



# Concussion in Athletes: Information for Team Physicians on the Neurologic Evaluation

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The evaluation and management of concussion (ie, mild traumatic brain injury) in athletes is typically the responsibility of team or school physicians. The great majority of these physicians are orthopedists, family physicians, internists, pediatricians, or sports medicine specialists who have not had specialty training in neurology or neurosurgery. The evaluation and management of mild traumatic brain injury is primarily guided by a neurological clinical evaluation of the patient. The purpose of this article is to review relevant aspects of the neurological history and examination as well as the neurological approach to the concussed athlete.

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The clinical definition of concussion should be broad-based to err on the side of diagnostic caution in identifying concussion, which is also called mild traumatic brain injury (MTBI). It was not long ago when the diagnosis of concussion was primarily determined by a patient having sustained loss of consciousness (LOC). It is now generally accepted that, although LOC may or may not be present in concussion, its presence is not imperative for a diagnosis, and in fact is present in only a minority of sports-related MTBIs. The authors of a number of recent studies and consensus conferences have addressed concussion.<sup>1-7</sup>

We recommend use of the following definition for concussion.<sup>8</sup> Concussion is a complex pathophysiological process affecting the brain caused by traumatic biomechanical forces. It is manifested by:

- signs and symptoms commonly associated with postconcussion syndrome, including but not limited to headache, dizziness, nausea, fatigue, confusion, amnesia, photopho-

bia, phonophobia, loss of balance, unsteadiness, syncope or near syncope, tinnitus, blurred vision, diplopia, loss of vision, drowsiness, lethargy, fatigue, disorientation to time, place and events and change in personality; and

- an alteration in awareness, memory, and/or consciousness.

## Neurological Examination and Management of Concussion

### The Initial On-Field Evaluation

The initial priority of the physician when evaluating an athlete who has sustained a head injury is to determine whether there is a need for immediate life-saving procedures, such as cardiopulmonary resuscitation, defibrillation, or intubation and to initiate any of such procedures that may be required. Concomitantly, the physician must be certain that the cervical spine has been appropriately immobilized until it is certain that there is no significant injury to that area. Once it has been determined that such interventions are not necessary, the next priority is to determine whether there is any suspicion of an acute neurosurgical emergency, such as intracranial hemorrhage (epidural, subdural, or parenchymal) or diffuse cerebral edema that would require emergent transport to a hospital for immediate brain imaging and neurosurgical consultation. The initial determination of the possibility of acute neurosurgical emergency is determined largely by the physician's immediate observations and examination of the injured athlete.

Observed LOC lasting longer than 1 minute,<sup>9</sup> vomiting, persistent drowsiness or lethargy, or seizure activity, either

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focal (ie, jerky clonic movements of one limb, one side of the body or face, with or without accompanying LOC) or generalized (ie, LOC accompanied by tonic stiffening of the trunk and bilateral limbs with or without bilateral jerky clonic movements of the limbs or face) should raise suspicion of an acute neurosurgical emergency and prompt immediate ambulance transport to a hospital facility with emergency brain scanning (computed tomography or magnetic resonance imaging) and neurosurgical capabilities. Initial neurological examination findings of inability to answer questions or follow commands, decreased level of consciousness, a unilaterally dilated pupil, deviation of the eyes to one side, disconjugate eye movements, weakness of one side of the face, slurring of speech, or weakness of one side of the body should raise similar suspicions and prompt the same response. To make these observations and recognize these neurological signs, the physician must know in advance how to approach the concussed athlete in the initial minutes.

In the helmeted sport setting, an adequate neurological assessment requires that the helmet, face mask, and mouthguard be removed (obviously this should not be done in instances of suspicion of cervical spine injury until stability of the cervical spine has been assured). Unless the physician has actually witnessed the concussion or observed that the athlete is still unconscious when the physician begins the examination, it can often be very difficult to accurately determine if the athlete sustained LOC, and if so, the duration of the LOC. The physician usually depends on the patient's report of whether there was LOC, which adds a significant amount of subjectivity to making a determination of whether the player had LOC for longer than 1 minute. However, the observant physician who calmly observes the injured athlete for a few moments can usually easily ascertain whether there is seizure activity or vomiting.

If the athlete is upright (sitting or standing) under their own volition and speaking, the physician should proceed to the more thorough neurological examination that is discussed later in this article. If, by contrast, the athlete remains lying on the playing surface or needs assistance to sit or stand or is not speaking, the physician should pursue a focused examination to quickly determine whether immediate transportation to a hospital is warranted. The physician can often observe whether the athlete is drowsy or lethargic because the eyes will be closed, there will usually be no spontaneous speech, and the player will not respond appropriately to questions or commands. At other times, however, the physician will need to perform a more formal evaluation to make an accurate determination regarding drowsiness, lethargy or other alterations of level of consciousness. To make such a determination, the physician should first observe whether the eyes are open or closed and whether the player is speaking spontaneously.

The physician should then ask the player a simple question, such as "What is your name?" or "How do you feel?" to determine whether the athlete is responding appropriately to questions. The player can then be told to stick out their tongue or open or close their eyes to determine if they are responding appropriately to commands. If there is no re-

sponse to questions or commands, the physician should apply mildly noxious stimuli, such as pressing on a fingernail, or applying supraorbital pressure with one finger and observing if the player speaks, grimaces, pushes the examiner away, develops posturing of the limbs or does not respond at all. As noted previously, players with altered levels of consciousness at the time of initial physician evaluation should be treated as potential neurosurgical emergencies. If the patient speaks, the physician should listen carefully for evidence of slurring.

