Managing concussion in a young athlete

BY DILIP R. PATEL, MD

Although we have no consensus definition of concussion, it is generally agreed that key features of concussion are confusion, loss of memory, and impaired information-processing speed, occurring immediately or within several minutes after an injury.\textsuperscript{1-8} Guidelines on concussion in sports developed by the American Academy of Neurology (AAN) define concussion as a trauma-induced alteration in mental status that may, or may not, be associated with loss of consciousness.\textsuperscript{1-3} An alternative to the AAN definition arose from the Second International Conference on Concussion in Sport, Prague, (hereafter, The Prague Conference),\textsuperscript{5} which states that concussion:

- is caused by a direct blow to the head, face or neck, or by an otherwise impulsive force transmitted to the head
- is typically marked by rapid-onset, tran-
A "rung bell" is common and can do significant acute and long-term harm to a developing brain. Because no guideline or protocol has been adequately studied for application to children and adolescents, take a cautious approach to management of concussion in youth, the author advises.

Intermittent impairment of neurologic function
- May result in neuropathologic changes, although acute clinical symptoms largely reflect a functional disturbance rather than structural injury
- May result in a graded set of clinical syndromes that may, or may not, involve loss of consciousness. Resolution of clinical and cognitive symptoms typically follows a sequential course.
- Is typically associated with grossly normal structural neuroimaging studies.

Individual signs and symptoms of concussion are listed in Table 1. Concussion can occur in contact sports and in those that involve rapid acceleration, deceleration, or rotational forces applied to the brain (see Table 2). Postconcussion syndrome—persistent symptoms and signs following brain injury that can last weeks, months, or years—indicates severe injury that precludes an athlete’s return to participation in high-risk sports.

Although estimates are that concussion accounts for 3% to 5% of all high-school sport-related injuries, the true incidence is likely higher; an athlete may not report an injury or symptoms because he (she) does not want to be prevented from playing. Transient signs and symptoms also may delay or prevent an injured athlete from obtaining timely medical attention.

My goal in this article is to review those aspects of sport-related concussion that you, the generalist pediatrician, are likely to manage.

Evaluating the young athlete
Symptoms and signs of concussion may appear immediately after the brain injury or be delayed for days or weeks (See Table 1). Although no single symptom or cluster is pathognomonic,

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**Key points**

Concussion

- No consensus exists to guide evaluation and management of concussion in children, which can have significant acute and long-term effects on the developing brain
- Assessment of cognitive function and neurologic examination are essential components of evaluation of athletes with concussion
- Concussion should not be ruled out simply because no history of direct impact to the head or elsewhere on the body supports the diagnosis; a meticulous history and focused physical examination are key elements of diagnostic evaluation
- Changes in a child or adolescent’s behavior, mood, or personality may be sequelae of concussion, and warrant probing the history for head trauma
- Compared with adults, children and adolescents with concussion generally require more time to recover and are at greater risk of repeat concussion
and most are nonspecific in nature, impaired mental status of any degree is a hallmark of concussion. A contemporaneous relationship should be established between the time of initial injury to the brain and development of symptoms and signs based on history and examination.

Consider other conditions that present with clinical features similar to those of concussion: heat-related illness, dehydration, hypoglycemia, and acute exertional migraine can mimic concussion. Many delayed symptoms of concussion are nonspecific, necessitating careful delineation of the differential diagnosis or concomitant conditions such as depression, attention deficit hyperactivity disorder, sleep disorder, cerebellar or brain stem lesion, or somatization.

An adolescent athlete is more likely than a young child to present with concussion. I focus this discussion on the older age group, therefore. You may see an athlete with concussion on the field, or, more often, in the office. The athlete on the field may have a history of a direct blow to the head or other part of the body, a collision with another player, a fall, or being struck by an object such as a ball, puck, or bat (see “Managing acute injury on the field,” above). In some cases, the athlete does not recall the incident. Because concussion can be caused by indirect shearing or rotational forces imparted to the brain, without direct impact, an injured player’s teammate may report something amiss with the athlete or, the athletic trainer or coach—or even a spectator—may notice that the player appears confused and unable to execute moves or follow commands that are expected during play.

