

Pediatric Assessment and Management of Concussions

Gerard A. Gioia, PhD

Concussions and mild traumatic brain injuries have become more widely recognized and understood during the past 5 to 10 years. Earlier and more active evaluation and management of this brain injury is necessary to reduce risk to the developing child and adolescent. Pediatricians play a central role in the evaluation and management of concussions and should develop a working understanding of the injury and its clinical manifestations.

An individualized approach to evaluation and management by the pediatrician requires the development of a skillset to define the characteristics of the injury, conduct a full assessment of post-concussion symptoms, and define any risk history that may modify recovery.

This evaluation forms the basis of concussion treatment, which involves the active management of the child's daily routines at home, school learning

Gerard A. Gioia, PhD, is Chief, Division of Pediatric Neuropsychology; Director, Safe Concussion Outcome, Recovery & Education (SCORE) Program, Children's National Medical Center; and Associate Professor, Depts. of Pediatrics and Psychiatry & Behavioral Sciences, George Washington University School of Medicine, Division of Pediatric Neuropsychology.

Address correspondence to: Gerard A. Gioia, PhD; fax 301-765-5497; or email: ggioia@childrensnational.org.

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and performance, and sports/recreational activities. The Acute Concussion Evaluation (ACE) and ACE Care Plan, published in the CDC's "Heads Up: Concussion in Your Practice," are presented as a set of tools that can assist the pediatrician in this endeavor.

PEDIATRICIAN'S RESPONSIBILITY

The primary care pediatrician's office is the first stop for most medical illnesses or injuries, and should be so in the case of concussions as well. The practitioner, however, must be appropriately prepared with the proper protocol to assess this brain injury to give appropriate management guidance to the patient and family.

Furthermore, the pediatrician is in a unique central position to interact with the family, child, school, and other aspects of medical system, necessitating accurate

knowledge of the patient's post-injury status. Without the pediatrician's active and informed involvement, service coordination is not likely to be as effective, resulting in the possibility of increased risk to the child with poor management.

Injury to the child's brain can have both obvious and subtle consequences for their daily functioning at school and their social life. Proper management is critical to facilitate recovery and reduce risk of re-injury or protracted recovery. As a foundation, the pediatrician must possess appropriate knowledge of concussions and the associated symptom domains¹ as well as the necessary tools to carry out an effective evaluation and management plan. Further training for the pediatrician is available in the CDC's "Heads Up to Clinicians" Concussion Training video at preventingconcussions.org.

This paper describes a practical approach to the assessment and management of pediatric concussion, using the ACE and ACE Care Plan, as further detailed in the CDC's "Heads Up: Brain Injury in Your Practice" toolkit.²

A concussion is a type of mild traumatic brain injury (mTBI) that has gained significant attention over the past 10 years with a better understanding of the reach of its functional effects. The CDC defines a concussion as a complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head.

The blow to the head or body results in significant movement of the brain with shear strain disrupting its function due to changes in neurometabolism and neurotransmission.

This disturbance of brain function is typically associated with normal head CT and MRI findings, as concussion does not typically result in structural damage to the brain tissue or blood vessels. A constellation of physical, cognitive, emotional, and sleep symptoms ensues, infrequently involving loss of consciousness (less than 10% to 20%). The duration of these symptoms can vary widely from minutes to months, and even longer in a small number of cases.²

EVALUATION OF CONCUSSION

Typically, most children present early post-injury in which the concussion evaluation focuses on acute symptom assessment. In most cases, with proper diagnosis and management, recovery is relatively rapid, with symptoms resolving in most individuals within a few weeks to a few months. A small minority of individuals will exhibit persisting symptoms/neurocognitive changes. Fundamental to the pediatric concussion evaluation is a thorough understanding of the injury characteristics, and the type and severity of post-concussion symptoms in the context of the child's history. The job of the pediatrician is to

determine the new onset of symptoms or exacerbation of pre-existing symptoms.

Understanding the child's developmental, medical, family, educational, and psychological history is, therefore, critical to defining the post-injury symptoms, as there can be a tendency to over-ascribe symptoms to the injury.

