td>14 frontal</td>
</tr>
<tr>
<td>EEG: positive findings (%)</td>
<td>71</td>
<td>87</td>
</tr>
<tr>
<td>Most common finding (%)</td>
<td>29 temporal</td>
<td>53 temporal</td>
</tr>
<tr>
<td></td>
<td>14 frontal</td>
<td>23 frontal</td>
</tr>
<tr>
<td></td>
<td>43 slowing</td>
<td>69 slowing</td>
</tr>
<tr>
<td></td>
<td>14 spiking</td>
<td>27 spiking</td>
</tr>
<tr>
<td>Neuropsychological testing (%)</td>
<td>100 Deficits</td>
<td>100 Deficits</td>
</tr>
<tr>
<td>Most common finding (%)</td>
<td>73 memory</td>
<td>85 memory</td>
</tr>
<tr>
<td></td>
<td>55 executive functioning</td>
<td>65 executive functioning</td>
</tr>
</tbody>
</table>

Abbreviations: EEG, electroencephalogram; SPECT, single-photon emission computed tomography

(1) Fuji DE, 2014
Cognitive function compared between psychosis following TBI (n=10), TBI (n=10), schizophrenia (n=23), and healthy controls (n=23) (3)

- Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) administered
- 70% of psychosis+TBI patients classified as “extremely low” or “low average” range
- Between-group analyses showed that psychosis+TBI patients had the lowest scores in
  - Immediate Memory
  - Attention
  - Delayed Memory
  - Total Score
- Evidence of impaired cognitive neuropsychological processing in patients with psychosis + TBI using a standardized and replicable battery

(1) Batty RA, 2016
PSYCHOSIS

- **Treatment**
  - **Pharmacological**
    - Based on clinician judgment (1)
    - Similar to treatment of primary psychotic disorders (1)
    - TBI patients are more sensitive to SE of antipsychotics—dystonia, akathisia, EPS (2)
    - Antipsychotics may impede neuronal recovery (1, 3)
    - Risperidone, Olanzapine, Quetiapine preferred within 2nd generation antipsychotics
    - Molindone and Fluphenazine – 1st generation with lowest potential for lowering seizure threshold (4)
    - Prescribing AED prior to antipsychotics - if mood lability or irritability present (1)
    - Clozapine – high anticholinergic load, decreases seizure threshold
  - **Non-pharmacological (1) - not well researched, may need to be adapted to post-TBI psychosis patients**
    - Assertive community training
    - Supported employment
    - Cognitive behavior therapy
    - Family-based services
    - Skills training
    - Psychosocial interventions for alcohol and substance use disorders
    - Psychosocial interventions for weight management
    - Medication adherence
    - Cognitive remediation
    - Peer support and peer-delivered services

(1) Fuji DE, 2014; (2) Wolf et al, 1989; (3) Feeney et al, 1982; (4) Oliver et al, 1982
ANXIETY DISORDERS

• Prevalence
  – GAD – 8-24% (1-3)
  – PD – 3-11% (3, 4)
  – Phobias – 6-11% (3, 5)
  – OCD – 4.7-14% (3, 5)
  – ASD – 14% (6)
    • 73% of people with ASD have PTSD at 2 years
  – PTSD – 3-27% (7, 8)
    • Fewer intrusive memories (19%)
    • Emotional reactivity (96%)

SYMPTOMS IN CO-MORBID PTSD AND TBI

- **Shared symptoms (1):**
  - Sleep disruption
  - Irritability
  - Difficulty concentrating
  - Slowed thinking
  - Memory impairment

- **Shared co-morbidities:**
  - Depression
  - Substance use disorders
  - Pain
  - Somatic disorders

- **Symptom overlap can cause false positive diagnoses of PTSD after TBI.** (2, 3)

(1) Kennedy et al 2007; (2) Sumpter 2006; (3) McMillan 2001
# Symptom Overlap in PTSD and TBI