More common, however, is an office visit in which an athlete, with or without symptoms, comes to see you for follow-up of a head injury and needs a medical clearance to return to play. Or, an athlete reports symptoms or signs of concussion days or weeks after the head injury, because he (or she) did not appreciate the significance of the symptoms, new symptoms emerged, or existing symptoms persisted or became worse. A parent may seek your help after observing poor academic performance or change in their child’s behavior, mood, or personality. It is critically important that you recognize these problems as sequelae of concussion and probe the history for head trauma.

A review of systems should elicit any preinjury neurologic problems or learning disability; attention deficit hyperactivity disorder, depression, academic function before and since the injury; use of drugs, performance-enhancing supplements, and therapeutic medications. The psychosocial history should assess the athlete’s interest in sports and any evidence of parental pressure to return to sport.

(A sports preparticipation evaluation [PPE] is also an opportunity to explore an athlete’s history of head injury. Ask when the most recent concussion occurred, what symptoms and signs manifested, time before full recovery, number of concussions and intervals between, and results of any neuropsychological testing or neuroimaging studies. A PPE visit is also an...

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**Managing acute injury on the field**

On-field priorities in the management of severe head and neck injury, however rare in youth sports, are recognition, stabilization, and appropriate disposition of the athlete. A patient who loses consciousness for any duration should be immediately stabilized and transported to an emergency department. Symptoms that become worse or fail to resolve within a few minutes, or abnormal findings on the neurologic examination in a patient who has not lost consciousness, also warrant a trip to an ED for evaluation and management.

A young athlete who is recognized to have concussion but who has not lost consciousness also must be removed from practice or play for the day. The athlete should not be left unattended on the sideline, and must be assessed periodically for evolving symptoms and signs. Acute symptoms typically resolve within a few minutes, after which the athlete may be allowed to go home. In addition to instructing parents to bring the patient in for a follow-up office visit the next day, the Prague Conference statement recommends that immediate medical attention be sought when the athlete exhibits any of the following symptoms:

- Worsening headache
- Drowsiness, or difficulty waking
- Difficulty recognizing people or places
- Repeated vomiting
- Increased confusion
- Increased irritability
- Seizure
- Arm or leg weakness
- Unsteady gait
- Slurred speech
excellent opportunity for prevention education.)

**Assess cognitive function**

As noted, any degree of impaired cognitive function is a hallmark of concussion. Cognitive function can be affected by variables other than the effects of concussion, such as baseline (preinjury) intellectual ability, learning disability, attention deficit hyperactivity disorder, substance abuse, level of education, cultural background, lack of sleep, fatigue, anxiety, age, and developmental stage. The technique chosen to assess cognitive function should be appropriate to the athlete's age, level of education, and stage of development.

**Field tests.** Orientation to person, time and place; attention; memory; and higher cognitive function are among the areas assessed in a brief mental status examination of athletes suspected of having sport-related concussion. On-field assessment of memory and orientation can be performed using Maddocks' questions (see Table 3). Inability to correctly answer any one of the Maddocks' questions suggests concussion.

Tests that involve thinking with numbers or words, such as digit span, serial seven, or spelling backward, can be used to gauge the patient's attention. To perform the digit span, ask the athlete to repeat back to you a series of two digits that you speak at a rate of about one per second. If he (she) correctly repeats the two digits, recite a series of three numbers, then four, five, and so on. If the athlete makes an error, try once more with another series of the same length, and stop the exercise if he fails the second attempt. Similarly, have the athlete repeat the digits backward, starting with a series of two. A person whose attention is intact should be able to repeat correctly at least five digits forward and four backward.

To perform serial seven, ask the athlete to subtract seven from 100 and keep subtracting. Typically, the athlete should be able to complete a serial seven in 90 seconds with fewer than four errors. If he finds serial seven too difficult, have him do serial three. In addition to digit span and serial subtraction, have the patient say and then spell a five-letter word, and then spell it backwards.

To assess memory, have the athlete repeat five words you speak; one who has intact registration and immediate recall should be able to correctly repeat the five words. Without informing the athlete that he will be asked to recall these words later, move on to another assessment. Five minutes later, ask the athlete to recall the five words. The athlete with intact delayed recall should be able to recall the five words. Other tasks to gauge memory and concentration are to have the athlete:

- recite the months of the year in reverse order, starting with a month other than December or January (test of concentration)
- tell you the current score of the game, the quarter of play, and the name of the school or league of the opponent or opposing team (test of recent memory)
- tell you the name of his or her elementary school (if a high school athlete) or place of birth (test of remote memory).

