What is Traumatic Brain Injury?

• “… a nondegenerative, noncongenital insult to the brain from an external mechanical force, possibly leading to permanent or temporary impairments of cognitive, physical and psychosocial functions with an associated diminished or altered state of consciousness”
Concussion

- A clinical syndrome characterized by immediate and transient alteration in brain function, including alteration of mental status and level of consciousness, resulting from mechanical force or trauma.

Concussion Symptoms

- Prolonged headache
- Vision disturbances
- Dizziness / “fogginess”
- Nausea or vomiting
- Impaired balance
- Confusion
- Irritability
- Labile / exaggerated emotions
- Memory loss
- Ringing ears
- Difficulty concentrating
- Sensitivity to light
- Sensitivity to sound
- Loss of smell or taste
- Sleep disturbances
- Repetitive questioning

Post Concussive Syndrome

- May last for weeks or months.
- Symptoms include memory and concentration problems, mood swings, personality changes, headache, fatigue, dizziness, insomnia and excessive drowsiness.
- Patients with postconcussive syndrome should avoid activities that put them at risk for further injury.
Normal Head CT

Epidural Hematoma
- Collection of blood between the skull and the dura
- Often caused by laceration of middle meningeal artery by parietal skull fracture
- Classic: + LOC, lucid interval, neurologic decline (signs of ↑ ICP)
- Biconcave on CT
- Most common in temporal area
- Often little or no contusion
- May be surgically evacuated (~1 cm)

EDH – Signs / Symptoms
- Lucid period then decreased LOC
- Headache
- Vomiting
- Seizure
- Unilateral Babinski
- Contralateral hemiparesis
- Ipsilateral pupil dilation
- Mortality 20-55%
Subdural Hematoma

- collection of blood below the dural membrane
- usually venous
- may develop more slowly (venous vs. arterial bleeding)
- may spread over wider surface (not restrained by dura)
- often associated with cerebral contusion and edema
- May occur spontaneously in alcoholics and elderly (atrophy)
- Crescent shaped on CT
- May be surgically evacuated if large mass effect (>1 cm)

SDH - Signs / Symptoms

- Headache
- Decreased level of consciousness
- Abnormal cortical function

Subarachnoid Hemorrhage

- Collection of blood between arachnoid membrane and brain
- Often little “mass effect”, due to diffuse spread
- Irritating to brain
SAH – Signs / Symptoms

- “worst headache of my life”
- Hypertension
- Obtunded
- Nuchal rigidity

Intraparenchymal Hemorrhage

- Bleeding into the tissue of the brain
- Symptoms dependent on area of brain affected

- Symptoms vary depending on size and location of bleed.
- May require surgical intervention / craniotomy
Diffuse Axonal / Shear Injury

- Usually occur with sudden rotation of the head
- Shearing forces “stretch” axons.
- If axon injured but not severed, may recover without secondary injury.

DAI Symptoms

- Headache
- Vary depending on
  - Location
  - Number
  - Size
- May be asymptomatic
- Rarely fatal
- May result in ‘persistent vegetative state’

“At Risk” Groups

- Males are more likely to incur TBI compared to females, (3.4:1)
  - GSW 6:1
  - MVC 2.4:1
- Highest rate of injury: 15-24 years old.
- Also at higher risk:
  - Children <5 years old
  - Elderly > 75 years old
Position Statement
AAST

The Acute Care Surgery Curriculum
The Committee on Acute Care Surgery American Association for the Surgery of Trauma

- ICP monitor placement
- EVD placement

Journal of Trauma, 2007

Position Statement
AAST

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The Committee on Acute Care Surgery American Association for the Surgery of Trauma

- ICP monitor placement
- EVD placement

“Desirable”

Brandon Harris
Brandon Harris SNL after-party 2011
Brandon Harris
- 17 yr old fell asleep at the wheel
- Brother with him
- Parents typical
- Nashville Song Writers
- Arrived by EMS at 6a

