Concussion Management for the Orthopaedic Surgeon

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Toufic R. Jildeh, MD
Lina Shkokani, BS
Fabien Meta, MD
Joseph S. Tramer, MD
Kelechi R. Okoroha, MD

Investigation performed at the Department of Orthopaedic Surgery, Henry Ford Health System, Detroit, Michigan

Abstract

» Orthopaedic surgeons functioning as team physicians are in a unique position to recognize subtle changes in an athlete’s behavior and may be the first responders to concussions at sporting events.

» The rate of sports-related concussions has increased over the past few decades, necessitating that orthopaedic team physicians gain a greater understanding of the diagnosis and management of this condition.

» During the sideline evaluation, life-threatening injuries must be ruled out before concussion evaluation may take place.

» In most cases, patients experience a resolution of symptoms within a week; however, a smaller subset of patients experience persistent symptoms.

» Physicians covering sporting events must remain current regarding recommendations for treating sports-related concussions and must document their management plan to minimize potential harm to an athlete.

The incidence of sports-related concussions in the United States has increased over the past few decades, and concussion-related research, media coverage, and policy are projected to evolve accordingly. A number of guidelines and consensus articles in sports-related concussions have recently been developed, including the 2016 Berlin Concussion in Sport Group Consensus Statement and the American Medical Society for Sports Medicine position statement. Orthopaedic surgeons often are on the sidelines during competition and are the first responders to athletic injuries. Team physicians are in a unique position to recognize subtle changes in an athlete’s behavior or personality, as they are familiar with the athlete at baseline. Although it would be ideal for the dedicated team physician to be present at every competitive event, sometimes this is not feasible and, thus, many orthopaedic surgeons and residents may spend time filling in or covering sporting events, even if they are unfamiliar with individual athletes. During their time on the sideline, they remain responsible for the acute care of sports-related concussions during play. Thus, it is important to be familiar with all aspects of concussion, including diagnosis, management, current assessment tests, and legal implications. The aim of this article was to serve as an informative guide to aid orthopaedic surgeons in providing sideline medical care during sports events and in ongoing management of concussed athletes.

Diagnosis of Concussion

Concussion was formally defined by the Concussion in Sport Group (CISG) as “traumatic brain injury induced by biomechanical forces.” Because of its subtle

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presentation and the nonspecific symptoms that often overlap with those of other conditions, concussion can be a challenging diagnosis for a physician to make. To aid in the diagnosis of concussion, in 2017, the CISG identified common features of a concussive head injury. First, a sports-related concussion is often the result of a direct or indirect force to the head. Sports-related concussions typically result in rapid-onset, transient symptoms of neurological impairment, although delayed-onset symptoms are possible. These symptoms should not be explained by other causes such as drug or medication use, alcohol use, comorbidities, or other injuries. In most cases, symptoms resolve within a week; however, persistent symptoms may be seen in a smaller number of patients. Lastly, these symptoms are due to a functional disruption to neural pathways rather than a result of a structural injury. Thus, a concussion injury cannot be visualized on standard structural neuroimaging tests.

Epidemiology
Sports-related concussion affects athletes at all levels of play. The U.S. Centers for Disease Control and Prevention estimated that a total of 1.6 to 3.8 million individuals each year sustain a sports-related traumatic brain injury in the United States, and concussion may account for as much as 15% of all sports-related injuries in high school athletes. These numbers may be even larger, as many athletes fail to report concussion-related symptoms. Potential barriers that prevent athletes from reporting concussion-related symptoms have been found to include not wanting to be removed from play, being unsure of the cause of their symptoms, and not experiencing any pain or disability from symptoms. Nonetheless, the reported rate of concussion has increased over the past few years, which may be explained by improved identification of concussion and an actual increase in the number of sports-related concussions due to the growing power and strength of athletes.

Clinical Evaluation

Before the Injury
Before practice or competition begins, a physician should assess each athlete’s readiness to participate in sport through a thorough pre-participation examination. Pre-participation assessments should evaluate cognition, brain injury history, concussion-related symptoms, and balance. In the case of a history of multiple prior concussions or persistent symptoms from a previous concussion, orthopaedic surgeons should refer the athlete to a neurologist. Pre-participation examination may be a multidisciplinary effort to ensure that athletes are prepared both medically and physically for competition.

