An Update on the Diagnosis and Management of Concussion

Stephen J. Almasi, MD, MS; John J. Wilson, MD, MS

ABSTRACT

Concussion is a common medical problem with significant morbidity and sometimes devastating consequences. Awareness of this injury has increased dramatically in recent years, and our understanding of its pathophysiology and treatment is rapidly evolving. This article reviews the current concepts of concussion pathophysiology and epidemiology, and will provide an overview of proper diagnosis and management. Complications and risk reduction also will be reviewed. By understanding the essentials of concussion medicine, health care professionals will be equipped to manage this injury, including common complications.

INTRODUCTION

Concussion is a common medical problem with significant morbidity and sometimes devastating complications. Awareness of this condition and the importance of proper management has increased significantly in recent years. High profile cases involving athletes, large numbers of US armed services personnel sustaining battlefield injuries, as well as new research revealing the long-term risks of this injury have brought concussion to the forefront of mainstream medicine and the mass media. The goal of this article is to provide physicians with a review of the current state of concussion medicine, including recommendations for management and strategies to minimize risk of both short- and long-term complications.

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Author Affiliations: University of Wisconsin School of Medicine and Public Health; Department of Family Medicine (Almasi, Wilson).

Corresponding Author: John J. Wilson, MD, MS, Assistant Professor, University of Wisconsin School of Medicine and Public Health, Department of Family Medicine, 1100 Delaplaine Court, Madison, WI 53715; phone 608.845.9531; fax 608.845.8684; e-mail john.wilson@fammed.wisc.edu.

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Definition

The currently accepted definition of concussion, established in 2008, is as follows:

> Concussion is defined as a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

1. Concussion may be caused by either a direct blow to the head, face, or neck or elsewhere on the body with an "impulsive" force transmitted to the head.
2. Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously.
3. Concussion may result in neuropathological changes but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury.
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 a small percentage of cases post-concussive symptoms may be prolonged.
5. No abnormality on standard structural neuroimaging studies is seen in concussion.[1]

Notably absent from the current definition of concussion are the previously used grading systems that were abandoned in 2001.[2] In 2004, a classification system including simple and complex concussion was established.[3] A simple concussion was defined as an injury that progressively resolves without complication over 7 to 10 days. In contrast, complex concussion was defined as an injury with persistent symptoms, specific sequelae such as concussive convulsion, loss of consciousness lasting more than one minute or prolonged cognitive impairment. This classifica-

Table 1. Signs and Symptoms of Concussion

Physical	Cognitive	Emotional	Sleep
Headache	Feeling mentally "foggy"	Irritability	Drowsiness
Nausea	Feeling slowed down	Sadness	Sleeping less than usual
Vomiting	Difficulty concentrating	More emotional	Trouble falling asleep
Balance problems	Difficulty remembering	Nervousness	
Dizziness	Forgetful of recent information or conversations		
Visual problems			
Fatigue			
Sensitivity to light	Confused about recent events		
Sensitivity to noise	Answers questions slowly		
Numbness/Tingling	Repeats questions		
Dazed or stunned			

tion system was discarded in 2008 amid concerns that it did not adequately describe concussions. It has been replaced by a group of modifying factors that help assess the severity of an injury (discussed further in the Management section).

Pathophysiology

The most common mechanism of head injury is dynamic loading caused by either direct impact to the head or by impulse, a sudden movement of the head produced by an impact elsewhere. Both impact and impulse injuries produce acceleration forces that can damage the brain.[4] It appears that rotation of the head is necessary to produce diffuse lesions in the brain, causing concussion, while translation of the head in the horizontal plane tends to produce focal lesions such as cerebral contusions and intracranial hematomas.[5]

The neurometabolic response to concussion has been studied in animal models. Biomechanical injury to the animal brain triggers unchecked neurotransmitter release and ion flux through channels in the axonal membrane. An acute efflux of potassium depolarizes the neuronal cellular membrane. The sodium-potassium pump utilizes increasing amounts of adenosine triphosphate in an effort to restore the membrane potential. This hypermetabolic state in the presence of relatively decreased cerebral blood flow creates an energy deficit that may account for post-concussive symptoms, as well as injury vulnerability, leaving the brain less able to respond to a second injury or leading to more persistent deficits.[6]