**PCL – 17 items, rated 1-5**

1. Repeated, disturbing *memories, thoughts, or images*
2. Repeated, disturbing *dreams*
3. Suddenly *acting or feeling* as if a stressful experience *were happening* again (as if you were reliving it)?
4. Feeling *very upset at reminders*
5. *Physical reactions at reminders*
6. Avoid *thinking/talking about* a stressful events or avoid *feelings* related to it?
7. Avoid *activities or situations*
8. Trouble *remembering important parts* of a stressful experience from the past?
9. Loss of *interest in things that you used to enjoy*?
10. Feeling *distant or cut off* from other people?
11. Feeling *emotionally numb* or being unable to have loving feelings for those close to you?
12. Feeling as if your *future* will somehow be *cut short*?
13. Trouble *falling or staying asleep*?
14. Feeling *irritable or having angry outbursts*?
15. Having *difficulty concentrating*?
16. Being *“super alert” or watchful on guard*?
17. Feeling *jumpy or easily startled*?

**NSI 18 items, rated 0-4**

1. Feeling Dizzy
2. Loss of balance
3. Poor coordination, clumsy
4. Headaches
5. Nausea
6. Vision problems, blurring, trouble seeing
7. Sensitivity to light
8. Hearing difficulty
9. Sensitivity to noise
10. Numbness or tingling on parts of my body
11. Change in taste and/or smell
12. Loss of appetite or increased appetite
13. Poor concentration, can’t pay attention, easily distracted
14. Forgetfulness, can’t remember things
15. Difficulty making decisions
16. Slowed thinking, difficulty getting organized, can’t finish things
17. Fatigue, loss of energy, getting tired easily
18. Difficulty falling or staying asleep
19. Feeling anxious or tense
20. Feeling depressed or sad
21. Irritability, easily annoyed
22. Poor frustration tolerance, feeling easily overwhelmed by things

*PCL – posttraumatic symptoms checklist; NSI – Neurobehavioral symptoms inventory*
SYMPTOMS IN CO-MORBID PTSD AND TBI

• Contribution of TBI to PTSD symptoms
  – Re-experiencing and hyperarousal symptoms are higher in PTSD w/ TBI than PTSD w/o TBI (1)
  – Avoidance and sleep disturbance greater in PTSD w/ moderate/severe TBI than PTSD w/o TBI (1)
  – Re-experiencing symptoms higher in blast mTBI than non-blast mTBI (2)

• Contribution of PTSD to postconcussive symptoms (PCS)
  – PTSD and mTBI independently associated with PCS reporting (3)
  – Those with both conditions were at greater risk for PCS than those with either PTSD, mTBI, or neither (3)
  – Few differences in PCS, psychological symptoms, and neurocognitive performance between blast and nonblast mTBI (4)

(1) Simonovic et al, 2011; (2) Kennedy et al, 2010; (3) Brenner et al, 2010; (4) Luethcke et al, 2011
COGNITIVE DYSFUNCTION IN PTSD

- Definite attentional impairment
- Mixed evidence for impairment in
  - Learning
  - Memory
  - Executive functions
  - Visuospatial function
- Attention and new learning both impaired in veterans with PTSD

Qureshi et al, 2011
COGNITIVE DYSFUNCTION IN CO-MORBID PTSD AND TBI

• By self-report
  – mTBI associated with greater PTSD symptoms in military service personnel (1)
  – PTSD associated with greater cognitive dysfunction and worse health status in civilians with TBI of all severity (n=3047) (2)
  – More mTBI than moderate or severe TBI veterans report PCS (3)
  – Between-group difference no longer significant when the PTSD symptom severity was controlled (3).

• By objective neurocognitive tests
  – mTBI+PTSD vs. mTBI-PTSD veterans scored worse on processing speed and executive functioning (4)
  – Mild-moderate TBI vs. no TBI veterans scored worse on verbal memory, same on nonverbal memory (5)
  – Verbal memory in the TBI group was unrelated to PTSD severity (5)
  – In 53 mTBI veterans, mTBI+PTSD vs. mTBI-PTSD scored worse on processing speed (4)
  – Processing speed accounted for 43% of the variance in performance on Trails B and 50% of the variance on Stroop task (4)

• Subjective vs. objective tests
  – Self reported cognitive dysfunction among mTBI veterans correlated poorly with objective test performance (6, 7)

