

Concussion in the Adolescent Athlete

Ben Tseng, MD
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Objectives

- Diagnose concussion
- Be familiar with the natural history of concussion
- Know when to refer the concussed athlete for imaging
- Manage the adolescent athlete acutely after a concussion
- Manage return to learn and return to play in the concussed athlete
- Be familiar with complications, including chronic traumatic encephalopathy (CTE)

Media Exposure

Epidemiology

- ~3.8 million estimated sport-related traumatic brain injuries occur annually in US
- Represents 13% of all injuries in sports
- Compared to adults, children <18 are at increased risk and tend to have more severe and prolonged symptoms
- Master, C.L., L. Balcer, and M. Collins. "In the clinic: Concussion." *Annals of Internal Medicine* 160 (2014): ITC 2: 1-16.
- Master, C.L., L. Balcer, and M. Collins. "In the clinic: Concussion." *Annals of Internal Medicine* 160 (2014): ITC 2: 1-16.

Epidemiology

- In a study from 2012, pooled incidence rate across 20 sports was 2.5/10,000 athlete exposures (AE's)
- Rate for competition was 6.4/10,000 vs. 1.1/10,000 for practice; rates were higher in competition than practice for every sport except cheerleading
- Highest total numbers of concussions were in football, followed by girls' soccer and boys' wrestling
- Maraz, M., et al. "Epidemiology of concussions among United States high school athletes in 20 sports." *American Journal of Sports Medicine* 40 (2012): 747-755.

Epidemiology

- Highest rates of concussion: football (6.4/10,000), followed by boys' ice hockey (5.4/10,000) and boys' lacrosse (4.0/10,000)
- Highest rates in girls' sports were lacrosse (3.5/10,000) and soccer (3.4/10,000)
- Overall rates of concussion were higher in boys (3.1/10,000) than in girls (1.6/10,000)
- However, for sports where both genders have similar rules (such as soccer and basketball), rates were higher in girls than boys

Epidemiology

Figure 3. Impact Expectation by Sport



Definition

- From the 4th International Conference on Concussion in Sport:
- “Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by biomechanical forces. Several common features that incorporate clinical, pathologic, and biomechanical injury constructs that may be utilised (sic) in defining the nature of a concussive head injury include:
 1. Concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an “impulsive” force transmitted to the head”

• McCrory, P., et al. “Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, November 2012.” *British Journal of Sports Medicine*. 47 (2013): 250-55.

Definition

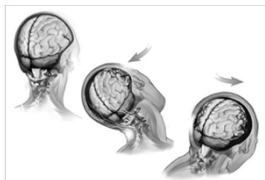
2. “Concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.
3. “Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies”

Definition

4. “Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged.”
- Concussion is a **clinical** diagnosis, made in the context of an injury to the brain causing acute impairment of neurologic function

Pathophysiology

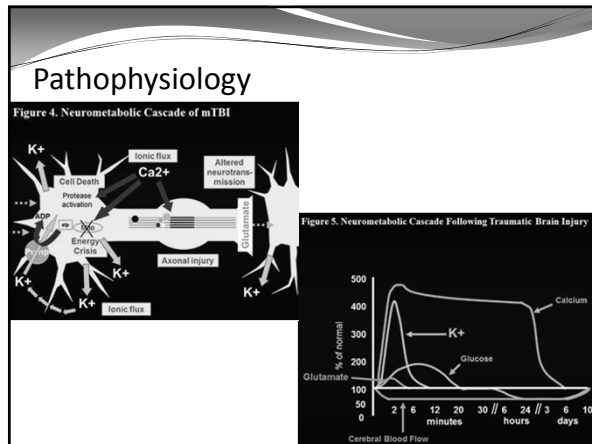
- Forces transmitted to the head impart linear or rotational acceleration to the brain within the closed space of the skull
- There does not need to be direct trauma to the head, as long as force is transmitted to the head (e.g. whiplash)



Pathophysiology

- During acute traumatic injury to brain, neuron cell membranes are disrupted leading to flux of ions (including K out and Ca in) and release of neurotransmitters (particularly glutamate)
- In response, the cell membrane Na/K ATP-dependent pump has to work overtime to restore normal concentrations, leading to depletion of energy stores
- Cerebral blood flow also decreases, leading to mismatch between energy supply and energy demands
- Mitochondrial dysfunction also occurs after an injury, causing most metabolism to be glycolytic, leading to lactate accumulation

Giza, C.C., and D.A. Hovda. “The neurochemical cascade of concussion.” *Journal of Athletic Training* 36 (2001): 228-335.