The physician should observe the size and symmetry of both pupils under ambient light and then shine a light at each pupil individually and observe if the appropriate pupillary constriction occurs in both eyes in response to the light stimulus. Asymmetry of the pupils (a difference in size of 2 mm or more) or failure of one or both pupils to constrict in response to the light stimulus could be signs of increased intracranial pressure with impending uncal herniation on the side of the larger pupil; therefore, such findings require immediate ambulance transport to a hospital equipped to deal with such emergencies. The physician should then observe the position of the eyes to determine whether there is conjugate deviation of both eyes to one side or if the eyes are in the midline. A spontaneous conjugate deviation or preponderance of eye position to 1 side is a sign of cerebral or brainstem/cerebellar dysfunction. An upward or downward deviation of the eyes indicates upper brainstem or thalamic dysfunction. Disconjugate eye movements are another sign of brainstem dysfunction. The presence of any of these eye movement abnormalities indicates the need for urgent brain imaging.

The physician should observe the injured player to determine whether the face is spontaneously symmetric and if there are symmetric spontaneous movements of all 4 extremities. If the player's limbs are not moving spontaneously, the physician should hold up and then let go of one arm and then the other as a means of detecting unilateral weakness. The presence of unilateral weakness of the face and/or limbs indicates the need for immediate transport to the hospital. At all times, the physician should maintain a high level of suspicion of a serious intracranial injury and a low threshold for sending an injured player to a hospital for urgent brain imaging.

## The Sideline Evaluation

If the initial evaluation does not indicate the need for immediate transport to a hospital, the physician should then perform a more thorough sideline neurological evaluation. The purpose of this evaluation is 2-fold:

1. Observe for signs or symptoms that may suggest the development of a delayed life-threatening neurosurgical problem, such as epidural or subdural hematoma. These types of hemorrhages may not be obvious at the time of initial examination and may present with a worsening of the neurological status in the minutes or hours after the concussion. It is well known that a potentially fatal epidural hematoma can on occasion masquerade initially as a mild head injury; physicians should therefore maintain vigilance of their recently concussed patients.

2. Determine whether the athlete will be allowed to return to play (RTP) on the day of the concussion. Because the initial step in making a decision regarding return to play is to determine whether the player is asymptomatic and has a normal neurological examination, it is imperative that the team physician knows how to elicit the symptoms of MTBI and perform an appropriate neurological examination on the athlete who has sustained an MTBI. RTP decisions on the day of concussion usually rely on sideline evaluation of the athlete, whereas RTP decisions on the following days depend on examinations in the training room or the doctor's office.

The player's uniform, footwear, and protective gear can limit the physician's ability to perform a thorough neurological examination. Limited space and noise from coaches, other players, announcers, and fans can challenge the physician's ability to obtain a complete history, especially in regards to the presence or absence of the myriad symptoms that can occur as the result of MTBI. It therefore behooves the team physician to know in advance what symptoms to ask about, what signs to look for and how to go about performing a neurological examination when called upon to evaluate a concussed athlete on the sideline.

### The Sideline Neurological History

Taking a history is a vital part of the neurological evaluation. Before taking the history, the physician may wish to remind the athlete that it is in his or her best interest to be forthcoming and honest in answering the physician's questions because the physician will use these answers to help determine the best treatments for the player. The player should be asked to recount the events occurring just before, during, and after the head injury. If the player cannot remember all the events leading up to the impact, they are clearly exhibiting retrograde amnesia as part of their MTBI symptomatology. If the player cannot fully recollect all the events of the actual impact or what occurred after the impact, then they are manifesting signs of posttraumatic amnesia (PTA). The duration of the posttraumatic amnesia has been used by some physicians as a marker of the severity of the concussion.

While realizing the subjective nature of the question, the physician should ask the player whether they lost consciousness and, if so, for how long. Players, as well as nonathlete patients will often find it hard to answer this question because they confuse posttraumatic amnesia with LOC. For example, a player who sustains a concussion on the field with no LOC observed by teammates, athletic trainers, or even videotape review of the events at a later time may develop PTA of 5 minutes' duration and the next thing they remember is talking to the physician on the sideline 5 minutes after the concussion. Such patients will often equate this with LOC and believe that because they cannot remember anything during that 5-minute period they must have lost consciousness for a 5-minute period, even though that is clearly not the case. By contrast, it is well known to neurological clinicians that any person who sustains LOC because of head trauma

will have PTA for duration at least as long, and often for a longer period, as the duration of the LOC. This means that a player who does not have PTA did not sustain LOC because of the concussion but that the presence of PTA does not indicate that the player necessarily also experienced LOC.<sup>10</sup>

The physician should then ask open-ended questions of the athlete regarding how they feel and what symptoms they are experiencing. This questioning allows the player the opportunity to inform the physician of any and all symptoms that are being experienced even if they are somewhat vague and not easily classifiable. Athletes may voice symptoms, such as "I just don't feel right" or "I feel like I am floating" or "I don't feel like myself," which are a result of the head injury but are vague or nonspecific enough that the player may not voice them in response to specific questions about specific symptoms, such as headaches, dizziness, confusion or memory loss. If the athlete endorses any symptoms in response to these open-ended questions, the physician should follow up with more open-ended questions to give the player the opportunity to explain in more detail.

