Concussion in the Pediatric Patient: An Update

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Learning Objectives

1. Describe the physiologic injury that occurs in concussion
2. Describe the particular risk and burden of concussion in the pediatric population
3. Describe the most current guidelines regarding pediatric concussion management including Return-to-Learn and Return-to-Play
Disclosures

- There are no relationship or commercial sponsorships to disclose
Concussion defined: Mild Traumatic Brain Injury

- Traumatically induced, transient disruption in brain function that results from a complex pathophysiologic process
- Concussion injury is a result of direct or indirect biomechanical forces to the head.
- The injury initiates a ‘neuro-metabolic cascade’ that follows microscopic axonal injury and involves alterations in the axon’s normal ionic and metabolic functions.
- This disruption requires increased energy use to repair, but decreased cerebral blood flow and disruptions of mitochondrial function results in imbalances in supply & demand

Neurometabolic Cascade

Mechanical impact or Force (Linear & rotational) →
→ Mechanical stretch and injury to axons →
→ Release of excitatory Neurotransmitters
→ Disruption of ion channels
→ Efflux of K+ from and influx of Ca+ into the neuron
→ Results in cellular inflammation (microglial activation) and diminished blood flow hinder cell’s ability to function normally
→ Na+/K+ Pump overworked attempting to restore balance
→ Increased need for ATP to restore ionic balance, repair the neuron while continuing ‘normal’ neurologic functioning
→ Increased Glycolysis leads to Lactic Acid production
→ Acidosis contributes to impaired cellular function & cerebral edema
→ Influx of Ca+ impairs mitochondrial production of ATP
→ Cellular energy crisis

→ Clinical symptoms of concussive injury
Mechanical forces in Concussive Injury

- Coup injury to brain
- Contrecoup injury to brain

Closed Head Injury
- Diffuse brain injury
- Contusion
- Brain swelling
- Cerebrovascular effects
- Alterations in blood-brain barrier
- Biochemical effects
- Microglial activation
- Immunoexcitotoxicity
Neuronal Injury in Concussion

NORMAL AXON

- Myelin sheath
- Axon
- Cell body
- Nucleus in cell body

SHEARING OF AXON

Forces applied to brain cause axons to twist and tear

POST-TRAUMA CONDITION

Neuronal (brain cell) death results

© Artery Studios Inc 2013
Cellular Processes affected

- Derangement in ion functioning
- Neurotransmitter release
- Alterations in cerebral blood flow; perfusion, autoregulation & vasospasm
- Alteration in metabolism; increased ATP requirement coupled with mitochondrial dysfunction (hence, decreased ability to produce ATP)
- Slowed synaptic functioning
- Altered axonal connectivity
- Possible cell death

Concussive injury

- Symptoms are a direct result of the brain trying to function in the presence of this metabolic imbalance.
- Concussed brain is less responsive to neural activation; premature cognitive & physical activity may prolong dysfunction.
- Until recovery is achieved, there is increased vulnerability to second injury and that such injury results in worsening of the metabolic derangements at the cellular level.
- Symptoms of concussion are often more pronounced in children and adolescents, raising concern for unique impact of concussion on the immature brain.
Some Statistics

- Direct & indirect costs from MTBI totaled an estimated $12 billion in the US in 2000.
- In 2010 >2.5 million people were seen with TBI in ED’s nationwide.
- In 2009 estimated 248,418 persons < 19 years of age sustained a head injury annually from sport & recreational activities (CDC, MMWR, 10/2011).
- During the last decade the number of sport & recreational concussions in children and adolescents have increased by 60% (Gilchrist, et al. MMWR 2011:60(39);1337-42).
- A history of concussion is associated with a 2-5.8 times >risk of a repeat concussive injury.
More data...

