Concussion in the Pediatric Patient

Mary T. Grace, MS, CPNP-PC

KEY WORDS

Concussion, second impact syndrome, neuropsychological testing, return to play protocol

CHIEF COMPLAINT

A 15-year-old white girl presented for evaluation of a headache of 15 hours' duration.

HISTORY OF PRESENT ILLNESS

The previous night, the patient fell during volleyball practice. The back of her head hit the floor, and another player fell on top of her. She did not lose consciousness. Immediately after the incident and until the present time, she has had a headache, dizziness, photosensitivity, sleepiness, and difficulty concentrating. She rates her headache as a "6" out of "10." She has taken naproxen for her headache with minimal relief.

MEDICAL HISTORY

The patient has no significant medical or surgical history. She is a sophomore in high school and receives grades of As and Bs. She plays varsity and club volleyball and works part time at a restaurant. She has no allergies, takes no medications, and her immunizations are up to date. As a prerequisite to playing a high school sport, she underwent Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) last year. ImPACT is a computerized neurocognitive test. It is first conducted before participation in sports to determine the athlete's baseline brain function. When it is administered after head trauma is sustained, ImPACT can identify changes in mental capacity, thus determining the extent of concussion damage and tracking recovery (ImPACT Applications Incorporated, 2012).

PHYSICAL EXAMINATION

The patient reclines on the examination table with her eyes closed but sits up and is alert and oriented to person, place, and time when addressed. Her head is erect, normocephalic, and atraumatic, with symmetrical facies. She has no marks, lumps, or ecchymoses. Her neck is nontender and supple with full range of motion. Her pupils are equal and reactive to light and accommodation. No lid lag is present, her corneal light reflexes are equal, and her extraocular movements and visual fields are intact. Her funduscopic examination shows well-defined vessels and discs with no papilledema. She has symmetrical tone and strength in her upper and lower extremities. Her deep tendon reflexes are normal and symmetrical. Performance on finger-to-finger, finger-to-nose, and thumb-to-finger tests is intact, but results of a Romberg test are positive, and her tandem gait is unsteady. Her hearing is intact. Respiratory and cardiac findings are normal.

Mary T. Grace, Nurse Practitioner, Private Practice, Baltimore, MD.

Conflicts of interest: None to report.

Correspondence: Mary T. Grace, MS, CPNP-PC, 1119 Vineyard Hill Rd, Catonsville, MD 21228; e-mail: tomteretal@gmail.com.

J Pediatr Health Care. (2012) ■, ■-■.

0891-5245/$36.00

http://dx.doi.org/10.1016/j.pedhc.2012.10.004

CASE STUDY QUESTIONS

1. What is the evidence-based definition of a concussion?
2. What are the current evidence-based diagnostic criteria for a concussion or mild traumatic brain injury?
3. How is concussion evaluated and managed?
4. What is the role of neuropsychological testing in concussion management?
5. Are measures to prevent concussion effective?

CASE STUDY ANSWERS

1. What is the evidence-based definition of a concussion?

The patient's history and symptoms support a diagnosis of concussion. Conflicting opinions exist regarding the term for this diagnostic condition. Some authors contend that using the word *concussion* instead of *mild traumatic brain injury* (mTBI) implies a less severe state (Halstead, Walter, & the Council on Sports Medicine and Fitness, 2010). DeMatteo et al. (2010) found that children were more likely to be diagnosed with a concussion when they had a Glasgow Coma Scale score of 13 to 15, and the concussion label was predictive of earlier hospital discharge and return to school. A concussion diagnosis also was more likely when computed axial tomography scan results were normal and the child had lost consciousness (DeMatteo et al., 2010). In a hospital setting, concussion most often refers to an impact-related brain injury without clinical indicators other than perhaps loss of consciousness (DeMatteo et al., 2010). Health care providers may use the term *concussion* to imply to parents that there is less cause for concern of significant long-term effects (DeMatteo et al., 2010).