Brandon Harris
- Right Wrist fracture
Brandon Harris
- Right Wrist fracture
- Right Femur Fracture
- Atrio-caval Disruption
- Mild TBI
Overview

• Background
• Causes
• Physiologic effects
• Treatment
• Outcomes

Traumatic Brain Injury
Background

• 1.4 million people sustain TBI annually
  – Does not include
    • non-diagnosed
    • military
    • sports-related
  – $56 billion direct/indirect costs
• 50,000 die annually
• Approximately 100,000 long-term disability
  – Over 5 million TBI-related patients

Introduction

• Traumatic Brain Injury (TBI)
  – Accounts for 51.6% of mortality amongst trauma patients
    Dutton J Trauma. 2010
• Intracranial hemorrhagic injury (IHI) progression
  – Longer hospitalizations (14.4 d vs. 9.7 d, p <0.01)
  – Increased mortality (24% vs. 3%, p <0.01)
Traumatic Brain Injury
Overview

- Traumatic brain injury effects all levels of society
- Majority (75 to 90%) recover quickly
  - “Mild” = 90%
- 10 to 25% have long-term deficit
- The “Hidden” TBI patient
  - Emotional distress/cognitive issues

Langlois JHTR 2006
Iverson, Current Opinions Psych, 2005
Cicerone, JHTR, 2004
Gordon, JHTR, 1998
Traumatic Brain Injury

Overview

• 34% are unable to return to work rapidly
  – Majority require up to 3-6 months
  – 25% over one year
• 58% of years of trauma-related lost productivity
• If mortalities included
  – 1.5 million life years lost

Rimel Neurosurgery 1981
Boake Neurosurgery 2005
Max JHTR 1991

Traumatic Brain Injury

Overview

• Costs:
  – Acute care: $8000/day
  – Rehabilitation: $2500/day

• Employment:
  – Approx 60% at time of injury
  – 28% post-injury

Rimel Neurosurgery 1981
Boake Neurosurgery 2005
Max JHTR 1991

Mechanism of Injury

Blunt

• Leading causes of TBI:
  – Falls: 35%
    • Half of children (under 14)
    • Two-thirds >65y
  – MVC: 17%
    • Leading cause of TBI-death (32%)
  – Struck (auto-ped): 17%
  – Assault: 10%

Faux, Inj Prev/Control, 2010
Mechanism of Injury
Blunt

Mechanism of Injury
Blunt

Mechanism of Injury
Blunt
Mechanism of Injury
Blunt

Helmet Safety
Impact of Motorcycle Helmets and State Laws on Society’s Burden
A National Study
Martin A. Cruse, MD, Ron L. Zarraga, MD, Louis J. Magno, MD, and Timothy C. Fabian, MD

- Worse injuries
- More costly
- Consume more resources
- Lower socio-economic status

Annals of Surgery 2009

Traumatic Brain Injury
Severity of Injury

- Concussion
  - Less than 30 min
  - Greater than 30 min
- Post-traumatic amnesia
- Intracranial Hemorrhage (ICH)
- Glasgow Coma Score (GCS)
  - Mild  13-15
  - Moderate  9-12
  - Severe  3-8
Traumatic Brain Injury

Glasgow Coma Score

3-15

- Motor (1-6)
  - Follows commands
  - Localizes to pain
  - Withdraws to pain
  - Flexion
  - Extension
  - No movement

- Verbal (1-5)
  - Oriented/Conversant
  - Confused
  - Inappropriate
  - Incomprehensible
  - None

- Eyes (1-4)
  - Opens Spontaneously
  - Opens to voice
  - Opens to pain
  - None

Teasdale, Lancet, 1976

Traumatic Brain Injury

Intervention

- Immediate
  - Time is brain
- Short-term: Intensive care
  - Monitors
  - Surveillance
  - Management
- Long-term: Post-discharge