In a related vein, the evaluation of a concussion can be complicated because the symptoms are also common to those of other medical or psychiatric conditions (eg, posttraumatic stress disorder, depression, attention-deficit/hyperactivity disorder, headache syndromes).

Determining their temporal proximity to the injury is an important aspect of the evaluation. The pediatrician's knowledge of the patient's past developmental, medical, school, and social-emotional history can be of significant benefit in placing the post-injury symptomatology into proper context.

The concussion evaluation focuses on four main components: (1) defining injury characteristics; (2) identifying symptom status and neuropsychological dysfunction; (3) establishing the reported symptoms as greater than pre-injury status; and (4) determining effects on the individual's life (eg, social, school, work). To assist the pediatrician's assessment, the ACE³ (Figure 1, see page 200) was developed to provide a systematic, evidence-based protocol to assess patients (both children and adults) with known or suspected concussions. The ACE is available online in the CDC's "Heads Up: Brain Injury in your Practice" toolkit (www.cdc.gov/concussion).⁴ The ACE Symptom Checklist can be used serially to track symptom recovery over time. The ACE is appropriate for patients in which concussion is clearly indicated (eg, loss of consciousness or change in mental status, confusion or amnesia) and where concussion is suspected (eg, forcible blow to the head or body with functional changes).

A description of the ACE protocol follows, including defining injury character-

istics, conducting an assessment of post-concussion symptoms, and establishing any history factors that may modify the injury's presentation or recovery.

DEFINE INJURY CHARACTERISTICS

Injury Description

The first task in the evaluation is to define the nature of the injury. Assess how the injury occurred, the type of force, and location on the head or body where the force (blow) was received. The force to the head may be indirect, such as with an individual being struck in the body resulting in the head accelerating forward and then backward quickly (eg, whiplash).

Establishing the cause and mechanism of the injury may help to estimate the force of the hit or blow the patient sustained. Generally, the greater the force, the more significant the symptoms. Symptoms associated with a relatively light force, however, may indicate increased vulnerability to concussion, or the presence of other physical or psychological factors contributing to symptom presentation.

Acute Injury Signs

Besides defining the nature of the injury, the next step is to assess the acute injury signs that may have occurred around the time of the injury. It is helpful to ask those who know the patient (parent, friend, etc) about any observed signs of the concussion. Assess for any changes to the child's level of consciousness and general capability to process information at the time of the injury.

An assessment of disruption of memory processing includes defining the presence of retrograde and anterograde amnesia. Determine whether amnesia (memory loss) has occurred for events before the injury (retrograde) or after the injury (anterograde) and attempt to determine the length of time of memory dysfunction.

Anterograde amnesia is also referred to as posttraumatic amnesia (PTA). Specific questions are provided on the ACE protocol to assess these two types of amnesia.

All images courtesy of US Center for Disease Control and Prevention.

ACUTE CONCUSSION EVALUATION (ACE)
PHYSICIAN/CLINICIAN OFFICE VERSION
 Gerard Gioia, PhD¹ & Mickey Collins, PhD²
Children's Hospital Medical Center
 University of Pittsburgh Medical Center

Patient Name: _____
 DOB: _____ Age: _____
 Date: _____ ID/MR#: _____

A. Injury Characteristics Date/Time of Injury: _____ Reporter: Patient Parent Spouse Other _____

1. Injury Description _____

1a. Is there evidence of a forcible blow to the head (direct or indirect)? Yes No Unknown
 1b. Is there evidence of intracranial injury or skull fracture? Yes No Unknown

1c. Location of impact: Frontal Left Temporal Right Temporal Left Parietal Right Parietal Occipital Neck Indirect Force

2. Cause: MVC Pedestrian-MVC Fall Assault Sports (specify) _____ Other _____

3. **Amnesia Before (Retrospective)** Are there any events just BEFORE the injury that your person has no memory of (even brief)? Yes No Duration _____

4. **Amnesia After (Anterograde)** Are there any events just AFTER the injury that your person has no memory of (even brief)? Yes No Duration _____

5. **Loss of Consciousness:** Did your person lose consciousness? Yes No Duration _____

6. **EARLY SIGNS:** Appears dazed or stunned Is confused about events Answers questions slowly Repeats Questions Forgetful (recent info)