The most recent of three International Symposia on Concussion in Sports (CIS), convened in 2008, concluded that concussion and mTBI refer to two different injury constructs and that the terms should not be used interchangeably (McCrory et al., 2009). However, the recently issued "Concussion (Mild Traumatic Brain Injury) and the Team Physician: A Consensus Statement—2011 Update" from the American Academy of Family Physicians (AFP), the American Medical Society for Sports Medicine (AMSSM), the American Academy of Orthopaedic Surgeons (AAOS), the American Orthopaedic Society for Sports Medicine (AOSSM), the American College of Sports Medicine (ACSM), and the American Osteopathic Academy of Sports Medicine (AOASM) uses the terms interchangeably (Herring, Cantu, Guskiewicz, Putukian, & Kibler, 2011). The Veterans Administration/Department of Defense "Clinical Practice Guideline for Management of Concussion/mild Traumatic Brain Injury (mTBI)" does so as well (Department of Veterans Affairs, Department of Defense, 2009).

According to the Consensus Statement on Concussion in Sport drafted at the 2008 International Conference, concussion is defined as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces" (McCrory et al., 2009, p. i76) and includes the parameters listed in Table 1. The aforementioned AFP, AMSSM, AAOS, AOSSM, ACSM, and AOASM Consensus Statement concurs with this definition (Herring et al., 2011), as does the American Academy of Pediatrics (AAP) Clinical Report (Halstead et al., 2010). However, the Department of Veterans Affairs/Department of Defense guideline, which applies to patients 18 years and older, states, "Currently, there are no universal standard criteria for the definition of concussion/mTBI and the diagnosis is based primarily on the characteristics of the immediate sequelae following the event" (Department of Veterans Affairs, Department of Defense, 2009, p. 7).

The forces that cause concussion interfere with neural membranes, which results in potassium efflux into the extracellular space; subsequent increases in calcium and excitatory amino acids lead to further potassium efflux and suppression of neuron activity (Halstead et al., 2010). Sodium-potassium pumps increase activity to restore balance, resulting in an increased energy requirement, but a concomitant decrease in cerebral blood flow occurs (Scorza, Raleigh, & O'Connor, 2012). This effect on metabolism can be evident within 24 hours and has persisted as long as 10 days in experimental models (Meehan & Bachur, 2009). The hypometabolic state has been shown in animal models to persist up to 4 weeks after injury (Halstead et al., 2010). During this recovery period, the brain may be prone to further injury (Scorza et al., 2012).

2. What are the current evidence-based diagnostic criteria for a concussion or mild traumatic brain injury?

Signs and symptoms of concussion include headache, nausea, vomiting, tiredness, problems with vision and balance, sensitivity to light and noise, difficulty with concentration and memory, irritability, sadness, emotional lability, and sleep dysfunction (Halstead

TABLE 1. Definition of concussion—Consensus Statement on Concussion in Sport

1. Concussion may be caused either by a direct blow to the head, face, 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, postconcussive symptoms may be prolonged.
5. No abnormality on standard structural neuroimaging studies is seen in concussion.

From McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., & Cantu, R. (2009).

et al., 2010). Headache is the most commonly reported symptom (Halstead et al., 2010). Symptoms generally present immediately after injury but may be delayed by several hours; they usually last less than 72 hours and most concussions (80% to 90%) resolve in 7 to 10 days (McCrory et al., 2009). Although loss of consciousness occurs in fewer than 10% of concussions, it, along with amnesia, may be an indicator of more severe injury and suggests the need for imaging (Halstead et al., 2010). Mental fogginess, prolonged headache for longer than 60 hours, tiredness, or the presence of more than three symptoms may predict a slower recovery (Scorza et al., 2012). Concussive impact can be associated with intracranial structural pathology, and therefore concussion should be differentiated from cervical spine injury; skull fracture; or subdural, epidural, intracerebral, or subarachnoid hemorrhage (Halstead et al., 2010). Signs of intracranial structural injury include "severe headache; seizures; focal neurological findings on examination; repeated emesis; significant drowsiness or difficulty awakening; slurred speech; poor orientation to person, place, or time; neck pain; and significant irritability" (Halstead et al., 2010, p. 601). Neuroimaging should be considered for these patients (Halstead et al., 2010).