SUBSTANCE USE DISORDERS

• Prevalence
  – Initial reduction in substance use in the 1st year post-injury, and greater abstinence
  – Return to pre-injury alcohol (7-48%) and drug misuse (6-28%) over time
    • > 25% consuming alcohol at hazardous levels
    • 15% demonstrated alcohol dependence at 2 years post-injury
    • 8.4% reported problem drug use
    • 53% reported both alcohol and drug misuse

Zgaljardic DJ, 2014
SUBSTANCE USE DISORDERS

• Risk factors
  – Substance use and misuse (esp. alcohol) is a risk for TBI
  – Risks for continued post-TBI use/misuse
    • Pre-injury history of an SUD
    • Intoxication at the time of injury
    • Family history of an SUD
    • Denial of dangers associated with continued substance use
    • Younger age (i.e., < 25 years)
    • Male gender
    • Fewer cognitive and physical impairments stemming from injury
    • Less involvement in productive activities that produce income
    • Less community access
  – Risk factors for a new use/misuse after TBI
    • Most had an extensive pre-injury history of substance misuse
    • Some evidence that TBI may be a risk factor for developing an SUD
    • Children with mTBI more likely to demonstrate SUD during adolescence
    • New alcohol misuse after TBI in 11-30% of those without such pre-injury

Zgaljardic DJ, 2014
SUBSTANCE USE DISORDERS

• Consequences
  – Greater cerebral cortical atrophy
  – Post-traumatic seizures
  – Poor psychosocial functioning
  – Mood disorders
  – Poor long-term vocational outcomes
  – Decreased life satisfaction
  – Increased risk for suicide
  – Increased risk for sustaining a second TBI

• Treatment
  – Education about the negative effects of continued substance use
  – Motivational interviewing and multimedia psychoeducational materials may enhance retention of information
  – Pharmacological treatments – as adjunct to traditional therapies: Naltrexone, acamprosate, and disulfiram

Zgaljardic DJ, 2014
SLEEP IN TBI

• 50% with some sleep disturbance
• 46% with a diagnosable sleep disorder
• 30% with Insomnia –c/w 10% in the gen. population
  – Depression and mild TBI severity correlate with insomnia
  – Pain may be a contributor
• 23% with Sleep apnea –c/w 2% in the gen. population
• 11-49% with hypersomnia –c/w 10% in the gen. population
  – Abnormalities on MSLT
  – Sleep-disordered breathing
  – Differentiate from apathy
• Circadian rhythm disorders – possibly up to 1/3
• 6% with Narcolepsy – c/w 0.047% in the gen. population
• 7% with PLMD – c/w 4% in the gen. population

(1) Castriotta RJ, 2011; (2) Ouellet et al, 2004; (3) Mathias J, 2012
SLEEP IN TBI

• More SWS than healthy controls, and reduced evening melatonin production (1)
• Insomnia ⇐ neuropsychiatric sequelae of TBI
• Drugs for comorbid issues may interfere with sleep
• Post-TBI fatigue in 33-44% of individuals with mod-severe TBI (2)
• Treatment (2)
  – Caution with BZD related hypnotics
  – Sleep hygiene, physical activity, lighting
  – Treatment of specific disorders

(1) Shekleton et al, 2010; (2) Cantor JB, 2012; (3) Castriotta RJ, 2011
COGNITIVE CHANGES

- Cognitive problems are well documented in TBI
  - Slow cognitive processing speed
  - Executive dysfunction
  - Memory problems
  - Within the first 6-12 months post injury, many TBI subjects experience a relatively rapid cognitive improvement due to natural regenerative brain processes
  - After about 12 months, such improvements plateau, subjects reach a new cognitive baseline that is frequently abnormal and contributes to disability
COGNITIVE CHANGES
PHARMACOTHERAPY

• A 24-week, randomized, placebo-controlled, double-blind crossover trial.
  – 18 post acute TBI patients with cognitive impairment.
  – Patients randomly assigned to donepezil for 10 weeks and then placebo for 10 weeks OR placebo for 10 weeks followed by donepezil for 10 weeks.
  – OUTCOME MEASURES: Short-term memory and sustained attention at baseline, week 10, and week 24
  – RESULTS:
    • Donepezil associated with increased testing scores compared with baseline
    • No significant change between baseline and the end in the placebo group during placebo period
    • Significantly improved testing scores in donepezil group over placebo group
    • Improved testing scores with donepezil sustained after the washout period and placebo phase
  – CONCLUSIONS: Donepezil associated with increased neuropsychological testing scores in short-term memory and sustained attention in post acute TBI patients