7. **Seizures:** Were seizures observed? No Yes Detail _____

B. Symptom Check List* (Since the injury, has the person experienced any of these symptoms any more than usual today or in the past day? Indicate presence of each symptom (0=No, 1=Yes). Lovell & Collins, 1998 JNTR)

PHYSICAL (10)		COGNITIVE (4)		SLEEP (4)	
Headache	0 1	Feeling mentally foggy	0 1	Drowsiness	0 1
Nausea	0 1	Feeling slowed down	0 1	Sleeping less than usual	0 1 N/A
Vomiting	0 1	Difficulty concentrating	0 1	Sleeping more than usual	0 1 N/A
Balance problems	0 1	Difficulty remembering	0 1	Trouble falling asleep	0 1 N/A
Dizziness	0 1	COGNITIVE Total (0-4) _____		SLEEP Total (0-4) _____	
Visual problems	0 1	EMOTIONAL (4)		Exacerbate: Do these symptoms worsen with: Physical Activity <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A Cognitive Activity <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A Overall Rating: How different is the person acting compared to his/her usual self? (circle) Normal 0 1 2 3 4 5 6 Very Different	
Fatigue	0 1	Irritability	0 1		
Sensitivity to light	0 1	Sadness	0 1		
Sensitivity to noise	0 1	More emotional	0 1		
Numbness/Tingling	0 1	Nervousness	0 1		
PHYSICAL Total (0-10) _____		EMOTIONAL Total (0-4) _____			
(Add Physical, Cognitive, Emotion, Sleep totals) Total Symptom Score (0-22) _____					

C. Risk Factors for Protracted Recovery (check all that apply)

Concussion History? Y N	Headache History? Y N	Developmental History	Psychiatric History
Prior # 1 2 3 4 5 6+	Prior treatment for headache	Learning disabilities	Anxiety
Longest symptom duration Days, Weeks, Months, Years	History of migraine headache Personal Family	Attention-Deficit/Hyperactivity Disorder	Depression
If multiple concussions, less force caused re-injury? Yes No		Other developmental disorder	Other psychiatric disorder

List other comorbid medical disorders or medication usage (e.g., hypothyroid, seizures)

D. RED FLAGS for acute emergency management: Refer to the emergency department with sudden onset of any of the following:
 * Headache that worsens * Looks very drowsy/can't be awakened * Can't recognize people or places * Neck pain
 * Seizures * Repeated vomiting * Increasing confusion or irritability * Unusual behavioral change
 * Focal neurologic signs * Slurred speech * Weakness or numbness in arms/legs * Change in state of consciousness

E. Diagnosis (ICD): Concussion w/ LOC 850.0 Concussion w/LOC 850.1 Concussion (Unspecified) 850.9 Other (854) _____
 No diagnosis

F. Follow-Up Action Plan Complete ACE Care Plan and provide copy to patient/family.
 No Follow-Up Needed _____
 Physician/Clinician Office Monitoring: Date of next follow-up _____
 Referral: _____
 Neuropsychological Testing _____
 Physician: Neurosurgery _____ Neurology _____ Sports Medicine _____ Physiatrist _____ Psychiatrist _____ Other _____
 Emergency Department _____

ACE Completed by: _____ © Copyright © Gioia & M. Collins, 2006
 This form is part of the "Success Up/Down Injury: Our Patient" tool kit developed by the Centers for Disease Control and Prevention (CDC).

Figure 1. Acute Concussion Evaluation (ACE).

Regarding loss of consciousness (LOC), inquire whether LOC occurred or was observed (including by whom) and the estimated length of time the child lost consciousness. Assess for the presence of other early signs that may have been observed by others such as appearing dazed or stunned, confusion about events, answering questions slowly, repeating questions, or being forgetful about recent information.

Finally, inquire whether seizures were observed (although this is uncommon).

POST-CONCUSSION SYMPTOMS

Symptom Assessment

The ACE Symptom Checklist assesses 22 post-concussion symptoms⁵ reported by the patient and/or parent, if necessary, in each of the four symptom areas: physical; cognitive; emotional; and sleep. The ACE checklist asks for the presence (1) or absence (0) of the symptom, and not for the severity of the symptom.