Concussion grading scales traditionally have been used in concussion evaluation; however, the 2008 CIS group (McCrory et al., 2009) and the AAP Clinical Report (Halstead et al., 2010) recommend abandoning their use. The concussion Consensus Statement from the AFP, AMSSM, AAOS, AOSSM, ACSM, and AOASM adds that the number and duration of concussion signs and symptoms other than loss of consciousness are more precise in determining concussion severity and outcome than are grading scales (Herring et al., 2011). This report emphasizes that concussions are unique to each individual and that symptoms may vary with each concussion sustained (Herring et al., 2011).

Concussions may lead to complications that affect memory, personality, and communication (Herring et al., 2011). Convulsive motor phenomena may be seen soon after concussion but are usually benign, requiring no management other than standard emergency care (McCrory et al., 2009). Posttraumatic seizures may occur days to months after concussion and require anticonvulsant therapy (Herring et al., 2011). Postconcussion syndrome occurs when concussion symptoms persist for 3 months or longer (Herring et al., 2011). Having a prior concussion increases the risk of having others, and multiple concussions as well as postconcussion syndrome can increase the risk of depression (Herring et al., 2011). Multiple concussions also have been found to be related to an enhanced risk of mild cognitive impairment later in life and also of earlier onset of this deterioration (Herring et al., 2011).

Concussion presents unique considerations for youth. Possibly because of their developing brain, children and adolescents are more susceptible to concussion than are adults, take longer to recover, and have more neurocognitive consequences (Sim, Terryberry-Spohr, & Wilson, 2008). Concussion may have longer-lasting effects than previously thought, because persistent neuroelectric deficits have been found in young adults at 3 years after injury that were not clinically evident (Broglio, Ponifex, O'Connor, & Hillman, 2009). The rapid cognitive development in children younger than 15 years complicates accurate determination of postconcussion cognitive function, and the size disparities among athletes on teams of children younger than 16 years imposes greater risk for those of smaller size (Johnson, 2012). Further, youth are susceptible to second impact syndrome, a catastrophic event in which a second concussion occurs within weeks, resulting in diffuse cerebral swelling, brain herniation, and perhaps death (Bey & Ostick, 2009). Talavage et al. (2010), using neurocognitive testing and functional magnetic resonance imaging in high school football players without clinically evident concussion, found neurocognitive and neurophysiological deficits that may have been due to undetected or unreported concussion or to the effect of repeated subconcussive impacts. Ominously, chronic traumatic encephalopathy (CTE), which is associated with early dementia, depression, suicide, disinhibition, and unstable behavior and is only diagnosable on autopsy, has been found in an 18-year-old multisport athlete with a history of football-associated concussion (Center for the Study of Traumatic Encephalopathy, 2012). Finally, researchers have found evidence of the deposition of Tau proteins suggestive of CTE in football athletes in their 20s with no history of concussion, implying that a relationship may exist between youth football and CTE (Schwartz, 2010).

Data from the National Electronic Injury Surveillance System—All Injury Program from 2001-2009 show that about 2,651,582 of children ≤19 years of age were treated annually for sports- and recreation-related injuries (Centers for Disease Control and Prevention [CDC], 2011). About 6.5% of these injuries were traumatic brain injuries (TBIs) (CDC, 2011). The number of annual TBI-related emergency department visits increased 62% in this period, with the highest rates in boys aged 10 to 19 years; these findings may suggest enhanced participation in sports and recreation, greater awareness of concussion and TBI, or actual increased incidence in TBI (CDC, 2011). The activities most associated with TBI for both sexes were, in decreasing order, bicycling, football, playground activities, basketball, and soccer (CDC, 2011). For boys aged 10 to 14, 15 to 19, and ≤ 19 years overall, football was the most common TBI-associated activity. For girls, the most common TBI-associated activity for those aged 10 to 14 years was bicycling; for those aged 15 to 19 years it was soccer, followed closely by basketball, and for girls ≤ 19 years overall it was playground activity (CDC, 2011).

> …any athlete who is injured but not unconscious or who quickly regains consciousness and is not suspected of having a cervical spine injury can be evaluated on the sidelines using a standardized assessment tool.