- Highest number of TBI ED visits in children and adolescents were related to bicycling, football, playground activities, basketball and soccer.
- Numbers and rates are the highest for football and girl’s soccer.
- Fewer than 10% of sports-related concussions have associated loss of consciousness & 25% have some degree of amnesia.
- 71% of sport & recreation-related TBI ED visits were in males.
- 70.5% of all sport & recreation-related TBI ED visits were among 10-19 years old.
- Children and teens are more likely to get a TBI, including concussion, and generally take longer to recover than adults.
1. Consensus Statement on Concussion in Sport- The 4th International Conference on concussion in Sport held in Zurich, November 2012


4. CDC, Heads Up to Concussion program, 2003- present
|--------|-----------------------------------------------|---------------------------------|---------------------------------|
| **Diagnosis/Evaluation Recommendations** | - Remains a clinical diagnosis to be made by licensed health care providers  
- Graded symptoms checklist  
- Cognitive evaluation (including orientation, past and present memory, new learning, and concentration tests)  
- Balance testing  
- Neurological physical exam  
- Standardized assessment tools  
- Baseline testing (effects are currently unclear but is becoming common practice among experts) | - Graded symptoms checklist  
- Use of the Standardized Assessment of Concussion (standardized sideline evaluation tool that assesses orientation, immediate memory, delayed recall, and concentration) - can be used by non physicians  
- Balance Error Scoring System (assesses balance)  
- Neuropsychological assessments  
- Combining the diagnostic tests mentioned above will likely increase diagnostic accuracy | - Initial assessment of symptoms + continued serial assessments  
- Immediate evaluation of cognition through brief neuropsychological (NP) tests, like SCAT3 or SAC.  
- Detailed history of event and past concussion history  
- Gait and balance testing  
- Comprehensive neuropsychological testing performed by a neuropsychologist (not part of immediate sideline evaluation, in which abbreviated NP testing is recommended)  
- Baseline assessments are recommended although research in this area is limited |
| **Recommendations Based Upon:** | Uses a strength of recommendation taxonomy (SORT) to grade recommendations based upon a review of the literature. | Systematic literature review from 1955 to 2012. Assessed the evidence level in coming up with recommendations. | 4th International Conference on Concussion in Sport held in Zurich, November 2012. A consensus statement was formulated that incorporated data from a systematic literature review, in conjunction, with expert opinions. |
What does this mean? Why so many guidelines?

- Inadequate consensus and too little evidence-based data to support a specific approach
- Research is being done on athletic concussions, but management for all concussion is based on the same principles
- Concussion remains a clinical diagnosis based more on clinical judgment than results on any currently available concussion-related tools
- No current concussion tools that are universally accepted to measure presence or severity of concussion or to predict recovery time
- Imaging can only rule out hemorrhage
So what can be done for these kids?

- Understand the risks for children and when those risks are most concerning
- Know the rules in your state that schools are required to operate by concerning concussion and utilize resources in the school to help children with concussion return to full functioning
- Know your local and internet resources for support in providing good concussion care
- Use these resources to find a fair balance between safety and risk in getting children back to full participation at school & sport
HEADING: Helpful online resource

HEADING: HEADS UP

HEADS UP to Youth Sports

CDC > HEADS UP

To help ensure the health and safety of young athletes, CDC developed the HEADS UP Concussion in Youth Sports initiative to offer information about concussions to coaches, parents, and athletes involved in youth sports. The HEADS UP initiative provides important information on preventing, recognizing, and responding to a concussion.

Specific Concussion Information for...

- Coaches
  - Concussion resources for youth sports coaches
  - More

- Parents
  - Concussion resources for parents of youth athletes
  - More

- Sports Officials
  - Concussion resources for youth sports officials
  - More

- Young Athletes
  - Concussion resources for youth athletes
  - More
Another resource available online:

Guidelines for Concussion Management in the School Setting

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Office of Student Support Services
Albany, New York 12234
June 2012
Leading Causes of MTBI (seen in Emergency Depts)

- Falls
- Motor Vehicle trauma
- Unintentionally struck by/ against events
- Sports
- Assaults
Clinical Timeline for Recovery

- Most concussions (80-90% in adult athletes) resolve without interventions by 7 days post-injury.
- In children and adolescents, most symptoms resolve within 3 weeks.
- Physical symptom resolution may not always mean full cognitive recovery.
- In sports concussion research, risk of a second concussion is particularly increased in the 10 days after the concussive injury (80-92% of repeat injuries occur in the 7-10 days post-initial injury).
- Post-concussion syndrome is characterized by prolonged symptoms of concussion beyond 3 months in children and adolescents.
Period of Vulnerability; especially in teens

Another concussion during this period can lead to irreparable damage or death.

