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CLINICAL Pediatric Emergency Medicine

Concussions in Sports and Recreation

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In 2004, 475 000 children between 0 and 14 years old sustained a traumatic brain injury, and 90% were treated and released from emergency departments (EDs). Concussions are considered one of the most pressing issues in sports medicine and are challenging to diagnose. The clinician has to rely on gross clinical symptoms and/or the athlete's willingness to admit to clinical symptoms. Computed tomography results are often negative and are therefore not helpful for determining the extent of a child's injury or his or her prognosis. Computerized neuropsychologic assessment programs have made the evaluation of athletes easier and more sensitive and are in fact considered the criterion standard for diagnosing and monitoring sports concussions. All athletes presenting to EDs with suspected concussion should be discharged with careful follow-up. Furthermore, return to play should be guided by a gradual increase in activity as recommended by the Prague conference on concussion. A young athlete should never be allowed to return to his or her sport until asymptomatic.
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Traumatic brain injury (TBI) is the leading cause of death and disability for children and adolescents in the United States. In 2004, the Centers for Disease Control and Prevention reported that an estimated 475 000 children between 0 and 14 years sustain a TBI and that 90% are treated and released from emergency departments (EDs) in the United States per year [1]. It is not known how many more sustain an injury and are seen in doctor's offices or not at all.

In 1966, the Congress of Neurological Surgeons proposed a consensus definition of concussion that persisted for many years and was limited by the lack of knowledge of the pathophysiology of concussion [2]. In 2001, a group of sports physicians, neuropsychologists, neurosurgeons, and neurologists formed a consensus group in Vienna to revise the previous consensus definition of concussion using scientific data. This definition is as follows: "Sports concussion is defined as a complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces" [3]. In 2004, this same consensus group reconvened a Second International Conference in Prague on concussion in sport to revise and update the consensus recommendations presented in the first conference. No changes were made to the definition of concussion [4].

Currently, there is no standard for the management of concussion in the ED setting. There is no consensus as to when someone with a head injury needs a computed tomography (CT) scan. Furthermore, when the CT result is negative, emergency physicians tend to discharge to home patients without further assessment and with minimal to no follow-up despite the fact that the literature clearly shows that some of these children, while not having structural injuries to the brain, likely do have injuries on the cellular level, leading to persistent symptoms and cognitive dysfunction [5]. Furthermore, there is emerging evidence that demonstrates that the immature brain is more vulnerable to injury [6]. Even though most of the head injuries in children presenting to the ED are mild to moderate in severity, the impact of

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continuing symptoms and neuropsychologic deficits on the quality of a child's life are not well understood.

Epidemiology of Sports Concussion

In the United States, it is estimated that approximately 30 million children between the ages of 5 and 17 participate in organized sports programs [7]. Overall, injuries in sports participants are considered common, and injury rates have increased proportionally to the rate of participation. The Centers for Disease Control and Prevention 2004 data show that 85% of traumatic brain injuries in children treated in EDs were not assault or motor vehicle related. Therefore, a significant number of these 85% are perhaps sports and recreation related. However, it is unclear which specific activities account for this number of head injuries. A number of studies have shown that collision sports, such as football and hockey, are responsible for the largest number of overall injuries in children and adolescents. Of 10 sports studied in 235 high schools, soccer was second only to football with regard to traumatic brain injuries [8]. Next in risk include wrestling, basketball, field hockey, baseball, softball, and volleyball [8-10]. In some sports, the risk of concussion is dependent on the position played, and there is a higher rate of concussions sustained in games rather than practices [8,9].

Concussion is considered one of the most pressing issues in sports medicine. In fact, The Institute of Medicine published the proceedings of a workshop, "Youth soccer: neuropsychological consequences of head impact in soccer" in 2002. This workshop was convened to bring together experts in the field to discuss the alarming rates of head injury in soccer. The primary concerns of the conference participants were the high concussion rate in soccer, the persistence of impaired brain functions after other more obvious symptoms disappear, and the lack of consensus with regard to when it is safe to return to play. Despite this concern, data on incidence and outcomes of concussion in children as well as evidence for management are slim.