It is becoming increasingly common for computerized neurocognitive tests to be used as additional baseline assessments. These tests should not replace the patient history or physical examination. Overall, if there is any doubt by the physician with regard to the athlete’s health or safety, the athlete should not be allowed to participate in sport.

Concussion education should also be offered to all athletes prior to participation in sport. Athletes should be advised on the importance of reporting symptoms to their team physician in a timely manner. Lastly, as concussion prevention methods continue to be investigated and developed, orthopaedic surgeons are encouraged to utilize their expertise in medicine to help to identify areas of improvement in competition and practice such as protective equipment, training strategies, and concussion education that may offer further protection to athletes.

On-Field and Sideline Evaluations
Orthopaedic surgeons are often responsible for sideline recognition of concussion symptoms, which is the first and most critical step taken to mitigate the risk of further injury. Thus, orthopaedic surgeons must be able to recognize warning signs of concussion and must be aware that initial actions that must take place on the field in the case of suspected concussion evaluate for the signs of a more serious injury, prior to sideline evaluation.

In the case of a traumatic event, an on-field evaluation of the athlete should begin with an assessment of airway, breathing, and circulation. If there is a problem with any of these, the basic principles of first aid should be followed. Next, the physician’s priority must be to rule out more serious injuries that require emergency care including cervical spine injury, skull fracture, and intracranial hemorrhage. The first step in evaluating for a more serious injury is to determine the athlete’s level of consciousness. If an athlete demonstrates a prolonged loss of consciousness, the athlete should be cared for as if he or she has sustained a substantial intracranial or cervical spine injury. Manual in-line stabilization of the cervical spine or immobilization using a spine board should take place before the athlete is transferred to a nearby emergency department. Physicians should also look for signs of skull fracture, such as mastoid or periorbital ecchymosis, eyelid hematoma, and bloody otorrhea. A neurological examination should be completed to assess for signs of intracranial injury, including uneven pupils, disconjugate eye movements, and asymmetric motor function. A Glasgow Coma Scale (GCS) score may also be calculated and may be used as an indicator of moderate to severe brain trauma. An athlete demonstrating signs of skull fracture, focal neurological deficit, or a GCS score of <15 should be transferred to a nearby ED for emergency neuroimaging.

Other symptoms that require emergency medical services include declining mental status, posttraumatic seizure, repeated emesis, extremity numbness, difficulty walking, and severe or worsening headache. Once serious injuries that require immediate transfer to the ED have been excluded, assessment for concussion may begin. Concussion injury disrupts...
neural pathways, resulting in variable and nonspecific signs and symptoms including headache, loss of consciousness, amnesia, gait unsteadiness, behavioral changes, cognitive impairment, and sleep or wake disturbances. It should be noted that headache is the symptom most commonly reported by concussed athletes and that a loss of consciousness is uncommon, seen in 10% of concussed athletes. An athlete displaying any signs of concussion should immediately be removed from play for sideline evaluation. As alluded to earlier, the distinction between the on-field and sideline evaluations is heavily predicated on determining the severity and need for imminent intervention. If suspicion for concussion remains high, even after a benign on-field evaluation, the athlete should be brought to the sidelines for a more thorough evaluation.

A sideline evaluation for concussion should begin with questions that assess the athlete’s orientation and memory. For example, the physician may ask about the venue name, the current date, or events related to the game prior to or after the injury. The physician should then evaluate the athlete using specific sideline concussion assessment tools. Serial assessment tests in the initial few hours after the injury should be administered to monitor for delayed-onset or worsening symptoms. Physicians should also note any history of previous concussion or comorbid conditions, such as attention-deficit/hyperactivity disorder (ADHD), learning disorders, depression, and migraines. All of these conditions have been associated with a greater risk of concussion or a prolongation of concussion symptoms.