The physician should then ask whether the athlete is experiencing any of the following symptoms: headaches, neck pain, nausea, dizziness, feelings that they may faint or lose consciousness, vertigo (ie, spinning sensation, feeling that the player or their surroundings are moving or tilting), unsteady feelings, feelings of imbalance, blurred vision, fuzzy vision, double vision or other alterations of vision, sensitivity to light or noise, hearing difficulty, tinnitus (ringing sensation in the head or the ears, clicking noise in the ears, pulsating noise or sensation in the ears or head), fatigue, drowsiness or grogginess, anxiety, irritability, sluggish feelings, feeling "slowed down," feeling dazed or stunned, "seeing stars," feeling "not right," confusion, memory difficulties, forgetfulness or difficulty concentrating.

Many physicians carry a list of the common signs and symptoms of MTBI with them to be sure that they inquire about all the symptoms. Table 1 shows an example of a standardized list that can be used by the physician.<sup>5</sup> This list can be customized as the physician gains experience. The signs and symptoms of MTBI listed in Table 2 include the frequency of occurrence during a 6-year period in NFL players.<sup>8</sup> The author's NFL experience with concussion has been described in a series of papers in *Neurosurgery*.<sup>11-15</sup> The data in Table 2 reflect the relative occurrence of the various signs and symptoms after American professional football MTBI. These signs and symptoms occur in similar frequencies in college and high school sports-related concussions as well as in non-sports related concussions.<sup>15-23</sup>

The physician should ask the athlete to explain in detail any symptoms that are present. For example, if the athlete states that he or she has a headache, the physician should follow-up with questions about the location (eg, unilateral or bilateral), the nature (eg, pounding, throbbing, pulsating, dull, squeezing), and the severity (eg, mild, moderate or severe) of the headache and then inquire about possible associated symptoms, such as nausea, vomiting, photophobia, and phonophobia to determine whether the headache has migrainous or muscle contraction characteristics. Such infor-

**Table 1** Two-Side Card Handout with Information on Sideline Evaluations and the Signs and Symptoms of Concussion

**SIDELINE EVALUATION OF CONCUSSION SIGNS**

**Mental status**

- (1) Orientation—general (month, date, day of week, year, time of day) and/or football related (name of opponent, quarter, score, stadium, city—turn player away from field and scoreboard first)
- (2) Memory—anterograde and immediate recall—repeat 3 to 5 words, repeat again after concentration tasks—retrograde—what happened in recent quarter?, what is last thing remembered before the hit?
- (3) Concentration—repeat days or months backwards, repeat 3 to 5 digits backwards, Oral Trails B asking player to say letters and numbers alternately, ie, 1A2B3C4D, etc.

**Neurologic exam**

Speech, eye movements, pupil size and reaction to light, symmetry of smile, pronator drift, rapid finger movements, routine gait and tandem gait, dysmetria (finger to nose)

**Exertional tests**

Player sprints 40 yards, does pushups, situps—observe performance and ask player how he or she feels after the test.

(Derived from the sideline evaluations of the Bears, Falcons, Giants, and Steelers.)

**Symptoms and signs of concussion**

**General symptoms**

- Headaches
- Neck pain
- Nausea
- Syncope
- Vomiting
- Back pain
- Seizures
- Cranial nerve
- Dizziness
- Blurred vision
- Vertigo
- Photophobia
- Tinnitus
- Diplopia
- Nystagmus
- Pupil response
- Pupil size
- Hearing loss

**Memory problems**

- RGA delayed
- Info processing problems
- Attention problems
- AGA delayed

**Cognition problems**

- Immediate recall
- Not oriented to time
- Not oriented to place
- Not oriented to persons

**Somatic complaints**

- Fatigue
- Anxiety
- Personality change
- Irritability
- Depression

**Loss of consciousness**

Adapted with permission from Casson et al.<sup>5</sup>

mation has prognostic significance because players with multiple symptoms and/or migrainous headaches are more likely to have a prolonged recovery than those with fewer symptoms and muscle contraction type headaches.<sup>7,11,12</sup> Noting information regarding the severity of the headaches will serve as a type of baseline against which to measure the severity of headaches over time. This is important to the clinician as progressively worsening headache or the development of new associated symptoms should raise the possibility of delayed onset intracranial bleeding or edema and thus prompt

immediate transfer to a hospital for brain imaging. Follow-up questions about other symptoms can be equally valuable to the physician.

**The Sideline Neurological Examination**

After taking the history, the physician can proceed with the neurological examination. This begins with observations of the head and face, specifically looking for bleeding exteriorly or from the nose or ears. Otosopic examination is performed to search for evidence of bleeding behind the tympanic membrane (a sign of basilar skull fracture).