- Demand for glucose
- Blood flow
- Metabolic rate for oxygen

150%
100 (Normal)
50
0
-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 days
Post Concussion Syndrome

- Diagnostic criteria: presence of at least 3 post-concussive symptoms that persist at least 3 months after concussive injury (DSM-IV)

- “Minimal, and at times contradictory, evidence exists to associate clinically available factors with eventual development of PCS in children”. Babcock, et al., JAMA PEDIATR/VOL 167 (NO. 2), FEB 2013

- Believed to be interplay of contributing physical, psychological and interpersonal factors in post-concussion syndrome including:
  - Injury severity  
  - Pre-existing conditions  
  - Parental anxiety/fear  
  - Child’s anxiety  
  - Depression/PTSD  
  - Unresolved lawsuits  
  - Initial treatment  
  - Re-habituation
So what’s everyone so afraid of?

✓ **Second Impact Syndrome**
  - Sudden, *catastrophic* brain swelling occurring rapidly after second concussive injury (particularly during the period of vulnerability)
  - Disproportionally affects young people (all reported cases have occurred <20yr olds except in boxing)
  - 1.5 people die after concussion annually in USA
  - Those who do not die are severely disabled

✓ **Chronic Traumatic Encephalopathy**
  - Chronic, progressive, degenerative encephalopathy only definitively diagnosed on autopsy
  - Occurs in individuals who have sustained recurrent concussion and is associated with accumulation of tau proteins.
  - Believed to be a “cumulative” result of previous traumatic brain injuries
Overarching Goals of Concussion Management

- Early identification & evaluation of concussive injury
- Prevent secondary concussive injury
- Expedite recovery
- Safe return to full activities
  ✓ Academics, then activity/sport participation
- Prevent permanent neuropathic changes associated with repeated concussion
Acute Symptoms of Concussion

- Dazed, Confused, Disorientation, LOC
- Poor balance and/or coordination
- Slow or slurred speech. Delayed response to questions
- Amnesia, usually retrograde, but may also be antegrade
- Vacant stare
- Poor concentration or recall
- Unusual emotions or behavior
- Irritability
- Headache, Dizziness
- Tinnitus or sensitivity to noise
- Visual changes and/or Sensitivity to light
- Vomiting
- Tiredness; general and/or “brain feels tired”
- Deterioration in Performance
Early identification & evaluation of concussive injury

- Concussion remains a *clinical diagnosis*. Widespread understanding of concussion risk, early symptoms in educational, sport & community settings is essential.

- In sport, any player suspected of having sustained concussion or shows ANY concussion symptom *must* be pulled from play for evaluation by athletic trainer or licensed provider.

- Sideline assessment tools can assist the layperson or athletic trainer determine likelihood of concussion in individual cases:
  - SCAT & Child SCAT3 (Sport Concussion Assessment Tool 3)
  - SAC (Standardized Assessment of Concussion)

- Further evaluation and monitoring in an Emergency Dept or office setting with HCP should be recommended; for early neuro assessment, injury details, to determine need for imaging to r/o serious brain injury.
**SAC example:**

**Standardized Assessment of Concussion (SAC)**

**ORIENTATION**

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<th>Score</th>
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<td>What is the date?</td>
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<tr>
<td>What day of the week is it?</td>
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<tr>
<td>What year is it?</td>
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<tr>
<td>What time of day is it? (within 1 hour)</td>
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**IMMEDIATE MEMORY**

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<td>Sugar</td>
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**NEUROLOGIC SCREENING**

- Loss of Consciousness: (occurrence; duration)
- Retrograde Amnesia
- Antegrade Amnesia
- Strength
- Sensation
- Coordination

