

**Detecting and treating
childhood head injuries
from falls and sports-
related accidents**

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Definitions

- ▶ Mild traumatic brain injury (TBI) occurs with head injury due to contact and/or acceleration/deceleration forces. It is typically defined as mild by a Glasgow Coma Scale (GCS) score of 13 to 15, measured at approximately 30 minutes after the injury. Some recommend classifying patients with a GCS score of 13 as moderate head injury (GCS score of 9 to 12)



Definitions

- ▶ Definition from a 2012 international multidisciplinary conference on concussion:
 - "Concussion is a brain injury and is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathological, and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include the following:



Definitions

- ▶ Concussion
 - may be caused by a direct blow to the head, face, neck, or elsewhere on the body with an 'impulsive' force transmitted to the head.
 - typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.

Definitions

- ▶ Concussion
 - may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than structural injury, and as such, no abnormality is seen on standard structural neuroimaging studies.
 - results in a graded set of clinical syndromes that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course, however, in some cases, symptoms may be prolonged.

Definitions

- ▶ Clinically Important Traumatic Brain Injury
 - Presence of an intracranial injury (eg, epidural hematoma, subdural hematoma, or cerebral contusion) on CT associated with one or more of the following:
 - Neurosurgical intervention (either surgery or invasive intracranial pressure monitoring)
 - Endotracheal intubation for the management of head injury
 - Hospitalization directly related to the head injury for at least 48 hours
 - Death
 - **OR**
 - Depressed skull fracture warranting operative elevation (ie, depressed past the inner table of the skull)
 - Clinical findings of a basilar skull fracture (periorbital ecchymosis, Battle's sign, hemotympanum, cerebrospinal fluid [CSF] otorrhea, or CSF rhinorrhea)





Epidemiology

- ▶ The Centers for Disease Control and Prevention estimate that as many as 3.8 million sport-related traumatic brain injuries occur annually.
- ▶ The vast majority of traumatic brain injuries that occur in sports are concussions.
- ▶ Approximately, 13 to 15 percent of all sport-related injuries sustained by high school athletes are concussions.
- ▶ The incidence of concussion is highest among boys playing collision sports, such as American football, ice hockey, and lacrosse. Among girls, those who participate in soccer, lacrosse, and field hockey have the highest incidences of concussion.
- ▶ Concussion also frequently accompanies motor vehicle collisions and injuries sustained during other recreational activities (eg, bicycle riding, skate-boarding, ice skating, or skiing) in children and adolescents.

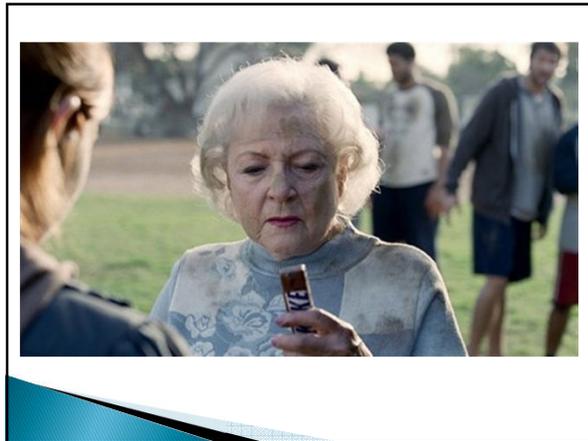
Pathophysiology

- ▶ Animal and human studies demonstrate that concussion results from a rapid rotational acceleration of the brain.
- ▶ Direct impact to the head is not required
- ▶ In concussions resulting from direct head trauma, top of the head impact was significantly more likely to cause loss of consciousness than front of the head or side of the head impact (8 versus 3.5 percent).