Return to play should be determined by a licensed medical professional and is contingent on the results of a concussion evaluation. Ideally, return to play should be guided by a team physician or primary care physician who is familiar with the patient, rather than a covering physician. Under no circumstances may the athlete return to play on the same day if there is any suspicion for concussion, regardless of symptom resolution. The physician should document the events of the evaluation, whether or not the athlete was cleared, and ongoing observation of the athlete.

Athletes who sustain a concussion and do not demonstrate signs of a more serious injury should be provided with in-home care information and should be asked to follow up with a physician within 3 days. Follow-up should be conducted by a physician familiar with the patient, whether that physician is an orthopaedic surgeon acting as the team physician or a primary care physician familiar with concussion care. At home, athletes may eat and sleep and do not need to be awakened for evaluation every hour. To treat headache symptoms, athletes may be counseled to use ice or acetaminophen; aspirin or nonsteroidal anti-inflammatory drugs should not be used until 24 to 48 hours after the injury, especially if there is a possibility of intracranial bleeding. Alcohol should be avoided, and athletes should be warned not to drive, as a concussion injury may prolong reaction time.

**Assessment Tests**

**Types of Neurocognitive Testing**

A number of neurocognitive tests have been increasingly used to determine an athlete’s baseline performance before training or competition begins. These tests include:

**TABLE I  On-Field Assessment of Injuries Necessitating Emergency Care**

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Immediate Care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: check ABCs</td>
<td></td>
</tr>
<tr>
<td>Airway</td>
<td>Voice</td>
</tr>
<tr>
<td></td>
<td>Heat tilt and chin lift</td>
</tr>
<tr>
<td></td>
<td>Breath sounds</td>
</tr>
<tr>
<td></td>
<td>Transfer to ED</td>
</tr>
<tr>
<td>Breathing</td>
<td>Respiratory rate</td>
</tr>
<tr>
<td></td>
<td>Seat comfortably</td>
</tr>
<tr>
<td></td>
<td>Chest wall movements or percussion</td>
</tr>
<tr>
<td></td>
<td>Rescue breaths</td>
</tr>
<tr>
<td></td>
<td>Transfer to ED</td>
</tr>
<tr>
<td>Circulation</td>
<td>Palpate pulse</td>
</tr>
<tr>
<td></td>
<td>Control bleeding</td>
</tr>
<tr>
<td></td>
<td>Capillary refill time</td>
</tr>
<tr>
<td></td>
<td>Elevate legs</td>
</tr>
<tr>
<td></td>
<td>Transfer to ED</td>
</tr>
<tr>
<td>Step 2: eliminate more serious injury*</td>
<td>Cervical spine assessment</td>
</tr>
<tr>
<td>Cervical spine injury</td>
<td>Immobilization of spine</td>
</tr>
<tr>
<td>Intracranial bleeding</td>
<td>Neurological examination</td>
</tr>
<tr>
<td>Skull fracture</td>
<td>Transfer to ED</td>
</tr>
<tr>
<td>Step 3: Evaluate for concussion injury</td>
<td>Physical examination of head</td>
</tr>
<tr>
<td></td>
<td>Transfer to ED</td>
</tr>
</tbody>
</table>

*Other symptoms that require emergency medical services include declining mental status, posttraumatic seizure, repeated emesis, extremity numbness, difficulty walking, severe or worsening headache, and a GCS score of <15.
tests may also be used to identify or monitor signs and symptoms of concussion. It should be noted that each athlete has a unique baseline before the injury to compare with testing after the injury, which may be more accurate than normative standardized values. The role of baseline assessments and sports-related concussion management in children and adolescents is not well established and may differ from older teenagers and adults. Currently, the Sport Concussion Assessment Tool, Fifth Edition (SCAT5), is the most widely used and readily available assessment tool and has versions for both older and younger athletes.

**The SCAT5**
The SCAT5 is a validated neurocognitive tool for sideline assessment of sports-related concussions in individuals who are 13 years of age or older. The SCAT5 should be performed in a distraction-free environment while the athlete’s heart rate is in its resting state.