**Mental Status**

A detailed mental status examination is an integral part of the sideline evaluation. It needs to cover the cognitive and memory functions that are most frequently impaired after MTBI (ie, orientation, memory and concentration). It is not enough to simply ask the athlete “how are you?” or question him/her only about the year, month, or date (ie, orientation) because clinical studies have demonstrated that only a small percentage of concussed athletes are disoriented on initial evaluation while much higher percentages have memory and/or concentration impairments.<sup>8</sup>

General orientation is assessed by asking the injured athlete about time (ie, year, month, date, day of the week, time of day), place (ie, name of city, town, state of current location), and person (ie, athlete’s name). More specific sport-related orientation should also be assessed by asking questions about the specific sporting event of the day (ie, name of opposing team or player, name of stadium or field, current quarter or period of athletic contest, current score). To prevent the player from purposely or inadvertently receiving clues to these answers, the physician should be sure to turn the player away from the field and scoreboards (or at least block the view) before asking these questions.

Anterograde memory functions are assessed by asking the athlete to repeat 3 to 5 words (eg, apple, penny, table or red, box, Broadway, or any other words that the examiner prefers) immediately and then asking the athlete to repeat them again after concentration tasks are completed. Experienced physicians find it useful to use different sets of words on subsequent testing of each athlete and at different times during the season to guard against prelearning of the words by athletes who hope to outsmart or “game” the examination. Retrograde memory functions are evaluated by asking the athlete questions about recent events just before and up to the concussion (for example, what is the last thing you remember before the hit? Do you remember the hit and if so tell me about it? What happened in the play or period/quarter before the concussion?).

The athlete’s concentration abilities are tested by asking him/her to repeat the days of the week or months of the year backwards, repeat random series of digits (in groups of 2, 3, 4, and 5) backwards or recite numbers from 1 to 10 and letters of the alphabet starting with A in alternating order (ie, 1-A-2-B-3-C-4-D, etc). After the concentration tasks have been completed, the physician should complete the anterograde memory testing by asking the athlete to repeat the 3, 4, or 5 words that were repeated immediately earlier in the examination.

Table 2 Initial Signs and Symptoms for Concussed Players in NFL Games

Signs and Symptoms	N	%	95% CI
<b>General Symptoms</b>	<b>487</b>	<b>61.9%</b>	<b>(58.5%, 65.3%)</b>
Median = 1, Range = 0-5			
Headaches	433	55.0%	(51.5%, 58.5%)
Neck Pain	99	12.6%	(10.3%, 14.9%)
Nausea	62	7.9%	(6.0%, 9.8%)
Syncope	13	1.7%	(0.8%, 2.6%)
Vomiting	9	1.1%	(0.4%, 1.8%)
Back Pain	3	0.4%	(0.0%, 0.8%)
Seizures	1	0.1%	(-0.1%, 0.3%)
<b>Cranial Nerve Symptoms</b>	<b>416</b>	<b>52.9%</b>	<b>(49.4%, 56.4%)</b>
Median = 1, Range = 0-4			
Dizziness	329	41.8%	(38.4%, 45.2%)
Blurred Vision	128	16.3%	(13.7%, 18.9%)
Vertigo	31	3.9%	(2.5%, 5.3%)
Photophobia	32	4.1%	(2.7%, 5.5%)
Tinnitus	21	2.7%	(1.6%, 3.8%)
Diplopia	16	2.0%	(1.0%, 3.0%)
Nystagamus	8	1.0%	(0.3%, 1.7%)
Pupil Response	5	0.6%	(0.1%, 1.1%)
Pupil Size	0	0.0%	(0.0%, 0.0%)
Hearing Loss	0	0.0%	(0.0%, 0.0%)
<b>Memory Problems</b>	<b>311</b>	<b>39.5%</b>	<b>(36.1%, 42.9%)</b>
Median = 0, Range = 0-4			
RGA Delayed	142	18.0%	(15.3%, 20.7%)
Info Processing Problems	138	17.5%	(14.8%, 20.2%)
Attention Problems	102	13.0%	(10.7%, 15.3%)
AGA Delayed	74	9.4%	(7.4%, 11.4%)
<b>Cognition Problems</b>	<b>217</b>	<b>27.6%</b>	<b>(24.5%, 30.7%)</b>
Median = 0, Range = 0-4			
Immediate Recall	201	25.5%	(22.5%, 28.5%)
Not Oriented to Time	63	8.0%	(6.1%, 9.9%)
Not Oriented to Place	40	5.1%	(3.6%, 6.6%)
Not Oriented to Persons	23	2.9%	(1.7%, 4.1%)
<b>Somatic Complaints</b>	<b>158</b>	<b>20.1%</b>	<b>(17.3%, 22.9%)</b>
Median = 0, Range = 0-4			
Fatigue	71	9.0%	(7.0%, 11.0%)
Anxiety	41	5.2%	(3.6%, 6.8%)
Personality Change	39	5.0%	(3.5%, 6.5%)
Irritability	25	3.2%	(2.0%, 4.4%)
Sleep Disturbance	6	0.8%	(0.2%, 1.4%)
Loss of Appetite	2	0.3%	(-0.1%, 0.7%)
Depression	1	0.1%	(-0.1%, 0.3%)
Loss of Libido	0	0.0%	(0.0%, 0.0%)
Total Signs & Symptoms	2158		
Median = 2, Range = 0-12			
<b>Unconsciousness (623 reported cases)</b>	<b>58</b>	<b>9.3%</b>	<b>(7.0%, 11.6%)</b>

Reprinted with permission from Pellman et al.<sup>8</sup>

Many physicians carry a list of mental status questions with them and refer to it on the sideline as a reminder to ensure a thorough complete examination. An example of such a list that is used by some NFL team physicians is seen in Table 1. As part of a cautious, conservative approach to the evaluation and management of MTBI in athletes, physicians should consider any errors or mistakes in answering any of these mental status questions an indication of an abnormal

examination. In addition, the physician should observe the speed and facility with which the athlete performs these mental status tasks and also consider slowed or hesitant responses as abnormal.