**CONCENTRATION:** Digits Backwards

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<thead>
<tr>
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<th>Form D</th>
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<td>4-8-5-2-7</td>
<td>6-1-8-4-3</td>
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<tr>
<td>8-3-1-9-8-4</td>
<td>7-2-4-8-5</td>
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**Months in Reverse Order**

Dec, Nov, Oct, Sept, Aug, Jul, Jun, May, Apr, Mar, Feb, Jan

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<th>Delayed Recall</th>
<th>Score: _____ / 5</th>
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<td>Word 2</td>
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<td>Word 3</td>
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</tr>
<tr>
<td>Word 4</td>
<td>0</td>
</tr>
<tr>
<td>Word 5</td>
<td>0</td>
</tr>
</tbody>
</table>

**SCORE TOTALS**

- Orientation = _____ / 5
- Immediate Memory = _____ / 15
- Concentration = _____ / 5
- Delayed Recall = _____ / 5

**Overall Score**

/ 30
Prevent secondary concussive injury

- If diagnosed with concussion they must be pulled from play and not allowed to return to play on day of injury
- “When in doubt, pull them out”
- Player must be evaluated by healthcare provider and followed for persistent symptoms or deterioration of neurological status
- Clearance for activity participation required by HCP AND successful completion of Return to Play criteria is meant to ensure adequate brain recovery before full contact sport is allowed
Expedite Recovery from Concussion

- Provide the nervous system with initial cognitive and physical rest to facilitate healing, but just for up to 1 week.
- Avoid requiring “too much, too early” of injured brain, but guide them to slowly return to their baseline.
- Seek to prevent depression from inactivity or hyper-vigilance of symptomatology. Move to slowly increase academics, then activity.
- May need periods of rest if symptoms reappear when pt tries to do more. Then they may return later that day or the next to try again. Notes to schools can help with rest periods or for extra time on tests/projects for a few weeks.
- Re-emergence of symptom is the current “boundary” of tolerance - convey you expect the boundary to improve day by day.
- Requires clinical judgment involving both reserve and encouragement.
COGNITIVE
- Feeling Mentally Foggy
- Difficulty Concentrating
- Difficulty Remembering
- Repeats Questions
- Feeling Mentally Slowed Down
- Forgetful of Recent Information
- Confused About Recent Events
- Answers Questions Slowly

PHYSICAL
- Headache
- Nausea/Vomiting
- Balance Problems
- Numbness/Tingling
- Sensitivity to Light/Noise
- Visual Problems
- Dizziness
- Dazed or Stunned

EMOTIONAL
- Irritability
- Sadness
- More Emotional
- Nervousness

SLEEP
- Drowsiness
- Sleeping Less Than Usual
- Sleeping More Than Usual
- Trouble Falling Asleep
Return to Learn