Pathophysiology

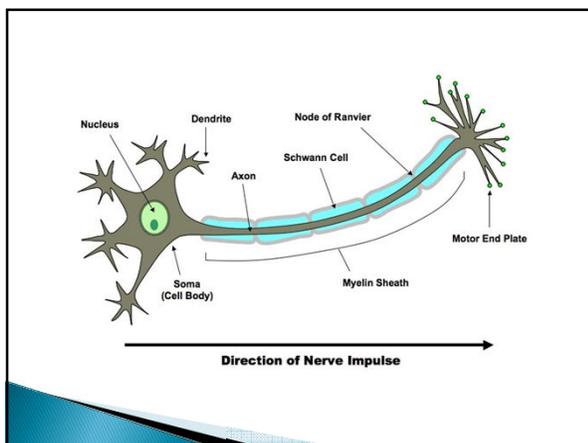
- ▶ Rotational acceleration of the brain can cause:
 - **Neuronal depolarization** - This can cause rapid, massive release of ions (especially sodium and potassium) in neurons, as well as release of neurotransmitters.
 - **Local lactic acid accumulation** - As ionic homeostasis is disrupted, affected neurons are suppressed and cannot fire normal, purposeful action potentials until ionic homeostasis is restored leading to local lactic acid accumulation.
 - **Decreased cerebral blood flow with mismatch of cerebral glucose supply and demand** - Therefore, there is a decrease in cerebral blood flow for a period of days to weeks after concussion. Since glucose is delivered to the brain via the blood stream, the increased demand for glucose and its end product, ATP, go unmet. This supply-demand mismatch is thought to result in the cognitive dysfunction and symptoms of concussion.





Pathophysiology

- ▶ Mild head injury may result in cortical contusions due to coup and contrecoup injuries.
- ▶ Contributing factors/ effects:
 - axonal rupture from shear and tensile forces
 - disruption of axonal neurofilament organization
 - release of excitatory neurotransmitters
 - acetylcholine, glutamate, and aspartate, and the generation of free radicals may contribute to secondary injury



Pathophysiology

- ▶ There is no absolute certainty about the pathophysiologic causes of concussion and traumatic brain injury, but these are the leading theories

CLINICAL FEATURES

Acute symptoms and signs

- ▶ Children and adolescents who sustain a concussion may manifest a variety of acute clinical findings including:
 - Headache
 - Confusion and disorientation (eg, walking in the wrong direction, not aware of the time, date, or place)
 - Difficulties with memory (eg, asking the same question over and over again)
 - Blank stare or "stunned" appearance
 - Inattentiveness (eg, difficulty following instructions or focusing on a task)
 - Slow or incoherent speech
 - Dizziness
 - Gait abnormalities and imbalance (stumbling, falling)
 - Vomiting
 - Emotional lability (eg, inappropriate laughing or crying)

Acute symptoms and signs

- ▶ Seizures
 - Early post-traumatic seizures are those that occur within the first week after head injury.
 - Occur in fewer than 5 percent of mild or moderate traumatic brain injury (TBI), and they are more common with more severe TBI.
 - About half occur within the first 24 hours of the injury; one quarter occur within the first hour.
 - The earlier a seizure begins, the more likely it will be generalized in onset; after the first hour more than half are either simple partial (pure motor) seizures or focal with secondary generalization.
 - Early seizures increase the risk of post-traumatic epilepsy by fourfold, to more than 25 percent.

ACUTE EVALUATION AND MANAGEMENT

Initial Evaluation

- ▶ Depending on the severity of the injury patients should be medically evaluated by a trained licensed health professional, whether on an athletic field sideline, in a medical office, or in an emergency room.
- ▶ The acute evaluation of an individual includes a neurologic assessment and mental status testing.
- ▶ Prolonged unconsciousness, persistent mental status alterations, or abnormalities on neurologic examination require urgent neuroimaging and neurosurgical consultation

Evaluation– Athletic Field Sideline

- ▶ Standardized examinations are frequently helpful in establishing the diagnosis of concussion.
- ▶ In the ideal situation, preparticipation baseline scores of cognitive function and balance performance are available from from standardized assessment tools.
- ▶ A difference from baseline relative to scores taken after a suspected concussion along with the physical findings can support the diagnosis.
- ▶ If no preparticipation score was done on a standardized instrument, the instrument can still be used and compared to normative data.

Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)

- ▶ A mini neurocognitive test
- ▶ Commonly used by the Sports Medicine physicians at St. Elizabeth's and Children's
- ▶ Can be done pre-season in order to compare a baseline score to a post-injury score
- ▶ To be valid it must be done according to strict guidelines
- ▶ Risk: Some high school athletes will invalidate the test by faking wrong answers

Immediate Postconcussion Assessment and Cognitive Testing (ImPACT)

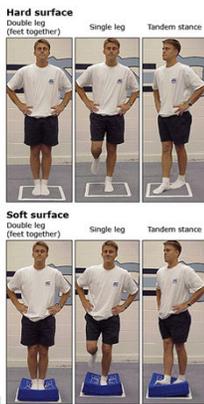
- ▶ The program measures multiple aspects of cognitive functioning in athletes, including:
 - Attention span
 - Working memory
 - Sustained and selective attention time
 - Response variability
 - Non-verbal problem solving
 - Reaction time

Evaluation- Athletic Field Sideline

- ▶ **Sideline assessment tools** - Although tests vary, most sideline tests include measurements of orientation, symptoms, gross cognition, and physical examination findings.
- ▶ **Symptom inventories** - These measures are derived from age- appropriate sideline concussion instruments.

Evaluation- Athletic Field Sideline

- ▶ **Balance, eg, the Balance Error Scoring System (BESS)** - The BESS is useful for detecting the often subtle changes in balance that may occur after sport-related concussions.
 - With the eyes closed, the athletes are asked to do the following on both soft and firm surfaces over 20 seconds with the hands placed on the iliac crests:
 - Single-leg stance
 - Double-leg stance
 - Tandem stance
 - Errors are recorded each time athletes open their eyes, lift their hands off of their iliac crests, stumble, move into greater than 30 degrees of hip flexion or abduction, lift their heel or forefoot, or remain out of position for more than five seconds.
- ▶ For patients not assessed on the field but rather referred directly to a health care provider, these tests can be helpful in the initial assessment as well



Evaluation- Subacute or Office Assessment- History

- ▶ Key historical features to identify in children and adolescents with a suspected concussion include:
 - **Mechanism of injury** - The location and force of impact and presence of high risk mechanisms (eg, double hit).
 - **Loss of consciousness (LOC) or seizures** -Significant loss of consciousness is unlikely in patients who clearly remember details of the incident. Loss of consciousness, particularly with a duration greater than one minute and concussive seizures are uncommon among children and adolescents with sport-related concussions, occurring in <10 percent and approximately 1 percent of patients, respectively.
 - **Neurologic symptoms** - Numbness, tingling, or paralysis at any time after the injury, even if transient, suggest a possibility of serious spinal cord injury.

Evaluation- Subacute or Office Assessment- History

- ▶ Symptoms suggesting concussion:
 - Headache
 - Fatigue
 - Dizziness
 - Nausea
 - Self-limited vomiting occurring soon after the injury
 - Unsteadiness with standing or walking
 - Feeling mentally slow or foggy
 - Difficulty remembering including anterograde amnesia (ie, difficulty remembering the event or things that happened after the event [eg, coming off the field or transport home or to the hospital]) or retrograde amnesia (ie, difficulty remembering things that happened before the event [eg, who he or she was playing, the score of the game, or what he or she ate at the meal prior to the game])
 - Trouble with concentration
 - Disturbance of sleep (eg, drowsiness while awake, sleeping more or less than usual, difficulty with falling asleep)
 - Emotional changes, such as emotional lability, irritability, sadness, or nervousness

Evaluation- Subacute or Office Assessment- Physical Examination

- ▶ **Neck** - Some patients will sustain a concomitant neck injury including muscle strain, ligamentous sprains or, rarely, bony injuries. Thus, the cervical spine should be carefully assessed. Immobilization and appropriate imaging should be performed if cervical spine injury is suspected
- ▶ **Neurologic examination** - The patient should undergo a detailed neurological assessment, including mental status, cognitive functioning, gait, and balance. Cranial nerve, sensory, and motor findings typically are normal in concussed children and adolescents. Any focal neurological deficits noted on physical examination should prompt the clinician to evaluate for intracranial and/or spinal cord injuries.

