



Concussion in Sports

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It is the league soccer finals on a crisp fall day. NM, a star forward for the Farview Falcons (who are behind, 0-1), collides with an opposing player while trying to head the ball. Both players tumble to the ground. The opposing player immediately jumps to his feet, but NM arises slowly and starts walking towards the goal, appearing dazed. NM is immediately brought to the sidelines by his teammates where they are met by the team trainer. NM complains of a headache and dizziness but denies any tinnitus, nausea or vision changes. He is oriented to person, place and time, but is unable to recall what period they are playing in or the current score. His symptoms abate after 30 minutes. He denies any other symptoms and desperately wants to continue in the game. A prolonged discussion commences on the sideline between the trainer, the assistant trainer and the player, NM, about when he can return to the game. NM maintains that he “feels completely normal” and he must help his team to win the league finals.

Key Clinical Questions

What role does “loss of consciousness” play in the definition of concussion?

What are the different grades of concussion and what are the implications of the different grades in a player returning to play?

What evaluation can be done on the sidelines to determine the severity and course of a concussion?

Is there a role for neuropsychological testing in the evaluation of concussion?

What should health care providers who care for concussed athletes be aware of in terms of patient instruction and followup?

Background, Risk Factors and Epidemiology

Concussion in sports is a ubiquitous problem. Estimates differ, but the general consensus is that there are approximately 200,000 to 300,000 concussions per year in sports in the United States alone. (1) This number can only be approximated because many concussions in sports are evident only to the individual player, who may be motivated to not report his injury out of fear that he may be removed from play. This is especially true when the concussion does not involve loss of consciousness (LOC), the traditional lay definition of concussion. This is problematic when it is appreciated that more than 75% of mild concussions may not involve LOC. (2) Unfortunately, the concept that one must lose consciousness to have suffered a concussion continues to persist in sections of the medical community as well.

Definition of concussion: Although transient loss of consciousness has long been appreciated as a manifestation of a concussion, the current definition is much broader. In 1966, the Committee of Head Injury Nomenclature of the Congress of Neurological Surgeons defined concussion as “a clinical syndrome characterized by immediate and transient post traumatic impairment of neural function due to brainstem involvement.”(3) This definition has been further broadened to include any posttraumatic alteration in mental status that may or may not involve loss of consciousness. (4) This latter definition, sometimes with minor modifications, tends to be widely accepted today. The Concussion in Sport Group proposed a very general (and lengthy) definition in 2001 which begins, “concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces” and continues for 5 more paragraphs. (5)

As mentioned above, the medical definition of concussion is somewhat problematic, as many athletes who suffer momentary confusion after a collision do not realize that they have sustained a concussion and therefore the event goes unreported. Delaney, in his study of university football and soccer players, found that only one-sixth of the football players and less than one-third of the soccer players who sustained concussions were aware that they had suffered this injury due to their understanding of the definition. (6) Of note, the term “mild traumatic brain injury” has begun to be used in lieu of the term “concussion.” (7)

A major dilemma surrounding concussion in sports is the decision, after a player sustains a concussion, of when the player can be cleared to return to competition. This subject has generated much controversy that is unfortunately based on very limited evidence. A significant concern is returning an athlete to competition who is not capable of meeting the cognitive and physical performance expectations and is therefore at risk of sustaining further injury. An additional major concern about allowing a player to return prematurely to competition is the dreaded, but rare, second-impact syndrome first described in 1984 by Saunders. (8) In this entity, an individual not yet recovered from an initial mild traumatic brain injury sustains a blow to the head (that may be very minor) that results in swift, uncontrollable increase in intracranial pressure due to diffuse brain swelling resulting in death or a permanent vegetative state. (9) This entity, although rare, has been supported by animal studies. (10) Only 21 cases, mainly involving adolescent males or young adults, have been reported in the literature, although the true incidence is questioned by some. (11,12,13) Fear of this entity has been a major motivating factor in the development of multiple “return-to-play” guidelines, all based on little empiric data.

