Traumatic Brain Injury
A Trauma Surgeon’s Perspective

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Vanderbilt University
Nashville, Tennessee

@goscar
Conflicts of Interest

• None- except I would rather be with my children or riding the bike right now.
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 post-concussive syndrome should avoid activities that put them at risk for a repeated concussion.
“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
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

CDC, Report to Congress TBI, 2003
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

Background

Langlois JHTR 2006
Traumatic Brain Injury
Overview

• Children and Adolescents:
  – Over 600,000 to ED annually
    • Does not include the majority of PCP visits…
  – Concussion/mild TBI

• Mechanism:
  – Sports: 67%
  – Fall: 24%
  – MVC: 1.8% * (2x)

• One third will have ongoing symptoms

Zemek, NEJM 2016
Eisenberg, J Pediatrics 2014
Post Concussive Symptoms

Children

---

Eisenberg, J Pediatrics 2014
Post Concussive Symptoms
Children

Eisenberg, J Pediatrics 2014
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

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%

Mechanism of Injury

Blunt
Mechanism of Injury

Blunt
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. Croce, MD, Ben L. Zarzaur, MD, Louis J. Magnotti, MD, and Timothy C. Fabian, MD

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

Annals of Surgery 2009
Helmet Safety

Repeal of the Michigan helmet law: the evolving clinical impact

Rebecca H. Striker, D.O.¹,*, Alistair J. Chapman, M.D.¹, Rachel A. Titus, M.D.¹, Alan T. Davis, Ph.D.²,³, Carlos H. Rodriguez, M.D., F.A.C.S.¹,²,⁴

- Worse injuries
  - 2x mortality
  - Worse GOS
- More costly
- Consume more resources

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

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
- Decompressive craniotomy
- Induced coma
- Hypothermia
Traumatic Brain Injury
Immediate Intervention

• Repeat head CT scans
  – Beneficial in setting of neurological deterioration
    
  
  – Debated for patients with normal or stable clinical exams
    
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>Injury Type</th>
<th>Immediate</th>
<th>Delayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Subdural hematoma</strong></td>
<td>46</td>
<td>3</td>
</tr>
<tr>
<td><strong>Epidural hematoma</strong></td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>Axonal shear injury</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Intraparenchymal contusion</strong></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>
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<tr>
<td><strong>Total (out of 1185)</strong></td>
<td><strong>94</strong></td>
<td><strong>14</strong></td>
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# Traumatic Brain Injury

## CT scan Outcomes

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Traumatic Brain Injury
Immediate Intervention

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

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

Cooper, NEJM, 2011
Traumatic Brain Injury
Immediate Intervention

CORRESPONDENCE

Cranietomy in Diffuse Traumatic Brain Injury

• 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
Traumatic Brain Injury
Immediate Intervention

- CT scans?
- Head up
- Sedation
- ICP/CPP management
  - Osmolar therapy
  - Hypertonic saline
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## Traumatic Brain Injury
### Immediate Intervention

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<thead>
<tr>
<th>IHI progression</th>
<th>Mild (13-15)</th>
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<tbody>
<tr>
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<td>5.1% (3)</td>
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<td>3.4% (2)</td>
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<td>10.3% (11)</td>
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<td>91.5% (54)</td>
<td>91.4% (21)</td>
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**Immediate Intervention**

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9% 1-2%

Koehler, *JoT*, 2011
Traumatic Brain Injury
Immediate Intervention

• 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)

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, 1990
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
Traumatic Brain Injury
Immediate Intervention

• Hyperosmolar Therapy
  – Mannitol to maintain ICPs <20mmHg
    • Early okay
    • Late not much data
  – Hypertonic Saline
    • Does decrease ICPs
    • No change in outcomes

Shackford, JoT, 1998
Himmelseher, Cur Op An, 2007
Strandvik, Anaesthesia, 2009
Traumatic Brain Injury
Immediate Intervention

Figure 1: Percentage of Patients Reaching Goal Osmolality and Osmolality Values at Goal while on HTS

- Patients Reaching Goal Osmolality: 93.9%, p=0.003
- Osmolality Values at Goal on HTS: 73.3% and 80%, p=0.032