Evaluation- Subacute or Office Assessment- Ancillary Studies

▶ Indications for neuroimaging in Children and Adolescents.

- High-risk patients have one or more of the following signs or symptoms, and should undergo a head CT:
 - Suspicion of child abuse
 - Focal neurologic findings
 - Acute skull fracture, including depressed or basilar fracture
 - Altered mental status change (eg, lethargy or irritability)
 - Bulging fontanelle
 - Persistent vomiting (recommendations vary between vomiting that persists for more than 4-6 hours after the acute injury).
 - Seizure following injury
 - Definite loss of consciousness if longer than a few seconds and especially if associated with other clinical predictors of clinically important TBI

Evaluation- Subacute or Office Assessment- Ancillary Studies

▶ Indications for neuroimaging in Children and Adolescents.

- Intermediate-risk patients may be managed with close observation for four to six hours after the injury (with imaging obtained for any worsening condition during this period), or they may be evaluated immediately by head CT. Patient at intermediate-risk have any one or more of the following signs or symptoms:
 - Vomiting that is self-limited
 - Loss of consciousness that is uncertain, or isolated and very brief (less than a few seconds)
 - History of lethargy or irritability, now resolved
 - Behavioral change reported by caregiver
 - Injury caused by high-risk mechanism of injury (eg, fall more than three feet, patient ejection, death of a passenger, rollover, high-impact head injury)
 - Scalp hematoma (particularly nonfrontal)
 - Skull fracture more than 24 hours old (nonacute)
 - Unwitnessed trauma of concern (eg, fall heard in adjacent room with possible loss of consciousness)
 - Age younger than three months with nontrivial trauma

Scalp hematoma



Frontal hematomas in a 20-month-old child.
Credit: Grand / Science Source Images

Evaluation- Subacute or Office Assessment- Ancillary Studies

- **Functional MRI and other advanced imaging techniques** - In very specific children with persistence of, other highly specialized studies such as functional MRI (fMRI), proton magnetic resonance spectroscopy, and whole brain diffusion tensor imaging have been associated with specific cognitive deficits in children with concussion. These should not be performed routinely, however.

Evaluation- Emergency Department Setting

- ▶ Rule out multiple trauma- Level of alertness, vital signs, careful physical examination
- ▶ Rule out a cervical spine injury

Evaluation- Emergency Department Setting

- ▶ Rule out serious head injury
 - **High risk** - Patients who are generally well appearing but have any one of the following findings warrant prompt neuroimaging to exclude serious intracranial injuries):
 - Focal neurologic findings
 - Skull fracture, especially findings of basilar skull fracture
 - Seizure
 - Persistent alteration in mental status
 - Prolonged loss of consciousness

Evaluation- Emergency Department Setting

- ▶ Rule out serious head injury (Continued)
 - **Moderate risk** - Patients with headache, vomiting, a questionable or brief loss of consciousness, or injury caused by a high-risk mechanism warrant observation to determine if symptoms improve or worsen. Those with worsening symptoms warrant neuroimaging. However, many children or adolescents with suspected concussion will improve during the observation period and not require imaging.
 - **Low risk** - Neuroimaging should be avoided in patients with no loss of consciousness, a normal mental status, no signs of basilar skull fracture, no vomiting, no other concerning factors, and a headache that is improving or responds to oral ibuprofen or acetaminophen. These children and adolescents are at very low risk for serious intracranial injury

Return to Play for Athletes (RTP)

