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Concussion Overview: Risks, Management, and Current Therapies

As we all are now aware, a concussion is not the benign injury it was once believed to be. Concussion in some patients leads to a disabling set of post-concussive symptoms with cognitive impairment, vertigo, and headaches. Long-term consequences of repeated concussions include permanent cognitive and memory deficits. It is thought that a blow to the head sets up an inflammatory cascade that leads to these later symptoms.

Repetitive concussions are common among athletes, particularly those in contact sports. Groups like the National Football League recently have devoted some resources to discovering ways to make their sport safer with a $25 million commitment to increase school trainers and $16 million to the National Institutes of Health for research. The NCAA has also made a large donation to fund concussion research. In May 2014, a White House Summit drew attention to the issue of concussion in athletes.

Because of these increased resources, our knowledge of concussion and its consequences is rapidly evolving. Emergency physicians and athletic coaches are generally the first contact (and sometimes only contact) for patients with concussion. This paper will provide an overview of our current knowledge and recommended treatment of concussion.

— Sandra M. Schneider, MD, Editor

Introduction

Head trauma and concussion are important public health concerns. As of 2006, there were 1.4 million patients with traumatic brain injury (TBI) evaluated in emergency departments (EDs) in the United States annually.[1] More recent data from 2010 place the incidence of ED visits for head injury at 2.5 million people in this country, discounting injuries primarily related to the face or eyes.[2] Estimates of sports-related TBI range from 1.6 million to 3.8 million persons per year in the United States; many of these do not seek medical attention.[3,4] More than 200,000 ED visits annually for concussions and other TBIs related to sports and recreational activities occur, with most among children aged 5-18 years. The highest rates were among males aged 10-19 years; these figures excluded violence-related incidents such as assault or intentional self-harm. The figure for sports-related TBI visits to the ED rose from approximately 153,000 in 2001 to more than 248,000 in 2009.[5] As many as 18-25% of the more than 1.5 million U.S. soldiers deployed in Afghanistan and Iraq as of 2008 sustained a concussion, most prominently from blast injuries secondary to improvised explosive devices.[6,7] Concussion is a frequent occurrence that involves a heterogeneous patient population, leading to perceived poor general health, medical visits, missed workdays, headache, irritability, fatigue, memory problems, difficulty concentrating, and a number of somatic and

Executive Summary

- Concussion and mild traumatic brain injury have a risk of serious short- and long-term sequelae.
- Concussion is a trauma-induced alteration in mental status, which does not necessarily involve loss of consciousness.
- Advanced imaging such as magnetic resonance spectroscopy and diffusion tensor imaging may be predictors of biochemical abnormalities in the brain and indicators of worse prognosis, but are generally not used in the emergency department.
- Return to learning as well as return to sports may be a critical discharge decision in the concussed patient.

post-concussive symptoms, including post-traumatic stress disorder.[7]

Since 2010, these trends were followed by the establishment of dozens of youth concussion clinics across America. These centers serve young athletes complaining of headaches, amnesia, dizziness, or problems concentrating. Physicians are frequently asked to provide written clearance for "return to play" after concussion. Several states have enacted concussion-specific laws pertaining to scholastic sports that may entail clearance from a health care professional before returning to play. Such health care professionals may include physicians, nurse practitioners, or physician assistants.[8] Compounding the problem for emergency physicians, there has historically been no agreed-upon, established formula for treating the injuries. Major League Baseball, the National Football League, the National Basketball Association, and Major League Soccer have all formulated policies for dealing with concussion issues, including awareness, examination, return to play, and testing.

Epidemiology and Risk Factors

The sports most commonly associated with TBI are bicycling, football, playground activities, basketball, and soccer. Horseback riding, ice skating, golfing, all-terrain vehicle riding, and sledding account for significant numbers as well.[5] Concussion risk seems greater among female athletes who participate in soccer or basketball.[3] Playing football on artificial turf has been proposed as a possible risk factor for more severe concussions.[9] The incidence of brain injury in football players may approximate 10% per season for college and 20% for high school athletes per season.[10]

As noted above, estimates of the incidence of sports-related concussions in the United States are in the millions of cases annually.[11] However, this number is almost certainly low, as many athletes may not want to let their teammates down by reporting an injury and seeking medical attention. Many others may think that a concussion is not a reason to leave a game, and, therefore, may not report the injury knowing they will be removed from competition.