### The Physical Neurological Examination

Once the mental status testing has been completed, the physician should proceed to a neurological physical examina-

tion. Basic cranial nerve functions should be assessed first. The physician should evaluate pupillary size and symmetry under ambient light and then in response to a bright light. Visual fields can be quickly evaluated by having the player look directly at the physician's nose while the physician wiggles one finger of each hand being held at arm's length in the periphery of both visual fields and asking the player how many fingers they see. Eye movements are observed for their conjugate nature by asking the player to move their eyes in both lateral and vertical directions (ie, right, left, up and down) and then follow the physician's finger with their eyes as the physician moves the finger in all 4 directions. During this test, the physician should closely observe the player's eye movements for evidence of nystagmus (jerky eye movements), which is a sign of vestibular dysfunction. Nystagmus may be horizontal, vertical or rotary in nature. Vertical nystagmus (up and down jerky eye movements usually noted with up or down gaze) is a sign of brainstem dysfunction and its presence should prompt immediate transport to the emergency room for brain imaging. Horizontal and rotary nystagmus are much more common after head injury than vertical nystagmus and usually indicate peripheral (inner ear) rather than central (brainstem) dysfunction and thus do not require the same urgent response.

The player should then be asked to smile and stick out their tongue as a means of assessing 7th and 12th nerve functions. The presence of slurred speech (indicating lower cranial nerve, brainstem-cerebellar or cerebral dysfunction in the absence of any obvious facial or oral injury) should have been noted by the physician during the history taking or mental status part of the examination.

Motor function of the upper extremities is evaluated by having the player stand with their eyes closed and both arms extended with palms up in front of their body. If one arm or the other does not pronate or drift downward spontaneously, the physician should gently apply light pressure in a downward direction to first one palm and then the other and observe whether any pronation or downward drift develops. The physician should then ask the athlete to move the fingers of both hands in a rapid piano-playing or finger to finger tapping motion and observe for any asymmetry of these rapid movements.

Motor function of the lower extremities is evaluated by having the player stand and hop on each leg individually (eyes open) and then rapidly move both feet in toe tapping, heel tapping and side to side movements at the ankle observing for any asymmetry of these movements. Cerebellar functions are then further assessed (looking for nystagmus on eye movement testing has already assessed some cerebellar functions) by asking the player to touch their index finger to the tip of the examiner's index finger held in front of the athlete and then repeating with the other hand. The athlete is then asked to close their eyes and touch first one and then the other index finger to the tip of the athlete's nose. During these maneuvers, the physician should observe for signs of tremor and/or dysmetria (ie, breakdown and decomposition of movement) that would suggest cerebellar hemispheric dysfunction.

Gait and balance should then be assessed by observing the player as they walk away from the physician and then turns and walks toward the physician in a routine manner, then walks on the toes and then the heels and then performs tandem gait. The player should then be observed while running a few yards away from the physician, then turning and running toward the physician. The physician should look for signs, such as veering to one side or the other, walking with a wide-based gait, limping on one leg, dragging of one leg, asymmetry of armswing (often most noticeable with walking on the heels) or difficulty with turns as manifested by turning slowly, turning with multiple short steps or tending to lose balance while turning. Such gait abnormalities can indicate motor weakness or vestibular/ cerebellar dysfunction.

It is important to note that certain elements of a more thorough neurological examination are not usually included in the sideline evaluation of the concussed athlete. Sensory testing and deep tendon reflex testing are not necessary at this point unless spinal cord, nerve root, or plexus or peripheral nerve injury are suspected in addition to the head injury. Evaluation of the extrapyramidal system is not necessary on the day of the concussion unless the athlete is known to have a preexisting condition involving this system. Fundoscopic evaluation is usually deferred until subsequent examinations because, even in the presence of acutely increased intracranial pressure resulting from traumatic intracranial bleeding or cerebral edema, papilledema will not develop for at least several hours.<sup>24</sup> Plantar stimulation aimed at eliciting a Babinski sign is not usually included in the sideline evaluation because its performance requires the removal of all the player's footgear and that the player be lying flat on their back, both of which create several logistical problems.

However, if the injured athlete is being evaluated in the locker room, rather than on the sideline, then the footgear should be removed and lateral aspect plantar stimulation with a mildly noxious stimulus should be performed. When performing this test, the physician should closely observe the initial movement of the big toe of each foot in response to the stimulation. A Babinski sign is present when the initial movement of the big toe in response to plantar stimulation is in the rostral direction (ie, toward the head, up going, extensor).<sup>25</sup> The Babinski sign indicates dysfunction in the pyramidal tracts and is a definitive sign of dysfunction in the spinal cord or the brain. A unilateral Babinski sign in an athlete sustaining a head injury would lead most physicians to obtain urgent brain imaging to rule out intracranial hematoma. Bilateral Babinski signs could have the same implication but would also indicate a need for urgent neurosurgical evaluation for possible spinal cord injury in the thoracic or cervical spine regions.