- ▶ Various guidelines have been developed, including the
 - 2012 Consensus Statement on Concussion in Sport
 - American Academy of Neurology 2013 systematic review and evidence-based guideline
 - 2013 American Medical Society for Sports Medicine position statement
- ▶ There is controversy regarding the reliability of these guidelines
- ▶ Premature return to play, when an athlete is still symptomatic, places that athlete at great risk for subsequent injury, including recurrent concussion.
- ▶ Having a concussion puts an athlete at greater risk for having future concussions

Return to Play for Athletes- (RTP)

- ▶ Current recommendations
 - Athletes suspected of having a concussion should be removed from play and evaluated by a licensed health professional.
 - An emergency department evaluation is indicated for any athlete who suffers loss of consciousness
 - Athletes with diagnosed concussion should be removed from play or practice (contact-risk activity) until symptoms have resolved off medication.

Return to Play for Athletes

- ▶ Current recommendations (continued)
 - A more conservative approach is probably appropriate for children and adolescents.
 - Individuals with a history of multiple concussions should undergo a more detailed evaluation regarding neurobehavioral symptoms; if these are present, they should be referred for neurologic and neuropsychological assessments
 - Patients with persistent neurobehavioral complaints or objective deficits should be counseled about the risk of chronic traumatic encephalopathy and possible retirement from contact sports.

Return to Play for Athletes (RTP)

- ▶ **RETURN TO PLAY (RTP)** — It is suggested that young athletes fully complete the consensus graduated return to play protocol after an individualized period of cognitive and physical rest before clearance for competition.
- ▶ Prior to returning to full athletic participation, recovered athletes should complete a course of non-contact exercise challenges of gradually increasing intensity.
- ▶ The graded RTP protocol advances through the following rehabilitation stages: light aerobic exercise, more intensive training, sports-specific exercises, non-contact participation, full practice, and ultimately, game play.

Return to Play for Athletes (RTP)

- ▶ The following are requirements for children and adolescents to begin the RTP protocol:
 - Successful return to school.
 - Symptom-free and off any medications prescribed to treat the concussion.
 - Normal neurologic examination.
 - Back at baseline balance and cognitive performance measures. If baseline assessments are unavailable, age-adjusted normative data are available and can be useful in attempting to estimate premorbid levels of functioning for a given athlete. Given the variability in performance between athletes, however, baseline data are ideal.
- ▶ Athletes should be symptom-free during and after exertion at a given activity level before progressing to the next level. According to the American Academy of Pediatrics, children and adolescents should remain at each stage of rehabilitation no less than 24 hours before advancing to the next level. Thus, a **minimum** of five days should pass before consideration of full return to competition.

Return to Play for Athletes (RTP)

- ▶ If there is return of symptoms at any level, the athlete should rest until the symptoms resolve, and then attempt the protocol again beginning at the previous level of symptom-free exertion.
- ▶ Because of the concern for complications and permanent brain injury that are associated with overly aggressive return to play in children and adolescents, it is suggested that athletes younger than 13 years of age and those at higher risk (eg, longer duration of symptoms, higher numbers of previous concussions, or returning to higher risk sports) engage in a longer symptom-free waiting period before returning to play.
- ▶ Some clinicians have advocated a requirement of equal number of symptom-free weeks as there were symptomatic weeks during recovery before return to contact practice and play is considered.

Return to Play for Athletes (RTP)

- ▶ Thus, the plan for RTP after a concussion should be individualized, gradual, and progressive.
- ▶ The final decision for RTP should be made by a licensed clinical provider with experience in the evaluation and management of sports-related concussions.
- ▶ The prognosis for RTP cannot be easily predicted by the presenting features of a concussion. Full RTP exercise progression may take days, weeks, or months although most athletes will be cleared to play within one month.

Sequelae

- ▶ Second Impact Syndrome
- ▶ Postconcussion Syndrome
- ▶ Post-Traumatic Headaches
- ▶ Post-Traumatic Epilepsy
- ▶ Post-Traumatic Vertigo
- ▶ Other Cranial Nerve Injuries
- ▶ Chronic Traumatic Encephalopathy
