Concussions: Diagnosis, Management and the world of known unknowns

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Disclosures

• I have no Financial Conflicts of Interest to Declare

• I will discuss a small study of an off-label use of IV fluids
Lecture Overview

- Focus of Sports Related Concussion (SRC)
- Definitions
- Scope of Problem/Epidemiology
- Mechanisms of Concussion
- Presenting signs/symptoms
- Diagnosis/Neuroimaging/Biomarkers
- Management Strategies
- Long-Term Prognosis
- The CTE debate

Why is Concussion so vexing?

- Hard to define
- Mechanisms are variable
- Diagnosis is mostly based on subjective symptom report
- No ‘Gold Standard’ for diagnosis
- Significant overlap with other physical and psychological conditions
- Recovery trajectory is variable
- Confounding motivations regarding return to activities without objective benchmarks
Lots of Definitions!

Definitions

Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016

Berlin Consortium Definition

Concussion is a traumatic brain injury induced by biomechanical forces

- Either direct blow or transmitted force
- Rapid onset, short lived, spontaneously resolving impairment of neurologic function
- Functional imaging without evidence on standard neuroimaging
- Results in a range of clinical symptoms, with or without LOC, with sequential course. In some cases may be prolonged
- Cannot be explained by drugs or other injuries

Epidemiology

- Estimates up to 3.8 million SRCs annually
  - 1.1 to 1.9 million annual concussions in children
  - This does not include many patients who do not report
  - 40-80% of high school athletes did not report concussion symptoms
Concussion rates

- Of Local interest....
- 16.9 concussions per 1,000,000 person-years for skiers
- 17.4 concussions per 1,000,000 person-years for snowboarders.

### TABLE 1 Concussion Rates in High School Sports

<table>
<thead>
<tr>
<th>Sport</th>
<th>Concussions per 1000 AEY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys' tackle football</td>
<td>0.54-0.94</td>
</tr>
<tr>
<td>Girls' soccer</td>
<td>0.80-0.73</td>
</tr>
<tr>
<td>Boys' ice hockey</td>
<td>0.54-0.62</td>
</tr>
<tr>
<td>Boys' wrestling</td>
<td>0.17-0.58</td>
</tr>
<tr>
<td>Girls' lacrosse</td>
<td>0.20-0.55</td>
</tr>
<tr>
<td>Girls' field hockey</td>
<td>0.10-0.44</td>
</tr>
<tr>
<td>Girls' basketball</td>
<td>0.16-0.44</td>
</tr>
<tr>
<td>Boys' soccer</td>
<td>0.17-0.44</td>
</tr>
<tr>
<td>Girls' softball</td>
<td>0.10-0.36</td>
</tr>
<tr>
<td>Boys' basketball</td>
<td>0.07-0.25</td>
</tr>
<tr>
<td>Girls' volleyball</td>
<td>0.05-0.25</td>
</tr>
<tr>
<td>Cheerleading</td>
<td>0.06-0.22</td>
</tr>
<tr>
<td>Boys' baseball</td>
<td>0.04-0.14</td>
</tr>
<tr>
<td>Girls' gymnastics</td>
<td>0.07</td>
</tr>
<tr>
<td>Boys' and girls' track and/or field</td>
<td>0.02</td>
</tr>
<tr>
<td>Boys' and girls' swimming and/or diving</td>
<td>0.01-0.02</td>
</tr>
</tbody>
</table>

Data compiled from Gessel et al., Lincoln et al., Rosenbloom et al., Maier et al., Meekan et al., O’Connor et al., Curran et al., and Gable et al.

Biomechanical model

- Head acceleration/deceleration leads to brain tissue deformation
  - Biomechanics to not reliably predict injury
- Unregulated axonal depolarization
- Considered as a non-localized functional 'network injury'
- Advanced imaging questions this
  - fMRI
  - nNIRS
Symptom Types

- Somatic (Headache in 86-96% of Concussions)
- Vestibular/Oculomotor
- Cognitive
- Affective/Emotional
- Sleep

Concussion Symptom Domains
Diagnosis

• Concussions do not require (or show on) standard neuroimaging
  – Good decision rules at to who needs a CT – but that is a different talk!

