What is TBI?

• TBI Model Systems Definition
  – “Damage to brain tissue caused by external force as evidenced by loss of consciousness (LOC) due to brain trauma, post-traumatic amnesia (PTA), skull fracture, or objective neurological findings that can be reasonably attributed to TBI on physical exam or mental status exam.”

See http://www.neuroskills.com/tbi/facts.shtml

Mechanisms of Injury (Adults)

• 1) Transportation accidents
  – MVA, motorcycle, boating
• 2) Falls
• 3) Assaults/guns
• 4) Sports and recreation

Facts About TBI (in the USA)

• An estimated 1.7 million people sustain a TBI annually

• Of them: 52,000 die, 275,000 are hospitalized, and 1.365 million, nearly 80%, are treated and released from an emergency department.

Facts About TBI (in the USA)

• TBI is a contributing factor to a third (30.5%) of all injury-related deaths in the United States

• Direct medical costs and indirect costs of TBI, such as lost productivity, totaled an estimated $60 billion in the United States in 2000.
Mechanisms of Injury (Youth)

<table>
<thead>
<tr>
<th>Before Age 14</th>
<th>After Age 14</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVA</td>
<td>11%</td>
</tr>
<tr>
<td>Falls</td>
<td>39%</td>
</tr>
<tr>
<td>Assaults</td>
<td>4%</td>
</tr>
<tr>
<td>Other</td>
<td>46%</td>
</tr>
</tbody>
</table>

Keenan & Bratton, 2006; Langlois, Rutland-Brown, & Thomas, 2004

TBI (Youth)

- Leading cause of death and disability for children and adolescents
- Each year in the U.S.:
  - 475,000 children under age 14
  - ~2,685 pediatric deaths
  - Children < age 4 most ED visits
  - Older adolescents (14-18 yrs) most hospitalizations and deaths

Keenan & Bratton, 2006; Langlois, Rutland-Brown, & Thomas, 2004

Individuals Most Likely

- 2:1 male-to-female ratio
- Ethnicity: (controversial) higher in minorities
- | with previous TBI
- | with lower SES
- | with substance use
- | with previous psychiatric diagnosis
- | with learning/attention difficulties

Kraus & Chu, 2005

Measurements of Injury Severity

GCS
- Mild TBI
  - = 13 - 15
- Moderate TBI
  - = 9 – 12
- Severe TBI
  - = 3 - 8

Glasgow Coma Scale

<table>
<thead>
<tr>
<th>Motor Response</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obey commands</td>
<td>5</td>
</tr>
<tr>
<td>Localizing responses to pain</td>
<td>4</td>
</tr>
<tr>
<td>Generalized withdrawal to pain</td>
<td>3</td>
</tr>
<tr>
<td>Flexor posturing to pain</td>
<td>2</td>
</tr>
<tr>
<td>Extensor posturing to pain</td>
<td>1</td>
</tr>
<tr>
<td>No motor response to pain</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Verbal Response</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oriented</td>
<td>4</td>
</tr>
<tr>
<td>Confused conversation</td>
<td>3</td>
</tr>
<tr>
<td>Inappropriate speech</td>
<td>2</td>
</tr>
<tr>
<td>Incomprehensible speech</td>
<td>1</td>
</tr>
<tr>
<td>No speech</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eye Opening Response</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spontaneous eye opening</td>
<td>3</td>
</tr>
<tr>
<td>Eye opening to speech</td>
<td>2</td>
</tr>
<tr>
<td>Eye opening to pain</td>
<td>1</td>
</tr>
<tr>
<td>No eye opening</td>
<td></td>
</tr>
</tbody>
</table>
Measurements of Severity

- Length of loss of consciousness
  - Can initially be a good predictor
  - Big problem, however, with medically-induced comas
  - Often confound the LOC prediction
- Time to follow commands
  - Best predictor of TBI-related outcomes in many studies

What Happens During a TBI?