Pathophysiology of Concussion

There is a wide variability in reported outcomes associated with concussion. Some studies have shown that although most cognitive deficits are resolved by 3 months postinjury, a subgroup of children continue to demonstrate persistent behavior problems as well as difficulties with working memory, attention, and planning skills beyond this period [11,12]. It is not clear who is at risk for persistent problems and why.

The physical and anatomic abnormalities of concussion have only recently been described and are still emerging. During head impact causing concussion, the brain is violently moved within the skull causing damage to brain cells and blood vessels. This can disrupt brain chemicals responsible for brain function. Animal studies have shown that concussion causes an excess of potassium and calcium ions that can cause damage to cells [5]. These ions can cause the blood vessels within the brain to constrict, decreasing blood flow, and hence, the cells do not get the glucose necessary for normal brain function. This phenomenon can last for weeks.

The most common symptoms of concussion include headache, dizziness, nausea, vomiting, fatigue, and cognitive symptoms such as decreased attention span, decreased concentration, decreased mental speed, and impaired short-term memory. Also included are affective symptoms such as irritability, emotional lability, depression, and anxiety [12]. This disruption also may leave the brain more vulnerable to further serious injury if there is another impact to the head [13]. This rare but devastating consequence of a subsequent impact to the head after concussion is called *second impact syndrome*. This happens primarily in adolescents and occurs when a concussed child or adolescent sustains a subsequent impact to the head before resolution of the first concussion. The result can be tragic. The child can die or suffer devastating and permanent neurologic consequences. More commonly, those children who sustain more than one concussion tend to have symptoms that can persist for weeks to months [10]. There is a subset of concussed patients who develop chronic headaches [14]. This is why concussions are classified into 2 groups, simple and complex. Simple concussions are defined as those that resolve in 7 to 10 days, whereas complex concussions are defined as those with persistent symptoms such as prolonged cognitive impairment. Complex concussions typically occur in athletes who sustain multiple head injuries [4].

There is emerging evidence that there may be a genetic vulnerability to increased severity of brain injury in certain individuals. Apolipoprotein E (APOE) has been shown to have a role in modifying neurologic outcome after concussion. Specifically, the APOE epsilon 4 allele has been shown to be associated with an unfavorable outcome in TBI [15]. One study showed that there is an increased risk of late posttraumatic seizures associated with APOE epsilon 4 allele, whereas another study demonstrated an association with chronic TBI in boxers [16,17]. It is not clear whether APOE is a factor in all persons with the APOE epsilon 4 allele, only in those with severe head injury, or if APOE plays a role in persistent symptoms of concussion.

Concussions are difficult to diagnose because the clinician has to rely on gross clinical symptoms and/or the child's willingness to admit to clinical symptoms. The results of head imaging studies such as CT and magnetic resonance imaging are often negative and are therefore not helpful for determining the extent of a child's injury or his or her prognosis [18]. Therefore, other more

Table 1 Concussion grading scales.

	Grade 1 (Mild)	Grade 2 (Moderate)	Grade 3 (Severe)
American Academy of Neurology [20]	No LOC; symptoms, <15 min	No LOC; symptoms, >15 min	LOC
Colorado Medical Society [21]	No LOC, confusion without amnesia	No LOC, confusion with amnesia	LOC
Cantu [22]	No LOC or posttraumatic amnesia	LOC <5 min; posttraumatic amnesia, 1-24 h	LOC >5 min; posttraumatic amnesia, >24 h

LOC indicates loss of consciousness.

practical screening tools are needed to guide the management of patients with concussions.