• Diagnostic tools depend on setting and timing

• SCAT5 is valuable sideline tool, but sensitivity decreases over 1st few days

• Symptom checklists exist and are good for following progress/not sufficient for diagnosis

Critical Point:

No assessment tool is diagnostic for concussion.

Concussion remains a clinical diagnosis.
Diagnosing Concussion

• “On-field” identification may/may not be easy
  – Role of the medical provider on-site is not to definitively diagnose concussion
  – Initial “Go/No-go” decision
  – Consider sideline exertion challenge

• Subsequent assessment in the clinic
  – Mechanism/Timing and constellation of symptoms
  – Exam findings/Standardized test results
  – Requires clinical judgment based on all available information

Physical Findings

• Neurologic exam with focus on eyes and vestibular
  – Pupils
  – Extra-ocular movements
    • Nystagmus (spontaneous, persistent, direction-changing)
  – Convergence
    • Intact to 6 cm from nose tip
    • Symptom-provocation
Physical Findings

• Balance tests
  – BESS (Balance Error Scoring System)
  – Romberg
    • Single leg Romberg
  – Normal and tandem gait

• Again – no single test is diagnostic

Neuroimaging/Biomarkers

• Increasing number of research tools
  – Diffusion Tensor Imaging
  – Susceptibility Weighted Imaging
  – Functional MRI
  – Functional Near-Infrared Spectroscopy

• Blood Biomarkers
  – SB100
  – NSE
  – Tau
  – AMPAR

• Objective measures for diagnosis and recovery
Prognostic Factors for Prolonged Symptoms

Table 1. Selected Predictor Variables for Multivariate Model of Persistent Postconcussive Symptoms (PPCS) at 28 Days in the Derivation Cohort

Table 2. Risk Categories for Persistent Postconcussive Symptoms (PPCS) in the Validation Cohort


Neuropsychological Testing

- Since 1990s - computerized Neuropsych testing gained popularity
- 85+% of NCAA trainers, NFL, NHL
  - Lots of confounders
    - Testing situation
    - ‘Sandbagging’
    - Lack of baseline
  - Neither sensitive nor specific
- Comprehensive concussion centers do use neuropsychologists as part of multi-modal treatment
Management Focus

• Vast majority of concussions spontaneously resolve (most within 10 days)
  – Rest with gradual return to activity
    • Physical and cognitive
  – Supportive Care
    • Healthy diet, hydrate, sleep hygiene
    • Avoid toxins
  – Symptomatic treatment
    • Analgesics, anti-emetics

A tip from ancient Rome

‘Moderation in all things is the best policy’

– Plautus (c.250–184 BCE)
How much rest is too much rest?

- Of course, it is never that easy!
- General rules
  - Restrict cognitively demanding activities that exacerbate symptoms
  - Allow cognitively demanding activities that are tolerated
  - Routine “Electronic lock down” is not advised
  - School or work note to allow modifications
- Too much rest has potential adverse effects

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Lets get moving?

- General thoughts
  - Avoid high-risk activities and activities that exacerbate symptoms
  - Allow graded return to activity/exercise as tolerated
  - Routine bed rest/ “cocoon therapy” is not advised
- Exercise can help recovery
  - Evidence for faster recovery with moderate activity post-injury
  - Emerging concepts
    - Sub- symptom threshold exercise
    - Exercise intolerance as a sign of concussion
Return to activity strategies

<table>
<thead>
<tr>
<th>Stage</th>
<th>Aim</th>
<th>Activity</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Daily activities at home that do not give the child symptoms</td>
<td>Typical activities of the child during the day as long as they do not increase symptoms (eg, reading, texting, screen time). Start with 5-10 min at a time and gradually build up.</td>
<td>Gradual return to typical activities</td>
</tr>
<tr>
<td>2</td>
<td>School activities</td>
<td>Homework, reading or other cognitive activities outside of the classroom</td>
<td>Increase tolerance to cognitive work</td>
</tr>
<tr>
<td>3</td>
<td>Return to school part time</td>
<td>Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day</td>
<td>Increase academic activities</td>
</tr>
<tr>
<td>4</td>
<td>Return to school full time</td>
<td>Gradually progress school activities until a full day can be tolerated</td>
<td>Return to full academic activities and catch up on missed work</td>
</tr>
</tbody>
</table>