Another means of concussion quantification is the High School Reporting Information Online surveillance system, affiliated with the National Athletic Trainer's Association, which reported that during the 2009-2010 academic year, 14.6% of sport-related injuries were concussions (Meehan, d'Hemecourt, Collins, & Comstick, 2011). Male athletes accounted for 75.7% of concussions, and rates of concussion were highest for collision sports (Meehan et al., 2011). For boys, ice hockey was responsible for the greatest number of concussions followed by football, lacrosse, basketball, soccer, wrestling, and baseball; for girls, cheerleading was most injurious, followed by lacrosse, soccer, softball, field hockey, basketball, and volleyball (Meehan et al., 2011).

3. *How is concussion evaluated and managed?*

Initial care of a person with a concussion involves assessment of airway, breathing, and circulation and stabilization of the cervical spine (Halstead et al., 2010; Herring et al., 2011). A cervical spine injury should be suspected in a patient who has lost consciousness or who is not coherent, and sports equipment such as a helmet and shoulder pads should not be removed before assessment (Grady, 2010). Midline cervical tenderness, altered level of consciousness, abnormal neurologic findings, or a painful distracting injury suggests further cervical spine evaluation at an emergency facility (Grady, 2010).

However, any athlete who is injured but not unconscious or who quickly regains consciousness and is not suspected of having a cervical spine injury can be evaluated on the sidelines using a standardized assessment tool. Several such instruments are available, including Maddocks questions, Standardized Assessment of Concussion, Balance Error Scoring System, and the Sport Concussion Assessment Tool 2 (SCAT2; Halstead et al., 2010). The SCAT2 includes a symptom checklist, physical signs score, concentration and memory assessment (Maddocks questions), cognitive assessment (Standardized Assessment of Concussion), postural stability testing (the Balance Error Scoring System), and coordination examination (Halstead et al., 2010). Although it has not been validated, the SCAT2 is widely used and considered to be the most sophisticated instrument available (Scorza et al., 2012). The SCAT2 is included in the third CIS Consensus Statement, which identifies its validation as a key area for research (McCrory et al., 2009) and in the AAP Clinical Report (Halstead et al., 2010). The SCAT2, intended for children aged 10 years and older, is available for free distribution and can be found at http://www.cces.ca/files/pdfs/SCAT2[1].pdf. The concussion Consensus Statement from the AFP, AMSSM, AAOS, AOSSM, ACSM, and AOASM references another instrument, the National Football League Sideline Tool (Herring et al., 2011). The SCAT2 and similar tools are not meant to replace more comprehensive neuropsychological testing, nor are they intended to be used as independent tools for concussion management (McCrory et al., 2009). Monitoring for several hours is imperative, because symptoms may continue to evolve (Scorza et al., 2012). It is recommended that situation-relevant questions should be used in lieu of simple assessment of orientation to person, place, and time (Grady, 2010).

Pre-existing learning disabilities, poor academic performance, and conditions such as mood disorders must be considered when evaluating these patients because concussion may exacerbate these problems and complicate management (Grady, 2010). Additionally, factors such as exertional headaches, migraine headaches, and dehydration can present as headaches after exercise, and anemia, inadequate sleep, and overtraining can present with fatigue, all of which can confound the diagnosis of concussion (Grady, 2010).

Researchers are attempting to determine predictors of prolonged recovery in patients who have sustained a concussion. Lau, Knotos, Collins, Mucha, and Lovell (2011) reported that dizziness and balance, which often are linked together in assessment, do not predict

TABLE 2. Graduated return to play protocol

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective of each stage
1. No activity	Complete physical and cognitive rest	Recovery
2. Light aerobic exercise	Walking, swimming, or stationary cycling keeping intensity <70% maximum predicted heart rate; no resistance training	Increase heart rate
3. Sport-specific exercise	Skating drills in ice hockey, running drills in soccer; no head impact activities	Add movement
4. Noncontact training drills	Progression to more complex training drills, for example, passing drills in football and ice hockey; may start progressive resistance training	Exercise, coordination, and cognitive load
5. Full contact practice	After medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6. Return to play	Normal game play	

From McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., & Cantu, R. (2009).

recovery similarly; rather, dizziness was the only significant risk factor for protracted recovery. In another study, Lau, Lovell, Collins, and Pardini (2009) found that self-reported cognitive decline, immediate post-concussion reaction time, and migraine headache symptoms were related to prolonged recovery and were retrospectively indicative of concussions that were classified as complex. Identifying prognostic indicators may help clinicians improve concussion care and make evidence-based return-to-play (RTP) and return-to-classroom decisions.