The evaluation and management of concussion continues to be a controversial topic with inconsistent management and lack of objective data and confusion with regard to assessment techniques and return-to-play decisions [19]. Various definitions and classification schemes exist to describe concussions clinically. In fact, there are at least 19 concussion grading systems available. Some of the most commonly used scales include the American Academy of Neurology guidelines [20], the Colorado guidelines [21], and those developed by Cantu [22] (Table 1). Others that are considered practical and effective for the sideline at sporting events include questions of Maddocks et al [23] and the standardized assessment of concussion [24]. However, they do not take into account the underlying mechanisms of brain injury, and these schemes do not necessarily agree with one another. These systems do not provide physicians, coaches, trainers, or families with consistent guidance regarding how long to expect symptoms and, more importantly, when it is safe for the child to return to play. In the athletic arena, because of the dearth of knowledge about concussions, return-to-play decisions are often based on these non–evidence-based schemes or are arbitrarily decided.

Neuropsychologic Assessment of Concussion

The 2001 Vienna consensus group of sports professionals using current scientific evidence revised the definition of concussion and created guidelines for return-to-play decisions. They also determined that neuropsychologic testing is the gold standard in the assessment of concussions. This is because there is evidence that underlying brain functions continue to be impaired even after reported clinical symptoms of concussion are gone [25]. Neuropsychological testing demonstrates poorest cognitive performance in athletes at 24 and 48 hours postinjury with full recovery occuring 10 to 30 days after the concussion was sustained [26,27]. Given these variable findings of recovery, it remains unclear when athletes should be allowed to play and what effect this impairment has on school function. Moreover, there are no studies in children examining the effect of repeated concussions over the course of a season or athletic career.

Computerized neuropsychologic assessment programs have made the evaluations of athletes easier and more sensitive [27,28]. Several computerized neuropsychologic assessment tools are currently available on the market. To date, these tools have only been used in older adolescents and adults, but studies are currently ongoing to develop these tools for younger age groups. In this country, ImPACT is perhaps the most widely studied neuropsychologic computerized assessment program. This program has undergone, and continues to undergo, assessment for reliability and validity in determining deficits in neuropsychologic function in athletes (and others) with concussion [26]. Currently, age-based norms are being developed for children younger than 13 years, and the validity of these testing programs in pediatric populations is also currently under investigation. Computerized neuropsychologic batteries have several advantages as clinical tools. Practically, they are relatively quick to administer (20-30 minutes vs 2-3 hours of traditional neuropsychologic testing), they have alternate versions of tasks, which can minimize the impact of practice effects during repeat evaluations, and these standardized computerized test batteries can be administered by various individuals who have been trained to administer the tests (eg, athletic trainers, coaches, and team physicians). Computerized test batteries that include measures used to assess memory, executive functions, and processing speed have been found to be very sensitive at detecting mild cognitive dysfunction and can be followed over time to recovery. These measures also record reaction time recorded in milliseconds as an outcome measure, which is highly susceptible to disruption after mild TBI (mTBI) and concussion [23]. The precise assessment of reaction time allows for tracking of performance efficiency and variability over time [25].

Current ED Practices

There are little data and consensus to date with regard to the management of children with mTBI in the acute care setting. Furthermore, the few studies that have been ED based have differing definitions of mTBI and varied methods of assessment [29-31]. One study surveyed

35 level 1 trauma centers to determine their practices with regard to children with mTBI. The investigators found that "there is currently no standard practice for defining, evaluating, or managing mTBI at level I trauma centers" [29]. They found that less than half of the centers formally evaluate all trauma patients with mTBI, and only 35% of the centers refer for further evaluation, and this follow-up advice was not specific. In another study by Bazarian et al [30], 43% of children discharged from their ED with a diagnosis of concussion followed up with their primary care physician. However, the investigators did not adopt the best methodology in that their "neurobehavioral assessments" were conducted in the ED immediately after injury and at 1 month postinjury by telephone. It is now well documented that postconcussion cognitive deficits do not manifest until at least 24 hours postinjury, and that the symptoms of mTBI in many patients resolve in 2 weeks. It is not known how the deficits found in children with concussion impact on their schoolwork and home life. Another study by Ponsford et al [11] found that 17% of children treated for mTBI in the ED with follow-up at 1 week and 3 months had shown "significant ongoing problems," and the authors suggest identifying high-risk children in the ED.