Onset of post-traumatic amnesia, a key feature of concussion, may appear as late as 20 minutes after injury to the brain. Resolution of post-traumatic amnesia is indicated by the athlete's ability to recall, fully, the events

**TABLE 1**

<table>
<thead>
<tr>
<th>Mental status</th>
<th>Physical or somatic</th>
<th>Behavioral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amnesia</td>
<td>Ataxia or loss of balance</td>
<td>Emotional lability</td>
</tr>
<tr>
<td>Confusion</td>
<td>Blurred vision</td>
<td>Irritability</td>
</tr>
<tr>
<td>Disorientation</td>
<td>Decreased performance</td>
<td>Low tolerance for frustration</td>
</tr>
<tr>
<td>Easily distracted</td>
<td>or playing ability</td>
<td>Personality changes</td>
</tr>
<tr>
<td>Excessive drowsiness</td>
<td>Dizziness</td>
<td>Nervousness, anxiety</td>
</tr>
<tr>
<td>Feeling &quot;dinged,&quot; stunned, or &quot;in a fog&quot;</td>
<td>Double vision</td>
<td>Sadness, depressed mood</td>
</tr>
<tr>
<td>Impaired level of consciousness</td>
<td>Fatigue</td>
<td></td>
</tr>
<tr>
<td>Inappropriate play behavior</td>
<td>Headache</td>
<td></td>
</tr>
<tr>
<td>Poor concentration and attention</td>
<td>Lightheadedness</td>
<td></td>
</tr>
<tr>
<td>Seeing stars or flashing lights</td>
<td>Nausea, vomiting</td>
<td></td>
</tr>
<tr>
<td>Slow to answer questions or follow directions</td>
<td>Seizure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Slurred, incoherent speech</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tinnitus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vacant stare, glassy eyes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vertigo</td>
<td></td>
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</tbody>
</table>

**TABLE 2**

<table>
<thead>
<tr>
<th><strong>Risky business: Sports associated with a high risk of concussion</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>American football</td>
</tr>
<tr>
<td>Ice hockey</td>
</tr>
<tr>
<td>Soccer</td>
</tr>
</tbody>
</table>
that preceded injury to the present (continuous memory).\textsuperscript{28,16}

In the office, general knowledge and vocabulary are good indicators of intellectual function. Assess calculation ability by asking the athlete to perform a simple task of answering how many nickels make a quarter, or, the square root of 64. Abstract thinking can be assessed by asking the athlete to explain the meaning of a common proverb ("A rolling stone gathers no moss"), or by similarities test (how a train and an airplane are similar). Constructional abilities provide an indication of visual motor ability, and can be tested by having the athlete draw a clock face, numbers, and hands. The quality of the drawing should provide some indication of the patient's intellectual function.

In addition to attention, memory, higher cognitive function, and orientation to person, time, and place, assess the patient's judgment, affect, insight, and mood.

**Neurologic examination.** A complete neurologic examination is essential in the evaluation of an athlete with concussion. The examination should cover speech; visual acuity and fields, ocular fundi, pupillary reactions, and extraocular movements; muscle strength and deep-tendon reflexes; and tandem gait, finger-nose, pronator drift, and Romberg tests.

Results of the neurologic examination in a patient with concussion should, with the exception of mental status, be normal. Abnormal or focal findings on neurologic examination should prompt consideration of a focal intracranial pathology and emergent evaluation and management of the athlete.

**The role of advanced testing**

Neuroimaging is indicated in an athlete who has focal neurologic signs, severe acute headache, loss of consciousness lasting more than several seconds, progressively severe symptoms and signs, or failure of symptoms to resolve after two weeks.\textsuperscript{24}

Static imaging with magnetic resonance imaging (MRI) and computerized tomography do not demonstrate structural abnormalities of the brain in concussion. Positron emission tomography (PET), functional MRI (fMRI), and single photon-emission computed tomography (SPECT) provide information on brain metabolism and regional blood flow. Application of any of the latter three modalities in clinical evaluation and management of athletes with concussion is limited, however.

Important domains of cognitive function assessed by neuropsychological (NP) testing include memory; information-processing speed (reaction time); visual, spatial, and motor abilities; and components of executive function (working memory, attention, planning, and organization).\textsuperscript{29,26} Memory and reaction time are important domains impaired by concussion that can be measured by NP testing. A return to baseline neuropsychological profile is a sensitive indicator of resolution of concussion in an adult; in an adolescent, however, neurologic maturation continues, with continued acquisition of skills, knowledge, and neurocognitive ability.\textsuperscript{14} This continued neuromaturation during adolescence may complicate the matter of whether a patient's return to baseline NP profile indicates full recovery. This confounding factor should be taken into account in interpreting NP test results in an adolescent.