The SCAT5 assesses the patient function via multiple domains including a symptom checklist, the GCS, memory assessment Maddocks score, the Standardized Assessment of Concussion, the Balance Error Scoring System, a coordination examination, a neck examination, and the Standardized Assessment of Concussion delayed recall. If baseline test scores are used for reference, a physician should attempt to replicate baseline testing conditions. The Child SCAT5 should be used to evaluate concussion in 5 to 12-year-old children, as it is accommodated to the developmental stages and language barriers of children of that age range and also considers symptoms reported by parents.

**Computerized Neurocognitive Testing**

The Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) is the most commonly used computer-based neurocognitive test in North America. The ImPACT consists of the following tasks: Word Memory, Immediate; Design Memory, Immediate; X’s and O’s; Symbol Match; Color Match; Four Letters recall; Word Memory, Delayed; and Design Memory, Delayed. The results of these tasks are used to compute output scores in verbal memory, visual memory, reaction time, oculomotor processing speed, and impulse control. The ImPACT also collects demographic information and includes a 22-item post-concussion symptom scale.

**Concussion Vital Signs**
The Concussion Vital Signs (CNS Vital Signs) is another online assessment tool composed of 7 tests. These 7 tests include the Visual Memory Test, the Visual Memory Test, the Finger Tapping Test, the Symbol Digit Coding Test, the Stroop Test, the Shifting Attention Test, and the Continuous Performance Test. The results of these tests are used to measure reaction time, processing speed, attention, and memory.

**Concussion Resolution Index**
The Concussion Resolution Index (HeadMinder) is an online neurocognitive assessment. The Concussion Resolution Index consists of 6 subtests that are used to calculate 3 composite scores: simple reaction time, complex reaction time, and processing speed.

**Automated Neuropsychological Assessment Metrics (ANAM)**
The ANAM (Vista Life Sciences) is an online neurocognitive assessment tool. The following tests are found on the ANAM: Simple Reaction Time, Procedural Reaction Time, Code Substitution Learning, Code Substitution Delayed, Mathematical Processing, Matching to Sample, and a second administration of the Simple Reaction Time. These tests are used to measure a variety of neurocognitive functions, including reaction time, processing speed, attention, and memory.

**Vision-Based Measures**
Recent research has focused on the use of oculomotor evaluations to aid in the identification of concussion. A majority of individuals diagnosed with traumatic brain injury experience some type of oculomotor dysfunction, and identifying the oculomotor pathways disrupted may provide physicians with insight into the areas of the brain impacted by concussion. Oculomotor functions that are commonly disrupted by concussion include convergence, saccades, and pursuits.

**The King-Devick (K-D) Test**
The K-D test (King-Devick Technologies) is a 2-minute sideline assessment tool that has been increasingly used to assess horizontal, saccadic eye movements and attention. To complete the K-D test, individuals are required to read single-digit numbers from left to right and top to bottom from a set of 3 paper cards or an electronic tablet. Each card is unique, and the difficulty level increases with each successive card. The quickest time (in seconds) that it takes an athlete to complete each of the 3 cards without error is added up for a measure of total time. Worse scores have been demonstrated in individuals who sustained a concussion.

**Ongoing Management of Concussions**
The strategies for the ongoing management of concussion continue to evolve. Currently, considering the heterogeneity in concussion presentation, treatment plans are often individualized. However, treatment plans for all patients tend to follow a similar sequential order, beginning with physical and cognitive rest. The majority of athletes who have sports-related concussions have a resolution of symptoms within 7 days, about 10% of athletes may have prolonged post-concussive symptoms. Rest involves minimizing physical and cognitive stimuli and is the most widely used intervention for individuals diagnosed with concussion. The aim of this intervention is to prevent the aggravation of symptoms and subsequent injury by reducing energy demands placed on the brain. To further ensure adherence to rest, physicians should inform patients, family members, coaches, and educators about...
the aim of this intervention and the complications that may arise if the physician recommendation is not followed. Patients should also be made aware that activities that may seem restful, such as watching television, reading, and texting on mobile devices, can be rather stimulating and, therefore, should be limited according to the symptom threshold.