Concussion and Post-concussion Syndrome Defined

Concussion is defined as a neurologic injury as a result of an injury to the head or body causing an alteration in mental status, neurologic deficits such as imbalance, incoordination, impairment of vision, amnesia, or loss of consciousness.[6] The injury may consist of a blow to the head, acceleration-deceleration forces, or blast exposure. The neurologic impairment is transient.[12] This may be associated with all or any of the following: nausea, vomiting, headache, balance problems with subjective dizziness, blurred vision, sleep impairment, drowsiness, sensitivity to noise or light, difficulty concentrating, or memory impairment.[8] Concussion has been defined by the American Society for Sports Medicine as a "traumatically induced transient disturbance of brain function." The temporary disruption of brain function typically resolves spontaneously. As such, it is a subset of mild TBI, and usually self-limited.[13] It is not equivalent to loss of consciousness, which may or may not have occurred and which likely accounts for the often unrecognized and unreported nature of concussion. Alteration of brain function typically affects memory and orientation, lack of awareness of surroundings, and may involve loss of consciousness.[3] Transient cortical neurologic deficits, including cortical blindness and global amnesia, can occur.[14,15] No abnormality of standard structural neuroimaging is seen on concussion.[16]

Acute Concussion Evaluation

Descriptions of concussed athletes commonly use terms such as "seeing stars," "having your bell rung," and being "dazed." This is due to the hallmark symptoms of confusion, amnesia, and imbalance. Amnesia typically involves the traumatic event itself but can also be anterograde and retrograde in nature. Although not always immediately present, common early symptoms of concussion include headache, nausea and vomiting, decreased awareness to surroundings, and vertigo/imbalance.[17] Common delayed symptoms developing over the hours and days following a concussive event include insomnia and changes in mood and cognition.[18] Loss of consciousness is not necessary to diagnose concussion. It is important to understand that concussion and mild TBI can be

present in the absence of preceding loss of consciousness.[19]

While no definitive diagnostic tool or modality currently exists, several standardized assessments have been offered with varying degrees of utility in the emergency department setting. As is the case with most diagnoses, a detailed history and physical exam will provide the most useful information for the emergency care provider, as concussion remains a clinical diagnosis with changes to cognitive, neuropsychological, and somatic features. Diagnostic tools, scoring systems, and checklists have all been used to evaluate for suspected concussion. Many of these tools were initially derived out of attempts to identify the concussed athlete on the sideline.

One such assessment tool is the Standardized Assessment of Concussion (SAC). SAC consists of five areas of evaluation: orientation, immediate memory recall (immediate recall of 5 words), exertional maneuvers, concentration (reciting months in reverse), delayed memory recall (delayed recall of 5 words), and an assessment for gross neurological deficits. Each section is given a point total, with a total summation of 30 points. This tool is most useful when post-concussive scores can be compared to pre-injury baseline testing. A decrease of one or more points from baseline is considered consistent with cognitive impairment.[20] SAC has a 94% sensitivity and 76% specificity when the one-point difference is used and it is applied immediately after injury.[21]

Another standardized assessment tool is the Sport Concussion Assessment Tool 2 (SCAT2). SCAT2 incorporates the SAC cognitive assessment, Glasgow Coma Scale, subjective symptoms, and evaluations of coordination and balance. These factors are used to create a score of 0 to 100; however, no definitive scoring cutoff has yet been identified. SCAT2 was endorsed by the Consensus Statement on Concussion in Sport in 2008 and SCAT3 is expected in the near future.[16]

Additional assessment tools that can be used are the Westmead Post-traumatic Amnesia Scale (WPTAS), Post-Concussion Symptom Scale (PCSS), and the Graded Symptom Checklist. Both the PCSS and Graded Symptom Checklist ask patients to assign a severity rating from 0 to 6 to a list of symptoms associated with concussion. These tools, again, are most useful when compared to baseline testing.[3,20]

As both retrograde and anterograde amnesia are common findings in concussion,[20] the Westmead PTAS or WPTAS is a fast and simple tool to assess for amnesia. The following questions are posed to the patient, and a single incorrect answer is considered a positive test:[22]

- What is your name?
- What is the name of this place?
- Why are you here?
- What month are we in?
- What year are we in?
- In what town/suburb are you?
- How old are you?
- What is your date of birth?
- What time of day is it (i.e., morning, afternoon, evening)?

Three pictures are then presented and recall evaluated.