Traumatic Brain Injury

Immediate Intervention

- Trauma Team:
- Protection
  - Anoxia
  - Hypotension
- 25% Incr Mortality
  - Individually
- 75% Incr Mortality
  - Combined

Chestnut, JOT 1993
**Traumatic Brain Injury**

Immediate Intervention

- Intubation?
- CT scans?
- Head up
- Sedation
- ICP/CPP management
  - Osmolar therapy
  - Hypertonic saline
- Decompressive craniotomy
- Induced coma
- Hypothermia
- Ancillaries

**Traumatic Brain Injury**

Immediate Intervention

- Repeat head CT scans
  - Beneficial in setting of neurological deterioration
  - *Brown, J Trauma. 2007.*
  - *Koehler, JoT.* 2011
  - Debate for patients with normal or stable clinical exams
  - *Wang, J Trauma. 2006.*
  - *Sifri, J Trauma. 2006.*

**Traumatic Brain Injury**

Immediate Intervention

- Overall IHI progression rate of 16.1%

- IHI progression significantly associated with more severe arrival GCS and H/N AIS scores and requires increased neurosurgical intervention

  *Koehler, JoT, 2011*
### Traumatic Brain Injury

#### CT scan Outcomes

<table>
<thead>
<tr>
<th>Condition</th>
<th>Immediate</th>
<th>Delayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Subdural hematoma</td>
<td>46</td>
<td>3</td>
</tr>
<tr>
<td>Epidural hematoma</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>Axonal shear injury</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Intraparenchymal contusion</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Intraventricular hemorrhage</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vasogenic cerebral edema</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Total (out of 1185)</td>
<td>94</td>
<td>14</td>
</tr>
</tbody>
</table>

#### Immediate Intervention

- Head up
- Sedation
- ICP/CPP management
  - Osmolar therapy
  - Hypertonic saline
- Decompressive craniotomy
- Hypothermia
- Ancillaries
Traumatic Brain Injury
Immediate Intervention

The NEW ENGLAND JOURNAL of MEDICINE

Decompressive Craniectomy in Diffuse Traumatic Brain Injury
D. James Cooper, M.D., Jeffrey V. Rosenfeld, M.D., Lynnette Marines, B.App.Sc., Vassil M. Zakhil, M.D.

- Decreased ICPs
- Decreased LOS
- Worse GOS(E)

Cooper, NEJM, 2011

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Traumatic Brain Injury
Immediate Intervention

CORRESPONDENCE

Cranectomy in Diffuse Traumatic Brain Injury
Koehler,
JoT,
2011

- Bad patient selection
- Bad operative intervention
- Intervention period too long
- ICP elevation too low
- Poor oxygenation remains a problem
- No measure of cerebral blood flow

Editorial Reply, NEJM, 2011

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Traumatic Brain Injury
Immediate Intervention

<table>
<thead>
<tr>
<th>IHI</th>
<th>Mild (12-15)</th>
<th>Moderate (9-12)</th>
<th>Severe (3-8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trit</td>
<td>3.1% (3)</td>
<td>4.3% (1)</td>
<td>2.3% (1)</td>
</tr>
<tr>
<td>ICPM/EVD</td>
<td>3.6% (2)</td>
<td>4.3% (1)</td>
<td>10.3% (11)</td>
</tr>
<tr>
<td>No intervention</td>
<td>91.3% (56)</td>
<td>91.4% (21)</td>
<td>86.9% (95)</td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>23</td>
<td>107</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HHI</th>
<th>0.3% (2)</th>
<th>3.3% (2)</th>
<th>1.0% (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICPM/EVD</td>
<td>0.3% (1)</td>
<td>0.0% (0)</td>
<td>2.3% (0)</td>
</tr>
<tr>
<td>No intervention</td>
<td>99.2% (382)</td>
<td>96.7% (59)</td>
<td>96.2% (38)</td>
</tr>
<tr>
<td>Total</td>
<td>388</td>
<td>63</td>
<td>312</td>
</tr>
</tbody>
</table>