Recent research suggests that prolonged rest may contradict the aim of this intervention. Thomas et al. completed a randomized controlled trial on rest following concussion, which consisted of 2 groups: an intervention group who were recommended strict rest at home for 5 days before gradually returning to regular activity, and a control group who were typically recommended only 1 to 2 days of rest before gradually returning to activity. The study found no significant difference in neurocognitive or balance outcomes between the 2 groups, but the intervention group reported a greater number of post-concussive symptoms and was more likely to experience prolonged symptom recovery. Additionally, prolonged rest may be associated with psychological complications, such as anxiety and depression, and physical deconditioning. The current recommendation is that physicians advise patients to rest only during the acute phase (24 to 48 hours after the injury). After this period, patients may gradually engage in activity according to their symptom threshold and physician recommendation (Fig. 1).

### Table II: Phases of Concussion Recovery

<table>
<thead>
<tr>
<th>Phase</th>
<th>Estimated Duration</th>
<th>Activity</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase I</td>
<td>0 to 5 days</td>
<td>Patient symptoms limit cognitive and physical activity. Rest may be recommended by the treating physician. Medication may be used to manage symptoms.</td>
<td>To avoid exacerbation or worsening of symptoms</td>
</tr>
<tr>
<td>Phase II</td>
<td>2 to 10 days</td>
<td>Patient symptoms limit cognitive and physical activity to a lesser degree. Gradual return to activity may be recommended by the treating physician as symptoms allow. Medication may be tapered.</td>
<td>To gradually engage patients in usual daily activities that do not significantly exacerbate symptoms</td>
</tr>
<tr>
<td>Phase III</td>
<td>7 to 14 days</td>
<td>Patient no longer experiences symptoms upon return to regular activity. Increased physical and cognitive exertion may be recommended by the treating physician as symptoms allow. Medication should not be used.</td>
<td>To ensure that a patient can handle increased exertion without experiencing a return of symptoms and to allow for an accurate assessment of a patient’s readiness to return to full a day of sport and school.</td>
</tr>
</tbody>
</table>


**Return to Sport**

During the initial phase of a concus- sive injury, the brain is vulnerable to subsequent injury or second-impact syndrome. Second-impact syndrome occurs when an individual sustains a second impact to the brain before recovering from a prior concussion and may be a real cause of permanent brain damage; therefore, extra caution should be taken to avoid this condition. Additionally, athletes who are diagnosed with subsequent concussions are likely to experience

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Fig. 1

less common symptoms of concussion, specifically a loss of consciousness, and symptoms that persist beyond the initial phase of the injury. To prevent recurrent concussions and persistent symptoms in athletes, it is critical that sports medicine professionals make appropriate return-to-sport decisions.

To assist medical professionals in making return-to-sport decisions, the CISG developed a return-to-sport strategy consisting of 6 stages (Table III). The first stage of this protocol is a period of rest, in which no activity is recommended to athletes. Afterwards, athletes may progress to the next stage in which light, symptom-limited physical activity is recommended. As long as concussion-related symptoms do not return, patients may continue to proceed to subsequent levels. However, if these symptoms do return, then it is recommended that the athlete returns to the previous asymptomatic level for at least 24 hours. Ultimately, athletes must pass through levels of sports-specific, complex physical activity, and all concussion-related symptoms should be resolved before an athlete returns to unrestricted sports.

It is recommended that this step-wise approach is led by a physician who is familiar with the athlete, such as the team physician, as he or she will likely be best at determining an athlete’s readiness to proceed to the next level. Additionally, although the timing of this protocol may be individualized on the basis of factors such as age, symptom severity, and level of sport, all athletes should remain in each level for a minimum of 24 hours. Thus, a minimum of 1 week should be provided for all athletes to complete this rehabilitation protocol. Lastly, it is recommended that physicians continue to monitor athletes who return to sport after concussion and that sideline observation is best at determining an athlete’s readiness.

### Persistent Symptoms

The current limitations in the prognostic indicators of concussion make it difficult for a physician to predict recovery time. In most cases, patients experience a resolution of symptoms within a week. However, a small subset of patients experiences symptoms that persist beyond this period. Patients are said to have persistent symptoms if they continue to experience symptoms longer than 10 to 14 days after the injury in adults and longer than 4 weeks after the injury in children.