Concussion can occur in almost any sport, but has a higher incidence in those sports where high velocity collisions between players or between a player and an immovable object are prevalent. Gerberich has estimated that each American high school football player runs a 20% risk of sustaining a minor traumatic brain injury in each year of play, although there is evidence that this percentage may be decreasing. (15,16) Other documented high risk school team sports include wrestling, soccer, basketball, baseball, softball, field hockey, ice hockey, lacrosse and volleyball. (7,17) Soccer poses the additional risk that the head is often used to strike and direct the ball. There is much discussion and debate about whether or not this contributes to traumatic brain injury in soccer players. (18,19)

For reasons that are not yet clear, a history of concussion predisposes a player to suffering an additional brain injury. In a 1994, it was found that a previously concussed football player had up to a six times greater chance of suffering an additional concussion as compared to the unconcussed player. (17) There is valid concern that repeated concussions may cause cumulative long-term brain damage. (20)

There is also developing evidence that there may be a genetic component to the brain’s susceptibility to concussion. Studies of retired boxers and football players demonstrated that those with the apolipoprotein E epsilon-4 gene tended to be more impaired or scored worse on cognitive tests than those without this allele. (21)

Anatomy and Pathophysiology

The pathophysiology of traumatic brain injury is covered extensively in other modules of this series. It has been demonstrated that there are three types of forces that can cause injury to the brain: 1) compressive forces or direct pressure; 2) tensile forces or negative pressure, and 3) rotational or shearing forces. It is this last category that has been shown to be responsible for the most devastating of intracranial injuries. Shortly after the assault of force, the affected areas of the brain may enter a state of metabolic dysfunction that produces an extended state of cellular vulnerability manifested by a large potassium ionic flux, increased cellular metabolic requirement (glucose demand) and decreased cerebral blood flow. It is felt that this mismatch between fuel supply and metabolic demand creates a hostile environment with the development of lactate accumulation and intracellular acidosis. This puts compromised brain cells at risk for permanent damage.

Presentation

Although confusion and amnesia are the cardinal features of concussion, they may manifest themselves in a multitude of ways. Table 1 lists the frequently observed neurobehavioral features of concussion. (22) Table 2 lists the symptoms commonly reported following concussion. (22) The concussed individual may present with one or more of any of these and may do so either immediately following the traumatic insult or at some delayed time.

Vacant stare (befuddled facial expression)
Delayed verbal and motor responses (slower to answer questions or follow instructions)
Inability to focus attention (easily distracted and unable to follow through with normal activities)
Disorientation (walking in the wrong direction; unaware of time, date, place)
Slurred or incoherent speech (making disjointed or incomprehensible statements)
Gross observable incoordination (stumbling, inability to walk tandem/straight line)
Emotionality out of proportion to circumstances (appearing distraught, crying for no apparent reason)
Memory deficits (exhibited by the athlete repeatedly asking the same question that has already been answered or inability to memorize and return 3/3 words and 3/3 objects for 5 minutes)
Any period of loss of consciousness (paralytic coma, unresponsiveness to stimuli)

Table 1: Frequently observed neurobehavioral features of concussion

<u>Commonly Seen Early (min to hours)</u>	<u>Commonly Seen Late (days to weeks)</u>
Headache	Persistent low-grade headache
Dizziness or vertigo	Lightheadedness
Lack of awareness of surroundings	Poor attention and concentration
Nausea and vomiting	Memory dysfunction
	Easy fatigability
	Irritability and low frustration tolerance
	Intolerance of lights or difficulty focusing vision
	Intolerance of loud noises, sometimes ringing in ears
	Anxiety and depressed mood
	Sleep disturbance

Table 2: Commonly reported symptoms associated with concussion

Over the years, multiple attempts have been made to develop criteria to grade concussions in terms of severity and then to propose return-to-play guidelines based upon the severity of the concussion. As many as 25 sets of criteria to grade concussions have been developed, all based upon experience, expert consensus or both, with only slight support from empiric data. (12) Currently, probably the three most commonly used concussion in sports guidelines include those promulgated by Cantu (23,24), those developed under the auspices of the Colorado State Medical Society (CMS) (25) and those published by the American Academy of Neurology (AAN) as a practice parameter or guideline. (26) This latter set has the advantage of having been developed by a multi-disciplinary panel with an externalized methodology that included an extensive literature search and grading of evidence presented in the applicable journal articles. As will be seen, all three have much in common but do differ in some classification categories and recommendations. Unfortunately, all of these have little firm support in the literature and are of un-

clear clinical validity. Table 3 delineates the concussion classification schemes of the three guidelines.