As various symptoms can be present before the injury (eg, inattention, headaches), it is important to assess any changes from typical presentation. Using this methodol-

ogy, a Total Symptom Score greater than “0” indicates the presence of post-injury symptoms and should be factored into the diagnosis and management plan.

Assessment of Exertion Effects

Besides the assessment of the full array of possible post-concussion symptoms, children can often experience a worsening or re-emergence of certain symptoms with exertional activity.

Ask the child whether they experience any worsening of symptoms with physical activity (eg, running, climbing stairs, bike riding) and/or cognitive activity (eg, academic studies, multi-tasking, reading or other tasks requiring focused concentration). As discussed in the concussion management section, this information is important in guiding treatment recommendations.

Overall “Difference” Rating

The ACE contains an overall 0-6 rating from the patient (and/or parent) to gauge the overall perceived change from the child’s pre-injury status. This rating can be helpful in summarizing the overall impact of the symptoms and the child/parent’s view of how close the child is to recovery.

HISTORICAL FACTORS THAT IMPACT RECOVERY

A set of risk factors have been associated with a longer period of recovery from a concussion, including prior concussions, chronic headaches, developmental disabilities, and psychiatric diagnoses. Their assessment can be helpful to understand the recovery process, and the possibility of a longer time frame. Assess for a history of prior concussions, including the duration of symptoms for each injury.

The effects of multiple concussions may be cumulative, especially if there is a minimal duration of time (ie, months) between injuries and less biomechanical force results in subsequent concussion. Assess for a personal and/or family history of diagnosis of chronic headaches, migraines,

Returning to School (Continued)

Until you (or your child) have fully recovered, the following supports are recommended: (check all that apply)

No return to school. Return on (date) _____

Return to school with following supports. Review on (date) _____

Shortened day. Recommend _____ hours per day until (date) _____

Shortened classes (i.e., rest breaks during classes). Maximum class length: _____ minutes.

Allow extra time to complete coursework/assignments and tests.

Lessen homework load by _____%. Maximum length of nightly homework: _____ minutes.

No significant classroom or standardized testing at this time.

Check for the return of symptoms (use symptom table on front page of this form) when doing activities that require a lot of attention or concentration.

Take rest breaks during the day as needed.

Request meeting of 504 or School Management Team to discuss this plan and needed supports.

Returning to Sports

1. You should NEVER return to play if you still have ANY symptoms – (Be sure that you do not have any symptoms at rest and while doing any physical activity and/or activities that require a lot of thinking or concentration.)

2. Be sure that the PE teacher, coach, and/or athletic trainer are aware of your injury and symptoms.

3. It is normal to feel frustrated, sad and even angry because you cannot return to sports right away. With any injury, a full recovery will reduce the chances of getting hurt again. It is better to miss one or two games than the whole season.

The following are recommended at the present time:

Do not return to PE class at this time

Return to PE class

Do not return to sports practices/games at this time

Gradual return to sports practices under the supervision of an appropriate health care provider (e.g., athletic trainer, coach, or physical education teacher).

- Return to play should occur in **gradual steps** beginning with aerobic exercise only to increase your heart rate (e.g., stationary cycle); moving to increasing your heart rate with movement (e.g., running); then adding controlled contact if appropriate; and finally return to sports competition.
- Pay careful attention to your symptoms and your thinking and concentration skills at each stage of activity. Move to the next level of activity only if you do not experience any symptoms at the each level. If your symptoms return, let your health care provider know, return to the first level, and restart the program gradually.

Gradual Return to Play Plan

1. No physical activity
2. Low levels of physical activity (i.e., symptoms do not come back during or after the activity). This includes walking, light jogging, light stationary biking, light weightlifting (lower weight, higher reps, no bench, no squat).
3. Moderate levels of physical activity with body/head movement. This includes moderate jogging, brief running, moderate-intensity stationary biking, moderate-intensity weightlifting (reduced time and/or reduced weight from your typical routine).
4. Heavy non-contact physical activity. This includes sprinting/running, high-intensity stationary biking, regular weightlifting routine, non-contact sport-specific drills (in 3 planes of movement).
5. Full contact in controlled practice.
6. Full contact in game play.