The physician must rely upon their clinical experience, judgment, and acumen to determine whether the athlete's performance on the various aspects of the physical neurological examination is normal or abnormal. As part of the cautious, conservative approach to the evaluation and management of MTBI, we recommend that physical findings that the physician does not clearly determine to be normal should be considered abnormal.

### Exertional Testing

If the athlete is completely asymptomatic and has a normal neurological examination (including mental status), the physician should proceed to exertional testing. Such testing sometimes will cause symptoms and/or signs to appear that were not noted during the initial evaluation. Exertional testing is done by asking the player to sprint for a short-distance and/or perform a series of situps or pushups. The physician should ask the player about any symptoms that are noted after the exertion and briefly reexamine the player after exertion to determine if any abnormal neurologic signs have developed.

### Ongoing Evaluations on Day of Concussion

If the player remains asymptomatic with a normal neurologic examination after exertion, they may be considered for RTP by the physician (see further discussion of RTP later in this article). Regardless of whether the athlete returns to play on the day of the concussion, the physician should perform frequent periodic reevaluations of the player's status during the first few hours after the concussion. It is not uncommon for the signs and symptoms of MTBI to fluctuate over time, and the physician must remain ever vigilant in observing the injured athlete for any symptoms and/or signs that may point toward neurologic deterioration that would require immediate brain imaging. After the athletic contest has been completed, the physician should reexamine any player who has sustained an MTBI that day, whether or not the player returned to play on the day of the concussion.

### Instructions to the Athlete on First Night After Concussion

If the physician determines that it is safe for that player to return home after the game (as opposed to requiring evaluation at a hospital or emergency department), the physician should ensure that the injured player will have a reliable person (ie, family member, friend, roommate, teammate) with them that night and be sure to instruct the player and the caregiver on what to look out for and what to do if certain symptoms develop. The player and caregiver should be instructed on the necessity of follow-up examinations by the physician on the day following concussion. Many physicians and organizations find it useful to give the player and the caregiver a written information-instruction sheet to read and take home after the concussion (Fig. 1).

### The Day-After-Concussion Examination

Every concussed player should be reevaluated the day after the concussion. The physician should again inquire about any symptoms that the player may be experiencing. In addition to the symptoms that were inquired about on the day of the concussion, the day after evaluation should also include questions about sleep disturbances (ie, excessive sleep or drowsiness, difficulty falling or staying asleep, early morning awakening), changes in mood (ie, sadness, depression, anxiety, nervousness, irritability, anger, fear), changes in appetite (ie, decreased or increased, nausea) and the presence or

absence of fatigue—all symptoms of MTBI that are more likely to occur during the days after concussion than on the day of the concussion.

The physician should again conduct a thorough neurologic examination (including mental status) being certain to include aspects that may have been omitted on the day of the concussion (eg, fundoscopic examination, testing deep tendon reflexes, plantar stimulation looking for Babinski signs, sensory examination, evaluations for rigidity, bradykinesia and involuntary movements). If the athlete is asymptomatic and has a normal neurological examination (including mental status), exertional testing similar to that performed on the day of the concussion should be undertaken and the athlete reexamined after the exertion.

If the athlete complains of worsening headaches or dizziness, or if they have been vomiting, the physician should arrange for immediate brain imaging. If the athlete is drowsy or lethargic or seems “out of it” or “in a daze,” or if family or friends report such symptoms, urgent brain imaging should also be considered. If the mental status testing shows a worsening compared with that on the day of the concussion, brain imaging should be considered. If the neurological examination reveals abnormalities of cranial nerve, sensory, motor, reflex or cerebellar function, or if there is papilledema on fundoscopic examination, the physician should arrange for immediate brain imaging. Even if none of the aforementioned conditions are present, the physician should send the player for brain imaging if their clinical judgment calls for it.

Neuropsychological testing (NP), if available, is usually administered to players who have sustained an MTBI (even those who had been cleared to return to play on the day of the concussion) on the day after concussion. The team physician should become familiar with the specific type(s) of NP testing that is being used by the neuropsychologists who are consulting with each team, league, school or individual to be able to best use the information provided by these tests. Details of NP testing in the NFL have been published.<sup>13,15,26</sup>

### The RTP Decision

The ultimate responsibility for determining when a concussed athlete is medically cleared to RTP rightly lies with the player's physician. Although much has been written about guidelines and criteria for making this decision, at the end of the day the physician must make the decision on an individual case by case basis using their best clinical/professional knowledge, skills and judgment. Input from team trainers and/or neuropsychologists is often of invaluable assistance in helping the physician make appropriate RTP decisions. The team or individual athlete's physician should not hesitate to seek neurological or neurosurgical consultations to assist in making these decisions when necessary. Although there are many factors that may play a role in the decision-making process, nonmedical pressures from coaches, team or school officials, boosters, and fans should not be allowed to influence the physician's medical decisions regarding medical clearance to return to play. It is the physician's role to determine when it is medically safe for the athlete to return to play, but it is up to the player (and their parents for a minor) to

**What is a concussion?**

A concussion is an injury to the brain caused by a blow to the head. This injury causes the brain not to function normally for a period of time. Concussions may be referred to as mild traumatic brain injuries and get better with time. However, occasionally there can be a more significant problem, and it is important that the symptoms from a concussion be monitored. When you suffer this injury, you may have problems with concentration and memory, notice an inability to focus, feel fatigued, have a headache or feel nauseated. Bright lights and loud noises may bother you. You may feel irritable or have other symptoms.

