TMI on TBI: Everything You Wanted to Know About TBI

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Disclosures

• No financial disclosures
• I do work in academia
Charleston SC
Disclosures

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For updated slides

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Objectives

• Review the basic pathophysiology behind traumatic brain injury

• Describe the treatment strategies that can be employed, as well as those that should be avoided by emergency physicians in their care of the TBI patient
TBI Epidemiology

- It matters!
  - 1.7 million cases per year in the US
  - 52,000 deaths with 275,000 hospitalizations
    - And these numbers are rising
  - Primary cause of mortality in trauma for children
  - 473,000 ED visits in children 0-14 per year

- CDC data, pub 2010
Traumatic Brain Injury

- TBI is a heterogeneous pattern of injury with devastating outcomes
  - This clinical heterogeneity is a challenge
    - Poor markers and prognostic information
    - Poor surrogates for trials
    - Classification is rudimentary
- Interventions are essentially unchanged in the last 20 years and outcomes can be devastating
- Oxidative stress is known to be a major cause of pathology in TBI
Mechanisms of traumatic brain injury

- ICP
- CPP
- Swelling
- Hematoma
- Contusion
- Hypoxia/ischemia
- Diffuse axonal injury
- Systemic insults
Pathophysiology of TBI

• **Primary Injury**
  - The direct injury from trauma

• **Secondary Injury**
  - Inflammation, ischemia, reperfusion, apoptosis, oxidative stress, uncoupling in the mitochondria
  - Formation of free radicals in oxidative stress results in further injury
    - Can be measured- 8-Isoprostone, F4Neuroprostone
  - Further cell injury over subsequent days
    - Cytokine elevation, further apoptosis, necrosis
    - Other stresses in ICU or polytrauma
Oxidative Stress

Zhang et al. Critical Care, Volume 9:1, 66-75, 2005
Oxidative Stress in TBI

• Primarily studied in animal models of TBI
  – Controlled trauma
  – Reproducible
  – Whole brain samples
• Correlates with outcome in animal models
• Limited human experience
TBI is heterogeneous

• Many types
  – Epidural
  – Subdural
  – Intraventricular or intracerebral hemorrhage
  – Subarachnoid
  – Diffuse Axonal Injury
  – Penetrating
Intracerebral/parenchymal

- Bleeding within brain parenchyma with edema
- Traumatic and nontraumatic causes

Traumatic-MVA
SUBDURAL

- Collection of blood below the inner layer of the dura
- External to the brain and arachnoid membrane
- Concave
- Most common type of traumatic intracranial mass lesion
EPIDURAL

- Accumulation of blood in the potential space between dura and bone
- Separation of the periosteal dura from bone and disruption of interposed vessels due to shearing stress
- Convex due to limitation by tight attachment of dura at suture lines
Epidural Hematoma
Epidural

- Skull fractures in 85-95% of adults but much less common in children
- Can be surgical emergency—requires immediate diagnosis and surgical intervention
- Variable presentation
Subarachnoid

- Extravasation of blood into the subarachnoid space between the pial and arachnoid membranes
- Spontaneous or traumatic rupture of artery

SAH in right sylvian fissure (MCA)
**DIFFUSE AXONAL INJURY**

- Traumatic deceleration injury - shearing of tissue and disruption of axons
- Most significant cause of morbidity in TBI (e.g. frequent cause of PVS)
- Several focal white matter lesions 1-15mm in diameter (petechial hemorrhages)
- Classically located at the gray-white matter interface
- 50-80% have normal CT upon presentation
HERNIATION

• Supratentorial
  – 1. Uncal/transtentorial-unilateral pupil dilation
  – 2. Central-fatal
  – 3. Cingulate/subfalcine-most common
  – 4. Transcalvarial

• Infratentorial
  – 5. Upward cerebellar/transtentorial
  – 6. Tonsillar or downward cerebellar
PENETRATING TBI
Concussion

Concussion: A traumatic brain injury that changes the way your brain functions.