- Recognition & accommodation for “invisible” injury of concussion
- Founded on evidence that using a concussed brain to learn may worsen concussion symptoms and perhaps prolong recovery
- **GOAL:** Cognitive rest and paced return to full academic load *BEFORE* attempting Return to Play
- Neuropsych Tests (Impact & Others) cannot determine when the child is “ready” for return to full academics but can identify where problems exist and strategies for overcoming them
- Minimize/Limit stressors that trigger symptom return;
  - Homework
  - Reading/Testing
  - Texting/video games/TV
  - Smartboards
  - Bright lights/Noisy environments
<table>
<thead>
<tr>
<th>Sign/Symptom</th>
<th>Potential Implications in School</th>
</tr>
</thead>
</table>
| Headache                                 | Most common symptom reported in concussions  
Can distract the student from concentration  
Can vary throughout the day and may be triggered by various exposures, such as fluorescent lighting, loud noises, and focusing on tasks |
| Dizziness/lightheadedness                | May be an indication of injury to vestibular system  
May make standing quickly or walking in crowded environment challenging  
Often provoked by visual stimulus (rapid movements, videos, etc) |
| Visual symptoms: light sensitivity, double vision, blurry vision | Troubles with various aspects of the school building  
Slide presentations  
Movies  
Smart boards  
Computers  
Handheld computers (tablets)  
Artificial lighting  
Difficulty reading and copying  
Difficulty paying attention to visual tasks |
| Noise sensitivity                        | Troubles with various aspects of the school building  
Lunchroom  
Shop classes  
Music classes (band/choir)  
Physical education classes  
Hallways  
Organized sports practices |
| Difficulty concentrating or remembering | Challenges learning new tasks and comprehending new materials  
Difficulty with recalling and applying previously learned material  
Lack of focus in the classroom  
Troubles with test taking  
Troubles with standardized testing  
Reduced ability to take drivers education classes safely |
| Sleep disturbances                       | Excessive fatigue can hamper memory for new or past learning or ability to attend and focus  
Insufficient sleep can lead to tardiness or excessive absences  
Difficulty getting to sleep or frequent waking at night may lead to sleeping in class  
Excessive napping due to fatigue may lead to further disruptions of |
<table>
<thead>
<tr>
<th>Sign/Symptom</th>
<th>Potential Adjustments in School Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent breaks</td>
<td></td>
</tr>
<tr>
<td>Identify aggravators and reducing exposure to them</td>
<td></td>
</tr>
<tr>
<td>Rests, planned or as needed, in nurses office or quiet area</td>
<td></td>
</tr>
<tr>
<td>Allow student to put head down if symptoms worsen</td>
<td></td>
</tr>
<tr>
<td>Give student early dismissal from class and extra time to get from class to class to avoid crowded hallways</td>
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<tr>
<td>Reduce exposure to computers, smart boards, videos</td>
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<tr>
<td>Reduce brightness on the screens</td>
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</tr>
<tr>
<td>Allow the student to wear a hat or sunglasses in school</td>
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<tr>
<td>Consider use of audiotapes of books</td>
<td></td>
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<tr>
<td>Turn off fluorescent lights as needed</td>
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<tr>
<td>Seat student closer to the center of classroom activities (blurry vision)</td>
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<tr>
<td>Cover 1 eye with patch/tape 1 lens if glasses are worn (double vision)</td>
<td></td>
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<tr>
<td>Allow the student to have lunch in quiet area with a classmate</td>
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<tr>
<td>Limit or avoid band, choir, or shop classes</td>
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<tr>
<td>Avoid noisy gyms and organized sports practices/games</td>
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<tr>
<td>Consideration of the use of earplugs</td>
<td></td>
</tr>
<tr>
<td>Give student early dismissal from class and extra time to get from class to class to avoid crowded hallways during pass time</td>
<td></td>
</tr>
<tr>
<td>Avoid testing or completion of major projects during recovery when possible</td>
<td></td>
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<tr>
<td>Provide extra time to complete nonstandardized tests</td>
<td></td>
</tr>
<tr>
<td>Postpone standardized testing (may require that 504 plan is in place)</td>
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</tr>
<tr>
<td>Consider 1 test per day during exam periods</td>
<td></td>
</tr>
<tr>
<td>Consider the use of preprinted notes, notetaker, scribe, or reader for oral test taking</td>
<td></td>
</tr>
<tr>
<td>Allow for late start or shortened school day to catch up on sleep</td>
<td></td>
</tr>
<tr>
<td>Allow rest breaks</td>
<td></td>
</tr>
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</table>
Return to Learn

- Individualized approach geared to support progressive return to full academic responsibilities
- Geared toward acknowledging child’s specific symptoms and adjusting for symptoms, while expecting full recovery to occur
- Message should be to continue to try to push up to limit (symptom return) but not really beyond; expectation is that the limit will ‘expand’ with time as brain heals and habituation occurs
Safe Return to Full Physical Participation

- Physical rest includes (particularly in the first few days)
  - Adequate nightly sleep
  - Rest periods or (brief) naps
  - Avoiding physical exertion - both organized and recreational