Koehler, JoT, 2011
Traumatic Brain Injury
Immediate Intervention

<table>
<thead>
<tr>
<th>BBB</th>
<th>Mild (1-3)</th>
<th>Moderate (4-8)</th>
<th>Severe (9-30)</th>
<th>9%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craniotomy</td>
<td>3.1% (1)</td>
<td>4.3% (1)</td>
<td>2.8% (3)</td>
<td></td>
</tr>
<tr>
<td>ICPM/EVD</td>
<td>3.4% (2)</td>
<td>4.3% (1)</td>
<td>10.3% (11)</td>
<td></td>
</tr>
<tr>
<td>No intervention</td>
<td>91.5% (16)</td>
<td>95.4% (23)</td>
<td>86.9% (93)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39</td>
<td>25</td>
<td>107</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Moderate (4-8)</th>
<th>Severe (9-30)</th>
<th>1-2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craniotomy</td>
<td>0.5% (2)</td>
<td>3.3% (2)</td>
<td>1.0% (3)</td>
<td></td>
</tr>
<tr>
<td>ICPM/EVD</td>
<td>0.5% (1)</td>
<td>0.0% (0)</td>
<td>2.5% (5)</td>
<td></td>
</tr>
<tr>
<td>No intervention</td>
<td>99.2% (303)</td>
<td>96.7% (59)</td>
<td>96.5% (381)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>308</td>
<td>63</td>
<td>312</td>
<td></td>
</tr>
</tbody>
</table>

Mortality rates for neurosurgical interventions:
- Immediate craniotomy: 23.4% (22/94)
- Late craniotomy: 0% (0/14)
- Immediate ICPM/EVD: 31.9% (45/141)
- Late ICPM/EVD: 43.5% (10/23)

CT scans?
- Head up
- Sedation
- ICP/CPP management
  - Osmolar therapy
  - Hypertonic saline
- Decompressive craniotomy
- Hypothermia
- Ancillaries

Koehler, JoT, 2011
Traumatic Brain Injury
Immediate Intervention

• Intracranial Pressure Monitoring
  – All ‘salvageable’ severe TBI patients
    • GCS <8
    • CT scan with pathology
      – ICH
      – Swelling
      – Herniation
  – Normal CT scan
    • Age >40
    • Posturing
    • Sys BP <90mmHg

Eisenberg, 1996
Koehler, 2011

Traumatic Brain Injury
Immediate Intervention

• Does ICP monitoring improve outcomes?
  – Hypotension and HIGH ICP: BAD
  – Hyper-osmolar therapy for HIGH ICP: BETTER
  – Decompressive Crani for HIGH ICP: WORSE

• What is known:
  – centers utilizing ICP monitors have better outcomes

Strandvik, Anaesthesia, 2009
Himmelseher, Cur Op An, 2007
Shackford, Anz, 1998

Traumatic Brain Injury
Immediate Intervention

• Hyperosmolar Therapy
  – Mannitol to maintain ICPs <20mmHg
    • Early okay
    • Late not much data
  – Hypertonic Saline-no current evidence to support the use/disuse
    • Does decrease ICPs
    • No change in outcomes

Himmelseher, Cur Op An, 2007
Strandvik, Anaesthesia, 2009
Traumatic Brain Injury
Immediate Intervention

• Prophylactic Hypothermia
  – Not significant data
  – Early work suggests mortality benefit

Abiki, Br Inj, 2000
Clifton, Neuro, 2001

J Neurotrauma, 2007
**Traumatic Brain Injury**

**Immediate Intervention**

- **Antiseizure Prophylaxis**
  - Decrease incidence of EARLY seizures (<7d)
  - Dilantin, maybe Valproate
  - NO prevention of LATE seizures (PTS)

- **Steroids**
  - No use

- **Hyperventilation**
  - No use

Temkin, Br J 1999

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**Traumatic Brain Injury**

**Immediate Intervention**

- **Sedation for EEG burst suppression**
  - Prophylactically not recommended
  - Refractory elevated ICP after med mgmt: YES