**What should I watch for?**

After evaluation by your team physician, it may be determined that you are safe to go home. Otherwise, you may be taken to the hospital. **If you are sent home, you should not be left alone. A responsible adult should accompany you.**

Symptoms from your concussion may persist when you are sent home but should not worsen, nor should new symptoms develop. You should watch for such things as:

1. Increasing headache.
2. Increasing nausea or vomiting.
3. Increasing confusion.
4. Unusual sleepiness or difficulty being awakened.
5. Trouble using your arms or legs.
6. Garbled speech.
7. Convulsions or seizure.

If you notice any of these problems or have any other problem that appears worse as compared to how you felt at the time you left the stadium or practice, immediately call the physicians or athletic trainers. In an emergency, have someone transport you to a hospital.

**Is it okay to go to sleep?**

Concussion many times makes a player feel drowsy or tired. As long as you are not getting worse, it is all right for you to sleep. We do want the responsible adult to be at home with you in case any problems arise.

**May I take something for pain?**

Do not take any medication unless your team physician has told you to do so. Normally, we do not advise anything stronger than Tylenol. Avoid the use of aspirin, Motrin, Aleve, or any other anti-inflammatory medication that you may have been taking. We also ask that you not consume any alcohol and avoid caffeine and any other stimulants. If you are taking any supplements, we would suggest that you discontinue the use of them as well. The team physician will determine when you can restart medications and supplements.

**May I eat after the game?**

It is fine for you to eat if you are hungry. Remember, some players do have a sense of nausea and fatigue, and often find that their appetite is depressed immediately after a concussion. Do not force yourself to eat.

**Do I need a CT scan or MRI examination?**

If the team physicians have determined that you are able to go home after the game, these types of diagnostic tests are not necessary. If you are sent to the hospital with a more serious injury, a CT scan or MRI examination is likely. If your symptoms linger for several days after a concussion, CT scan or MRI examination may be a consideration.

**How long will I be observed?**

You are to report to the training room the morning after your concussion. You will be assessed by the team physicians and athletic trainers. You will take a neurocognitive test and your symptoms will be monitored. Return to play decisions vary by individual, and will be based on physical exam and a return to baseline on the neurocognitive test.

**Telephone Numbers:** Athletic Trainers: \_\_\_\_\_, Team Physicians \_\_\_\_\_

**You are to report to the training room on:** Day \_\_\_\_\_ Time \_\_\_\_\_

**Figure 1** Information on concussions for players and their family. Reprinted with permission from Casson et al.<sup>5</sup>

decide whether they are willing to return to play and then up to the coaching staff to determine when the player actually returns to play.

**Concussion Guidelines**

During the past 20 years, several organizations and individuals have promulgated guidelines intended to help team physicians in making RTP decisions.<sup>1-5,27-29</sup> These have usually started by grading the severity of concussions according to criteria, including presence or absence of LOC and amnesia

and how long it takes for the initial symptoms of MTBI to resolve. Some guidelines also consider the number of prior MTBIs sustained by the athlete. The guidelines then proceed to recommend specific minimum lengths of time that the athlete should be held out of play based upon the grade of the concussion. These types of guidelines have been criticized for failing to consider the wide range of clinical symptoms and signs that are part of the MTBI spectrum as well as for being based largely on consensus or individual expert opinion rather than on clinical scientific evidence.



Based upon the June 2007 Conference on NFL player health and safety, the MTBI Committee reaffirms the following:

- Team physicians and athletic trainers should continue to exercise their clinical judgment and expertise in the treatment of each player who sustains a concussion and to avail themselves of additional expert consultation when clinically indicated. We encourage team physicians and athletic trainers to continue to take a conservative approach to treating concussion.
- Team physicians and athletic trainers should continue to take the time to obtain a thorough history, including inquiring specifically about the common symptoms of concussion, and to conduct a thorough neurological examination, including mental status testing at rest and post-exertion, before making return to play decisions in a game or practice.
- The essential criteria for consideration of return to play remain unchanged. The player should be completely asymptomatic and have a normal neurologic examination, including mental status testing at rest and post-exertion, before being considered for return to play.
- Team physicians and athletic trainers should continue to take into account certain symptoms and signs that have been associated with a delayed recovery when making return to play decisions. These include confusion, problems with immediate recall, disorientation to time, place and person, anterograde and retrograde amnesia, fatigue, blurred vision and presence of three or more signs and symptoms of concussion.
- If the team medical staff determines a player was unconscious, the player should not be returned to the same game or practice.
- Team physicians and athletic trainers should continue to consider the player's history of concussion, including number and time between incidents, type and severity of blow, and time to recover.
- Team physicians and athletic trainers should continue to educate players about concussion and to emphasize the need for players to be forthright about physical and neurological complaints associated with concussion. Player input assists the medical staff and athletic trainers to render appropriate care.