An additional hallmark of concussion is a reduced ability to maintain normal balance. While tests such as the Romberg Test are commonly used, these are often subjectively interpreted. Therefore, the Balance Error Scoring System (BESS) has been developed and can be employed. The BESS is used to objectively evaluate for postural control. The BESS includes testing balance in three different stances on two different surfaces. The patient is tested for balance standing with a double-legged stance, single-leg stance, and heel-to-toe stance. These three stances are performed on standard solid ground and then again on a firm foam surface. Patients must keep their hands to their hips during these evaluations and maintain the posture for 20 seconds.[20] The errors in balance over the 20-second period are added up and a deviation of greater than 3 from their baseline testing is considered abnormal.[23]

While no single assessment tool can be exclusively used to evaluate for concussion, the aforementioned tools can be helpful in the diagnosis of concussion.

Second Impact Syndrome and Other Sequelae

There is evidence that athletes with a history of previous concussions are more likely to have future concussive injuries than those with no previous history of concussion. One study of 2905 collegiate football players noted that those athletes reporting a history of three or more previous concussions were three times more likely to have another concussion, frequently within 7-10 days of the first injury. It was estimated that one in 15 players with a concussion may have additional concussions within the same playing season. Offensive linemen, linebackers, and defensive backs were most prone to concussion, in that order.[24]

The major categories of concern regarding return to competition are, respectively, second impact syndrome (SIS), post-concussion syndrome or prolonged recovery from sequential injury, and chronic traumatic encephalopathy (CTE). Second impact syndrome derived its name in 1984 after a college football player suffered a head injury with brief loss of consciousness. He returned to play, collapsed 3-4 days later, and died. On autopsy, there was cerebral edema but no space-occupying hematoma.[25] SIS occurs in people who have not recovered from the initial incident, and may be catastrophic with intracerebral swelling.[8,26] It has been demonstrated that athletes with prior concussions are more likely to have amnesia or confusion during subsequent concussions.[27] Encephalopathy from repeated traumatic brain injury has been described in boxers, professional football players, and other contact sport participants. This may manifest itself in decreased intellect, impaired memory and balance, and other behavioral changes. These symptoms present years after concussive injuries, often with

Table 1: PECARN Guidelines for Head CT Scanning in Children

PECARN Guidelines very low risk of clinically significant findings on CT in Children[43]

For children younger than the age of 2 years, negative predictive value of 100%:

- **Normal mental status**
- **No scalp hematoma except for a frontal hematoma**
- **No loss of consciousness or no loss lasting more than 5 seconds**
- **Non-severe mechanism of injury**
- **No palpable skull fracture**
- **Acting normally per parent**

For children older than 2 years, negative predictive value of 99%:

- **Normal mental status**
- **No loss of consciousness**
- **No vomiting**
- **Non-severe mechanism of injury**
- **No sign of a basilar skull fracture**
- **No severe headache**

Parkinson-type symptoms.[28]

The increased risk of recurrent concussion within a 7-10 day period is consistent with findings reported from animal studies. These show a neurometabolic cascade involving increased lactate production after concussion. Cerebral autoregulation, or the vascular tone of the arterial tree, generally keeps cerebral blood flow constant during normal conditions in which the mean arterial pressure is 50-150 mm Hg. Traumatic brain injury can impair autoregulation for days to weeks, predisposing the brain to extremes in blood pressure from catecholamine release, ischemia, and vasodilation.[29] Neurons may be more vulnerable to secondary ischemic injury during this period, leading to increased intracellular calcium, mitochondrial dysfunction, impaired oxidative metabolism, axonal disconnection, neurotransmitter disturbances, and cell death. Decreased cerebral blood flow has been reported for 10 days after concussive injuries, leaving cells more vulnerable to further injury.[3] Ionic shifts from neuronal membrane disruption may lead to an increase in intracellular glutamate and calcium.[31] Neurofibrillatory tangles and accumulation of tau protein may simulate the processes that result in Alzheimer's disease.[8] Microscopic axonal injury, axon retraction bulbs, evidence of cytotoxic edema, and microglial clusters are found on autopsy.

Most patients who sustain a concussion have resolution of their symptoms within 7-10 days. Post-concussion syndrome has been described in those whose symptoms last from six weeks to three months after injury. Post-traumatic headaches are the most common symptom reported after a concussion, and, since there may be an increased risk of hemorrhage within 24-48 hours of a concussion, it has been recommended that aspirin and non-steroidal anti-inflammatory drugs be withheld during this period. There is evidence for the efficacy of a variety of agents in treating post-concussive headaches: antidepressants such as amitriptyline, intravenous dihydroergotamine plus metoclopramide, anticonvulsants including valproic acid, topiramate, gabapentin, and triptans.[31] There is less evidence that pharmacologic treatment for chronic dizziness, fatigue, or nausea following a concussion is efficacious, although meclizine, scopolamine, and dimenhydrinate have been proposed.[32] Patients with post-concussive syndrome may have trouble falling asleep or staying asleep. They may report irritability, depression, personality changes, or anxiety.

