Disclosures

- I have no financial interest, arrangement or relationship that could be perceived as a real or apparent conflict of interest in the context of the subject of this presentation.

Concussion - Agenda

- Presentation
- Evaluation
- Management
FIFA World Cup 2014

World soccer players’ union calls on FIFA to conduct concussion investigation after Alvaro Pereira’s injury

By Matt Bonesteel | June 30, 2014

May 29, 2014

Chris Borland retires from NFL at just 24 years old, makes his own sense of head injuries

May 29, 2014
Concussion Grading Scales

### Concussion Grading Scales

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SCALE</th>
<th>GLOSSARY</th>
<th>CONCUSSION SIGNS AND SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>Cantu</td>
<td>No loss of consciousness</td>
<td>Loss of consciousness for less than 5 minutes</td>
</tr>
<tr>
<td></td>
<td>Cantu</td>
<td>Posttraumatic amnesia for</td>
<td>Loss of consciousness for more than 5 minutes</td>
</tr>
<tr>
<td></td>
<td>Cantu</td>
<td>5 minutes</td>
<td>Posttraumatic amnesia for more than 10 minutes</td>
</tr>
<tr>
<td></td>
<td>Cantu</td>
<td>No loss of consciousness</td>
<td>Posttraumatic amnesia for more than 15 minutes</td>
</tr>
<tr>
<td>1991</td>
<td>Cantu</td>
<td>No posttraumatic amnesia</td>
<td>Posttraumatic amnesia for more than 15 minutes</td>
</tr>
<tr>
<td>1997</td>
<td>Cantu</td>
<td>No loss of consciousness</td>
<td>Posttraumatic amnesia for more than 15 minutes</td>
</tr>
</tbody>
</table>

Concussion Guideline Updates

- 4th International Conference on Concussion in Sport, Zurich, November 2012
  - 1st, Vienna 2001
  - 2nd, Prague 2004
  - 3rd, Zurich 2008


Rotational Acceleration

- Rapid head rotations generate shear forces throughout the brain.

Understanding the Basis of Concussion

- How does acceleration move and deform the brain tissues?
- What is the effect of these forces on the living tissue and neural networks?

- The patterns of strain (tissue deformation) within the brain are markedly different if the rotational acceleration is applied in the coronal (lateral), horizontal (axial), or sagittal plane.
Neurometabolic Cascade

- Mechanical trauma
- Acceleration and deceleration forces
- Disruption of neuronal cell membranes and axonal stretching
- Ion channel dysfunction


Neurometabolic Cascade

- Energy (glucose) depletion and abnormal metabolism (mitochondrial dysfunction)
- Cerebral hypofunction

Chronic Injury

- “Chronically, multiple concussions have been associated with cumulative effects on cerebral function and cognition, including early onset of memory disturbances and even dementia”

Chronic Injury

- **Chronic Traumatic Encephalopathy (CTE)**
  - Executive dysfunction, memory impairment, depression, poor impulse control
  - Distinct tauopathy with unknown incidence in athletic populations

- **Chronic Neurocognitive Impairment (CNI)**
  - Demonstrated on NP testing

- There is NO proven cause and effect relationship between CNI, CTE and concussion

Variable Recovery

Neuropsychological impairment in youth athletes < 18 yo may be more prolonged, up to 2 weeks post-concussion

- For some athletes, the time for complete recovery takes much longer
- Sometimes complex and unpredictable injury
- Team approach to concussion management

Concussion evaluation “on the field”
Recognize the Injury

- **The Big Hit?**
  - Magnitude of impact does NOT correlate with clinical injury (CFB)

  Guskiewicz et al. Neurosurgery 2007;61(6)

- **Loss of Consciousness**
  - *Brief* LOC does NOT correlate with concussion severity
  - *Prolonged* LOC (> 1 minute) has been shown to be associated with more severe injury

  (Zurich Consensus Statement, 2012)