This can lead to bruising and swelling of the brain, tearing of blood vessels and injury to nerves, causing the concussion.

The brain is made up of soft tissue and is protected by blood and spinal fluid. When the skull is jolted too fast or is impacted by something, the brain shifts and hits against the skull.

Most concussions are mild and can be treated with appropriate care. But left untreated, it can be deadly.
Prehospital

STOP SCREAMING...
"I'M SCARED TOO"
Prehospital Care of TBI

- Scene Safety
- PPE
- ABC
- Time and distance for transport
- New paradigms?
Pre-hospital Care

• Protect c-spine as indicated
• Cervical collar should be tight enough to prevent movement, but loose enough to allow you to easily stick a finger between collar and neck
• Overtightening limits jugular drainage which increases ICP
• Raise head of bed?
Oxygenation

- A **single episode** of hypoxia greatly increases the risk of death/disability
- Unclear if helpful if O2 sat >95% already

<table>
<thead>
<tr>
<th>O2 Sat</th>
<th>Mortality</th>
<th>Severe Disability</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;90%</td>
<td>14.3%</td>
<td>4.8%</td>
</tr>
<tr>
<td>60-90%</td>
<td>27.3%</td>
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<tr>
<td>&lt;60%</td>
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Ventilation

- pCO2 affects cerebral vasomotor tone
- EtCO2 is becoming standard of care
- Goal is 35 mmHg
- Over/Under-ventilation can be harmful
Fluid resuscitation

• TBI should not cause hypotension
• A **single episode** of hypotension greatly increases risk of death/disability (>2x)
• Saline currently IVF of choice
  – Maintain SBP > 100 mmHg
• Ongoing trials of Hypertonic Saline
**Herniation**

- **Signs & symptoms**
  - Anisocoria or nonreactive pupils
    - Sunsetting
  - Changes in mental status
    - GCS
    - Posturing
  - Vomiting
  - Headache

- **Emergency management**
  - Hyperventilate briefly-Avoid PaCO2 <30 mmHg
  - Mannitol 0.5 –1 gm/kg IV
  - 100% oxygen

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**Cushing’s Triad**
- Hypertension
- Bradycardia
- +/- Abnormal breathing
Case 1
Treatment

Primum non nocere
Immobilization

• Protect Cervical spine as indicated
• Injury that causes TBI can cause cervical spine injury especially in children
• Cervical collar should be tight enough to prevent movement, but loose enough to allow you to easily stick a finger between collar and neck
• Overtightening limits jugular drainage which increases ICP
• Minimize environmental exposure
Head of Bed Elevation

• Raising HOB to 30 degrees increases jugular venous drainage without decreasing arterial flow

• Easy to do
  – reverse trendelenburg if spinal precautions

• Avoid if systemic hypotension

• Can this be done in the field?
Killers in TBI

Chestnut 1993 J Trauma
Airway Management

• “GCS of 8 = Intubate”
• This can be complicated though
• ICP elevation with alternative airways?
• Unintentional hypoxia?
• Unintentional hyperventilation?
• Pre-treatment?
  – Lidocaine?
  – Defasciculating agent?
Airway Management

- If your patient needs intubation, do not withhold and maximize your chances.
- The only cardinal sin in EMS/EM is the unrecognized esophageal intubation.
- Tube displacement happens.
- Continuous waveform capnography helps.
Oxygenation

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- A single episode of hypoxia greatly increases the risk of death/disability
- Unclear if helpful if O2 sat >90% already
Ventilation

• pCO2 affects cerebral vasomotor tone
• ETCO2 is standard of care in EMS and EM
• Goal is 35 mmHg
• Hypocapnea is capable of reducing cerebral blood flow 4% for each mmHg drop in PaCO2
• Over/Under-ventilation can be harmful!
Perfusion: Fluid Resuscitation