In general, problems with memory, cognitive functioning, and concentration resolve within days to a few weeks following a concussion. Post-post concussion syndrome is a term used to describe patients whose symptoms persist past three months.[31,33]

Treatment Recommendations

The American Academy of Pediatrics Council on Sports Medicine and Fitness and Council on School Health has issued a report discussing aspects of care regarding cognitive rest and return to learning following a concussion. This reflects concerns that using a concussed brain to learn may worsen concussion symptoms or even prolong recovery. While most students with a concussion will recover within three weeks, symptoms such as fatigue, sleep disturbance, drowsiness, light and noise sensitivity, or irritability may prevent the student from attending school.[34]

Cognitive rest is more difficult. School attendance and academic workloads may need to be adjusted.[35] This includes the following recommendations, many of which may be difficult to enforce: minimal to no TV, no sports, no weight training, and no bike riding. The patient may return to play only when he or she can pass a neurocognitive and balance assessment, and is symptom-free at rest and during exertion. It has been recommended that the concussed patient be given no homework, a shortened school day, and increased rest and sleep.[36]

Further recommendations have included no cell phone use or text messaging, and no computer use. Learning may be maximized in 30-45 minute increments, necessitating standardized testing arrangements, special education

needs specified in an individualized education plan, or changes in class schedule.[34]

It has been proposed to minimize reading, schoolwork, games such as Scrabble and chess, and extracurricular activities pending full recovery. There should be a stepwise return to play, with balance retraining, low-level aerobic exercise, and possibly yoga and pilates. Cognitive return may be enhanced with the use of methylphenidate or amantadine.[35] (*See Table 2.*)

Some victims of concussion develop post-concussive headaches, which may be difficult to differentiate from migraines. Triptans and topiramate were effective in therapy of post-concussive headache in one report, whereas low-dose tricyclic antidepressants were not.[6] Amitriptyline 25-50 mg daily, nortriptyline 25-50 mg daily, valproate extended release 500 mg daily, topiramate 100 mg divided daily, and propranolol LA 80 mg divided daily have been used with variable success as prophylactic agents in post-traumatic headache.[6,37] Prazosin, an alpha-1 noradrenergic antagonist, has been found to be effective in improving headaches and sleep problems.[38] Opioid medications have proven ineffective, and avoidance of their use in chronic post-traumatic headaches has been proposed.[6,37,39,40]

Table 2: Sample Pharmacologic Agents for Symptoms of Concussion[6,31,37,38]

Symptom	Agents
Dizziness/vertigo/ lightheadedness	Meclizine Scopolamine Dimenhydrinate Benzodiazepines: lorazepam, diazepam, clonazepam
Nausea	Ondansetron Promethazine
Sleep disturbances	Zolpidem Trazodone Melatonin Prazosin
Headache	Analgesics: aspirin, acetaminophen, NSAIDs Antidepressants: amitriptyline, nortriptyline Anticonvulsants: valproate, topiramate, gabapentin Triptans Beta-blockers: propranolol (prophylaxis)
Cognitive functioning	Methylphenidate Amantadine

CT Scanning: Indications and Guidelines

This discussion must be prefaced with a caveat that CT imaging is obtained to rule out more serious TBI, and not to diagnose sports-related concussion (SRC), which is a clinical diagnosis. Therefore, a negative head CT still means that an athlete who has sustained a concussion should be prohibited from returning to play or practice until he or she is asymptomatic off medication.

Several guidelines have been promulgated for obtaining computed tomography after head injury. The rationale for reduction of CT use is generally based upon cost considerations and the risk for subsequent lethal or nonlethal malignancies, which has been cited as between 1 in 1000 and 1 in 5000 pediatric CT scans, with risk increasing with decreasing age of the patient.[41,42] One widely cited rule for children was developed by the Pediatric Emergency Care Applied Research Network (PECARN). This network identified variables that identified patients at very low risk for clinically significant findings on CT. These included:

For children age 2 years and older:

- Normal mental status, as defined by a Glasgow Coma Score of 15, no agitation, somnolence, repetitive questioning, or slow response to verbal communication;
- No loss of consciousness (LOC);
- No vomiting;
- Absence of a severe mechanism of injury. This was defined as motor vehicle crash with patient ejection, death of another passenger in the crash, rollover, pedestrian or bicyclist without a helmet struck by a motorized vehicle, falls of more than 5 feet (1.5 meters), or head struck by a high-impact object.
- No signs of basilar skull fracture;
- No severe headache.[43]

For children younger than 2 years:

- Normal mental status;
- Frontal scalp hematoma only, or no other scalp hematoma;
- No loss of consciousness, or LOC for less than 5 seconds;
- Non-severe mechanism of injury;
- No palpable skull fracture;
- Acting normally per parent.