Zhang L et al, 2004
COGNITIVE CHANGES
PHARMACOTHERAPY

• Rivastigmine
  – A 12 week prospective, double blind, placebo controlled trial (1)
    • 157 patients > 12 months post-injury
    • Rivastigmine 3-6mg per day vs. placebo
    • Response = change > 1 SD in NP tests of verbal learning and memory (HVLT), and response time to a stimulus (CANTAB RVIP A)
    • By week 12 49% of rivastigmine and 49% of placebo were responders
    • In a subgroup of patients with moderate-severe memory impairment (n=81), rivastigmine significantly better than placebo in improving cognitive measures
    • Rivastigmine shows promising results in the subgroup of patients with traumatic brain injury with moderate to severe memory deficits
  – Double blind RCT with cross over study (2)
    • 102 patients >12 months post-injury
    • Rivastigmine up to 12mg vs. placebo
    • Uptitration => 8 week maintenance => washout => cross-over => uptitration => maintenance
    • Computerized neuropsychological testing and standardized clinical interviews
    • 69 completers, 17 withdrew because of side effects
    • Rivastigmine better than placebo in two measures of computerized testing - subtraction test (p = 0.034) vigilance test (p = 0.048).
    • The clinical interviews did not yield significant results
    • Subjective: 45% of patients thought rivastigmine beneficial compared to 20% with placebo

(1) Silver JM et al, 2006; (2) Tenovuo O, 2009
COGNITIVE CHANGES
PHARMACOTHERAPY

- Stimulants
  - Block reuptake of NE and DA
  - MPH helps with cognition, rate of recovery (1,2)
  - MPH helps with mental fatigue and processing speed (8)
  - SE: paranoia, dysphoria, agitation, irritability, increased BP
  - No data for increased seizures with stimulants (3, 6)
- Amantadine up to 400mg per day
  - DA-ergic action, GABA-ergic, NMDA antagonist
  - Improved motivation, concentration, alertness, executive function, behavioral dyscontrol (4, 9)
  - No significant difference in attention on amantadine 100–300 mg/d compared with placebo (6, 7)
- Sinemet (carbidopa/levodopa) 10/100 to 25/250 qid led to
  - Better alertness and concentration;
  - Decreased fatigue, hypomania and sialorrhea
  - Improved memory, mobility, posture and speech (5)

COGNITIVE CHANGES
PHARMACOTHERAPY

• Bromocriptine
  – DA2 agonist, DA1 antagonist
  – May be useful in treating
    • Cognitive initiation problems
    • Nonfluent aphasia
    • Apathy
    • Akinetic mutism
  – SE: sedation, nausea, psychosis, delirium, headaches
  – One RCT showed no significant difference in attention with 6 weeks of bromocriptine 5 mg BID. Trend toward worse performance in treatment group (1)
  – Bromocriptine administered to 31 healthy controls and 26 mTBI 1 month post-injury (3)
    • Improved WM performance in the HC but not the MTBI group
    • The MTBI group showed increased activation outside of a task-specific region of interest.

(1) Chew E, Zafonte RD, 2009; (2) Whyte J, 2008; (3) McAllister TW, 2011
COGNITIVE CHANGES
PHARMACOTHERAPY

• Participants:
  – Sixty adults, 3-12 months post mTBI, who were experiencing cognitive difficulties

• Methods:
  – Enzogenol, a flavonoid-rich extract from Pinus radiata bark with antioxidant and anti-inflammatory properties
  – Enzogenol vs. Placebo X 6 weeks => Enzogenol for all X 6 weeks => Placebo for all X 4 weeks
  – Assessments at BL, 6, 12, and 16 weeks

• Results
  – Improvements in the frequency of self-reported cognitive failures
    Enzogenol > Pbo at 6-11 weeks