In the hospital or medical office, assessment should include a thorough history and comprehensive neurological examination, a determination of whether improvement or deterioration in the patient's status has occurred; and evaluation of the need for neuroimaging (McCrory et al., 2009). Because conventional structural neuroimaging findings are normal in persons with a concussion, a brain computed axial tomography scan is advised only with suspicion of an intracerebral structural lesion, as suggested by prolonged disruption of consciousness, focal neurological deficit, or condition deterioration (McCrory et al., 2009). Newer structural magnetic resonance imaging modalities cannot be recommended at this time (McCrory et al., 2009).

The disparity between increased cerebral glucose requirements and functionally reduced cerebral blood flow that occurs in persons who have had a concussion drives concussion management (Grady, 2010). The concussed brain is more susceptible to stress; physical brain injury may exaggerate cell damage, cognitive work will increase cellular metabolic demand, and physical activity will worsen symptoms (Grady, 2010). Thus complete cognitive and physical rest while the patient is symptomatic is the basis of treatment, with the aim of minimizing symptom exacerbation (Grady, 2010).

A patient with concussion symptoms should be removed from activity, and no same-day return to play should occur regardless of symptom resolution (Herring et al., 2011; McCrory et al., 2009). Cognitive rest may include avoiding text messaging and playing video games, limiting television and computer use, time off from and slow reintegration into school, reduction of school workload, allowance of extra time to complete assignments, and postponing of standardized testing (Scorza et al., 2012). Adequate sleep soon after the concussion appears to aid in the recovery process (Grady, 2010). Any physical activity that worsens symptoms or increases risk for re-injury should be avoided (McCrory et al., 2009; Scorza et al., 2012), and because reaction times may be slower, driving may need to be curtailed (Halstead et al., 2010). Sunglasses and earplugs may reduce discomfort if photophobia or phonophobia is present (Scorza et al., 2012). No evidence exists to establish the effectiveness of nonsteroidal anti-inflammatory drugs or acetaminophen in ameliorating the symptoms or reducing the duration of concussion (Halstead et al., 2010). The third CIS Consensus Statement recommends that the use of medications for prolonged symptoms such as sleep disturbance or anxiety only be considered by clinicians experienced in concussion treatment (McCrory et al., 2009). When evaluating for return to play, the patient must be symptom-free when he or she is not taking medication (Halstead et al., 2010; Herring et al., 2011; McCrory et al., 2009).

After symptoms have resolved, athletes may progress through a graduated RTP protocol; the recommendation of the third CIS group is widely accepted as the standard of care (Table 2) (Scorza et al., 2012). Each step in the process should take at least 24 hours, with a minimum of 5 days to progress through the protocol to return to full game participation, provided that no symptoms return (Halstead et al., 2010). If symptoms develop, activity should cease immediately; 24 hours after symptoms resolve, the protocol may resume at the previous step (Scorza et al., 2012).