• TBI should not cause hypotension
• A single episode of hypotension greatly increases risk of death/disability (>2x)
• Saline currently IVF of choice to maintain MAP
• Ongoing trials of Hypertonic S
Perfusion

- Intracranial pressure does not exist in a vacuum
- Intrathoracic pressure is bad
  - Increases ICP
  - Decreases venous return
  - Cerebral and systemic perfusion pressures drop
- Overbagging increases intrathoracic pressure
A Trial of Intracranial-Pressure Monitoring in Traumatic Brain Injury

Randall M. Chesnut, M.D., Nancy Temkin, Ph.D., Nancy Carney, Ph.D., Sureyya Dikmen, Ph.D., Carlos Rondina, M.D., Walter Videtta, M.D., Gustavo Petroni, M.D., Silvia Lujan, M.D., Jim Pridgeon, M.H.A., Jason Barber, M.S., Joan Machamer, M.A., Kelley Chaddock, B.A., Juanita M. Celix, M.D., Marianna Cherner, Ph.D., and Terence Hendrix, B.A.
Most pediatric TBI studies are of poor or moderate quality.

Virtually all of the recommendations are lowest level (III).
Case 2

- 8 yo girl riding her bike hits a post and falls to the ground
  - She has LOC on scene
  - Brought in by EMS fully immobilized
  - Normal vitals, normal neurologic exam
  - Bump on her forehead

- Does she need a CT?
- What do you tell the parents?
Who needs a CT?

• Challenging and tough question
Radiation Risk

- Very difficult question
- Age makes a large difference
- Dosing makes a large difference
- Maybe as high as 1 in 1000
- Maybe 500 cases out of 600,000 total scans


Brenner D, Elliston C, Hall E, Berdon W.
Center for Radiological Research, Columbia University, 630 W. 168th St., New York, NY 10032, USA.
Radiation Risk

xamination for a single typical CT examination of head (*broken dotted line*) and of abdomen (*broken solid line*). Note rapid increase in risk with decreasing age.
The Canadian CT Head Rule for patients with minor head injury

Ian G Stiell, George A Wells, Katherine Vandemheen, Catherine Clement, Howard Lesiuk, Andreas Laupacis,
R Douglas McKnight, Richard Verbeek, Robert Brison, Daniel Cass, Mary A Eisenhauer, Gary H Greenberg, James
Worthington, for the CCC Study Group

Panel 1: Canadian CT Head Rule

CT Head Rule is only required for patients with minor head injuries with any one of the following:

High risk (for neurological intervention)
- GCS score <15 at 2 h after injury
- Suspected open or depressed skull fracture
- Any sign of basal skull fracture (haemotympanum, ‘raccoon’ eyes, cerebrospinal fluid otorrhoea/rhinorrhoea, Battle’s sign)
- Vomiting ≥two episodes
- Age ≥65 years

Medium risk (for brain injury on CT)
- Amnesia before impact >30 min
- Dangerous mechanism (pedestrian struck by motor vehicle, occupant ejected from motor vehicle, fall from height >3 feet or five stairs)

Minor head injury is defined as witnessed loss of consciousness, definite amnesia, or witnessed disorientation in a patients with a GCS score of 13–15.
520 patients in phase one then
909 patients to validate

All GCS 15, positive LOC, normal neuro exam

About 6% positive CT scans
Age 3-97 mean 36, 65% male

Level 1 trauma center in New Orleans
PECARN HEAD CT GUIDELINE

Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study


42,412 children including 8502 and 2216 younger than 2 years

CT scans on 14,969 376 (0.9% with clinically important TBI)

Prospective cohort using PECARN
Less than 2

A

GCS=14 or other signs of altered mental status†, or palpable skull fracture

Yes

13.9% of population
4.4% risk of ciTBI

CT recommended

No

Occipital or parietal or temporal scalp haematoma, or history of LOC ≥5 s, or severe mechanism of injury‡, or not acting normally per parent