These findings suggest that patients meeting these criteria do not need a head CT. It has been estimated that there are 1 million children every year in the United States who are unnecessarily imaged with CT.[42]

Children presenting with a Glasgow Coma Score (GCS) of 14 or 15 after blunt head trauma, with a normal cranial CT scan, have a very low risk for subsequent findings on neuroimaging or the need for neurosurgical intervention. One report listed a negative predictive

Table 3: Guidelines for Obtaining Head CT After Minor Head Injury

Canadian CT Head Rule[45]
Inclusion criteria:
- **GCS 13-15**
- **Age 16 years or greater**
- **No coagulopathy or anti-coagulant use**
- **No gross open skull fracture**

Head CT *not* required if ALL of the following are *absent*:
High risk (for neurosurgical intervention)
- **Age > 65**
- **GCS < 15, 2 hours after injury**
- **Open or depressed skull fracture**
- **Signs of basal skull fracture**
- **Vomiting: 2 or more episodes**

Medium risk (for brain injury on CT)
- **Retrograde amnesia of > 30 min prior to injury**
- **Dangerous mechanism (such as pedestrian struck, ejected from vehicle, fall > 3 feet or > 5 stairs)**

New Orleans CT Head Rule[46]
Inclusion criteria:
- **Age > 18 years**
- **GCS 15**
- **Blunt head trauma occurring within previous 24 hours causing loss of consciousness, amnesia, or disorientation**

Head CT *not* required if ALL of the following are *absent:*
- **Headache**
- **Vomiting**
- **Age > 60 years**
- **Drug or alcohol intoxication**
- **Persistent deficits in short-term memory (amnesia), anterograde amnesia**
- **Visible signs of trauma above the clavicles**
- **Seizure**

value for neurosurgical intervention for a child with a normal CT scan and a GCS of at least 14 to be 100%.[44] In general, for patients presenting to the emergency department after minor head injury and with a normal GCS of 15, the rates of intracranial injuries requiring neurosurgical intervention due to positive CT findings has ranged from 0.3-1%.[23]

There are numerous clinical practice guidelines for obtaining CT after TBI in adults. Two of the better-established and clinically validated rules will be discussed. The Canadian CT Head Rule defined minor head injury as a patient with a history of loss of consciousness, amnesia, or disorientation and a GCS of 13-15. Primary outcome measures in this study were need for neurological (neurosurgical) intervention. The criteria for imaging were broken into five high-risk criteria and two medium-risk criteria. (*See Table 3.*) It is notable that the age cutoff is 65 by this rule. Absence of the high-risk factors was 100% sensitive and the medium-risk factors 98.4% sensitive for predicting the absence of clinically important brain injury.[45]

Another well-validated clinical practice guideline is known as the New Orleans CT Head Rule. This study was designed to identify a set of clinical criteria that could be applied to patients with minor head injury who did not need to undergo head CT. The investigators identified seven clinical findings that were indicative of subsequently positive CT head scans. In phase 1 of this study, all patients with positive CT findings had one or more of the following: headache, vomiting, age over 60 years old, drug or alcohol intoxication, deficits in short-term memory, physical evidence of trauma above the clavicles, and/or seizure. When these criteria were then applied to a set of 909 patients with minor head injury, a GCS score of 15, and normal findings on a brief neurological exam predicting no clinically significant CT findings, the sensitivity of the seven findings combined was 100%. In their study, all patients with a positive CT finding

had at least one of the seven aforementioned clinical findings.[46]

Other Imaging

While not of therapeutic or immediate diagnostic use in the emergency setting, there are other imaging modalities that have been used to shed light on the nature of concussive injury and, possibly, its prognosis for prolonged symptomatology. Magnetic resonance imaging (MRI) uses radiofrequency pulses of energy and a strong magnetic field to excite and detect hydrogen protons. Primary MRI sequences are T1- and T2-weighted. Fluid-attenuated inversion recovery, or FLAIR, is a T2-weighted sequence that may show edema more clearly. Echo Ta-weighted sequence may make punctate hemorrhages, as seen in diffuse axonal injury, stand out. Predictable changes in blood products with time allow estimation of their age on T1- and T2-weighted images. Therefore, MRI is more sensitive in detecting intraparenchymal injuries such as diffuse axonal injury and nonhemorrhagic contusions than is CT.[11] Nonetheless, for purposes of detection of intracranial injuries which will require neurosurgical intervention such as subdural and epidural hematoma, CT and MRI have equivalent sensitivity.