Concussion Grade	Cantu – 1998	CMS - 1991	AAN – 1997
Grade 1 – Mild	No LOC and Post-traumatic amnesia < 30 min	No LOC Post-traumatic confusion No post-traumatic amnesia	No LOC Post-concussive sx last < 15 min
Grade 2 – Moderate	LOC < 5 min or Post-traumatic amnesia > 30 min, < 24 hrs	No LOC Post-traumatic amnesia	No LOC Post-concussive sx last > 15 min
Grade 3 - Severe	LOC > 5 min or Post-traumatic amnesia > 24 hrs	Any LOC	Any LOC

Table 3: Classification of concussion severity: Cantu, CMS, AAN

Return-to-play (RTP) recommendations have been established by the respective authors based not only upon the severity of the concussion as scored above, but also duration of any ongoing post-concussive symptoms and the total number of concussions sustained during this season of play. Table 4 represents Cantu’s recommendations. (24)

	First Concussion	Second Concussion	Third Concussion
Grade 1	May RTP if asymptomatic for 1 week	RTP in 2 weeks if asymptomatic for 1 week	Terminate season; may RTP next season if asymptomatic
Grade 2	May RTP if asymptomatic for 1 week	Minimum of 1 month; may then RTP if asymptomatic for 1 week; consider terminating the season	Terminate season; may RTP next season if asymptomatic
Grade 3	Minimum of 1 month; may then RTP if asymptomatic for 1 week	Terminate season; may RTP next season if asymptomatic	

Table 4: Return to play recommendations: Cantu, 1998 (24)

Tables 5 and 6 represent the return-to-play recommendations based upon the CMS and AAN guidelines, respectively.

	First Concussion	Second Concussion	Third Concussion
Grade 1	May RTP if asymptomatic for > 20 min	RTP if asymptomatic for 1 week	Terminate season; may RTP in 3 months if asymptomatic
Grade 2	May RTP if asymptomatic for 1 week	Consider terminating season. May RTP after asymptomatic for 1 month	Terminate season; may RTP next season if asymptomatic
Grade 3	Minimum of 1 month; may then RTP if asymptomatic for 2 weeks	Terminate season; discourage any return to contact sports	

Table 5: Return to play recommendations: CMS, 1991 (29)

	First Concussion	Multiple Concussions
Grade 1	May RTP if asymptomatic in < 15 min at rest and with exertion	RTP in 1 week if asymptomatic at rest and with exercise
Grade 2	May RTP if asymptomatic for 1 week at rest and with exercise	May RTP if asymptomatic for 2 weeks at rest and with exercise
Grade 3	Transport to ED if appropriate; Brief (seconds) LOC: RTP if asymptomatic for 1 week at rest and with exercise; Prolonged (minutes) LOC: RTP if asymptomatic for 2 weeks at rest and with exercise	Transport to ED if appropriate; RTP for a minimum of 1 asymptomatic month or longer based on physician evaluation

Table 6: Return to play recommendations: AAN, 1997 (26)

As can be learned from the above tables, different guidelines vary not only in their definitions of the different grades of concussion, but also in their recommendations for return-to-play for similar presentations. It is important to note, however, that none of the many concussions in sports guidelines have been scientifically validated, being at best expert consensus recommendations. It is also important to appreciate what many of these guidelines have in common: (27)

- Any concussed athlete should be removed from competition, examined and observed
- Serial assessment of the athlete after the concussion is very important
- If the athlete shows any evidence of deterioration, no matter how mild the injury, they should be transported to a hospital for appropriate evaluation
- The athlete with LOC, even momentary, or post-event amnesia should not be allowed to immediately return to play
- The post-concussed athlete should not be returned to play until completely asymptomatic, both at rest and after exertion
- Multiple concussions may have a cumulative effect on the athlete

Most guidelines also stress that their use is only one aspect of the complete evaluation of the concussed athlete. Other factors may be considered in either shortening or lengthening the period before the athlete is allowed to return to play. Other factors would include previous brain trauma, the athlete's age and the athlete's thorough understanding of the risks involved.