- **History**
  - Many symptoms of concussion (e.g. headache, fatigue) are not specific to concussion
  - Do symptoms correlate to a history of traumatic blow to head or body?
Recognize the Injury

**Awareness**
- Teammates / Coaches / Parents / ATCs
- Athlete behavior

Diagnosis

**Examination**
- Concussion symptoms
- Physical Exam
  - Skull fracture
  - Cervical spine injury
    - Neck pain or tenderness
    - Pain with neck movement
    - Weakness and/or numbness or tingling of extremities
- Intracranial injury
- Neurologic examination
- Cognitive assessment
- Balance evaluation

Symptoms

**Somatic**
- Headache
- “Pressure in head”
- Neck pain
- Nausea or vomiting
- Dizziness
- Blurred vision / double vision / “seeing stars”
- Balance problems / unsteadiness
- Sensitivity to light
- Sensitivity to noise
- Ringing in ears
- Fatigue or Low energy
- Drowsiness
- Trouble falling asleep

**Cognitive**
- Feeling slowed down
- Feeling like “in a fog”
- “Don’t feel right”
- Difficulty concentrating
- Difficulty remembering
- Confusion

**Emotional**
- More emotional
- Irritability
- Sadness
- Nervous or Anxious
Do symptoms get worse with physical activity?
Do symptoms get worse with mental activity?

Physical Signs
- Loss of consciousness
- Concussive convulsion / impact seizure
- Annesia
- Vacant stare / glassy eyed
- Significantly decreased playing ability
- Gait unsteadiness / loss of balance
- Poor coordination
- Vomiting
- Slurred speech

Behavioral Changes
- Irritability
- Emotional lability
- Displaying unusual or inappropriate emotions
- Personality changes
- Inappropriate playing behavior
Cognitive impairment

- Slowed reaction time
- Slow to answer questions or follow directions
- Confusion
- Difficulty concentrating / easily distracted
- Difficulty remembering

Sleep Disturbance

- Drowsiness
- Insomnia

Sideline Evaluation

Physical Examination
- Head and neck evaluation
- Neurologic exam
- Glasgow coma scale

<table>
<thead>
<tr>
<th>Glasgow coma scale (GCS)</th>
<th>Best eye response (E)</th>
<th>Best verbal response (V)</th>
<th>Best motor response (M)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No eye opening</td>
<td>Incomprehensible sounds</td>
<td>No motor response</td>
</tr>
<tr>
<td></td>
<td>Eye opening in response to pain</td>
<td>Inappropriate words</td>
<td>Extension to pain</td>
</tr>
<tr>
<td></td>
<td>Eye opening to speech</td>
<td>Confused</td>
<td>Abnormal flexion to pain</td>
</tr>
<tr>
<td></td>
<td>Eyes opening spontaneously</td>
<td>Oriented</td>
<td>Flexion/withdrawal to pain</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Localize to pain</td>
</tr>
</tbody>
</table>

Glasgow Coma Score (E+V+M) of 15
Sideline Evaluation – Cognitive Assessment

- **Maddocks Score**
  
  **Modified Maddocks Questions** (1 point for each correct answer)
  
<table>
<thead>
<tr>
<th>Question</th>
<th>0</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>At what venue are we at today?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which half is it now?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Who scored last in this match?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What team did you play last week/game?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did your team win the last game?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

  Maddocks Score: 5

- **Standardized Assessment of Concussion (SAC)**
  
  Determine concussed vs nonconcussed athletes at time of injury

 实践效果：在一项研究中，头伤的运动员在受伤时的SAC得分比基线时高29%。


  • Sensitivity and specificity may be limited
Sideline Evaluation - Balance

- Modified Balance Error Scoring System (BESS)
  - Baseline testing
  - Affected by
    - Musculoskeletal instability issues
    - Learning/practice effects

Pocket SCAT 2 Balance Testing

Instructions for tandem stance

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.