Each case should be individually evaluated to assess healing through the use of neurocognitive testing, balance evaluation, and symptom scores after physical and cognitive effort (Grady, 2010; Herring et al., 2011). Factors that may suggest extended recovery and adjustment in RTP guidelines, and thus referral to a provider experienced in concussion management, include a history of loss of consciousness more than 60 seconds, headache lasting longer than 60 hours, amnesia, previous concussion, comorbid conditions, use of psychotropic or anticoagulant medications, dangerous style of play, and participation in a high-risk sport (Scorza et al., 2012). Gender may be a risk factor, because girls experience a higher rate of concussion than do boys in similar sports (Halstead et al., 2010). The literature suggests that symptoms, cognitive deficits, and sequelae may be more serious in girls (Dvorak, McCrory, & Kirkendall, 2007). Although no evidence-based guidelines exist for retiring an athlete from a sport, it is advised to consider a prolonged absence from sports for any athlete who has had three concussions in an individual season or who has had postconcussive symptoms for more than 3 months (Halstead et al., 2010). Athletes may be disqualified from sport if they sustain concussions with increasing frequency or by less impact, and all patients should be re-evaluated in several months to screen for depression (Scorza et al., 2012). Patients whose symptoms continue for more than a month may need a modified treatment plan, because several studies have found that such athletes who were allowed supervised active rehabilitation after early brain rest experienced symptom resolution without complications or setbacks in recovery (Gagnon, Galli, Friedman, Grilli, & Iverson, 2009; Sarmiento, Mitchko, Klein, & Wong, 2010). Because 80% of same-season concussion recurrences occur within 10 days of the initial injury, future guidelines may specify duration of nonparticipation and symptom-free periods before RTP (Grady, 2010).

Legislation exists in many states concerning concussion management, and many schools and school systems have protocols in place to ensure proper notification of head trauma. For example, the Maryland Public Secondary Schools Athletic Association (2011) mandates a process whereby the student is evaluated by the coach or athletic trainer, 911 is activated if applicable, the parent is called, and a notification of probable head injury is sent home to the parent. The student then must visit his or her health care provider for diagnosis, and the Notification of Probable Head Injury form is completed by the health care provider and returned to the athletic director. The athletic director communicates the diagnosis with the coach and athletic trainer and gives the Notification of Probable Head Injury form to the school health staff, who in turn communicate the diagnosis with the student's teachers, principal, and counselor. The counselor follows up with teachers to share suggestions for classroom accommodations.

Legislation exists in many states concerning concussion management, and many schools and school systems have protocols in place to ensure proper notification of head trauma.

4. What is the role of neuropsychological testing in concussion management?

The third CIS symposium recommended assessment of cognitive function as an important part of RTP protocol (McCrory et al., 2009). Neuropsychological testing contributes objective information about brain function but should not be the basis for management decisions (Halstead et al., 2010). It does not independently determine if the patient has had a concussion or if he or she may safely RTP, and a symptomatic athlete should not resume play even with normal results of neuropsychological testing (Halstead et al., 2010). Testing may be done via paper and pencil or computer; because of ease of use, however, computerized testing is more often used at the present time (Grady, 2010). A recent meta-analysis found no statistically significant differences in sensitivity 14 days after injury between written tests, computer tests, and the Standardized Assessment of Concussion (Broglio & Puetz, 2008).

Computerized neurocognitive tests measure verbal memory, visual design memory, concentration, visual processing speed, and reaction time; their use, along with symptom reporting and clinical assessment, results in more sensitive injury and recovery evaluation than symptom reporting alone (Meehan, d'Hemecourt, Collins, Taylor, & Cornstock, 2012). Computerized tests, which take about 30 minutes to administer, include the Automated Neuropsychological Assessment Metrics, developed for use in the military, the CogState, Headminder, and ImPACT, developed for sport-related concussion (Halstead et al., 2010).

ImPACT testing is conducted by health care providers, schools, and teams who contract with ImPACT Applications, Inc. (ImPACT Applications, Inc., 2012). The test can be given by anyone trained in its administration, but the medical professional who makes the RTP decision must be the one to interpret postinjury test results (ImPACT Applications, Inc., 2012). Cost is involved for this testing; baseline testing is not reimbursable by health insurance companies, although postinjury testing sometimes is reimbursable (ImPACT Applications, Inc., 2012). Lau, Collins, and Lovell (2011) found that adding ImPACT testing to symptom cluster scores increased sensitivity, specificity, positive predictive value, and negative predictive value of anticipating protracted recovery from concussion. The optimal situation is for baseline testing to be accomplished in the preseason and repeated after injury but when the patient is symptom-free; if baseline results are not available, neuropsychological testing can be compared with age-matched data with caution (Grady, 2010). Occasionally, testing is done when the patient is symptomatic to assist in determining management, usually in consultation with a trained neuropsychologist (McCrory et al., 2009). It is recommended that baseline assessment be updated every 2 years for high school and college athletes, but because of a lack of data over a 2- year period, yearly updated baselines could be beneficial for high school athletes if resources permit (Elbin, Schatz, & Covassin, 2011). At present, no computerized neuropsychological test has been validated for grade school athletes (Halstead et al., 2010).