Theadom A, 2013
PHARMACOTHERAPIES FOR COGNITIVE AND BEHAVIORAL OUTCOMES

• Setting: post-acute TBI (>4 weeks)
• Methods: Meta-analysis
  – Both RCT’s and open-label trials
  – 19 treatments by 30 independent studies
  – 395 treatment participants, 137 controls
• Results
  – Treatments administered in post-acute TBI:
    • Methylphenidate improved behavior (anger/aggression), psychosocial function
    • Donepezil improved cognition (memory, attention)
  – Treatments started in acute TBI and continued in post-acute TBI:
    • Methylphenidate, amantadine showed clinically useful treatment benefits for behavior
    • Sertraline markedly impaired cognition and psychomotor speed

Wheaton P, 2011
COGNITIVE REHABILITATION

- Cognitive Task Force of the American College of Rehabilitation Medicine (ACRM)
  - Systematically reviewed the literature from 2003-2008
  - 112 studies of cognitive rehabilitation interventions
- Conclusions for the effectiveness of cognitive rehabilitation in post-acute TBI
  - Cognitive rehabilitation is of greater benefit than conventional rehabilitation
  - Cognitive rehabilitation is the best treatment for people with neurocognitive impairment and functional limitations after TBI
  - Substantial evidence for the following interventions
    - Attention training (graded exercises to stimulate attention)
    - Metacognitive strategies (feedback, self-monitoring, self-regulation, strategy use) - promote generalization of the cognitive rehabilitation to real world tasks
TBI EVALUATION

• History of the accident(s)
  – When, where, type
  – Alteration in consciousness, LOC
  – Post Traumatic Amnesia
  – GCS at scene or ER if available
  – Associated trauma to other body parts/systems
  – Neurological/neurosurgical complications
    • Focal neurological findings
    • Hematomas, contusions, etc.
    • Sensory-motor deficits
    • Speech/language deficit
    • Surgical procedures – craniotomies, shunts, etc.
    • Post-traumatic epilepsy
TBI EVALUATION

• History of the accident(s)
  – Hospitalization and rehabilitation
    • Length of acute hospital stay
    • Functional recovery
    • Residual deficits
    • Rehabilitation hospitalization, interventions
    • Rehabilitation efforts since discharge from post-acute facility – residential rehab, vocational rehab, etc.

• Overview of life since TBI
  – Living situation
  – Employment
  – Rehabilitation activities – OT, PT, SLP, HI support groups
  – Finances – attempts to work, disability, workman’s compensation, lawsuits

• Collateral information from family
  – Patients report more physical impairment
  – Relatives report more behavioral problems
TBI EVALUATION

• Neuropsychiatric syndromes
  – Cognitive disturbances
    • Memory loss, external cueing, naming and word finding difficulties
    • Attention/concentration problems
    • Speed of information processing
    • Cognitive rigidity
  – Mood syndromes
    • Depression
    • Mania/hypomania
  – Personality changes
    • Dyscontrol – irritability, sexual behavior, apathy
  – Psychotic syndromes
  – Anxiety syndromes
  – Seizures and their consequences
TBI EVALUATION

• MSE
  – Appearance
    • Psychomotor activity
    • Involuntary movements
    • Motor, gait, speech deficits
    • Dress
  – Speech/language function
    • Coherence/articulation
    • Repetition
    • Naming
    • Prosody
  – Thought processes
    • Circumstantiality
  – Thought content
  – Mood/affect
    • Stability
    • Appropriateness to thought content
TBI COGNITIVE EXAMINATION

- MOCA +/-
- Additional “bedside” tests:
  - Attention:
    - Days of the week forward and backward
    - Months forward and backward
    - Digits forward and digits backward
    - Trails A
  - Complex attention/executive functioning:
    - Trails B
  - Speed of information processing
    - SDMT
  - Word generation:
    - FAS test – word fluency
    - Groceries, animals – semantic fluency
  - Short-term memory:
    - Important to note how many words remembered with cues and with multiple choice
  - Language:
    - Reading, repetition, writing
  - Praxis:
    - Test for apraxia
  - Luria’s motor sequencing task
  - Visual-spatial function
    - Clock drawing – good test, part of MOCA; CLOX 1 and 2 for further examination
    - Rey-Osterrieth figure copying test
ANCILLARY TESTS: NEUROIMAGING