Epidemiology

Traumatic brain injury (TBI) is a common medical problem in the United States with an estimated 1 million to 1.5 million injuries occurring each year.[7] Of these injuries, approximately 85% are considered mild traumatic brain injuries or concussions.[8] Other estimates of the number of concussions occurring annually are as high as 3.8 million injuries per year.[9] The incidence is difficult to measure due to the difficulty in diagnosis, lack of public awareness, and athletes frequently underreporting symptoms with the goal of returning to play.[10] The leading causes of concussions treated in emergency departments are falls, motor vehicle collisions, unintentional head trauma, assaults, and sports. The frequency of these mechanisms varies with age. At the extremes of age, falls are the most common cause of concussion. Assaults and motor vehicle collisions are most common among middle-aged adults, while sports and bicycle accidents are most common in children and teens.[8]

A subset of the US population with an unfortunately high incidence of TBI is military personnel deployed to Iraq and Afghanistan. Since 2001, over 1.5 million American military personnel have served and an alarming rate of 22% of all wounded soldiers have suffered a traumatic brain injury.[11] A recent study of 2500 US Army infantry soldiers returning from a 1-year tour of duty found an incidence of concussion of 15%.[12] This study defined concussion as an injury involving loss of consciousness or altered mental status. Compared to previous US military conflicts, the incidence of TBI has increased significantly, for several likely reasons. Advanced body armor allows soldiers to survive blasts that would have been deadly in previous wars. The frequency of blast attacks from improvised explosive devices predisposes current soldiers to concussive injuries. Finally, both soldiers' and the medical community's understanding of these injuries has increased significantly, likely resulting in increased diagnosis.[13]

The epidemiology of sports-related concussion has been well studied. It is estimated that 1.6 million to 3.8 million sports-related concussions occur annually. Of these, only 300,000 result in a loss of consciousness.[9] Among 15- to 24-year-olds, sports-related concussions are second only to motor vehicle crashes as the leading cause of TBI.[14] Sports-related concussions are reported to be more common in females in sports with both male and female participants.[15] It has been postulated that this is due to relatively decreased lower neck strength and girth, which results in greater head acceleration after impact.[16] Among high school and collegiate athletes, concussion rates were highest in football and soccer.[15] In all sports, collegiate athletes had a higher rate of concussion than high school athletes.[15]

DIAGNOSIS

Signs and Symptoms

The signs and symptoms of concussion fall into 4 categories: physical, cognitive, emotional, and sleep (Table 1).[17] Headache is the most common symptom, with frequency between 40%

and 86%.[18] The constellation of signs and symptoms in a given patient traditionally has been thought to offer insight into the severity of injury and need for further diagnostic testing. However, the importance of various symptoms in terms of predicting injury severity and prognosis is unclear and remains an area of debate. One early review found that loss of consciousness (LOC) at the time of concussion signals a more serious injury and carries a greater risk of associated intracranial pathology.[19] However, a subsequent study found no difference in post-concussion neuropsychiatric testing results between patients who had or had not suffered LOC with their injury.[20] Another review found that amnesia, not loss of consciousness, was the symptom most predictive of symptom and neurocognitive deficits.[21]

Initial Evaluation

The initial evaluation of a patient with a suspected concussion, conducted in an emergency department, office setting, or sporting event, should focus on several important areas. The history should cover common symptoms of concussion and review any past head injuries. The physical exam should include a neurologic exam (focused on mental status, balance, and gait) and examination of the cervical spine and head. A brief assessment of cognitive function also should be conducted. This may include 5-word recall, naming the months in reverse order, and reading random digits back in reverse order. Pocket-card concussion assessment tools, such as the Sport Concussion Assessment Tool (SCAT2) guide clinicians through a standardized evaluation. The SCAT2 is a collection of several previously validated assessment tools and symptom lists.[1] The final step in the initial assessment is determining the need for neuroimaging. While early studies suggested that all patients with loss of consciousness or amnesia after head injury should have a cranial computed tomography (CT) scan in the emergency department, subsequent findings refuted this approach.[22] The majority of patients (65%-85%) presenting to emergency departments after minor to moderate head injury have a Glasgow Coma Scale (GCS) of 15. Often, these patients do not require neurologic imaging. One study examining 2143 patients presenting to a large, urban level 1 trauma center with head trauma and a GCS of 15 found that no patients with the absence of nausea, vomiting, severe headache, and skull depression required neurosurgical intervention. Only 3.7% of these patients had abnormalities on head CT, none of which were clinically significant.[23] The current International Conference on Concussion in Sport consensus recommends neurological imaging only in situations of prolonged alteration of consciousness, focal neurological deficit, or worsening symptoms.[1]