Neuropsychological testing can provide valuable information to assist physicians with treatment planning, such as return to play decisions.

This referral plan is based on today's evaluation:

Return to this office. Date/Time _____

Refer to: Neurosurgery _____ Neurology _____ Sports Medicine _____ Psychiatrist _____ Other _____

Refer for neuropsychological testing _____

Other _____

ACE Care Plan Completed by: _____

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Figure 2B. ACE Care Plan: School Version, page 2 of form (page 1 of form is Figure 2A).

to define the child's typical daily schedule and types of activities at home and in the community. Patients should be advised to get adequate sleep at night and to take daytime naps or rest breaks when significant fatigue is experienced. Teach the child that the return or exacerbation of symptoms is their guide to the level of activity that is safe and tolerable, limiting physical and cognitive exertion accordingly.

Physical activity to be managed might include physical education class, school recess, sports practices, weight-training, running, exercising, and heavy lifting. Cognitive activities to be managed might

include heavy concentration, memory, reasoning, reading or writing (eg, homework, classwork, computer or other electronic screens, job-related mental activity).

As symptoms decrease, patients may return to their regular activities gradually. Return to high-risk activities such as driving or operating heavy machinery must be carefully considered, especially if the patient has problems with attention, processing speed, or reaction time.

Return to School

An under-recognized aspect of concussion treatment involves the management

of the student's return to school.⁶ First, the pediatrician should determine when return to school is appropriate.

In the first few days after a concussion, there is an increased likelihood of adverse symptom exacerbation with mental exertion, suggesting the student not be sent back to school until they can tolerate at least 30 minutes of sustained cognitive activity.

The school team (eg, teacher(s), the school nurse, psychologist/counselor, and administrator) should be informed of the student's injury, symptoms, and cognitive deficits. Teachers should be advised to monitor for increased problems paying attention/concentrating, problems remembering/learning new information, longer time required to complete tasks, increased symptoms (eg, headache, fatigue) during schoolwork, and greater irritability/less tolerance for stressors.

Active efforts must be made to put in place the appropriate supports for the student. Symptomatic students will require active supports and accommodations in school. Students with prolonged symptoms (ie, longer than several weeks) may require special accommodations and services, such as those provided under a Section 504 Plan.

As symptoms decrease, and/or as cognitive test results show improvement, patients may return to their regular activities gradually. However, the patient's overall status should continue to be monitored closely by a designated person at the school.

The School Version of the ACE Care Plan (Figures 2A, 2B, see pages 201, 202) was developed to assist management of cognitive tasks to accommodate the student's tolerance. For example, students who fatigue easily may benefit from regular rest breaks in the school nurse's office.

Students with neurocognitive deficits in attention or concentration may benefit from shorter assignments, breaking down larger assignments into smaller tasks, or lightening of the workload. Other supports to be considered include time off from school (especially the first several

days post-injury), shortened day, shortened classes (ie, rest breaks during classes), and scheduled rest breaks during the day.

Students may also need allowances for extended time to complete coursework/ assignments and tests, as well as a reduced homework/classwork load and no significant classroom or standardized testing while symptoms are present. The teacher, school nurse, and/or guidance counselor should monitor the student's symptoms periodically to modify the types and intensity of the academic supports across recovery.

Return to Work

Similar to school, for those adolescents who are working, return-to-work planning (see Work Version of ACE Care Plan) should be based upon careful evaluation of symptoms and cognitive status. Employers/work supervisors should be informed of the adolescent's injury, symptoms, and cognitive deficits with an active effort to put the appropriate supports in place.

Until a full recovery is achieved, the adolescent may need the following supports: schedule considerations such as a shortened workday, allowance for breaks during work when symptoms increase, and reduced task assignments and responsibilities.

Safety considerations while symptomatic also should be given, including no driving, heavy lifting/work with machinery, and no heights due to risk of dizziness and balance problems.

Return to Sports and Recreation

The return to sports and recreational activities is a strong motivating factor to recover for most children and adolescents. Collision sports (football, ice hockey, lacrosse, soccer) require special management to ensure full recovery before their return to play.