5. *Are measures to prevent concussion effective?*

Helmets and headgear have been demonstrated to reduce the incidence of concussion in skiing and snowboarding, but not in football or hockey; they provide mild protection from concussion due to colliding heads in soccer but not from heading the ball (Halstead et al., 2010). Herring and colleagues (2011) warn that ill-fitting helmets or protective equipment may increase the risk of concussion. Mouth guards are recommended to reduce dental trauma, but it is unclear whether they are effective in reducing concussions (Halstead et al., 2010). Education and awareness are of paramount importance in concussion prevention and improvement in concussion care: the ‘‘Heads Up’’ tool kit published by the CDC (2012) is an example of one of these resources and is available free on the Internet. Promoting safe playing environments, considering rule changes to promote safety, and addressing violence in sports may be protective measures as well (Herring et al., 2011).

PATIENT DISPOSITION

Because the patient did not experience loss of consciousness, focal neurological deficit, or condition deterioration, no imaging studies were performed. As the concussion occurred at the end of summer, the patient was given instructions for cognitive and physical rest and was advised to return to the office in 1 week for follow-up and to determine readiness for return to school. A note was provided to allow her additional time to complete summer assignments. The patient began school on time, attending half days, but was not allowed to return to sports or work at that time. The patient was symptom-free 2 weeks after sustaining her injury and underwent ImPACT testing again. Effective communication occurred between the primary care provider and multidisciplinary team at her school. The patient progressed through the CIS graduated RTP protocol described in Table 2, and all school-system requirements were followed. The patient enjoyed a subsequent injury-free season and performed well academically.

REFERENCES

Bey, T., & Ostick, B. (2009). Second impact syndrome. *Western Journal of Emergency Medicine, 10*(1), 6-10.

Broglio, S. P., Ponifex, M. B., O'Connor, P., & Hillman, C. H. (2009). The persistent effects of concussion on neuroelectric indices of attention. *Journal of Neurotrauma, 26*, 1463-1470.

Broglio, S. P., & Puetz, T. W. (2008). The effect of sport concussion on neurocognitive function, self-report symptoms and postural control: A meta-analysis. *Sports Medicine, 38*(1), 53-67.

Centers for Disease Control and Prevention. (2011). Nonfatal traumatic brain injuries related to sports and recreation activities among persons aged ≤ 19 years—United States, 2001-2009. *Morbidity and Mortality Weekly Report, 69*(39), 1337-1342.

Centers for Disease Control and Prevention. (2012). *Heads up: Concussion in youth sports*. Retrieved from http://www.cdc.gov/concussion/HeadsUp/youth.html

Center for the Study of Traumatic Encephalopathy. (2012). *18 year old high school football player.* Retrieved from http://www.bu.edu/cste/case-studies/18-year-old

DeMatteo, C. A., Hanna, S. E., Mahoney, W. J., Hollenberg, R. D., Scott, L. A., Law, M. C., … Xu, L. (2010). ‘‘My child doesn't have a brain injury, he only has a concussion.’’ *Pediatrics, 125*(2), 327-334.

Department of Veterans Affairs, Department of Defense. (2009). *Clinical practice guideline: Management of concussion/mild traumatic brain injury (mTBI).* Retrieved from http://www.healthquality.va.gov/mtbi/concussion_mtbi_full_1_0.pdf

Dvorak, J., McCrory, P., & Kirkendall, D. (2007). Head injuries in the female football player: Incidence, mechanisms, risk factors, and management. *British Journal of Sports Medicine, 41*(Suppl 1), i44-i46.

Elbin, R. J., Schatz, P., & Covassin, T. (2011). One-year test-retest reliability of the online version of ImPACT in high school athletes. *The American Journal of Sports Medicine, 39*(11), 2319-2324.