Paper-and-pencil (conventional) NP testing involves a battery of tests administered over one or more sessions, with results interpreted by a neuropsychologist. Although conventional NP testing can be useful in guiding management of academic difficulties in children and adolescents, conventional NP tests are neither designed nor validated to assess an athlete with sport-related concussion; cannot be easily adapted for mass application; and are expensive. In contrast, computerized NP tests are designed to assess athletes with sport-related concussion and are used in high-school, college, and professional sports to obtain baseline and post-concussion neuropsychological profile of athletes to monitor recovery.\textsuperscript{12,25-28} (Table 4 lists these examples.) Computerized tests are easy to administer, less expensive than conventional NP tests, can be administered to all members of a team, and yield results that are easily interpretable. Validity and reliability of computerized tests have been questioned, however.\textsuperscript{25}

NP testing—conventional or computerized—must not be used in isolation to assess or monitor recovery of an athlete with concussion, nor should the decision to return the athlete to play be determined only by NP test

**TABLE 3**

<table>
<thead>
<tr>
<th>Assessing memory and orientation on the field (Maddocks' questions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which field are we at?</td>
</tr>
<tr>
<td>Which team are we playing today?</td>
</tr>
<tr>
<td>Who is your opponent?</td>
</tr>
<tr>
<td>Which quarter is it?</td>
</tr>
<tr>
<td>How far into the quarter is it?</td>
</tr>
<tr>
<td>Which side scored last?</td>
</tr>
<tr>
<td>Which team did we play last week?</td>
</tr>
<tr>
<td>Did we win last week?</td>
</tr>
</tbody>
</table>

results. Properly constructed and administered formal NP testing is a valuable tool to objectively assess and monitor athletes with sport-related concussion but is, at present, indicated for such specific uses as defining impairments in an athlete who fails to recover as expected, deteriorates, or has had multiple concussions.

**Your role the day after, and beyond**

Because recovery from acute concussion is variable, an individualized, stepwise plan for return to play is preferable to conventional return to play guidelines. Both the Cantu concussion grading system and the AAN guidelines base return-to-play decisions on the severity of the injury, including whether the patient lost consciousness. This approach is somewhat flawed, however, because severity of concussion is more reliably determined after symptoms have resolved. Furthermore, loss of consciousness has not been shown to be a reliable indicator of severity of concussion.

**Grading severity of concussion, and determining the return to play**

Most grading systems for severity of concussion—the most widely known are the Cantu concussion grading system and the system of the American Academy of Neurology—are based on whether and how long the patient lost consciousness; whether he is confused; and duration of post-traumatic amnesia. None of these variables have been shown, however, to reliably predict the severity of the concussion or prognosis.\(^1\)\(^6\)\(^8\)\(^24\) The Prague Concussion in Sport Consensus Statement does not recommend use of conventional grading scales in the management of concussions.\(^6\)

Because the duration of symptoms and signs following initial brain injury has been shown to predict the severity of concussion and prognosis for recovery more reliably, the prevailing view is to consider the severity of concussion retrospectively, after clinical resolution of concussion.\(^2\)\(^6\)\(^8\)\(^24\) A simple concussion typically resolves in seven to 10 days and requires no further intervention; a complex concussion is characterized by failure of clinical resolution and associated sequelae.

Although most athletes recover within two to 12 weeks, each patient follows a variable trajectory to recovery, making a fixed period out before return to play a less valid approach.\(^1\)\(^2\)\(^3\)\(^8\)

The athlete must be seen in the office the day after injury. Management guided by the Prague Consensus statement is stepwise, with the athlete moving to the next level of activity only if he (she) remains asymptomatic at the current level. Recurrence of symptoms signals that the athlete should fall back to the to the previous, asymptomatic level for at least 24 hours before attempting the next level again.\(^6\) The athlete must be asymptomatic both at rest and on exertion provocation measures, such as a 40-yard sprint, five push-ups, five sit-ups, or five jumping jacks.