There are more sensitive MR techniques that have been used to measure molecular and microstructural injuries. These include magnetic resonance spectroscopy (MRS), microstructural axonal injury, and diffusion tensor imaging (DTI) and abnormal cortical activation patterns (functional MRI or fMRI) after concussion. Diffusion-weighted imaging has already achieved acceptance in the evaluation of stroke and diffuse axonal injury, using the principle that water molecules in ischemic brain tissue are restricted in their motion. Functional MRI has revealed abnormal neurocognitive activation patterns after concussion.

For example, one study after sports-related concussion showed a reduction in N-acetylaspartate (NAA) after sports-related concussion in the primary motor cortex and the dorsolateral prefrontal cortex by MR spectroscopy, when normalized to creatinine (Cr), a relatively stable marker. Higher NAA/Cr ratios heralded a prolonged clinical course.[47] Another recent report demonstrated evidence for shearing injury by DTI/magnetic resonance to the uncinate fasciculus linking the limbic system to the frontal lobes following concussive injury, thought to account for the much longer period required for full recovery among injured males (66.9 days on average for males, 26.3 days for females) in that study.[48]

Positive emission tomography uses radio-labelled fluoro-2-deoxyglucose to measure brain metabolic activity to demonstrate decreased metabolism after traumatic brain activity.[23] Other imaging, such as SPECT and CT perfusion, may show extensive areas of abnormality but are generally unavailable and of little clinical use to the emergency physician. However, the emergency provider should consider referring the patient for outpatient studies to include MRI imaging. These emerging imaging techniques are likely to guide rehabilitation and when it is safe to return to sports activity.

Table 4: Symptoms of Athletes Post Concussion by Percentage at Time of Injury[19,24]

Symptom	Percentage
Headache	85%
Dizziness/balance difficulties	77%
Cognitively "slowed down"	69%
Decreased concentration	61%
Sensitivity to light or noise	60%
Fatigue	58%
Drowsiness	47%
Problems with memory	46%

Table 5: Suggested Return to Play Guidelines for Sport Concussion

Recommendations that an athlete stop competition for the season:

- 3 or more concussions in one season
- Prolonged post-concussive symptoms
- 2 or more severe concussions in a single season
- Declining athletic or academic performance
- Clinically important findings on imaging

Recommendations that an athlete end athletic career:

- Intracranial hemorrhage
- Pathologic abnormalities such as Chiari malformation
- Decreased academic or cognitive function
- Prolonged post-concussion syndrome
- Three or more major concussions
- Decreased threshold for concussion
- Chronic traumatic encephalopathy

Risk Factors for Recurrent Concussion

Certain risk factors, such as the

presence of the APOE ε4 genotype and recurrent concussion place the patient at higher risk for brain injury following trauma. Risk factors for persistent neurocognitive problems include: early post-traumatic headache, fatigue/fogginess, early amnesia, alteration in mental status, disorientation.[3] These serve as the rationale for restricting return to play, as well as other activities, as enumerated below.

Return to Play: Recommendations and Guidelines

This is a critical decision because children and adolescents are at increased risk for both repeat concussion and for long-term sequelae, delayed recovery, and increased risk for future TBIs, depression, and dementia. In 2005, four phases were proposed in an approach to concussion management: recognition, response, rehabilitation, and return to play.[49] The initial response following a suspected concussion was to remove the athlete from play and assess the patient. General principles to be followed include rest, graded return to functional activities, and finally return to sport-specific activities.[8] There are clearly social, legal, and financial implications to limiting or recommending an end to an athlete's or soldier's activities or career.