Side line assessment: As is stressed by most return-to-play guidelines, the athlete must be evaluated initially and over time for the presence or absence of any post-concussion signs or symptoms. It has long been appreciated that the traditional orientation component (person, place, date) of a neurological examination lacks sensitivity to detect subtle defects in the athlete's neurocognitive status. Maddocks proposed in 1995 that other questions testing recent and remote memory should be substituted to provide improved sensitivity. (28) In an attempt to provide a more standardized and systematic evaluation tool, McCrea and his coworkers proposed the "Standardized Assessment of Concussion" (SAC) instrument in 1997 which subsequently has been demonstrated to be easy to administer by field staff, and is a reliable and sensitive adjunct for the evaluation of the post-concussed player. (29,30) This instrument tests the following, allowing for a point value to be assigned for the successful completion of each category:

- Orientation (Month, Date, Day of Week, Year, Time)
- Immediate Memory (3 trials of 5 words)
- Concentration (3, 4, 5 and 6 digit strings backwards)
- Delayed Recall (1 trial of 5 words, used above)

This instrument also includes a brief neurological screen including loss of consciousness, retrograde and post-event amnesia, strength, sensation and coordination. Exertional maneuvers are also included when appropriate: 5 jumping jacks, 5 sit-ups, 5 push-ups and 5 knee-bends. This tool allows for scoring in a field setting and can also be used to establish a pre-injury baseline score for use in comparison to the athlete's post-injury value (maximum total score of 30). A decrease of one point or more from an athlete's baseline value has a 94% sensitivity and 76% specificity in separating injured from non-injured players using the criteria in the AAN guideline. (30)

Imaging Studies

Neuroimaging studies (CT/MRI) in mild traumatic brain injury are covered in detail by other modules in this series. Athletes sustaining mild uncomplicated concussions will rarely require neuroimaging. (31) However, deterioration of the clinical picture, focal neurologic findings, persistent or worsening post-concussive symptoms or other high risk medical conditions such as anticoagulation or hemophilia may mandate neuroimaging. Although experience with MRI is increasing, general availability and ease of access have made axial CT the accepted standard for acute evaluation of head trauma. Studies continue on the evaluation of other imaging modalities such as single photon emission computerized tomography (SPECT) and positron emission tomography (PET) in the evaluation of minor traumatic brain injury.

Neuropsychological Testing

Over the last several decades, much study had been done on neuropsychological testing as it applies to concussion in sports. Formal neuropsychological testing can be an additional tool used in the evaluation of an athlete's recovery from concussion, but several caveats apply: because of the wide variation in tests, the best specific tests have yet to be conclusively demonstrated; baseline testing must be done for accurate determination of an athlete's post-concussive status, and

the time and attendant costs may preclude wide-spread application.(32) Computer and web-based testing may alleviate some of the time and cost constraints. (33,34) Although formal recommendations for neuropsychological testing have not been developed, this methodology may currently prove to be a helpful tool in evaluation and return-to-play recommendations for athletes suffering severe or prolonged post-concussive symptoms, severe concussions, multiple concussions or in situations where athlete truthfulness about symptoms may be an issue. (34). Appropriate neuropsychological testing has been endorsed by the international Concussion in Sport Group. (5)

Emergency Department Care

Immediate ambulance transport to an emergency department for further evaluation and treatment is indicated for those athletes suffering prolonged loss of consciousness during sport participation as well as any individual suffering deterioration after sustaining a concussion. These individuals should undergo appropriate trauma evaluation following accepted guidelines of trauma care, including assessment for concomitant injuries and neuroimaging and specialty consultation as indicated. These topics are covered in other modules of this series. There are several issues specific to concussions in sports, however, that are of concern.