**Step 1.** No activity; complete rest until symptoms resolve—then

**Step 2.** Light aerobic exercise such as walking, stationary cycling; no resistance training. If symptoms do not recur, begin

**Step 3.** Sport-specific exercise (e.g., a hockey player may resume skating, a soccer player may resume running), gradual resistance training. If the patient remains asymptomatic, begin

**Step 4.** Noncontact training drills, with gradual increase in resistance training

**Step 5.** Full contact training, after medical clearance

**Step 6.** Return to play

The decision to return to play is, of course, individualized, and based on your clinical judgment.\(^1\)\(^2\)\(^4\)\(^6\)\(^8\)\(^12\)

Evidence suggests that an athlete's self-report of symptoms is reliable and practical in both detecting concussion and monitoring recovery.\(^2\)\(^6\)\(^8\)\(^17\)\(^20\)\(^30\) Use of the Concussion Symptom Inventory (CSI), which is sensitive and specific to subjective symptoms after sport-
TABLE 5
Concussion Symptom Inventory

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nausea</td>
<td></td>
</tr>
<tr>
<td>Balance problems or dizziness</td>
<td></td>
</tr>
<tr>
<td>Fatigue</td>
<td></td>
</tr>
<tr>
<td>Drowsiness</td>
<td></td>
</tr>
<tr>
<td>Feeling &quot;in a fog&quot;</td>
<td></td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td></td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td></td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td></td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td></td>
</tr>
<tr>
<td>Blurred vision</td>
<td></td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td></td>
</tr>
</tbody>
</table>

TOTAL SCORE


related concussion, is recommended during postinjury monitoring (see Table 5). A preseason baseline CSI profile is valuable for comparing an athlete's postinjury profile later.

Children and adolescents require cognitive rest until full cognitive recovery is achieved. Return to school work should be gradual. The school should be informed of necessary accommodations during recovery. Although most student-athletes recover fully from concussion within a few days or weeks, others may need a Section 504 plan or an individualized education plan.

Effect of multiple concussions. The likelihood of long-term and permanent impairment in cognitive function increases with each concussion. An athlete can sustain multiple concussions during the same practice, game, season, or over his playing career. The effects of repeat concussion are cumulative, and short intervals between injuries increase the severity. There are no scientifically validated criteria for returning to play the athlete who sustains more than one concussion.

How many concussions are too many for continued participation in a high-risk sport? There is no agreement, although some have suggested three as the magic number. A more conservative approach is recom-

mended in the young athlete, however, and the patient's parents must be aware of the effects that the neurotrauma of multiple concussions have on the developing brain. The decision to allow the patient to play high-risk sport is often a difficult one.

Outcomes: Good news and bad

Most athletes with simple (mild) concussion recover cognitive function within seven to 10 days, and those with complex (severe) concussion recovery within one to three months. Physical and emotional symptoms may persist in a patient who recovers neurocognitive function. Compared with adults, children and adolescents with concussion generally require more time to recover and are at greater risk of repeat concussion—the effects of which are, as noted, cumulative. Poor academic achievement, emotional symptoms, and psychosocial difficulties are among the prolonged sequelae of concussion that may occur in a child or adolescent.

Second-impact syndrome—rapidly progressive brain edema, brain stem herniation, and high mortality within minutes of a second concussion—has been described in adolescent male athletes who, not yet clinically recovered from a concussion, suffer a second injury. Although recent reports have raised doubts about the occurrence or significance of second-impact syndrome, the matter has neither been fully elucidated or resolved. At present, no athlete should return to play until he is fully asymptomatic and has normal findings on examination at rest and on provocative exertion.

How to prevent concussion in a young athlete

Increased awareness of sport-related concussion among athlete, parent, coach, and public is key to prevention. You can educate parents and children about sport-relat-
ed concussion in anticipatory guidance during well visits, as well as during evaluation and management of athletes who present with concussion. Explain how to recognize concussion, the importance of seeking timely medical attention and of complete recovery before returning to play, and the consequences of concussion.

Although helmet use in American football has minimized the likelihood of severe skull injury, it has not been shown effective in preventing concussion.

REFERENCES


of a mouth guard, likewise, has been shown to reduce the incidence of orofacial injury, but its role in preventing concussion has not been established.49,50 Strengthening neck muscles may, theoretically, allow an athlete to tense these muscles and maintain the head and neck in a fixed position to dissipate the forces of an impact on the brain, but athletes have little time to anticipate the impact and fix the head and neck before impact.