It is now recognized that certain injuries in athletes may be season-ending, or career-ending. Suggested guidelines for recommending that an athlete stop competition for the season include: three or more concussions in one season, prolonged post-concussive symptoms, two or more severe concussions in a single season, decreased athletic or academic performance, or any clinically important finding on imaging. Career-ending injuries have been proposed as well: intracranial hemorrhage, pathologic abnormalities such as Chiari malformation, decreased academic or cognitive function, prolonged post-concussion syndrome, three or more major concussions, decreased threshold for concussion, or chronic traumatic encephalopathy.[8,33]

Primary and Secondary Prevention Strategies

The most obvious prevention strategy includes use of protective equipment such as use of a bicycle or motorcycle helmet. There is current research to develop football helmets to prevent or mitigate concussions. A so-called "intelligent mouthguard" is an example. This device is placed on the teeth and measures in-game head impacts, transmitting data on head orientation, position, velocity, and acceleration of any given impact. This will undergo trial use starting in 2014 with a football team in northeast Ohio.[50]

Coaching appropriate sports-specific skills, with an emphasis on safe practices and techniques, has been advocated. While it is likely that soccer is the sport with greatest risk for concussion in females, there are insufficient data to support use of protective soccer headgear. Concussion risk is greater among football players who are offensive linemen, linebackers, and defensive backs.[51] There are not sufficient data to support one particular type of helmet in preventing concussions.

Other proposed preventative techniques include:

- Adhering to rules of play, with good sportsmanship and strict officiating;
- Emphasizing strength and conditioning;
- Using secondary prevention, including awareness of signs and symptoms of TBI;
- Recognizing and responding quickly and appropriately to suspected TBI.

The CDC has developed the Heads Up initiative to provide concussion and mild TBI education to specific audiences, including health care providers, coaches, athletic trainers, school nurses, teachers, counselors, parents, and student athletes. An online course has been developed with support from the National Football League and the Centers for Disease Control.[52]

Conclusions

The topic of concussion is one that has merited increased attention in the medical literature and the lay press. It has become an epidemic among military personnel and in athletics. Physicians and health care providers are being asked to play an enhanced role in diagnosis, post-concussive care, return to play, and return to study guidance. Every concussion is unique, and the emergency physician must provide an individualized assessment. It has been difficult as yet to define a standard of care for concussion management. The medical establishment can expect more guidelines and legislation from concerned organizations and government authorities on this topic.

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Emergency Medicine Reports

CME Objectives

Upon completion of this educational activity, participants should be able to:

- recognize specific conditions in patients presenting to the emergency department;
- apply state-of-the-art diagnostic and therapeutic techniques to patients with the particular medical problems discussed in the publication;
- discuss the differential diagnosis of the particular medical problems discussed in the publication;
- explain both the likely and rare complications that may be associated with the particular medical problems discussed in the publication.

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CME Questions

1. What is the estimated concussion rate per season among high-school football players?
   A. 5%
   B. 20%
   C. 35%
   D. 45%

2. How does the American Society for Sports Medicine define concussion?
   A. confusion and cognitive impairment following a blow to the head
   B. loss of consciousness following head trauma
   C. traumatically induced transient disturbance of brain function
   D. head trauma not resulting in intracerebral hemorrhage

3. Loss of consciousness must be present to diagnose post-concussive syndrome.
   A. true
   B. false

4. What is the radiographic gold standard imaging modality for diagnosis of concussion?
   A. non-contrast CT head
   B. skull films
   C. cerebral angiography
   D. No radiologic gold standard exists.

5. Which of the following is *not* included in the scored portion of the Standardized Assessment of Concussion (SAC)?
   A. immediate and delayed memory recall

CME Instructions

HERE ARE THE STEPS YOU NEED TO TAKE TO EARN CREDIT FOR THIS ACTIVITY:

1. Read and study the activity, using the provided references for further research.
2. Scan the QR code below, or log on to **www.cmecity.com** to take a post-test; tests can be taken after each issue or collectively at the end of the semester. *First-time users will have to register on the site using the 8-digit subscriber number printed on their mailing label, invoice, or renewal notice.*
3. Pass the online tests with a score of 100%; you will be allowed to answer the questions as many times as needed to achieve a score of 100%.
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5. **Once the completed evaluation is received, a credit letter will be e-mailed to you instantly.** You will no longer have to wait to receive your credit letter.