On-field/Sideline Assessment

- By necessity, on-field assessment needs to be very quick
- Assess ABC's and evaluate for severe head and C-spine injuries requiring immediate referral to ED
- Any unconscious athlete should be assumed to have a C-spine injury and immobilized
- Refer to ED for worsening headache, lethargy/difficulty arousing athlete, nausea/vomiting, slurred speech, unsteady gait, focal weakness or numbness, inability to recognize people or places, seizures
- Otherwise, a more complete examination on the sidelines should include a thorough neurological exam and the Sideline Concussion Assessment Tool (SCAT-3)

* Putukian, M., et al. "Onfield assessment of concussion in the adult athlete." *British Journal of Sports Medicine* 47 (2013): 285-288.

On-field/Sideline Assessment

- If concussion is diagnosed or suspected, remove athlete from play and *do not allow to return same day*
- Up to 1/3rd of college football players with suspected concussion allowed to return to play same day eventually developed delayed onset symptoms
- Perform serial assessments on the sideline

Symptoms after Injury

- **Early (minutes and hours later)**
 - Headache
 - Dizziness or vertigo
 - Lack of awareness of surroundings
 - Nausea or vomiting
 - Balance problems
 - Visual disturbance
 - Mental confusion
 - Amnesia (retrograde or anterograde)
 - Perseveration
- **Late (days to weeks later)**
 - Persistent low-grade headache or head pressure
 - Lightheadedness
 - Poor attention and concentration
 - Memory dysfunction
 - Easy fatigability
 - Irritability and low tolerance of frustration
 - Intolerance of loud noises, sometimes with ringing in the ears
 - Anxiety and/or depressed mood
 - Numbness or tingling
 - Sleep disturbance
- Most commonly reported are headache (94%) followed by dizziness and difficulty concentrating

Master, C.L., L. Baker, and M. Collins. "In the clinic: Concussion." *Annals of Internal Medicine* 160 (2014): ITC 2: 1-6.

On-field/Sideline Assessment (SCAT-3)

- Includes several components, including symptoms, Glasgow Coma Score, balance, neurological signs, cognition
- In concussion, by definition, GCS should be ≥ 14 ; GCS should be done if more severe TBI is suspected
- Maddocks questions test orientation and recall of recent events; more sensitive than standard orientation questions
- Neurologic signs: loss of consciousness, poor balance/coordination, blank look, confusion, amnesia, visible facial injury
- 22-item post-concussion symptom score, scaled 0-6

* Guskiewicz, K., et al. "Evidence-based approach to revising the SCAT-2: introducing the SCAT-3." *British Journal of Sports Medicine* 47 (2013): 289-293.

On-field/Sideline Assessment (SCAT-3)

- Standardized assessment of concussion (SAC) is a 30-point test that tests orientation, immediate memory, concentration, and delayed recall
- SAC has been shown to be sensitive for detection of concussion within 48 hours of injury
- Coordination testing (finger-nose-finger test)
- Balance examination: modified BESS – BESS test on firm surface only, alternatively tandem gait
- Ideally, baseline testing would be available for comparison
- Repeat testing can be done to monitor athlete progress

On-field/Sideline Assessment (SCAT-3)

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

Physical Exam

- Full neurologic and C-spine exam should be performed
- Common exam findings in concussion include deficits in balance and neurocognitive, vestibular, and oculomotor function
- Assess smooth eye tracking, saccades, gaze stability, and convergence
- King-Devick tests oculomotor function, and has been shown to worsen from baseline in concussed athletes

- Master, C.L., et al. "In the clinic: Concussion." *Annals of Internal Medicine* 150 (2011): 1172-1176.
- Galetta, K.M., et al. "The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort." *Journal of the Neurological Sciences* 309 (2011): 34-39.

Neuropsychological Assessment

- Includes "paper and pencil" assessments such as the SAC and computerized tests such as ImpACT, Axon Sports, ANAM, and Headminder
- Of these, ImpACT is the most widely used
- Generally these computerized tests assess several cognitive domains, including verbal memory, visual design memory, visual processing speed, and reaction time
- Findings are reported in reference to normative data and as "reliable change index" from baseline
- Sensitivity/Specificity of ImpACT was reported to be 79-95%/89-97%
- These are part of the comprehensive assessment of concussion and should *not* be used as stand alone tests

- McCrea, M., et al. "Day of injury assessment of sport-related concussion." *British Journal of Sports Medicine* 47 (2013): 272-284.