Gagnon, I., Galli, C., Friedman, D., Grilli, L., & Iverson, G. L. (2009). Active rehabilitation for children who are slow to recover following sport-related concussion. *Brain Injury, 23*(12), 956-964.

Grady, M. F. (2010). Concussion in the adolescent athlete. *Current Problems in Pediatric and Adolescent Health Care, 40*, 154-169.

Halstead, M. E., Walter, K. D., & The Council on Sports Medicine and Fitness. (2010). Clinical report—Sport-related concussion in children and adolescents. *Pediatrics, 126*(3), 597-615.

Herring, S. A., Cantu, R. C., Guskiewicz, K. M., Putukian, M., & Kibler, W. B. (2011). Concussion (mild traumatic brain injury) and the team physician: A consensus statement—2011 update. *Medicine and Science in Sports and Exercise, 43*(12), 2412-2422.

ImPACT Applications, Inc. (2012). *About ImPACT.* Retrieved from http://impacttest.com/about/background

Johnson, L. S. (2012). Return to play guidelines cannot solve the football-related concussion problem. *Journal of School Health, 82*(4), 180-185.

Lau, B. C., Collins, M. W., & Lovell, M. R. (2011). Sensitivity and specificity of subacute computerized neurocognitive testing and symptom evaluation in predicting outcomes after sports-related concussion. *The American Journal of Sports Medicine, 39*(6), 1209-1216.

Lau, B. C., Knotos, A. P., Collins, M. W., Mucha, A., & Lovell, M. R. (2011). Which on-field signs/symptoms predict protracted recovery from sport-related concussion among high school football players? *The American Journal of Sports Medicine, 39*(11), 2311-2318.

Lau, B. C., Lovell, M. R., Collins, M. W., & Pardini, J. (2009). Neurocognitive and symptom predictors of recovery in high school athletes. *Clinical Journal of Sports Medicine, 19*(3), 216-221.

Maryland Public Secondary Schools Athletic Association. (2011). *Health and safety forms*. Retrieved from http://www.mpssaa.org/HealthandSafety/Forms.asp

McCrory, P., Meeuwisse, W., Johnston, K., Dvorak, J., Aubry, M., Molloy, M., & Cantu, R. (2009). Consensus statement on concussion in sport: The 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *British Journal of Sports Medicine, 43*(Suppl 1), i76-i84.

Meehan, W. P., & Bachur, R. G. (2009). Sport-related concussion. *Pediatrics, 123*(1), 114-123.

Meehan, W. P., d'Hemecourt, P., Collins, C. L., & Comstick, R. D. (2011). Assessment and management of sport-related concussions in United States high schools. *The American Journal of Sports Medicine, 39*(11), 2304-2310.

Meehan, W. P., d'Hemecourt, P., Collins, C. L., Taylor, A. M., & Cornstock, R. D. (2012). Computerized neurocognitive testing for the management of sport-related concussion. *Pediatrics, 129*(1), 38-44.

Sarmiento, K., Mitchko, J., Klein, C., & Wong, S. (2010). Evaluation of the Centers for Disease Control and Prevention's concussion initiative for high school coaches: ''Heads up: Concussion in high school sports.'' *Journal of School Health, 80*(3), 112-118.

Schwartz, A. (2010, September 13). *Suicide reveals signs of a disease seen in N.F.L*. Retrieved from http://www.nytimes.com/2010/09/14/sports/14football.html?pagewanted=2&_r=1

Scorza, K. A., Raleigh, M. F., & O'Connor, F. G. (2012). Current concepts in concussion: Evaluation and management. *American Family Physician, 85*(2), 123-132.

Sim, A., Terryberry-Spohr, L., & Wilson, K. R. (2008). Prolonged recovery of memory functioning after mild traumatic brain injury in adolescent athletes. *Journal of Neurosurgery, 108*, 511-516.

Talavage, T. M., Nauman, E., Breedlove, E., Yoruk, U., Dye, A., Morgaki, K., … Leverenz, L. (2010). Functionally-detected cognitive impairment in high school football players without clinically-diagnosed concussion. *Journal of Neurotrauma, 10*, 1-46.