When imaging is necessary, CT is the test of choice for the diagnosis of intracranial pathology in the first 24 to 48 hours after injury due to its availability, relatively low cost, and capability to detect fracture and intracranial hemorrhage. Forty-eight to 72 hours after injury, magnetic resonance imaging (MRI) becomes the superior imaging modality due to its ability to detect hematoma, contusion, and axonal injury.[24] However, the majority of concussed patients have no structural pathology and will therefore not have any abnormality on CT or MRI. The abnormalities in these patients' brains are more likely to be metabolic, raising the potential application of functional MRI (fMRI).[25] This potential was demonstrated in a study of high school athletes when the degree of brain activation detected with fMRI was found to be associated with symptom duration and performance on neuropsychological testing.[26] For now, fMRI remains experimental and needs further research before being used for routine evaluation of concussion.

Neuropsychological Testing

Traditionally, the diagnosis and management of concussion has relied heavily on the patient's self-reporting of symptoms. Because symptom resolution often precedes cognitive recovery and because patients may not report symptoms in an effort to return to activity, the addition of neuropsychological testing can be a useful adjunctive tool in monitoring recovery after concussion.[27] Currently, neuropsychological testing is conducted most commonly with computerized tests, although paper versions are also available. While several computerized neuropsychological tests are available (Axon Sports, Concussion Vital Signs, Headminder, Automated Neuropsychological Assessment Metrics), the ImPACT (Immediate Post-concussion Assessment and Cognitive Testing) battery has been validated extensively and is used commonly.[28] The National Football League, National Hockey League, Major League Baseball, and many collegiate and high school teams currently use ImPACT testing.[29] Neuropsychological tests commonly evaluate the athlete's decision-making ability, reaction time, attention, memory, and cognitive processing speed in an objective fashion. The value of neuropsychological testing lies in its ability to detect patients who are asymptomatic following a concussion but still are suffering from lingering neurocognitive effects of the injury. Neuropsychological testing is used commonly to assist clinicians in determining whether to return an athlete to competitive play following a concussion. However, neurocognitive testing can miss concussions and therefore must be used along with clinical judgment, never in isolation, when making return-to-play decisions. It has been shown that athletes who have suffered a concussion but are asymptomatic perform below controls on neuropsychological testing, and their symptoms resolve prior to return of baseline cognitive function.[30] One study found that 2 days after concussion 64% of athletes had significant symptoms while 83% demonstrated poorer

Table 2. Factors Influencing Concussion Management and Return to Play

Factors	Modifier
Symptoms	Number Duration (>10 days) Severity
Signs	Prolonged loss of consciousness (>1 minute)
Sequelae	Concussive convulsions
Temporal	Frequency—repeated concussions over time Timing—injuries close together in time "Recency"—recent concussion or traumatic brain injury
Threshold	Repeated concussions occurring with progressively less impact force or slower recovery after each successive concussion
Age	Pediatric (< 18 years old)
Co- and pre-morbidities	Migraine, depression or other mental health problems, attention deficit hyperactivity disorder, learning disabilities, sleep disorders
Medication	Psychoactive drugs, anticoagulants

performance on neurocognitive evaluation—a net increase of 19% in sensitivity.[27]

MANAGEMENT

Cognitive and physical rest are the fundamental treatments of concussion. Considering the postulated energy crisis occurring in the brain after a concussion,this treatment regimen is intuitively logical.[6] Cognitive rest involves minimizing activities that require concentration and attention. Unnecessary reading, schoolwork, television watching, texting, and video games should be avoided. For acutely symptomatic patients, staying home from school or work is advisable in the initial days after concussion. Once symptoms have improved or resolved, patients may begin shortened work days with decreased work loads.[31] Students may benefit from short periods of reading and studying with frequent breaks, and may require extended time to complete examinations or assignments until they have fully recovered. Adequate physical rest involves avoiding any activity that could result in a second concussion and all strenuous activity including both aerobic and resistance training. Once patients are able to return to a full work or school schedule without symptoms or medications for concussion symptoms, they may initiate a return to physical activity. Athletes are currently advised to follow a slow, stepwise return to play. This involves slowly progressing from no activity to light aerobic exercise, sport-specific exercise, noncontact training drills, full-contact practice and finally return to play. Each step in this plan may be completed in 24 hours if no symptoms occur or recur. A recent study demonstrated that strenuous physical activity in patients suffering from concussion resulted in poorer neurocognitive testing scores when compared with patients engaging in intermediate levels of activity.[32] This finding supports the use of the currently accepted graded return to activity protocol. If symptoms do occur, the athlete should return to the previous activity level before progressing.[33]