Yes

32.6% of population
0.9% risk of ciTBI

Observation versus CT on the basis of other clinical factors including:
• Physician experience
• Multiple versus isolated§ findings
• Worsening symptoms or signs after emergency department observation
• Age <3 months
• Parental preference

No

53.5% of population
<0.02% risk of ciTBI

CT not recommended¶

Older than 2

B

GCS=14 or other signs of altered mental status†, or signs of basilar skull fracture

Yes

14.0% of population
4.3% risk of ciTBI

CT recommended

No

History of LOC, or history of vomiting, or severe mechanism of injury‡, or severe headache

Yes

27.7% of population
0.9% risk of ciTBI

Observation versus CT on the basis of other clinical factors including:
• Physician experience
• Multiple versus isolated§ findings
• Worsening symptoms or signs after emergency department observation
• Parental preference

No

58.3% of population
<0.05% risk of ciTBI

CT not recommended¶
CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury

Martin H. Osmond MD CM, Terry P. Klassen MD, George A. Wells PhD, Rhonda Correll RN, Anna Jarvis MD, Gary Joubert MD, Benoit Bailey MD, Laurel Chauvin-Kimoff MD CM, Martin Pusic MD, Don McConnell MD, Cheri Nijssen-Jordan MD, Norm Silver MD, Brett Taylor MD, Ian G. Stiell MD; for the Pediatric Emergency Research Canada (PERC) Head Injury Study Group

- 3866 patients, mean age 9.2 years
- CT on 2043 patients
- GCS 13-15
- 4% had a brain injury

- Not prospectively validated yet
CATCH: a clinical decision rule for the use of computed tomography in children with minor head injury

Martin H. Osmond MD CM, Terry P. Klassen MD, George A. Wells PhD, Rhonda Correll RN, Anna Jarvis MD, Gary Joubert MD, Benoit Bailey MD, Laurel Chauvin-Kimoff MD CM, Martin Pusic MD, Don McConnell MD, Cheri Nijssen-Jordan MD, Norm Silver MD, Brett Taylor MD, Ian G. Stiell MD; for the Pediatric Emergency Research Canada (PERC) Head Injury Study Group

in a patient with a Glasgow Coma Scale score of 13–15.
Treatment and disposition of mild TBI

• Well it depends...
  – On other injuries
  – On the family
  – Timing of injury
  – On imaging
  – On follow-up
Case the third

- 12 yo boy playing soccer has an on field collision with another player. Falls to the ground. Gets up with assistance, at the sideline is unsteady and complains of being dizzy.
- But it’s the big game for the playoffs!
- Can he go back in?
- What do you tell the parents?
Consensus Statement on Concussion in Sport
3rd International Conference on Concussion in Sport
Held in Zurich, November 2008

Paul McCrory, MBBS, PhD,* Willem Meeuwisse, MD, PhD,† Karen Johnston, MD, PhD,‡
Jiri Dvorak, MD,§ Mark Aubry, MD,¶ Mick Molloy, MB,§¶ and Robert Cantu, MA, MD#$


Preamble
This paper is a revision and update of the recommendations developed following the 1st (Vienna) and 2nd (Prague) International Symposia on Concussion in Sport.1,2 The Zurich Consensus statement is designed to build on the principles outlined in the original Vienna and Prague documents and to develop further conceptual understanding of this problem using a formal consensus-based approach. A detailed description of the consensus process is outlined at the end of this document under the “Background” section (see Section 11). This document is developed for use by physicians, therapists, certified athletic trainers, health professionals, coaches and other people involved in the care of injured athletes, whether at the recreational, elite or professional level.

While agreement exists pertaining to principal messages conveyed within this document, the authors acknowledge that the science of concussion is evolving and therefore management and return to play decisions remain in the realm of clinical judgment on an individualized basis. Readers are encouraged to copy and distribute freely the Zurich Consensus document and/or the Sport Concussion Assessment Tool (SCAT2) card, and neither is subject to any copyright restriction. The authors request, however, that the document and/or the SCAT2 card be distributed in their full and complete format.

