

Chapter 2

Definition and Classification of Concussion

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2.1 Introduction

Traumatic brain injury (TBI) is a leading cause of hospitalization and death among children and adolescents and therefore represents a major public health problem (Langlois et al. 2006). Recent estimates of pediatric TBI suggest an annual incidence of 475,000 cases for children ages 0 to 14 (Langlois et al. 2006). However, most studies of TBI prevalence (i.e., all cases) and incidence (i.e., new cases) only include injuries associated with hospitalization resulting in fewer documented cases of milder forms of TBI such as concussions (Yeates 2010). Two relatively recent population based studies in Canada have documented estimated prevalence rates for pediatric concussion at 200 per 100,000 (Gordon et al. 2006) and 135 per 100,000 (Willer et al. 2004). However, these two studies are likely underestimates of the true prevalence of concussion, as the Gordon et al. (2006) study relied on retrospective report by parents of concussion that limited daily activity, and the Willer et al. (2004) study relied on narrative descriptions made by school staff not trained in recognizing the symptoms of concussion. Data from the US Centers for Disease Control and Prevention (CDC, Langlois et al. 2006) suggest that the prevalence rate for mild TBI in children is higher than these two studies when based on emergency department visits.

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In the past decade, increased attention has been given to milder forms of TBI, such as concussion. The increased recognition and diagnosis of concussion has occurred largely in the area of sports medicine. In fact, over 50% of pediatric concussions are estimated to occur in the context of sports participation (Gordon et al. 2006). Despite this increased recognition, and resulting scientific and professional literature regarding concussions, a substantial lack of agreement persists regarding the definition and classification of concussions. The goal of this chapter is to provide a review of the definition and classification of concussions, with special attention to pediatric populations, as well as to review several nosological issues that arise during the course of both clinical and research work.

2.2 Definitions of Relevant Terms

The term “concussion” is not well defined in either clinical or research contexts, leading to confusion among patients, families, and even many health providers regarding the importance of this diagnosis. As a diagnosis, concussion is often used interchangeably with terms such as mild traumatic brain injury (mTBI), minor closed head injury, and mild closed head injury. Concussion is more often used in the sports medicine community, whereas mTBI is sometimes the preferred term in other medical specialties (Tator 2009). Many authors use the term “concussion” in reference to head injuries that result in only transient neurological deficits. Others have argued that the term concussion should be used to place an emphasis on impaired functional status following a head trauma, whereas mild head injury should be used to place an emphasis on subsequent pathophysiology (Anderson et al. 2006).

Based on a 2010 study, DeMatteo found that using the term concussion when a patient is admitted to the hospital may unintentionally communicate to parents that a “brain injury” did not occur, resulting in less than adequate follow-up with appropriate healthcare providers. Therefore, recommendations were made for using “mTBI” instead of “concussion” (DeMatteo et al. 2010). An alternative perspective is that concussion is a variant of mTBI and that the term “minimal head injury” be used in place of “concussion” to denote an injury that is not accompanied by any loss of consciousness (LOC) and yields a Glasgow Coma Scale (GCS; Teasdale and Jennett 1974) score of 15; by contrast, “mild head injury” would denote a injury with brief LOC and GCS of 14–15 (Falk et al. 2005). For the purpose of this chapter, the term “concussion” will be used interchangeably with “mTBI.” Other chapters in this work will also reflect these differences in the use of terminology.

Several organizations have attempted to provide a definition for concussion or mTBI; however, a consensus has yet to emerge. One of the earliest attempts at a definition was made in 1966 by the Congress of Neurological Surgeons (1966). In that definition, concussion was defined as “a clinical syndrome characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision, equilibrium, etc. due to mechanical forces.”

Table 2.1 Definitional criteria for concussion/mTBI

| | LOC | PTA | Mental status | Neurological signs |
|------|---------|---------------|--|---|
| ACRM | ≤30 min | ≤24 h | Any alteration in mental status at time of injury | May or may not be transient |
| AAP | ≤1 min | Not specified | Normal mental status at time of initial evaluation | None at exam, but may have seizures or other signs immediately following injury |
| WHO | ≤30 min | ≤24 h | Confusion and disorientation | Transient neurological abnormalities |

LOC Loss of consciousness, *PTA* posttraumatic amnesia, *ACRM* American Congress of Rehabilitation Medicine, *WHO* World Health Organization, *AAP* American Academy of Pediatrics

The American Congress of Rehabilitation Medicine (ACRM; Mild Traumatic Brain Injury Committee 1993) developed the following definition for mTBI:

“A traumatically induced disruption of brain function, as manifested by at least one of the following: any LOC, any loss of memory for events immediately before or after the accident, any alteration in mental state at the time of the accident, and focal neurological deficit(s) that may or may not be transient; but where the severity of the injury does not exceed the following: LOC of approximately 30 min or less, after 30 min an initial GDS score of 13–15, and posttraumatic amnesia (PTA) not greater than 24 h.”