Deciding when an athlete should return to play is rarely an easy decision. The fundamental rules are that an athlete should never return to play on the day of a concussion and must have full clinical and cognitive recovery before returning to play.[34] However, some experts agree that same-day return to play may be considered in adult athletes when adequate resources are present: a team physician experienced in concussion management, access to neurocognitive testing, and neuroimaging.[1] Several modifying factors also influence concussion management and return to play (Table 2).[1] When these factors are present, the patient should be cared for by a physician with experience in concussion management.[1]

Most patients will recover from concussion spontaneously within 1 week. However, the length of time to recover depends on age. Athletes younger than 18 years old may take from 7 to 14 days to recover.[35,36] The National Collegiate Athletic Association concussion study found that on average, concussed collegiate football players had resolution of symptoms within 7 days, regained baseline cognitive function within 5 to 7 days, and had normal balance within 5 days. However, 10% of players required more than 7 days for symptoms to resolve.[37] If a patient's symptoms have exceeded the expected duration, or the symptoms are negatively affecting the ability to function, pharmacotherapy may be considered. Headache pain during the acute symptomatic period can be treated with analgesics such as acetaminophen and nonsteroidal anti-inflamatory drugs (NSAIDs). Aspirin should be avoided due to theoretical concerns of increased bleeding risk. If sleep hygiene is not adequate, diphenhydramine, melatonin, or other prescription sleep medications may be used for sleep disturbance. Finally, tricyclic antidepressants and selective serotonin reuptake inhibitor antidepressants may be used for persistent mood disturbances.[38]

COMPLICATIONS

The complications of concussion, though rare, are potentially serious. Recently, the potential for long-term complications of recurrent mild traumatic brain injury as commonly suffered in professional football players has gained widespread attention in the mass media. However, the risk of recurrent mild head trauma has been appreciated in sport for many years. Originally studied in boxers, it was first known as the "punch drunk" or "slug nutty" state and eventually came to be called dementia pugilistica.[39] Currently, the clinical and neuropathologic consequences of repeated mild head injury are known as chronic traumatic encephalopathy (CTE). The disease manifests years or decades after the inciting head injury(ies) with effects on behavior, cognition, and movement. Behavioral changes are often the first sign and include increased irritability, anger, apathy, or suicidality. Cognitive changes may occur early in the disease course as well and may include loss of executive function and poor memory. Dementia, movement, and speech disorders can develop late in the course of the disease.[40] The characteristic neuropathology seen in CTE is the deposition of neurofibrillary tangles and neuropil threads throughout the neocortex. These neurofibrillary inclusions are made up of the tau protein.[41] The prevalence of this disease in people who have suffered concussions and the factors that increase susceptibility have yet to be elucidated.

Postconcussion syndrome (PCS) is another potential complication of concussion. It is defined as the persistence of postconcussive symptoms beyond the expected time frame of 1 to 6 weeks.[42] The incidence is estimated to be approximately 10%. Comorbid psychiatric illness, advanced age, heightened symptoms, and intense emotions at the time of injury are all apparent risk factors for developing PCS.[43]

A widely feared complication of concussion is the second-impact syndrome. While very rare, it may have devastating consequences. It is proposed to occur when someone who is still recovering from a recent concussion suffers a second head trauma. Significant morbidity and even death can result from the proposed mechanism of diffuse cerebral edema caused by cerebral vascular congestion, which can progress to brainstem herniation.[44] Some doubt that the cause of diffuse cerebral edema is 2 closely spaced injuries, arguing instead that a rare physiologic vulnerability may predispose some patients to developing cerebral edema after a single minor head trauma.[45,46] What appears to be more clear is that the risk of a second concussion is higher in the 7 to 10 days after an initial concussion.[46]

RISK REDUCTION

Concussion risk reduction initiatives include education, use of protective equipment, rule changes, and legislation. While public awareness and professional understanding of the frequency and dangers of concussion are improving, there is still significant progress to be made. A recent survey of high school and collegiate certified athletic trainers revealed that while they would not allow an athlete to return to play if still symptomatic (95%), they would allow an athlete still scoring below baseline on ImPACT testing to return to play (89%).[47] Another study found that 15% of concussed high school football players returned to play before the currently accepted guidelines would allow.[48] While athletic trainers are responsible for concussion management at many larger schools, this is often the responsibility of coaches and staff without any medical training at smaller schools. A survey of New England high school football coaches without access to athletic trainers found that the coaches had a much better understanding of concussion than the general public. However, 30% of coaches stated they would allow an athlete to return to play after a head injury that left them appearing to move clumsily, and 5% would allow an athlete back into the game after a loss of consciousness.[49] This study also offered an interesting insight into concussion education. It revealed that most coaches received concussion education from coaching associations and conferences. The Centers for Disease Control and Prevention (CDC) concussion kit, "Heads Up" was the most helpful source, but also the least used/received. The CDC has educational materials for coaches, clinicians, parents and athletes available for order at no charge from its website.[17]