Typically returns to normal within 3 days post-injury


SCAT 3

- Combines several symptom scores, measures, and assessments into one tool
- Age 13 and older
- Has not been validated!

http://bjsm.bmj.com/content/47/5/259.full.pdf

King – Devick Test

- Developed in 1976 to evaluate saccadic performance in reading
- 2011 evaluated for use on sidelines as concussion screening tool (cognitive screen)
  - Decrements in time relative to baseline
  - Specific for concussion
  - No standard score deficit that determines concussion

Galetta et al. Neurology. 2011
The sensitivity and specificity of the diagnosis of concussion may increase when combining multiple assessment tools.

More research is needed to validate and improve sideline testing.


Vestibular / Ocular Motor Screening (VOMS)

Vestibular and ocular motor impairments and symptoms are common in sports concussions and may contribute to delay in recovery.

Support for utility of VOMS as brief screen after sports-related concussions.

“When in doubt, sit them out”

Concussion should be suspected in the presence of any one or more of the following:

- Symptoms
  - headache
- Physical signs
  - unsteadiness
- Impaired brain function
  - confusion
- Abnormal behavior
On-field or Sideline Evaluation

- When a player shows ANY features of concussion:
  1) Assess concussive injury
  2) A player with diagnosed concussion should not be allowed to return to play on the day of injury
  3) The player should not be left alone following the injury, and serial monitoring for deterioration is essential

(Zurich Consensus Statement)

Concussion Legislation

- Act 197(12)
- Signed into law July 3, 2012
- Mandates removal of athlete from field of play
- Requires medical evaluation and clearance for return to play
Disposition

- Athletes should be observed for the first few hours after injury and should not be left alone
- Monitor for deteriorating mental status or worsening symptoms
  - Worsening headache
  - Nausea or vomiting
  - Increased lethargy
  - Focal neurologic deficits

Neuroimaging

- Conventional structural neuroimaging is typically normal in concussive injury
- Noncontrast brain CT should be employed whenever suspicion of an intracerebral or structural lesion (e.g. skull fracture, intracranial hemorrhage) exists
  - Prolonged loss of consciousness
  - Focal neurological deficit
  - Worsening symptoms / clinical deterioration

Neuropsychological Testing

- Assessment and quantification of brain function by examining brain-behavior relationships
  - Reaction time
  - Attention
  - Concentration
  - Short-term and delayed memory
  - New learning
  - Problem solving
Neuropsychological Tests

- Comprehensive neuropsychological testing
  - "paper/pencil testing"
- Abbreviated computerized testing
  - ImPACT
  - CogSport
  - Headminder

Computerized Neuropsychological Tests

- Typically performed at least 24 to 48 hours after injury, when athlete is symptom free
- Comparison to preseason baseline tests
- Concussion symptoms may resolve completely before the resolution of cognitive deficits

Computerized Neuropsychological Tests

- Test-retest reliability: individuals found to test in the impaired range 20%-40% of the time when tests were compared to baseline, even when not concussed (Broglio et al. J Athl Train 2007;42(4))
- Multipronged approach: symptoms, physical exam, cognitive exam, balance testing

NP testing is just one tool in the toolbox
Neuropsychological Tests

- No universally agreed upon recommendations for use of NP testing
- At present, there is insufficient evidence to recommend the widespread routine use of baseline NP testing

(Zurich Consensus Statement, 2012)

Diagnostic Tools – Under Investigation

- Electrophysiology
  - Focal electroencephalography (EEG)
  - Quantitative electroencephalography (QEEG)
- Biomedical imaging
  - MRI
    - Functional MRI (fMRI)
      - Regional brain activation, symptom severity
    - Diffusion tensor imaging (DTI)
  - MR tractography
  - MR spectroscopy (MRS)
    - Cerebral metabolic recovery
- Single-photon emission tomography (SPECT)
  - Brain perfusion
  - Positron emission tomography (PET)
    - Brain metabolism
- Biomarkers
  - Serum testing (cleaved-Tau, S100B, etc)