Maguigan, PharmTh 2016
Traumatic Brain Injury
Immediate Intervention

- Superior effectiveness in decreasing ICPs
- No benefit long-term outcomes

Mortazavi JNSGY 2012
Traumatic Brain Injury
Immediate Intervention

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

  Abiki, *Br Inj*, 2000

<table>
<thead>
<tr>
<th>Study or sub-category</th>
<th>Hypothermia n/N</th>
<th>Control n/N</th>
<th>RR (random) 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abiki, 2000</td>
<td>12/15</td>
<td>4/11</td>
<td>2.20 [0.97, 5.00]</td>
</tr>
<tr>
<td>Clifton, 1993</td>
<td>13/24</td>
<td>8/22</td>
<td>1.49 [0.77, 2.89]</td>
</tr>
<tr>
<td>Clifton, 2001</td>
<td>92/190</td>
<td>76/178</td>
<td>1.01 [0.80, 1.28]</td>
</tr>
<tr>
<td>Jiang, 2000</td>
<td>20/43</td>
<td>12/44</td>
<td>1.71 [0.96, 3.04]</td>
</tr>
<tr>
<td>Marion, 1997</td>
<td>24/39</td>
<td>16/42</td>
<td>1.62 [1.02, 2.55]</td>
</tr>
<tr>
<td>Qiu, 2005</td>
<td>28/43</td>
<td>16/43</td>
<td>1.75 [1.12, 2.73]</td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td><strong>354</strong></td>
<td><strong>340</strong></td>
<td><strong>1.46 [1.12, 1.92]</strong></td>
</tr>
</tbody>
</table>

Total events: 179 (Hypothermia), 132 (Control)
Test for heterogeneity: Chi² = 9.53, df = 5 (P = 0.09), I² = 47.5%
Test for overall effect: Z = 2.76 (P = 0.006)

*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)

Temkin, Br Inj 1999
Traumatic Brain Injury
Keppra v Dilantin

- No difference in prevention
- No difference in safety

NeuroCC 2016
Traumatic Brain Injury
Immediate Intervention

• Steroids
  – No use

• Hyperventilation
  – No use
Traumatic Brain Injury
Immediate Intervention

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

Jiang, Neursurg, 2000
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
Traumatic Brain Injury
Who should manage these patients

• 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

James C. Jackson, PsyD, Kristin R. Archer, PhD, Rebecca Bauer, MD, Christine M. Abraham, MA, Yanna Song, MA, Robert Greevey, PhD, Oscar Guillamondeguí, MD, E. Wesley Ely, MD, and William Obremskey, MD

- 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
Symptomatology and Functional Outcome in Mild Traumatic Brain Injury: Results from the Prospective TRACK-TBI Study

Paul J. McMahon,1,2 Allison Hricik,1 John K. Yue,3 Ava M. Puccio,1 Tomoo Inoue,3 Hester F. Lingsma,4 Sue R. Beers,5 Wayne A. Gordon,6 Alex B. Valadka,7 Geoffrey T. Manley,3 and David O. Okonkwo3 and the TRACK-TBI investigators including Scott S. Casey,3 Shelly R. Cooper,3 Kristen Dams-O’Connor,6 David K. Menon,8 Marco D. Sorani,3 Esther L. Yuh,9 Pratik Mukherjee,9 David M. Schnyer,10 and Mary J. Vassar3

• 375 mTBI patients
  – GCS 13-15
  – 210 CT neg
  – 165 CT pos
  – All sent home from ED

McMahon, JNeurotrauma, 2014
6 and 12 month follow up

- 82% had at least one PCS symptom
- Reduced Satisfaction with Life scores
  - 44% at 6 months
  - 40% at 12 months
- 22% were still below full functional level at one year

McMahon, JNeurotrauma, 2014
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>Percentage</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community</td>
<td>10%</td>
<td>8 - 10%</td>
</tr>
<tr>
<td>Trauma Ctr</td>
<td>20%</td>
<td>12 - 20%</td>
</tr>
<tr>
<td>Rehab Ctr</td>
<td>30%</td>
<td>15 - 50%</td>
</tr>
<tr>
<td>Tertiary Care</td>
<td>35%</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 concomitant: 8-93%

AHRQ 11-EHC017-EF Apr ‘11
Traumatic Brain Injury
Long-term Outcomes

• Epilepsy
• Increased risk of CNS issues
  – Alzheimer’s
  – Parkinson’s Disease
  – Cerebrovascular issues
    • Stroke
• Cumulative effect shown to worsen outcomes
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, JHTR 1999
Traumatic Brain Injury