The use of mouth guards, new football helmets, and proper heading technique for the prevention of concussion all have been studied. While mouth guard use significantly reduces the risk of orofacial injuries, there is no evidence of preventing concussion.[50] Recently, new football helmet designs have been introduced with the goal of reducing the risk of concussion. One study revealed decreased rates of concussion with the new helmets.[51] However, additional large trials are needed to conclusively prove that new helmet technology can prevent concussions. While the majority of concussions sustained in soccer are the result of collision rather than heading the ball, prevention has focused on the latter. Proper heading technique, including tensing the neck muscles prior to impact and striking the ball at the hairline on the forehead, are the most effective preventive strategies. There is currently insufficient evidence to support the use of protective headgear for preventing concussion in soccer.[52]

Rule changes and their enforcement are an essential element of concussion prevention. In 2010, the National Football League expanded rules protecting defenseless players by banning direct blows to the head.[53] The Wisconsin Interscholastic Athletic Association (WIAA), the governing body for high school athletics in Wisconsin, recently adopted a new rule that directs game officials to remove any football player from competition if he shows signs, symptoms, or behavior consistent with concussion. This supplements the WIAA protocol for concussion which specifies that: (1) no athlete should return to play or practice on the day of a concussion; (2) any athlete suspected of having a concussion should be evaluated by a health professional that day and medically cleared prior to resuming practice or competition; and (3) after clearance, return to play should follow a stepwise protocol.[54]

Legislation regulating concussion management aims to prevent the potentially catastrophic effects of the injury. A law regulating concussion management was passed initially in the state of Washington in 2009 and many states have since passed similar legislation. In May 2011, a bill was introduced to the Wisconsin State Legislature that would require children and adolescents with symptoms consistent with concussion to receive written permission from a health professional before returning to organized athletic activities. The Wisconsin Medical Society, WIAA and Brain Injury Association of Wisconsin all support this legislation.[55]

CONCLUSION

Concussion is a common medical problem with significant morbidity and potentially devastating complications. As active research advances our knowledge of concussion, health care professionals must continue to improve their understanding of this injury in order to provide excellent patient care and to lead public health initiates aimed at risk reduction.

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Quiz: An Update on the Diagnosis and Management of Concussion

EDUCATIONAL OBJECTIVES

1. To understand the current concepts of the pathophysiology and epidemiology of concussion.
2. To understand the proper diagnosis and management of concussion.
3. To recognize the complications and late sequela of concussion.
4. To know strategies THAT are important to minimize the risk of short- and long-term complications of concussion.

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QUESTIONS

1. Concussion is defined as a complex pathophysiologic process affecting the brain induced by traumatic biomechanical forces. Common features may include:
   - ❑ A. 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.
   - ❑ B. Concussion usually results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously.
   - ❑ C. The acute clinical symptoms of concussion generally reflect a structural brain injury.
   - ❑ D. A and B only
   - ❑ E. All of the above

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2. The current consensus on concussion in sport recommends neurologic imaging only in situations of prolonged alteration of consciousness, focal neurological deficits, or worsening symptoms.
   - ❑ True
   - ❑ False

3. When imaging is necessary after concussion, magnetic resonance imaging (MRI) is considered the test of choice in the first 24 to 48 hours after the injury.
   - ❑ True
   - ❑ False

4. The management of concussion is supportive and involves cognitive rest (which minimizes activities that require concentration and attention) and physical rest.
   - ❑ True
   - ❑ False

5. Complications of concussion, although rare, include the following:
   - ❑ A. chronic traumatic encephalopathy, which is long-term as a result of repeated mild head injury.
   - ❑ B. postconcussion syndrome, defined as the persistence of symptoms beyond the expected time frame of 1 to 6 weeks.
   - ❑ C. second-impact syndrome which occurs when an individual recovering from a concussion suffers a second head trauma which can result in diffuse cerebral edema, brainstem herniation, and death.
   - ❑ D. A and B only
   - ❑ E. All of the above

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