Concussion evaluation in the office
Concussion Evaluation

- History
  - Graded symptom checklist (GSS)
- Physical Examination
- Objective Testing
  - VOMS
  - BESS
  - +/- Neuropsychological Testing
- Anticipatory Guidance
  - Physical activity restrictions
  - Cognitive restrictions
  - School accommodations (504 plan)
- Communication with school / training room
- Follow up

Concussion Management

- Physical and cognitive rest until acute symptoms resolve
  - TV, smartphones, texting, tablets
- Graded program of exertion prior to medical clearance and return to play

<table>
<thead>
<tr>
<th>Table 1: Graded return to play protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Symptom</strong>:</td>
</tr>
<tr>
<td><strong>Objectives of each phase</strong>:</td>
</tr>
<tr>
<td>1. No activity</td>
</tr>
<tr>
<td>2. Light activity</td>
</tr>
<tr>
<td>3. Heavy activity</td>
</tr>
</tbody>
</table>

(Zurich Consensus Statement, 2012)
Medical Referral Form for Concussed Athlete

Return to Activity Plan (R.A.P.)

Step 1. Complete cognitive rest. This may include staying home from school or limiting school hours and study for several days which would be determined by a physician or A.T.C. and supported by school administrators. Activities requiring concentration and attention may worsen symptoms and delay recovery.

Step 2. Return to school full time.

Steps 3-7. Will be supervised by the high school A.T.C. (Note step 6 is supervised by a minimum of at least 24 hours.)

Step 3. Light exercise. This step can begin until student athlete is cleared by the treating physician for further activity. At this point, the student athlete may begin walking or riding a stationary bike.

Step 4. Running in the gym or on the field.

Step 5. Non-contact training drills in full equipment. Weight training can begin.

Step 6. Full contact practice or training.

Step 7. Play in games.

Please Indicate Level of Clearance: To be filled out by Physician

[ ] Cognitive and Physical Rest Only
[ ] Limited school attendance, computer, TV, and Phone/Texting
[ ] Limited to Return to School with [ ] Physical activity. [ ] Physical education class or athletics

Follow-up appointment scheduled

Closed to begin “Return to Activity Phase” (see above)

PHYSICIAN’S NAME:

PHYSICIAN’S SIGNATURE:

Academic Accommodations / “Return to Learn”

Cognitive Rest and the Need to “Return to Learn”

Cognitive rest is the first step to recovery from a concussion. During the first 3-5 days post-injury, it is critical that the brain is able to rest. Similar to resting the ankle by using crutches when someone sprains their ankle, the brain needs to be at rest. The goal of cognitive rest is to keep cognitive activity below the level that triggers symptoms such as headaches, dizziness, or fatigue. Remember that means students need to miss school, no reading, no writing, no video games, no texting, and no computer time.

Return to Learn

Parents, teachers, and the Medical Doctor should agree when it will be beneficial for a concussed student to return to school. One option is to start out half-days where the student will go to school either the early half of school or the latter half of school. A general guideline to determine when a concussed student should return to school is:

1. If the student is able to concentrate during light cognitive activity by the morning or during homework for 30 minutes, they may be ready to return to school.

2. At the end of the school day, a parent, athletic trainer, or concussed student should evaluate how the student’s first day went as that adjustments may be made as soon as possible.

How Can Education Help?