The following focus questions formed the foundation for the Zurich concussion consensus statement:

Acute Simple Concussion
• Which symptom scale and which sideline assessment tool is best for diagnosis and/or follow up?
• How extensive should the cognitive assessment be in elite athletes?
• How extensive should clinical and neuropsychological (NP) testing be at non-elite level?
• Who should do/interpret the cognitive assessment?
• Is there a gender difference in concussion incidence and outcomes?

Return to Play (RTP) Issues
• Is provocative exercise testing useful in guiding RTP?
• What is the best RTP strategy for elite athletes?
• What is the best RTP strategy for non-elite athletes?
• Is protective equipment (e.g., mouthguards and helmets) useful in reducing concussion incidence and/or severity?

Complex Concussion and Long-term Issues
• Is the Simple versus Complex classification a valid and useful differentiation?
• Are there specific patient populations at risk of long-term problems?
• Is there a role for additional tests (e.g., structural and/or functional MR imaging, balance testing, biomarkers) in patients with persistent symptoms?
• Should athletes with persistent symptoms be screened for depression/anxiety?

Paediatric Concussion
• Which symptoms scale is appropriate for this age group?
• Which tests are useful and how often should baseline testing be performed in this age group?
• What is the most appropriate RTP guideline for elite and non-elite child and adolescent athletes?
Concussion

- 3rd International Conference on Concussion in Sport 2008
- A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.
  - May be caused by a direct blow or an impulsive force to the head
  - May result in neuropathological changes, but largely reflects functional rather than structural injury
  - No abnormality on standard structural neuroimaging
  - May or may not involve loss of consciousness
  - Typically results in rapid onset of short lived impairment of neurologic function that resolves spontaneously
  - Resolution of symptoms typically follows a sequential course; small percentage prolonged
- Concussion
Concussions

• Cumulative Effects from Repetitive Insults
• Concussion
• Evolving support for more severe sequelae after repetitive concussions for:
  • – Physiological recovery • Spectroscopy
  • – Electrophysiological recovery • Evoked Potential Studies
  • – Cognitive recovery • Neuropsychological Testing
  • – Balance recovery • Virtual Reality motion systems
  • – Symptom recovery: • Graded Symptom Scales
Concussion Symptoms

- **Physical**
  - Headache
  - Fatigue
  - Dizziness
  - Balance problems
  - Nausea
  - Sensitivity to light
  - Sensitivity to noise

- **Emotional**
  - Irritability
  - Sadness
  - Feeling more emotional
  - Nervousness

- **Cognitive**
  - Difficulty remembering
  - Difficulty concentrating
  - Feeling slowed down
  - Feeling mentally foggy

- **Sleep**
  - Drowsiness
  - Sleeping less than usual
  - Sleeping more than usual
  - Trouble falling asleep
Evaluation and Management of Concussion

- Need a program approach
- Education
- Preasessment, Baseline testing
- Injury protocol
- Clearance
- Impaired attention -- vacant stare, delayed responses, inability to focus
- Slurred or incoherent speech
- Gross incoordination
- Disorientation/Confusion
- Emotional reactions out of proportion
- Memory deficits
- Any loss of consciousness
• National Athletic Trainers Position Statement
• Activate Emergency Medical System – Deterioration of Neurological Function – Deceasing Level of Consciousness – Decrease or Irregularity of Respirations – Decrease or Irregularity of Pulse – Unequal, Dilated or Unreactive Pupils – Mental Status Changes – Seizure Activity – Mental Status Changes
Concussion

In-Season Concussion Management Removal from Play
• Zurich 2008 Guidelines
  – Any athlete suspected of concussion should be immediately removed from play and should not return to play that practice or game
  – Same day return to play possible in some adult athlete settings with sufficient resources to evaluate
Concussion should be suspected in the presence of any one or more of the following: symptoms (such as headache), or physical signs (such as unsteadiness), or impaired brain function (e.g. confusion) or abnormal behaviour.