Thoroughness of ED evaluation: As noted above, post-concussive symptoms and findings may be somewhat subtle and difficult to elicit unless carefully sought. Traditional approaches to the concussed athlete who appears grossly normal at presentation may not adequately test for these residual findings. The lack of a standardized approach to these patients, lack of knowledge of return-to-play guidelines, and inadequacies of discharge instructions further compromise their evaluation and treatment . Although somewhat dated, Genuardi and King studied adequacy of discharge instructions in 33 pediatric athletes admitted to hospital with sports-related traumatic brain injuries from 1987 to 1991. (35) They found that less than one-third of these patients had been provided with hospital discharge instructions that appropriately dealt with return-to-play recommendations. A similar study presented in 1996 found almost identical results when evaluating adequacy of aftercare instructions given to athletes with a sports-related mild brain injury discharged home from an emergency department.(36) A further study involving a survey of 1140 pediatricians, family practitioners, emergency physicians and nurse practitioners demonstrated, in 3 hypothetical concussion scenarios, significant deviation from the return-to-play recommendations of an accepted guideline (CMS) 92% of the time for Grade 1 injuries, 44% of the time for Grade 2 injuries and 72% of the time for Grade 3 injuries. (37) Although flawed in many respects, this study confirms an ongoing lack of appreciation of return-to-play recommendations amongst clinicians likely to be involved in the care of concussed athletes. This is clearly an area that could benefit from additional efforts in education and awareness. Clinicians must not only be aware of return-to-play guidelines, but they must also adequately and appropriately convey this information to the concussed athlete. Advice concerning real world activities such as driving a motor vehicle and activities in the work place should also be supplied to a post-concussive individual who has not fully clinically and cognitively recovered. Discharge instruction sheets should be updated to reflect these concepts.

Summary

- The majority of concussions sustained in sports by athletes do not involve loss of consciousness, but rather aspects of confusion and/or amnesia
- Although the many concussion grading criteria and return-to-play criteria have limited scientific grounding, they serve as useful tools to guide those caring for concussed athletes
- To avoid further injury and possibly the potentially lethal “second impact syndrome”, concussed athletes should not return to play until completely asymptomatic, sometimes requiring a prolonged period of absence from competition
- The sideline use of detailed mental status screening tools allows for more sensitivity and standardization in the evaluation of the concussed athlete
- Extensive neuropsychological testing may be warranted in situations of ongoing post-concussive symptoms, multiple concussions or severe concussions
- Ongoing education of athletes is necessary to reinforce the concept that one can sustain a concussion without any loss of consciousness
- Ongoing education of providers as to the existence of concussion in sports guidelines is necessary to insure appropriate and thorough evaluation of concussed athletes on the field, in the office and in the emergency department. These guidelines should be utilized as part of the decision-making process of when the athlete should be allowed to return to play and to insure the adequacy of patient post-injury education.

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Outcome of Case

After much discussion and argument (along with the trainer confiscating NM's shoes), NM relented and sat out the remainder of the game. As part of the trainer's initial evaluation of the athlete, he administered the Standardized Assessment of Concussion (SAC) tool to NM, evaluating not only orientation and a brief neurological screen, but also immediate memory, concentration and delayed recall. NM scored a 23 out of a possible 30. A baseline value had been established through testing before the season started for each team member; NM's baseline value had been 27. The value of 23 represented a significant decrease from his baseline. NM was carefully instructed by the trainer about symptoms to be aware of that could represent a worsening of his traumatic brain injury or could indicate a post-concussive syndrome. NM did have recurrence of his headache that evening, but it had abated by the next morning and he remained symptom free. Re-administration of the SAC instrument 48 hours post-injury revealed return to his normal baseline of 27. This time the tool had been administered with the evocative exertional maneuvers included. NM was counseled to not engage in contact sports for an additional week. Because he had not lost consciousness a signed note from his physician was not required for return to play. By the way, the Farview Falcons won the league title, 2-1.

Annotated Bibliography

1. **Johnston KM, McCrory P, Mohtadi NG, Meeuwisse W: Evidence-based review of sport-related concussion: clinical science. *Clin J Sport Med* 2001 Jul;11(3):150-159.**

A review of concussion in sports including definitions, clinical symptoms, injury severity grading, classification and sequelae. Where possible, the authors utilize an evidence-based approach in presenting and discussing many aspects of this entity.

2. **Kelly JP, Nichols JS, Filley CM, et al: Concussion in sports. Guidelines for the prevention of catastrophic outcome. *JAMA* 1991 Nov 217;266(20):2867-9.**

A presentation of a reported case of second impact syndrome with a fatal outcome with following presentation and discussion of the Colorado Medical Society guidelines for the management of concussion in sports.