**Figure 2** Statement on return to play decision. Reprinted with permission from Casson et al.<sup>5</sup>

Nevertheless, there is a place for the accumulated wisdom and clinical experience of the highly regarded experts in the field who have contributed to the formulation of these guidelines. Rather than discarding this advice, the medical community should use it to gain insights in how to approach RTP decision making on the individual case by case basis that is the centerpiece of modern concussion management. For example, although recent clinical studies indicate that LOC is not the only factor influencing time to recovery, they also demonstrate that LOC is one of the significant risk factors for the development of post concussion syndrome, leading many experts in the field to agree with the guidelines that players with observed LOC on the day of the concussion are not good candidates for RTP on the day of the concussion.<sup>5,6,12</sup> In addition, modern concussion management and the guidelines are in agreement that injured athletes should only be considered for return to play when the athlete is completely asymptomatic at rest and with exertion and has a normal neurological examination, including mental status.<sup>5,6,26</sup> This does not mean that every athlete who meets these criteria should automatically be medically cleared to return to play; it means that athletes who are symptomatic and/or have abnormalities on neurological examination should not be considered for return to play at that time.

In 2007, the NFL's MTBI Committee collected information on return to play from a wide range of people. The group included veteran athletic trainers, the medical adviser for the players' union, NFLPA executives and union president, current and former NFL players, and outside experts.<sup>5</sup> Informa-

tion was summarized on current NFL medical practices used to make RTP decisions. **Figure 2** provides a reaffirmation of practices used in the NFL and is a helpful list of items to consider before medically clearing a player to return to practice or a game.

The elicitation of symptoms of MTBI obviously requires the full honest cooperation of the injured player. Physicians, teams, schools, and leagues should therefore make every possible effort to educate all the players (and parents for minors) of the importance to their health and well-being of being fully open and forthright in reporting all head injuries and all symptoms to team medical personnel.

## Individualized Management of Concussion

Once the athlete meets these minimum criteria (ie, completely asymptomatic with a normal neurological examination) to be considered for medical clearance to RTP, the physician should use their clinical judgment and expertise and consider any of the other factors discussed below that they consider relevant to the specific individual athlete to determine if the player is medically cleared to return to play at that time. The age of the athlete may be considered in view of evidence demonstrating that high school players recover from MTBI more slowly than collegiate and professional athletes (in their 20s and 30s).<sup>15,27</sup> The gender of the athlete may be considered in light of evidence suggesting that females may recover from MTBI more slowly than their male counterparts.<sup>30,31</sup>

The nature of the sport in which the athlete will be participating may merit consideration, as the risks of repeat MTBI certainly vary from sport to sport. As an example of how such factors may influence the physician's decision-making process, one could easily understand how a professional male tennis player might be medically cleared to RTP sooner than a high school female soccer player, even though both are asymptomatic and have a normal neurological examination. The physician may also take into account whether the present concussion is the first, second or third (or more) that the individual athlete has sustained and, if it is not the first, the timing of the earlier MTBIs in relation to the present concussion. As noted previously, concussion guidelines often recommend delayed RTP for subsequent concussions as opposed to a first concussion, especially when they occur during the same sport season.<sup>1-4,28,29,32,33</sup> By contrast, clinical evidence from a large number of professional football players indicates that players manifested similar signs, symptoms and recovery times in subsequent compared with initial concussions even when they occurred during the same season.<sup>6,7,11</sup>

### The Role of Neuropsychological Testing

The results of NP testing, if available for that player, can be useful in helping the physician make RTP decisions. They provide objective data regarding the player's cognitive/memory functions that are much more detailed than can be gleaned from the mental status evaluation that is part of the neurological examination.<sup>17-19,26,34-38</sup>

By comparing the results to those obtained at baseline (before the current concussion), NP tests can provide information comparing the individual player's performance after MTBI to his or her performance before the concussion occurred. Although the usefulness of such information to the clinician is unquestionable, it must be emphasized that the NP test results should not be viewed in a vacuum but rather are best used as another type of ancillary testing that adds to the physician's information about the injured athlete.

NP tests alone should not be the sole decision maker regarding RTP. It is not uncommon for post-MTBI athletes to have persistent symptoms, such as headaches or dizziness coexisting with normal (back to baseline) NP test results. Players at higher levels of sport may attempt to "game" or outsmart the NP tests by purposely underperforming when taking baseline tests and thus making it more likely that they will perform at least at their baseline after concussion when they make an honest effort. Factors unrelated to MTBI (eg, pain in parts of the body outside the head, use of analgesics or other medications, lack of sleep, anxiety related to interpersonal relationships) can adversely affect NP test performance.

Even after considering all the aforementioned factors, the physician should always adopt a cautious, conservative approach to RTP decisions and only clear the athlete medically when they have no doubt that it is completely safe for the player to return to sporting activities.

## Conclusions

The purpose of the neurological evaluation of the concussed athlete is 2-fold: (1) to determine the need for urgent brain imaging and/or neurosurgical treatment of a potential intracranial catastrophe and (2) once the need for acute neurosurgical treatment has been ruled out, to determine when (and if) the player may safely return to play. Just as all athletes are different, so are all MTBIs different. The evaluation and management of concussions needs to be done on an individual case by case basis. The cornerstone of this process is the neurological evaluation of the concussed athlete. There are many valid ways to conduct neurologic history taking and clinical examination.

In this overview, we have presented some ideas that may help team physicians in developing their own examination procedures and processes. As we have emphasized, team physicians should take a cautious, conservative approach to the management of the concussed athlete and maintain a very high index of suspicion of serious intracranial injury along with a very low threshold for recommending emergency transport to an emergency room, urgent brain imaging and/or neurosurgical and/or neurological consultation. A similarly cautious, conservative approach to making individualized RTP decisions is also recommended.

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