Balance Assessment

- Tests using force plate technology have been studied, but are impractical for routine office or sideline use
- For physician use, the balance error scoring system (BESS) is commonly used
- Studies have shown significant increases from baseline (~6 errors) after concussion
- Findings generally resolve within 3-7 days
- Can be affected by fatigue, ankle injury; certain sports tend to do better, and there is a practice effect

- Guskiewicz, K.M. "Balance assessment in the management of sport-related concussion." *Clinics in Sports Medicine* 30 (2011): 89-102.

Balance Assessment

- <http://knowconclusion.org/wp-content/uploads/2011/06/BESS.pdf>

Natural History

- Good news!
- 80-90% of concussions will resolve within 10 days
- In the pediatric population, 80-90% will resolve within 21 days

- McCrory, P., et al. "Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, November 2012." *British Journal of Sports Medicine* 47 (2013): 250-258

Management

- Do not allow same day return to play
- Perform serial assessments of athlete symptoms and exam, arrange for athlete to be monitored closely at home if discharged home
- Imaging is generally not necessary, and should be considered for patients with mental status changes, focal neurologic findings, prolonged loss of consciousness, or progressively worsening symptoms
- Imaging is generally *normal* in concussion



Herring, S.A., et al. "Concussion (mild traumatic brain injury) and the team physician: a consensus statement - 2010 update." *Medicine & Science in Sport & Exercise* 43 (2011): 2412-2422.

Management

- Cognitive and physical rest until asymptomatic are the cornerstone of initial treatment of concussion
- Cognitive rest includes avoidance of activities requiring high concentration and attention (reading, schoolwork, using a computer screen, text messaging, video games)
- However, the data supporting this recommendation is scarce
- How much rest and for how long is unknown

Management

- One study showed an increased duration of symptoms in those with prolonged cognitive rest, but this was uncontrolled
- In another uncontrolled study, concussed athletes prescribed 1 week of cognitive and physical rest showed improved symptom scores and ImPACT scores
- In another, student-athletes were followed for one month after concussion, and classified according to self-reported cognitive and physical activity; those with moderate activity were found to have the best neuropsychological outcomes

• Schneider, K.J., et al. "The effects of rest and treatment following sport-related concussion: a systematic review of the literature." *British Journal of Sports Medicine* 47 (2013): 304-307.

Management

- Most recently, a study showed that compared to concussed athletes who were immediately removed from play, athletes who continued to play (for an average of 19 minutes) had significantly worse symptom scores, neurocognitive performance, and time to return to play (44 days vs. 22 days).
- Athletes who continued to play were also much less likely to have recovered by 3 weeks (31% vs. 80%)

• Elbin, R.J., et al. "Removal from play after concussion and recovery time." *Pediatrics* 138 (2016): 909-917

Management

- Small uncontrolled studies have shown that low levels of exercise were well tolerated and may be beneficial in patients with persistent symptoms
- Multimodal PT (C-spine manual therapy, neuromotor and sensorimotor retraining, vestibular rehab) was shown in one study to improve likelihood of athlete return-to-play at 8 weeks compared to controls
- No pharmacologic therapies have been shown to speed recovery from concussion
- Melatonin and Trazodone may help with post-concussion insomnia

• Schneider, K.J., et al. "Cervicovestibular rehabilitation in sport-related concussion: a randomised controlled trial." *British Journal of Sports Medicine* 48 (2014): 1291-1298.

• Mehan, W.P. "Medical therapies for concussion." *Clinics in Sports Medicine* 30 (2011): 115-124.

Management

- Amitriptyline may be beneficial in posttraumatic headache
- There is no strong data to suggest other treatments for headache (NSAID's, B-blockers, CCB's, valproic acid, topamax, gabapentin, triptans, or dihydroergotamine)
- Sertraline may be helpful for posttraumatic depression
- Methylphenidate and Amantadine may be helpful for cognitive symptoms

• Mehan, W.P. "Medical therapies for concussion." *Clinics in Sports Medicine* 30 (2011): 115-124.