Avoiding re-injury or prolonging recovery is a central management goal. As a fundamental tenet of sports concussion management, and as reinforced in the three international conferences on Concussion in Sport,⁷ an individual should never return

to competitive sport or recreational activities while experiencing any lingering or persisting concussion symptoms, including: PE class; sports practices and games; and other high-risk/high-exertion activities such as running, bike riding, skateboarding, climbing trees, jumping from heights, playful wrestling, etc. The individual must be completely symptom free at rest and with physical exertion (eg, sprints, noncontact aerobic activity) and cognitive exertion (eg, studying, schoolwork) before their return to sports or recreational activities. Parent and teacher input regarding signs or symptoms and objective data from neuropsychological testing can provide valuable information to assist with return to play decisions. It is important to educate coaches and PE teachers that athletes are not to return to play until they are symptom free and their cognitive function has returned to normal, both at rest and with exertion.

Furthermore, as articulated by the international Concussion in Sport Group,⁷ return to play should occur gradually and systematically with medical supervision, monitoring for symptoms, balance, and cognitive function during each stage of increased exertion. Therefore, the initial medical clearance of the student-athlete should be to begin the gradual Return-To-Play (RTP) program, not to return to full participation. The recommended progression, typically occurring during a 5- to 7-day period, includes rest, aerobic exercise (eg, stationary bicycle), sport-specific training (eg, running, skating), noncontact drills (includes cutting and other lateral movements), full contact controlled training, and full-contact game play.

The pediatrician should collaborate with the local school or league's athletic trainers, when available, in the gradual RTP program. To provide final written clearance, the pediatrician should assure that all criteria for recovery have been met, including successful completion of the RTP program. To provide final written clearance, the pediatrician should assure that all criteria for recovery have been met. For a sample medi-

cal clearance letter, search Healio.com; doi: 10.3928/00904481-20120426-10e.

CONCLUSION

Pediatricians play a pivotal role in the evaluation and management of a concussion in a child or adolescent. Preparation and training in the assessment and treatment of the child after this brain injury is an essential precondition to appropriate practice. This article presents an assessment and management model, using the ACE and Care Plans as tools to assist in the individualized evaluation and management of the concussion. Essential components of the evaluation include a thorough definition of the injury's characteristics, followed by a full assessment of post-concussion symptoms, and a definition of the child's risk history that may modify the course of recovery. The ACE and ACE Care Plan were developed to assist the pediatrician in this important endeavor. ■

REFERENCES

1. Halstead ME, Walters KD, and The Council on Sports Medicine and Fitness. Sport-Related Concussion in Children and Adolescents. *Pediatrics*. 2010;126:597-615. doi: 10.1542/peds.2010-2005.
2. Centers for Disease Control and Prevention (CDC). *National Center for Injury Prevention and Control. Heads Up: Brain Injury in your Practice*. Atlanta (GA): Center for Disease Control and Prevention; 2007. Available at: www.cdc.gov/ncipc/tbi/Physicians_Tool_Kit.htm. Accessed April 12, 2012.
3. Gioia GA, Collins MW, Isquith PK. Improving identification and diagnosis of mild TBI with evidence: Psychometric support for the Acute Concussion Evaluation (ACE). *J Head Trauma Rehabil*. 2008;23:230-242.
4. Gioia GA, Collins MW. Acute Concussion Evaluation. In: "Heads Up: Brain Injury in Your Practice" tool kit developed by the Centers for Disease Control and Prevention (CDC). 2006. Available at: www.cdc.gov/concussion/headsup/pdf/ACE-a.pdf. Accessed April 12, 2012.
5. Lovell MR, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabilitation*. 1998;13(2):9-26.
6. Sady MD, Vaughan CG, Gioia GA. School and the Concussed Youth: Recommendations for Concussion Education and Management. *Phys Med Rehabil Clin N Am*. 2011;22: 701-719.
7. McCrory P, Meeuwisse, W., Johnston, K., et al. Consensus Statement on Concussion in Sport: the 3rd International Conference held in Zurich, November, 2008. *Br J Sports Med*. 2009;43:i76-i84.