Jiang, Neursurg, 2000

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**Pentobarbitol Coma Protocol**

- 10mg/kg bolus over 30 minutes
- 5mg/kg/hr continuous infusion x 3 hours
- Then 1mg/kg/hr
- Titrte based on EEG burst suppression (2-5/min)
- Continue for at least 72 hours, then wean to keep ICP<20

**Failure**

- ICP 21-35 > 4 hrs, 36-40 for 1 hr, or > 40 for 5 minutes
- ICP not <20 in 7 days without pentobarbitol
- Brain death/herniation
- Side effect requiring discontinuation (hypotension, sepsis, etc)
Traumatic Brain Injury
Immediate Intervention

- Other issues – Unresolved:
  - Beta-blockade of adrenergic surge
  - Alpha agents for adrenergic surge
  - Progesterone for early TBI
  - Cerebral perfusion monitoring (LYCOX)
  - Jugular bulb O₂ saturation
  - DTI MRI/FLAIR MRI
    - Does it predict long-term status

Jiang, Neursurg, 2000

Traumatic Brain Injury
Who should manage these patients

Long-Term Cognitive, Emotional, and Functional Outcomes in Trauma Intensive Care Unit Survivors Without Intracranial Hemorrhage

- Retrospective review with prospective testing
- Independent of ISS, age, sex, vent days, etc
- Higher DEPRESSION, PTSD, ANXIETY
  - worse in those with concussion

Traumatic Brain Injury
Who should manage these patients

A Prospective Investigation of Long-Term Cognitive Impairment and Psychological Distress in Moderately Versus Severely Injured Trauma Intensive Care Unit Survivors Without Intracranial Hemorrhage

- Prospective enrollment with 1 year testing
- 55% long term cognitive impairment
  - VERY conservative method (2xSD off)
- Depression and PTSD double community
- “Screening tools should focus on potentially over-looked populations”

JoT, 2011
Traumatic Brain Injury
Long-term Outcomes

• Wide range of functional issues
  – Cognitive changes
    • Memory
    • Reasoning
    • Language difficulties (communication/understanding)
  – Senses
    • Loss of hearing, taste, smell
  – Mental Health:
    • Depression
    • Anxiety
    • PTSD

Traumatic Brain Injury
Long-term Outcomes: Depression

<table>
<thead>
<tr>
<th>Setting</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community</td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td>8 - 10%</td>
</tr>
<tr>
<td>Trauma Ctr</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>12 - 20%</td>
</tr>
<tr>
<td>Rehab Ctr</td>
<td>30%</td>
</tr>
<tr>
<td></td>
<td>15 - 50%</td>
</tr>
<tr>
<td>Tertiary Care</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td>16 - 77%</td>
</tr>
</tbody>
</table>

• It all depends on the denominator…
  • All major TBI patients
    – All patient analysis
  • Referral-based in-patient
    – Broad specialty view
  • Referral out-patient
    – Extreme specialty view

AHRQ 11-EHC017-EF Apr ’11

Traumatic Brain Injury
Long-term Outcomes: Associated Findings

• Anxiety:
  – 31% v 77%
• PTSD:
  – 11% v 37%
• Any concommitant:
  – 8.93%
Traumatic Brain Injury
Post-discharge Treatment

- Acute in-patient treatment ‘standardized’
  - ICU care by guideline
- Post-discharge treatment personalized:
  - TBI severity
  - Injury Severity
  - Age
  - Cost

Chestnut, JTR 1999

Traumatic Brain Injury
Cognitive Therapy

- Minimal intervention improves outcome
  - Contact post-discharge 48 hrs
  - Follow-up at 5-7 days
  - Cognitive assessment performed
  - Coping strategies for common symptoms
  - Follow-up at 3 months
- Control Group had increased PCS complaints at follow-up

Ponsford 2002

Questions?