• Structural
  – CT – tissue density
  – MRI – magnetic properties of tissue

• Functional
  – fMRI – BOLD
  – MRS – metabolite concentrations in tissue
  – PET – radioactive tracers
  – SPECT – radioactive tracers
  – EEG, Quantitative EEG – summed neuronal discharges
CT VS. MRI

- Sensitivity good
- Average time for examination 1 minute
- Plane of section axial
- Preferred conditions
  - Acute hemorrhage
  - Calcifications
  - Screening exam
  - Bone injury
  - Identifying path of missile
  - Foreign objects
- Cost - $370-$950 (1)

- Sensitivity superior
- Average time for exam 30-45 minutes
- Plane of section any
- Preferred conditions
  - Temporal lobe detail
  - Frontal lobe detail
  - Posterior fossa, pituitary
  - Contusions
  - Shearing injury
  - SDH and epidural hematomas
  - Diffuse axonal injury
- Sequences – FLAIR, DTI, SWI, volumetric analyses
- Cost - $725-$1850 (1)

(1) http://www.newchoicehealth.com/places/massachusetts/
ANCILLARY TESTS: NEUROIMAGING

• CT – tissue density
  – Sensitive for identifying intracranial hemorrhages that may require neurosurgical interventions in moderate and severe TBI patients presenting to the ED
  – Not useful for the prediction of functional recovery, even in moderate and severe TBI
  – Limited usefulness in the clinical evaluation of mTBI patients presenting to the ED
  – Likely overused in the evaluation of mTBI
ANCILLARY TESTS: NEUROIMAGING

• MRI
  – Moderate clinical utility in both CT-negative and CT-positive TBI
  – Significant utility for research into the evaluation of TBI
  – Increased sensitivity of MRI compared to CT – only 10% of DAI positive on CT because it is non-hemorrhagic
  – Findings rarely affect management in acute TBI
  – Utility in post-acute TBI to evaluate neurological symptoms not explained by CT findings
  – Sequences valuable in TBI:
    • DWI – acute ischemia and white matter injury
    • DTI – mainly for research
    • T2, FLAIR – edema
    • SWI – hemorrhage, though does not determine age of lesion

Amyot F, 2013
fMRI

• Mechanism – BOLD
• Uses (1)
  – During tasks
  – Resting state
  – Before and after treatment
• Limitations
  – Movement of subjects
  – Low signal to noise ratio
  – BOLD contrast relies on small changes of 1-5%
• fMRI in TBI (2)
  – WM tasks in mild TBI vs. healthy controls
  – Mild TBI with increased activation of R PL and R DLPFC during high memory load
  – No differences in performance
  – Mild TBI “work harder” to recall things

(1) Amyot F, 2013; (2) McAllister T et al, 1999
PET/SPECT VS. CT/MRI

• Functional imaging more sensitive
• SPECT abnormalities correlate with severity of trauma (1)
• Findings are nonspecific to TBI
• AAN concluded SPECT is investigational, insufficient evidence to diagnose TBI
• SPECT/PET can be used as part of overall evaluation to confirm findings (2)

(1) Jacobs et al, 1994; (2) Silver and McAllister, 1997
PET AND SPECT

• PET
  – Measures glucose metabolism, oxygen metabolism, neuroreceptor abnormalities, neuroinflammation, amyloid deposits
  – Relationship between clinical deficits and brain abnormalities in chronic TBI
  – Unclear clinical utility
• SPECT
  – Measures cerebral blood perfusion
  – Frequently co-registered with structural imaging
  – Affordable and available
  – Strong evidence for determining a positive prognosis in mTBI patients with normal SPECT perfusion imaging
  – SPECT can identify perfusion/blood deficits in mild, moderate, and severe TBI that anatomic imaging inaccurately identifies or misses altogether
MRS

- **Mechanisms**
  - Different atoms have different responses in a magnet
  - Spectra characterize different molecules
  - Measures concentration of different molecules
    - N-acetyl aspartate found in neurons, not glial cells
    - NAA decreases with decreased number of neurons
    - Creatine is an important energy substrate
- **Abnormal NAA in TBI**
  - Decreased NAA in splenium of 35 patients c/w DAI (1)
  - NAA changes in gray matter predictive of outcome in 14 patients (2)