B. concentration
C. Graded Symptom Checklist
D. exertional maneuvers

6. During what period of time following concussion are patients at highest risk for developing Second Impact Syndrome?
   A. 1-2 hours
   B. 3-5 days
   C. 7-10 days
   D. 20+ days

7. What are the most common post-traumatic symptoms exhibited by patients with post-concussive syndrome?
   A. headache
   B. vomiting
   C. light sensitivity
   D. paresthesias

8. Which of the following is *not* one of the six identified variables included in the PECARN imaging guidelines?
   A. GCS less than 15
   B. vomiting
   C. no vomiting
   D. presence of a frontal scalp hematoma

9. Which of the following is a suggested recommendation for ending an athlete's sports season?
   A. parental anxiety
   B. one or more concussions in a single season
   C. prolonged post-concussive symptoms
   D. sports that do not require helmet use

10. Which of the following is *not* included in the Canadian CT Head Rule?
   A. loss of consciousness
   B. age > 65
   C. evidence of basal skull fracture
   D. dangerous mechanism

In Future Issues

Cardiac Resuscitation

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Concussion Overview: Risks, Managment, and Current Therapies

PECARN Guidelines for Head CT Scanning in Children

PECARN Guidelines very low risk of clinically significant findings on CT in Children[43]
For children younger than the age of 2 years, negative predictive value of 100%:

- Normal mental status
- No scalp hematoma except for a frontal hematoma
- No loss of consciousness or no loss lasting more than 5 seconds
- Non-severe mechanism of injury
- No palpable skull fracture
- Acting normally per parent

For children older than 2 years, negative predictive value of 99%:

- Normal mental status
- No loss of consciousness
- No vomiting
- Non-severe mechanism of injury
- No sign of a basilar skull fracture
- No severe headache

Sample Pharmacologic Agents for Symptoms of Concussion

Symptom	Agents
Dizziness/vertigo/ lightheadedness	Meclizine Scopolamine Dimenhydrinate Benzodiazepines: lorazepam, diazepam, clonazepam
Nausea	Ondansetron Promethazine
Sleep disturbances	Zolpidem Trazodone Melatonin Prazosin
Headache	Analgesics: aspirin, acetaminophen, NSAIDs Antidepressants: amitriptyline, nortriptyline Anticonvulsants: valproate, topiramate, gabapentin Triptans Beta-blockers: propranolol (prophylaxis)
Cognitive functioning	Methylphenidate Amantadine

Guidelines for Obtaining Head CT After Minor Head Injury

Canadian CT Head Rule[45]
Inclusion criteria:

- GCS 13-15
- Age 16 years or greater
- No coagulopathy or anti-coagulant use
- No gross open skull fracture

Head CT *not* required if ALL of the following are *absent*:
High risk (for neurosurgical intervention)

- Age > 65
- GCS < 15, 2 hours after injury
- Open or depressed skull fracture
- Signs of basal skull fracture
- Vomiting: 2 or more episodes

Medium risk (for brain injury on CT)

- Retrograde amnesia of > 30 min prior to injury
- Dangerous mechanism (such as pedestrian struck, ejected from vehicle, fall > 3 feet or > 5 stairs)

New Orleans CT Head Rule[46]
Inclusion criteria:

- Age > 18 years
- GCS 15
- Blunt head trauma occurring within previous 24 hours causing loss of consciousness, amnesia, or disorientation

Head CT *not* required if ALL of the following are *absent:*

- Headache
- Vomiting
- Age > 60 years
- Drug or alcohol intoxication
- Persistent deficits in short-term memory (amnesia), anterograde amnesia
- Visible signs of trauma above the clavicles
- Seizure

Symptoms of Athletes Post Concussion by Percentage at Time of Injury

Symptom	Percentage
Headache	85%
Dizziness/balance difficulties	77%
Cognitively "slowed down"	69%
Decreased concentration	61%
Sensitivity to light or noise	60%
Fatigue	58%
Drowsiness	47%
Problems with memory	46%

Suggested Return to Play Guidelines for Sport Concussion

Recommendations that an athlete stop competition for the season:

- 3 or more concussions in one season
- Prolonged post-concussive symptoms
- 2 or more severe concussions in a single season
- Declining athletic or academic performance
- Clinically important findings on imaging

Recommendations that an athlete end athletic career:

- Intracranial hemorrhage
- Pathologic abnormalities such as Chiari malformation
- Decreased academic or cognitive function
- Prolonged post-concussion syndrome
- Three or more major concussions
- Decreased threshold for concussion
- Chronic traumatic encephalopathy

Supplement to *Emergency Medicine Reports*, June 15, 2014: "Concussion Overview: Risks, Management, and Current Therapies." *Authors:* **Jonathan Glauser, MD**, Faculty, Emergency Medicine, MetroHealth Medical Center, Cleveland, OH; and **Hans Steck, MD**, Senior Resident, Emergency Medicine, MetroHealth Medical Center, Cleveland, OH.