Prognosis has been found to differ according to patients’ sex and comorbid history. In their study, Iverson et al. analyzed 101 articles and 13 abstracts that examined the predictors of clinical recovery. Most of the literature supported that female patients were more likely to experience a delay in symptom resolution and persistent symptoms for more than a month after concussion compared with male patients. Individuals with a history of mental health problems or migraines before the injury or those who experienced depression or headaches after the injury may also be at greater risk of experiencing persistent symptoms. Lastly, in another study,
Iverson et al. found that, in a sample of 32,487 adolescent athletes, athletes with ADHD and/or a learning disorder reported a greater prevalence of prior concussion compared with athletes without neurodevelopmental conditions. Yet individuals with ADHD and learning disorders were not found to be at greater risk of persistent symptoms according to current literature. Ultimately, researchers found that the most consistent predictor of prognosis between studies was the number and severity of symptoms experienced during the first few days following the injury, with less severe symptoms being more favorable prognostic indicators.

When faced with a patient experiencing persistent post-concussive symptoms, physicians should complete a comprehensive clinical assessment, noting any other comorbidities or factors that may be contributing to such symptoms. These patients should be referred to an experienced concussion specialist. Physicians should also take note of an individual whose condition fits the diagnostic criteria of post-concussion syndrome. The diagnostic criteria for post-concussion syndrome include a history of head injury and persistent symptoms for longer than 3 to 4 weeks. Patients with post-concussion syndrome also experience symptoms in ≥3 symptom categories, which involve cognitive, somatic, and sleep-related symptoms. These patients should be referred to a concussion specialist and should be encouraged to document changes in their symptoms for future discussion with their long-term physician.

**Legal Implications**

Concussion legislation was implemented in 2009, following the case of Zackery Lystedt, who had sustained a traumatic brain injury during a football game. A medical professional was not available during this game, and Lystedt was allowed to continue playing despite demonstrating clear signs of concussion injury. As a result of his injury and premature return to play, Lystedt was left severely disabled. The Lystedt law was enacted to protect young athletes from the complications of traumatic brain injuries. Currently, in all 50 states, concussion law follows 3 principles: concussion education, removal of the athlete with the suspected concussion injury with no same-day return to play, and clearance by a licensed medical professional.

Litigation continues to be a highly concerning topic in sports medicine because of a growing number of court cases with regard to sports-related injuries, particularly when head trauma is involved. Furthermore, second-impact syndrome has become a common theory of causation in lawsuits with regard to head trauma.

Whether or not defendants in sports-related injury cases are found to be liable is dependent on their conformity to the standard of care. In their study, Pachman and Lamba defined the standard of care as “acting as a reasonable professional in that position or industry would have under the circumstances based on then-existing knowledge.”

Orthopaedic surgeons who fail to follow current guidelines may therefore be in violation of the standard of care and may be found guilty of negligence.

As the scientific evidence and incidence of concussion continue to grow, it is expected that the standard of care will evolve. To ensure that the standard of care is being met, it is recommended that orthopaedic surgeons stay updated on and act according to current guidelines and laws. It is also recommended that orthopaedic surgeons are thorough in following the return-to-sport protocol and in documenting their management plan. All initial and serial evaluations of concussion should also be documented, along with ongoing sideline observation, regardless of whether or not the athlete was diagnosed with a concussion.

Ultimately, the more detailed the documentation, the greater the defense that an orthopaedic surgeon will have in the case of a sports-related injury lawsuit.

**Conclusions**

The heterogenous presentation of concussion, lack of understanding of pathophysiology, limitations in definitive diagnostic markers, and rapidly evolving research surrounding concussion make the diagnosis and management of concussion challenging. However, there is sufficient literature to guide orthopaedic surgeons in their care for concussed patients. Orthopaedic surgeons who are caring for athletes with concussion must remain current regarding guidelines for the safe management of athletes with sports-related concussion.

**References**

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