Despite the paucity of data with regard to follow-up in the ED, it is clear that concussions are common and that cognitive deficits can occur and persist. Most ED physicians currently discharge children with mTBI to home with vague instructions to follow-up with their primary care doctor without determining who may need more specific follow-up and without instructions to families on how to manage postconcussive symptoms and cognitive deficits at home and school. Better data are needed to predict which children need follow-up for their concussions.

Guidelines for Acute Management

The acute management of concussion on the field and in the ED includes assessment and management of the ABCDs: airway, breathing, circulation, and immobilization of the C-spine. If the child needs transport to the ED, then the field-side medical personnel determine if it is by ambulance or car. In the ED, assessment and management of the ABCs continue, and more serious injuries are ruled out including C-spine injuries and intracranial hemorrhage. This may include x-rays for spinal injuries and computerized tomography to rule out intracranial pathology. Brain neuroimaging for mTBI continues to be controversial [29,31]. Factors to consider when deciding on neuroimaging include the length of the loss of consciousness, mental status deterioration, dramatic worsening of headache, focal neurologic deficits, and seizure activity [32].

Once it is determined that the athlete has no anatomic injury either clinically or by brain imaging, the athlete should be referred for formal follow-up with a physician. Follow-up is determined by the resources available in the geographic area. The athlete can follow up with their primary care physician, a neurologist, or a neuropsychologist. The player should not be allowed to return to play after sustaining a concussion, nor should he or she be allowed to return to play by the emergency physician. The athlete should be evaluated by a medical professional knowledgeable about concussion management. There are a variety of concussion checklists and inventories that the practitioner can use to assess recovery from concussion [33,34]; however, symptom reports are not always valid [35]. Furthermore, it should be noted that neuropsychologic testing has shown that reported symptoms resolve before neuropsychologic deficits, so that if neuropsychologic testing is available, it will best assess recovery and better help determine return to play [25].

The Prague concussion in sport group recommended a conservative return-to-play approach for children and adolescents. They outlined a return-to-play protocol that emphasizes initial physical and cognitive rest. For a child or adolescent, this may mean no participation in organized or recreational sports activities and physical education classes. Activities that require concentration and attention may worsen the symptoms, and there is some evidence that they may delay recovery. Therefore, it may also mean excusing the head-injured athlete from tests and major assignments, creating accommodations in the classroom or even excusing the student from school depending on the nature of the symptoms and the extent of the cognitive deficits. Each case is different so accommodations should be customized.

The Prague return-to-play protocol, which contains 6 levels, follows:

1. No activity, complete rest. Once asymptomatic, proceed to level 2.
2. Light aerobic exercise such as walking or stationary cycling, no resistance training.
3. Sports-specific exercise—for example, skating in hockey, running in soccer; progressive addition of resistance training at levels 3 or 4.
4. Noncontact training drills.
5. Full contact training after medical clearance.
6. Game play.

These should be followed in a stepwise fashion. If any symptoms reoccur, then the player should drop back to the previous level [4]. A player should never be allowed to return to play while still symptomatic.

Summary

There are thousands of children and adolescents per year who sustain a concussion, and yet, there is little scientific evidence to guide appropriate management especially in children. Many children and adolescent athletes sustain a simple concussion and recover in 7 to 10 days, but those who sustain a complex concussion may be impaired for a month or longer. Careful on-the-field and acute care setting assessments as well as careful follow-up of all athletes are important to the recovery of the athlete and are critical in determining the timing for return to play.

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