ADJUSTMENTS

For most concussion cases, the student/athlete will need school adjustments for a short period — usually for a couple of weeks. Adjustments are modifications in school that can be done immediately and for a short period of time. Some adjustments that may be implemented are:

- Shown as needed in a quiet place
- Preprinted class notes
- Additional time for assignments
- Additional help and tutoring
- Untimed or no testing until tolerating a full day of school

ACCOMMODATIONS

Accommodations are a formal confirmation of the student’s academic curriculum, schedule and plan. Concussed student/athletes may require accommodations if experiencing prolonged recovery. With the concussed student’s IEP and the school’s academic team, additional accommodations may be implemented.
“Return to Life”

- Appropriate home/school accommodation
- Emphasis on sleep hygiene
- Appropriate nutrition
- Exercise
- Socialization
- Graduated return

Medications

- Mostly low quality data and equivocal evidence
- Acute setting
  - Omega-3 Fatty Acids
  - N-acetylcysteine

Medications – Prolonged symptoms

- Sleep disturbance
  - Melatonin
  - Trazodone
- Somatic (e.g. headache)
  - Amitriptyline
  - Beta-blockers, Calcium channel blockers, Valproic acid, topiramate, triptans, dihydroergotamine, gabapentin
Medications

- Emotional (e.g. depression)
  - Sertraline, SSRIs
- Cognitive (e.g. memory, concentration, slowed processing)
  - Methylphenidate
  - Amantadine

Complicated Concussions

- Symptoms persisting > 7-10 days in adults and > 3 weeks in youth
- Failure to progress

Complicated Concussions

- Concussion is a heterogeneous disorder
- 6 clinical trajectories
- Management should be targeted, determined by these pathways
Complicated Concussions

- “Clinical Trajectories”
  - Clinical interview
  - Vestibular-Ocular Screening
  - Computerized Neurocognitive Testing

Car sick/motion sensitive
- Dizzy / foggy especially with busy environment or rapid movement
- VOMS provocation
- ImPACT: visual motor speed, reaction time

Vestibular rehab programs
- Progressive, staged exposure to dynamic motion
Fatigue, headache, “end of day” symptoms
More distractible
ImPACT: global mild deficits, deficits with “retrieval” rather than encoding

Physical / cognitive “breaks” through day
Monitored exertional progression
Amantadine, methylphenidate
Cognitive therapy

Frontal HA, fatigue, “focus” problems
Reading/computer/note taking
ImPACT: visual memory, reaction time deficits
VOMS provocation
- Vestibular therapy
- Vision therapy (near point convergence > 15cm)
  - Behavioral neuroptometry


- Variable headache
- Phono / phonosensitivity
- History of migraine
- ImPACT: verbal and visual memory deficits


- Migraine prophylaxis, abortive Rx
- Increased exercise activity
- Sleep / stress regulation
Tension type headache
Mechanical modalities, physical therapy, OMT, trigger point injections

Overwhelmed, sleep disruption
PHQ-9, PHQ-A

Exercise as treatment
May improve autonomic dysfunction / cerebral autoregulation
Improves anxiety / depression / sleep disturbance
Progressive, sub-symptom threshold program
"The severity of injury is likely best determined by the nature, burden, and duration of symptoms, as well as the time that cognitive and balance disturbances persist, and none of these can be determined at the time of injury."


Medical Retirement?

Kaiser Permanente Concussion Task Force

- Marsha Marumoto, MD (Pediatrics)
- Monique Canonico, MD (Neurology)
- Gina Kellner, MD (Behavioral Health)
- Jay Ishida, MD (Emergency Medicine)
- Mary Kawasaki, NP (Pediatrics)
- Kacy Nekoba, PT (Physical Therapy)
- Benjamin Chun, MD (Sports Medicine)
Helmets

- Effective at reducing linear acceleration forces
  - Skull fracture
  - Intracranial bleeding
- Poor at reducing angular acceleration forces

2005 – 2010: 8 collegiate football teams
- 64 concussions in 1,281,444 head impacts
- Relative risk of concussion 46.1% in Riddell Revolution helmet vs Riddell VSR4 helmet
Helmets

- 2012 – 2013: High school football
- 2081 players
- 211 concussions
- No difference in concussion incidence between Riddel, Schutt, or Xenith helmets
- Rate of concussion higher in players wearing custom mouth guard vs generic

Mouth Guards

- No strong evidence exists for the use of mouth guards to prevent concussions