Return-to-learn

- For the student athlete, successful return to school should precede any return to play decisions
- Multidisciplinary team that includes the student athlete, family, medical providers, school academic team, and school athletic team
- It is important that all members of the team are aware of the student's situation
- Time away from school may be required until the student can tolerate ≥ 30 minutes of concentration without symptoms; gradual return to class and school work can start once able to tolerate 30-45 minutes

• Halstead, M.E., et al. "Returning to learning following a concussion." *Pediatrics* 132 (2013): 948-957.

Return-to-learn

- Accommodations may be necessary: frequent breaks, trips to school nurse or study hall if symptomatic, avoiding screens, testing accommodations
- Physicians can use acute concussion evaluation (ACE) care plan form, available from CDC website
- Accommodations are temporary in the vast majority, but students who require prolonged symptoms may require a 504 plan or individualized education plan (IEP)

Return-to-learn

- https://www.cdc.gov/headsup/pdfs/providers/ace_care_plan_school_version_a.pdf

Return-to-play

Concussion Rehabilitation/Stepwise Return to Play

Rehabilitation Stage	Functional Exercise
1. No activity	Complete physical and cognitive rest
2. Light aerobic activity	Walking, swimming, stationary cycling at 70% maximum heart rate; no resistance exercises
3. Sport-specific exercise	Specific sport-related drills but no head impact
4. Noncontact training drills	More complex drills, may start light resistance training
5. Full-contact practice	After medical clearance, participate in normal training
6. Return to play	Normal game play

Each stage in concussion rehabilitation should last no less than 24 hours with a minimum of 5 days required to consider a full return to competition. If symptoms recur during the rehabilitation program, the athlete should stop immediately. Once asymptomatic after at least another 24 hours, the athlete should resume at the previous asymptomatic level and try to progress again. Athletes should contact their health care provider if symptoms recur. Any athlete with multiple concussions or prolonged symptoms may require a longer concussion-rehabilitation program, which is ideally created by a physician who is experienced in concussion management.

Prevention

- Helmets have been shown to reduce severe traumatic brain injury and skull fracture in football, ice hockey, baseball, lacrosse, and cycling
- Mouth guards have been shown to reduce oral and dental injury
- Neither has been proven to reduce incidence of concussion
- There is data to suggest that body checking rules in Pee Wee ice hockey (ages 11-12) do reduce rates of concussion

Danešvar, D.H., et al. "Helmets and mouth guards: the role of personal equipment in preventing sport-related concussions." *Clinics in Sports Medicine* 30 (2011): 445-495.

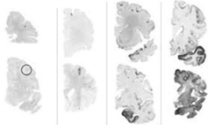
Benson, B.W., et al. "What are the most effective risk reduction strategies in sport concussion?" *British Journal of Sports Medicine* 47 (2013): 321-326

Risk factors for prolonged recovery

- History of concussion (especially recent or multiple)
- Total number and severity of symptoms
- Prolonged LOC (>1 minute)
- Hx of migraine, depression, anxiety, learning disabilities, ADHD
- Younger age

Complications

- Increased risk for subsequent concussion
- Postconcussion syndrome
- Posttraumatic seizures
- Depression
- Second Impact Syndrome?
- Chronic traumatic encephalopathy (CTE)



• Herring, S.A., et al. "Concussion (mild traumatic brain injury) and the team physician: a consensus statement - 2011 update." *Medicine & Science in Sport & Exercise* 43 (2011): 2412-2422.

Chronic Traumatic Encephalopathy (CTE)

- Originally described in boxers, characterized by dysarthria and pyramidal symptoms with or without cognitive symptoms
- "Modern" CTE appears to be somewhat different, originally described by Omalu et al
- Characterized by gait abnormalities, speech disorders, and pyramidal symptoms, with prominent neuro-psychiatric symptoms (mood disorders, paranoia, agitation, social withdrawal, aggression, poor judgment, and late cognitive impairment)

• Gardner, A., et al. "Chronic traumatic encephalopathy in sport: a systematic review." *British Journal of Sports Medicine* 48 (2014): 84-90.

Chronic Traumatic Encephalopathy (CTE)

- Neuropathologic findings include:
- Fenestrated septum pellucidum, cerebral atrophy, increased ventricular size, decreased pigmentation of substantia nigra and locus coeruleus, tau neurofibrillary tangle inclusion, and B-amyloid deposition
- Of note, in case series in the literature, many patients had co-existing neuropathology, and correlation between pathology and reported symptoms was poor
- In postmortem studies, neuropathologic findings are common in asymptomatic patients
- There is no conclusive evidence to date that repetitive concussions cause CTE

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