3. **Bailes JE, Cantu RC: Head injury in athletes. *Neurosurgery* 2001 Jan;48(1):26-45.**

A comprehensive (although somewhat biased) review of the state of knowledge of concussion in sports, including enlightening sections on the biomechanics and pathophysiology of concussion.

4. **Aubry M, Cantu R, Dvorak J, et al: Summary and agreement statement of the first international conference on concussion in sport, Vienna 2001. Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries. *Br J Sports Med* 2002 Feb;36(1):6-10**

Multiple international experts in the field of concussion in sports formed the Concussion in Sport Group. This article is a product of the first international conference and represents those areas of agreement and those of disagreement. A new (and very long) definition of concussion is proposed. No single concussion grading scale is endorsed. Neuropsychological testing is supported.

5. **AAN Quality Standards Committee: Practice parameter: the management of concussion in sports. *Neurology* 1997 Mar, 48(3): 581-585.**

The practice guideline from the AAN regarding grading of concussion in sports and return to play recommendations. This guideline, although only advisory in authority, was literature driven and involved representatives from multiple disciplines in its creation. One of the more widely cited concussion-in-sport guidelines.

6. **Grindel SH, Lovell MR, Collins MW: The assessment of sport-related concussion: the evidence behind neuropsychological testing and management. *Clin J Sport Med* 2001 Jul 11(3): 134-143.**

An informative review article that discusses the current evidence for neuropsychological testing in concussion in sports. A relatively honest and straight forward appraisal of the field.

- 7. McCrory P: The eighth wonder of the world: the mythology of concussion management. *Br J Sports Med* 1999 Apr 33(2): 136-137.**

A somewhat irreverent look at many aspects of the evaluation and treatment of concussion in sports that may have a paucity of data support.

Questions

1. Which of the following is NOT frequently observed as a neurobehavioral feature of concussion?
 - a. Any period of loss of consciousness
 - b. Delayed verbal and motor responses
 - c. Disorientation
 - d. Limb numbness
 - e. Slurred or incoherent speech

2. Which percent of concussions in sport DO NOT involve loss of consciousness?
 - a. 20%
 - b. 42%
 - c. 50%
 - d. 75%
 - e. 83%

3. Using the AAN guideline, an athlete who has dizziness and confusion for 30 minutes after sustaining a concussion would be considered as having a concussion of what severity?
 - a. Grade 0
 - b. Grade 1
 - c. Grade 2
 - d. Grade 3
 - e. Grade 4

4. Again, using the AAN guideline, an athlete suffering a second Grade 1 concussion in a sports season should have what type restriction placed upon his/her return to play?
 - a) May return to play after being asymptomatic for 15 minutes
 - b) May return to play after being asymptomatic for 1 week
 - c) May return to play after being asymptomatic for 1 week at rest and with exercise
 - d) May return to play after being asymptomatic for 1 month at rest and with exercise
 - e) May return to play after returning to baseline on neuropsychologic testing

5. Which of the following is NOT generally agreed upon by most return-to-play guidelines?
 - a) Any athlete sustaining loss of consciousness for any period of time should not be allowed to immediately return to play, even if asymptomatic
 - b) Any athlete sustaining loss of consciousness should have a CT or MRI imaging study
 - c) Multiple concussions may have a cumulative effect on the athlete
 - d) Serial observations of the athlete are important after sustaining a concussion
 - e) A major motivating factor in developing return-to-play guidelines is the avoidance of the second impact syndrome.

Answers

1. Answer: d.

Limb numbness is not commonly seen following a concussion, alone. Cervical spine trauma, peripheral nerve trauma or a central lesion must be considered in this situation.

2. Answer: d.

It is estimated that 75% of concussions in sports do not involve loss of consciousness. This requires education of the athletes and staff of this fact so concussions may be adequately detected and cared for.

3. Answer: c.

By the AAN criteria, any symptoms lasting longer than 15 minutes without LOC make the concussion a Grade 2.

4. Answer: c.

It is important that the patient remain symptom free both at rest and after exercise in terms of being totally asymptomatic.

5. Answer: b.

Neuroimaging should be reserved for those patients with prolonged loss of consciousness, worsening symptoms or findings, focal neurologic findings or other concerns.