Post-discharge disability

Disability Rating Scale

Percentage of Patients

- Rehab. Admit (n=10050)
- Rehab. DC(n=10043)
- 1 Yr. Post-Injury (n=7418)
Traumatic Brain Injury
Post-discharge disability

Disability Rating Scale

Average DRS Score

0 5 10 15 20 25 30

Rehab. Admission (n=10050) 12.39 Severe Disability
Rehab. Discharge (n=10043) 6.32 Moderate Disability
1 Yr. Post-Injury (n=7420) 2.84 Partial Disability
2 Yrs. Post-Injury (n=6156) 2.53 Partial Disability
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
Traumatic Brain Injury

Cognitive Therapy

• Increased intervention improves outcome
  – RCT (small: 24 cases/27 controls)
  – Intensive intervention led to more rapid progress
  – Those with progress discharged sooner
  – Intensity of therapy had no ‘ceiling effect’
  – Cost-effectiveness remains an issue

Shiel, *Clin Rehab* 2001
Traumatic Brain Injury

Post-discharge disability

**Functional Independence Measure**

Mean Scores converted to 7-point scale

<table>
<thead>
<tr>
<th></th>
<th>Complete Independence</th>
<th>Modified Independence</th>
<th>Supervision</th>
<th>Minimal Assistance</th>
<th>Moderate Assistance</th>
<th>Maximal Assistance</th>
<th>Total Assistance</th>
</tr>
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<tr>
<td>1 Yr. (n=7251)</td>
<td>6.32</td>
<td>6.39</td>
<td>5.1</td>
<td>2.9</td>
<td></td>
<td></td>
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<tr>
<td>2 Yr. (n=6001)</td>
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Rehab. Admit. (n=9861)
Rehab. Disch. (n=9781)
Traumatic Brain Injury
Who should manage these patients

- Trauma Surgery
Traumatic Brain Injury
Who should manage these patients

• Trauma Surgery
  – And everyone else.
Traumatic Brain Injury
Who should manage these patients

• Trauma Surgery
  – And everyone else.

• Neurosurgery when necessary
Traumatic Brain Injury
Who should manage these patients

• Trauma Surgery
  – And everyone else.

• Neurosurgery when necessary
  – Approximately 10% of TBI patients
Traumatic Brain Injury
Who should manage these patients

- Trauma Surgery
  - And everyone else.
- Neurosurgery when necessary
  - Approximately 10% of TBI patients
- Comprehensive Evaluation Clinic
Traumatic Brain Injury
Who should manage these patients

• Trauma Surgery
  – And everyone else.

• Comprehensive Evaluation Clinic
  – Cognitive analysis
  – Mental health survey
  – Quality of life survey
  – Social Work
  – Peer Group
Multidisciplinary TBI Clinic

• Team
  – Trauma Surgeon
  – Nurse Practitioner
  – Social worker
  – Speech Pathologist
  – Brain Injury Association of Tennessee
  – Program Manager
  – Trauma Survivor Network Peer Visitor
Multidisciplinary TBI Clinic

- **Program**
  - Identify patients with Intracranial Hemorrhage
    - Upon admission
    - Consult with Speech-Pathologist
  - Cognitive Assessment prior to discharge
    - Include RANCHO
    - GOAT, Digit Span (see form)
  - Head injury literature at discharge
    - Contact information
Multidisciplinary TBI Clinic

• Program- 3 month follow-up
  – No charge visit
  – Physical Exam
    • Follow-up on any issues related to trauma
  – Cognitive Evaluation
  – QoLIBRI survey
  – Mental Health Screening
    • HADS
Multidisciplinary TBI Clinic

• Program- 3 month follow-up
  – Peer group interaction
    • TSN involvement
    • Brain Injury Association of TN
  – Personalized information on referrals/resources
    • Jean Doster-TBI Foundation of TN
Traumatic Brain Injury

What Next?

• Radiologic Imaging
  – DTI
  – Others

• Genome analysis
  – ‘At risk’ populations

• Improved prevention methods
  – Not hurt = no sequelae
Traumatic Brain Injury
A Trauma Surgeon’s Perspective

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