Table 1: Graduated return-to-sport (RTS) strategy

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<tr>
<td>1</td>
<td>Symptom limited activity</td>
<td>Daily activities that do not provoke symptoms</td>
<td>Gradual reintroduction of work/school activities</td>
</tr>
<tr>
<td>2</td>
<td>Light aerobic exercise</td>
<td>Walking or stationary cycling at slow to medium pace. No resistance training</td>
<td>Increase heart rate</td>
</tr>
<tr>
<td>3</td>
<td>Sport-specific exercise</td>
<td>Running or skating drills. No head impact activities</td>
<td>Add movement</td>
</tr>
<tr>
<td>4</td>
<td>Non-contact training drills</td>
<td>Hurdle training drills, eg, passing drills. Must start progressive resistance training</td>
<td>Exercise, coordination and increased thinking</td>
</tr>
<tr>
<td>5</td>
<td>Full contact practice</td>
<td>Following medical clearance, participate in normal training activities</td>
<td>Return confidence and assess functional skills by coaching staff</td>
</tr>
<tr>
<td>6</td>
<td>Return to sport</td>
<td>Normal game play</td>
<td></td>
</tr>
</tbody>
</table>

Return to Learn

- Notify school of Concussion
- Graduated return to school activities
  - Focus on symptom exacerbation
- Exemption from significant/standardized tests
- Reduce homework
- Sub-clinical physiologic changes persist beyond clinical recovery – unclear if subtle changes in cognition/processing linger

- No ‘magic number’ for Sport Retirement
Symptom Recovery in NCAA astronauts


A new/old treatment for Concussion…?

- Randomized trial of 10 ml/kg 3% saline vs NS over 1 hour
- 44 patients 7-16 years of age
- 3% with greater improvement in FACES pain scale following fluids and 2-3 days after treatment
- Small study – lots of limitations
Post-Concussion Syndrome

- A “miserable minority” of patients with concussion experience a very protracted, or indefinite symptom course (PCS)
  - An ongoing syndrome after the acute neurophysiological effects of the concussion have ended
  - Deviation from expected history of concussion recovery
  - Probably a multi-factorial etiology
    - Iatrogenesis: inactivity related symptoms
    - Psychogenesis: stress, anxiety, depression, PTSD “nocebo” effects
    - Somatogenesis: cervicogenic, ocular, vestibular, “subclinical” autonomic effects
    - Sleep disruption: insomnia, obstructive sleep apnea
    - Premorbid predisposition: personality, comorbidities, somatic hypersensitivity
  - PCS remains a controversial diagnosis
    - Subjectivity of symptoms
    - Non-specificity of symptoms
    - Typical lack of objective findings

- Multi-disciplinary approach to these patients

Rehabilitation Strategies

- Vestibular therapy with balance and oculomotor exercises
- Aerobic rehabilitation for sub-symptom threshold exercise
- Speech therapy for working memory and executive functioning

The CTE Debate

• “Punch drunk syndrome” described in boxers by Martland in 1928
  – “cuckoo, goofy, cutting paper dolls, or slug nutty”
  – Later “dementia pugilistica”
  – CTE terminology coined in the 1960’s
• Histopathology
  – Distinct tauopathy with P-Tau deposition in neurons/astrocytes in perivascular areas and depths of sulci
• Clinical
  – Memory, cognition, emotional
  – Progress to frank dementia

CTE Debate

• Questions regarding the diagnosis
• Studies not consistent…but
  • Repetitive head trauma and/or concussions probably do have long-term adverse effects in some individuals.
  • CTE/TES probably requires significant exposure in a susceptible individual

• The brain is complicated!
Acknowledgements

• Thanks to JT Eckner, MD
  – Associate Professor
  – University of Michigan Neurosport Program

• Radiological Society of North America

• Christy and the organizers of MCEP!