1. Symptoms
Presence of any of the following signs & symptoms may suggest a concussion.

- Loss of consciousness
- Seizure or convulsion
- Amnesia
- Headache
- "Pressure in head"
- Neck Pain
- Nausea or vomiting
- Dizziness
- Blurred vision
- Balance problems
- Sensitivity to light
- Sensitivity to noise
- Feeling slowed down
- Feeling like "in a fog"
- "Don't feel right"
- Difficulty concentrating
- Difficulty remembering
- Fatigue or low energy
- Confusion
- Drowsiness
- More emotional
- Irritability
- Sadness
- Nervous or anxious
2. Memory function

Failure to answer all questions correctly may suggest a concussion.

“At what venue are we at today?”
“Which half is it now?”
“Who scored last in this game?”
“What team did you play last week’s game?”
“Did your team win the last game?”

3. Balance testing

Instructions for tandem stance

“Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. You should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes.”

Observe the athlete for 20 seconds. If they make more than 5 errors (such as lift their hands off their hips; open their eyes; lift their forefoot or heel; step, stumble, or fall; or remain out of the start position for more than 5 seconds) then this may suggest a concussion.

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, urgently assessed medically, should not be left alone and should not drive a motor vehicle.
Concussion Resources

- www.cdc.gov/tbi
  - Heads up! Program
  - Lots of program info
  - Education info
  - Data
MUSC Neurology Concussion Clinic

• 100+ patients experience
• Multidisciplinary group
• Neuropsychological testing and interventions
MUSC Sports Neuroscience Program

Attending Physicians

Neurology
• Jonathan Edwards, M.D. Pediatric/Adult concussion, seizures
• Rebecca Lehman, M.D. Pediatric concussion, child neurology
• David Stickler, M.D. Neuromuscular and concussion
• Aljoeson Walker, M.D. Headache

Neurosurgery
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• Alex Vandergrift III, M.D. Neurosurgery
• Abhany Varma, M.D. Neurosurgery

Residents
• Jay Madey, M.D Neurology  Jarom Hanson, M.D Neurology
• Nolan Williams, M.D Neurology  Matt McCaskill, D.O Neurology
• Jeff Bodle, M.D Neurology  Sam Taylor, M.D Neurosurgery
• Justin Nolte, M.D Neurology  Jonathan Lena, M.D Neurosurgery
• Neal Maru, M.D Neurology  Yana Mikhaylov, M.D. Neurosurgery
Each step requires 24 hrs!!

1. No activity, complete rest.
   Once asymptomatic, proceed to step 2.

2. Light aerobic exercise
   (walking/stationary cycling).

3. Sport specific training
   (skating in hockey, running in soccer).

4. Non-contact training drills.

5. Full-contact training after medical clearance.

6. Game play.
Case Three

• 12 yo boy playing soccer has an on field collision with another player. Falls to the ground. Gets up with assistance, at the sideline is unsteady and complains of being dizzy.
• But it’s the big game for the playoffs.
• Can he go back in?
• What do you tell the parents?
MUSC Sports Neuroscience Program

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Making a difference

• ATV Legislation
  – Chandlers Law

• Concussion Legislation

• Safety and Prevention

• Discussion with Patients
What can you do?

Rudolf Virchow
(1821-1902)

“Medicine is a social science, and politics nothing but medicine on a grand scale...”
Summary

- TBI is a common and serious injury especially in pediatric patients
- New guidelines can significantly decrease CT usage
- Concussion is a increasingly recognized problem
- Return to play guidelines and treatments have improved dramatically
Summary
For updated slides

- borgk@musc.edu
References
Acknowledgements
Thanks