(1) Cech et al, 1998; (2) Friedman SD et al, 1999
ANCILLARY TESTS:
ELECTROPHYSIOLOGY

• Techniques
  – EEG can detect seizures or abnormal functioning
  – qEEG
  – MEG
  – ERP

• Measures brain activity with temporal resolution superior to functional imaging

• Insufficient evidence to support use of these techniques in detection and diagnosis of TBI
NEUROPSYCHOLOGICAL TESTING

• Orientation
• Mental ability, e.g., WIS
• Speech and language
• Attention
• Memory
• Perception and neglect
• Visuospatial and constructional abilities
• Agnosia and apraxia
• Executive functions
• Conceptual functions, e.g., similarities, WCST
NEUROPSYCHOLOGICAL TESTING

• Group norms

• Indications for NP testing in TBI
  – To establish a baseline or as a follow up
  – To establish pre-injury intelligence
  – To establish ability to go back to work
  – To differentiate functional (i.e., psychiatric) from neurologic (i.e., from TBI) symptoms
  – To help establish whether disability should be covered

• Factors affecting NP test findings
  – Original baseline
  – Environment
  – Motivation and effort
  – Physical health
  – Psychological distress
  – Psychiatric disorders
  – Medications
  – Experience of neuropsychologist
  – Errors in scoring
  – Errors in interpretation
FACTORS AFFECTING TBI FUNCTIONAL OUTCOME

• Factors linked to worse post-injury functional outcomes and greater disability
  – Older age
  – Severity of injury
  – Longer post-traumatic amnesia
  – Anosmia
  – Apolipoprotein E status
  – Pre-injury unemployment
  – More disability at rehabilitation discharge
  – Pre-injury psychiatric history and substance abuse
  – Substance abuse history

• Protective factors
  – Higher baseline intellectual functioning
  – Social support
  – Higher income level
  – Higher education
  – Higher socioeconomic status

Chaytor N et al. 2007; Dikmen and Machamer, 1995; Rimel et al, 1981
FACTORS AFFECTING TBI FUNCTIONAL OUTCOME

• Post-injury factors influencing patients’ functional status
  – Challenging behaviors associated with lower levels of community integration
  – Cognitive impairment and depression strongly and independently related to problems in everyday functioning but weakly related to each other
  – The relationships between depression, cognitive impairment and social adjustment are inadequately studied
  – Appropriate post-injury interventions?
  – Access to rehabilitation programs?
  – Community and family supports?
  – Vocational reintegration?
  – Cognitive rehabilitation?

Chaytor N et al. 2007; Dikmen and Machamer, 1995; Rimel et al, 1981
TREATMENT

• Pharmacotherapy general principles
  – Review prior treatments for effectiveness, dose, side effects
  – Review diagnoses
  – Review indications and SE of meds
  – Review past/current nonpharmacological treatments
  – TBI patients are sensitive to SE of medications
  – Start low, go slow
  – Brain regenerative processes => continued reassessments of medication needs
  – Few double-blind RCT => treatment based on extensions from non-TBI patients
TREATMENT

• Behavioral treatments
  – 75% Effective in disruptive behaviors after TBI (1)
  – The importance of someone in charge of behavioral approaches

• Cognitive rehabilitation
  – Teaching patients new strategies

• Psychosocial interventions
  – Supportive psychotherapy with patient
  – Supportive therapy and education of family
    • 40% of TBI relatives showed depressive symptoms within 1 month;
    • 25% showed physical or psychological illness within 6-12 months (2)
  – Working with existing community resources
    • Rehabilitation programs
    • Communication strategies
    • Vocational rehabilitation

(1) Eames and Wood, 1985; (2) Oddy M, 1978
SUMMARY

• TBI is common
• Consequences of TBI are severe, long-lasting, under-recognized and under-treated
• Role for psychiatry in TBI treatment
  – Neuropsychiatric symptoms
  – Psychological, social, vocational consequences important
• Treatment model
  – Acute and chronic rehabilitation
  – Collaboration between many specialties
THE END