- Incremental, progressive return to normal daily activities

- Clearance to participate in formal Return to Play criteria
  - Can occur when symptom-free at rest for at least 24 hours
  - Takes at least 5 days to accomplish RTP steps
  - May progress to the next RTP activity if no return of concussion symptoms (not typical of pre-concussion status) occurs
  - If symptoms do re-appear with physical exertion, then child must return to previous level of activity and re-attempt new level after another 24 hr symptom-free period passes
Return to Play Criteria

- **Step 1 / Baseline**: Complete physical and cognitive rest for a minimum of 24 hours symptom free

- **Step 2 / Light Aerobic Exercise**: Increase heart rate for 5-10 min with exercise bike, walking, light jogging. No weight lifting, jumping or running

- **Step 3 / Moderate Exercise**: Increase muscle exertion and heart rate without significant trunk or head movement with moderate jogging, moderate intensity stationary bike, mild weight-lifting.

- **Step 4 / Non-Contact Exercise**: More intense workout but without risk of contact or collision with another individual

- **Step 5 / Return to Full Practice**: Full contact without full stress of competition

- **Step 6 / Play**: Return to competition
<table>
<thead>
<tr>
<th>Step/Stage</th>
<th>Activity</th>
<th>Description</th>
<th>Time Frame</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Activity</td>
<td>Complete rest</td>
<td>Variable-as long as it takes</td>
<td>Individual recovery</td>
</tr>
<tr>
<td>2</td>
<td>Light Aerobic</td>
<td>Exercise Walking or stationary bike</td>
<td>~ 15 minutes of activity</td>
<td>Increase heart rate (HR)</td>
</tr>
<tr>
<td>3</td>
<td>Sport specific activity</td>
<td>NON-CONTACT drills or resistance training. (away from practice)</td>
<td>20-30 minutes</td>
<td>Add movement &amp; increase HR</td>
</tr>
<tr>
<td>4</td>
<td>Practice-A</td>
<td>Full training drills, (Still NON CONTACT)</td>
<td>Full length practice</td>
<td>Increase physical and cognitive load</td>
</tr>
<tr>
<td>5</td>
<td>Practice-B</td>
<td>Full contact practice</td>
<td>Full length practice</td>
<td>Assessment of functional skills &amp; restore confidence</td>
</tr>
<tr>
<td>*</td>
<td></td>
<td><em>Completion of stage/step 5 warrants re-evaluation by sports medicine specialist</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Full return to sport without restrictions</td>
<td>Full game play</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>
Summary: Prevent permanent neuropathic changes

- Advocate for and adhere to rules & protective gear in sport that may minimize risk for concussive injury, most especially in the pre-pubescent athlete.

- “When in doubt, sit them out”

- Understand & educate that greatest risk for re-injury is in the first 7-10 days post-concussion and that children commonly recover more slowly than adults.

- Provide balanced approach; initial caution followed by progressive return to academic, then physical activities while providing assurance and re-assurance that full recovery is expected.
All concussions are serious. If you think you have a

CONCUSSION:

* Don’t hide it.
* Report it.
* Take time to recover.

HEADACHE
PRESSURE IN HEAD
NAUSEA OR VOMITING
BALANCE PROBLEMS OR DIZZINESS
DOUBLE OR BLURRY VISION
SENSITIVITY TO LIGHT OR NOISE
FEELING SLUGGISH, HAZY, FOGGY, OR GROGGY
CONCENTRATION OR MEMORY PROBLEMS
CONFUSION
JUST NOT “FEELING RIGHT” OR “FEELING DOWN”


-Halstead, et al., Returning to learning following concussion. *Pediatrics, 132 (5), 948-957*


-University of the State of NY. Guidelines for concussion management in the school setting. *NYS Education Dept, June 2012*
http://www.knowconcussion.org/about-concussion/


http://www.cdc.gov/traumaticbraininjury/get_the_facts.html

http://www.google.com/url?url=http://bianys.org/_literature_98853/Conc_in_the_Classroom&rct=j&frm=1&q=&esrc=s&sa=U&ei=L_5GVMjIE-KasQTUs0KYAw&ved=0CBoQFjAB&usg=AFQjCNHWuZ8YXc73Au_l_Au8MsX6-A_4vg