Classification of TBI

- Closed Head Injury
  - Skull intact, Brain tissue not exposed
  - 90% of civilian head injury
  - Diffuse effects are common
- Penetrating Head Injury (Open Head Injury)
  - Skull and dura are penetrated
  - Focal injury is more common

High Risk Areas for Contusion

From Bigler, 2007
Long-term Changes:

Generalized Atrophy

Length of PTA predicts atrophy: ventricle-to-brain ratio

Specific Atrophy

Structures with greatest degree of atrophy following M/S pediatric TBI

White Matter

Also note the generalized cortical atrophy
Epidemiology of Mild TBI

- Approximately 80% of all head injuries are mild
  - ~145 per 100,000
  - ~400,000 new cases each year
- 2:1 male-to-female ratio
- Age (bi-modal): 14 to 24 or 75+ years
- Treatment costs > $1 billion yearly

see McAllister, 2005

Recovery Following Mild TBI

- Long-term – controversial
  - Several studies show, generally, no effects of mild TBI after initial two-to-three months
    - Primarily use neuropsych or achievement tests
      - e.g. Carroll et al., 2004; Satz, 2001; Satz et al., 1997
  - Others show persisting emotional, behavioral, and physical changes
    - Primarily use subjective ratings of symptoms
      - e.g. Yeates & Taylor, 2005

Risk of Psychiatric D/O

- Increased propensity toward:
  - Depression (20 to 30% of MTBI)
  - Anxiety (24 to 55%)
  - PTSD/Acute Stress D/O (3 to 48%)

see Kirkwood et al., 2007 for review
Take Home for Mild TBI

- 90 to 95% of Mild TBI have full recovery after one year
  - Most asymptomatic after 3-to-6 months
  - Neuropsychological measures may not be extremely sensitive to subtleties
  - Emotional and behavioral sequelae may be better seen on self-report

See Kirkwood et al., 2007 for review

What about after moderate-to-severe TBI?

Cognitive Effects

- Slowed speed for processing information
- Mental fatigue
- Problems concentrating and sustaining attention
- Problems storing new information in memory
- Problems retrieving information from memory
- Difficulties with organization, planning and problems solving
- Problems with expressive and receptive language
- Poor impulse control
- Problems with initiation
- Problems stopping (inhibiting) an activity or a behavior

Physical Difficulties

- Fine motor problems
- Gross motor problems
- Difficulty with coordination and balance
- Physical fatigue
- Vision and hearing problems
- Speech problems

Behavioral Changes

- Low frustration tolerance
- Increased irritability
- Difficulty with changes in activities or schedule
- Decreased inhibitions
- Refusal to ask for or accept help
- Verbal or physical outbursts
- Problems using feedback
- Changes in appetite
- Disruptions of sleep patterns

Adapted from Vandersloeg, 2006
Emotional Difficulties

- Lack of awareness of self or others
- Immature behavior
- Inappropriate laughter or tears
- Constant happy state
- Carelessness in dress or hygiene
- Perseveration in thought, speech or actions
- Rude or obscene behavior
- Crying over small or unimportant things
- Withdrawal
- Denial of physical or cognitive impairments
- Anger and/or emotional outbursts
- Sadness and/or depression
- Negative remarks about self
- Anxiety
- Blunted or flat affect

Predictors of Long-term Outcome

- Injury characteristics
  - Severity
    - Duration of coma, time to follow commands, and PTA (rate of recovery) are generally better predictors of outcome than any static measure, such as lowest GCS
  - Injured area of anatomy
- Environmental influences
  - Pre- and post-injury family functioning
  - Family coping
  - Socioeconomic status

Predictors of Long-term Outcome

- Developmental variation
  - Age at injury
    - Injuries sustained during infancy to early childhood are associated with more persistent deficits than are injuries occurring during later childhood and adolescence (i.e., older at injury = better outcomes)
  - Pre-injury functioning
    - Higher academic achievement prior to injury associated with improved outcomes

Long-term M/S TBI

- Cognitive recovery tends to plateau after ~1 year
- Increased long-term behavior problems in both moderate and severe TBI
  - Predicted by SES and pre-injury behaviors
  - ~40% of severe pediatric TBI survivors showed persistent personality change

Long-term M/S TBI

- Emotional changes among most troubling changes for family members
- Generally decreased academic achievement
- Neuropsychological tests poor predictors of:
  - Changes in self-regulation
  - Interpersonal relationship changes
  - Poor school performance

Case Example