The American Academy of Pediatrics’ definition of minor closed head injury includes the following criteria: normal mental status at the initial examination, no abnormal or focal neurological findings, no physical evidence of skull fracture, LOC of less than 1 min; and can have seizures, emesis, headache, and lethargy immediately after the injury (AAP; Committee on Quality Improvement and Pediatrics 1999). More recently, the World Health Organization (WHO) has proffered a definition similar to that of ACRM (Carroll et al. 2004):

“MTBI is an acute brain injury resulting from mechanical energy to the head from external physical forces. Operational criteria for clinical identification include (1) 1 or more of the following: confusion or disorientation, LOC for 30 min or less, posttraumatic amnesia for less than 24 h, and/or other transient neurological abnormalities such as focal signs, seizure, and intracranial lesion not requiring surgery; (2) Glasgow Coma Scale score of 13–15 after 30 min postinjury or later upon presentation for healthcare. These manifestations of MTBI must not be due to drugs, alcohol, medications, caused by other injuries or treatment for other injuries (e.g., systemic injuries, facial injuries or intubation), caused by other problems (e.g., psychological trauma, language barrier or coexisting medical conditions) or caused by penetrating craniocerebral injury”.

Each of these more recent definitions places emphasis on four primary diagnostic criteria (see Table 2.1). Although similar, the three definitions do have important differences. The AAP definition is more conservative regarding length of LOC and does not specifically include length of PTA. The three definitions also differ with regard to when alterations in mental status are documented (i.e., at the time of injury in the ACRM definition vs. at the time of initial evaluation in the AAP definition). The ACRM and WHO definitions differ primarily on whether or not focal neurological signs must be transient.

The most recent consensus definition of concussion was provided by the International Symposia on Concussion in Sports (McCrory et al. 2009). This definition, often referred to as the Zurich definition, does not place an emphasis on LOC or PTA, but emphasis is placed on the functional changes that acutely follow concussion.

2.3 Classification of Concussion

Similar to the definition of concussion, much controversy exists in research and clinical contexts regarding the classification of concussions. Concussions have been classified along diagnostic and severity spectrums. Diagnostically, the International Statistical Classification of Diseases and Related Health Problems–10th revision (ICD-10; World Health Organization 1992) includes concussion as a separate code under the broader category of “intracranial injury, excluding those with skull fracture.” Furthermore, the ICD-10 includes several qualifiers: with or without LOC; duration of LOC; and with or without return to preexisting levels. Based on the argument that concussions occasionally lead to lasting neurobehavioral problems (Brown et al. 1994) the Diagnostic and Statistical Manual of Mental Disorders–Fourth Edition (DSM-IV; American Psychiatric Association 1994) included research criteria for a related diagnosis termed postconcussional disorder. These criteria include a history of head trauma that has caused significant cerebral concussion, evidence from neuropsychological testing of difficulty in attention and memory, and three out of eight somatic and affective postconcussion symptoms, as well as evidence that these symptoms cause clinically significant impairment. The ICD-10 also lists postconcussion disorder, but does not require objective evidence of cognitive deficits or clinical impairment. The inconsistency between these two widely used diagnostic manuals leads to poor diagnostic agreement (Boake et al. 2004, 2005). In addition, the criteria for postconcussion syndrome in both the DSM-IV and ICD-10 have been shown to have limited specificity (Boake et al. 2005). The relevance of postconcussion syndrome has been addressed in both general (Mittenberg and Strauman 2000) and pediatric (Mittenberg et al. 1997; Yeates et al. 1999) populations.

The classification of concussion severity occurs along a broader spectrum of TBI. This broader classification is based on GSC score, length of LOC, and length of PTA (see Table 2.2) (Bodin and Yeates 2010). Because of the heterogeneity of TBI, not

Table 2.2 Ratings of TBI severity

| Mild | Moderate | Severe |
|---|-------------------|--------------|
| GCS = 13–15 | GCS = 9–12 | GCS ≤ 8 |
| PTA ≤ 1 h | PTA = 1–24 h | PTA = >1 day |
| LOC < 30 min | LOC = 30 min–24 h | LOC > 24 h |
| <i>GCS</i> Glasgow Coma Scale, <i>PTA</i> length of posttraumatic amnesia, <i>LOC</i> length of loss of consciousness | | |

Table 2.3 Concussion grading systems

| | Grade 1 | Grade 2 | Grade 3 |
|-------------------------------|--|--|---|
| Colorado Medical Society | <ul style="list-style-type: none"> – Confusion without amnesia – No LOC | <ul style="list-style-type: none"> – Confusion with amnesia – No LOC | <ul style="list-style-type: none"> – Any LOC |
| American Academy of Neurology | <ul style="list-style-type: none"> – Transient confusion – No LOC – Symptoms or mental status abnormalities resolve within 15 min | <ul style="list-style-type: none"> – Transient confusion – No LOC – Symptoms or mental status abnormalities last more than 15 min | <ul style="list-style-type: none"> – Any LOC |
| Cantu – revised | <ul style="list-style-type: none"> – No LOC – PTA/PCSS < 30 min | <ul style="list-style-type: none"> – LOC < 1 min or – PTA > 30 min < 24 h – PCSS > 30 min < 7 days | <ul style="list-style-type: none"> – LOC ≥ 1 min – PTA ≥ 24 h – PCSS > 7 days |

all injuries fall neatly into one of these categories. For example, an injury can result in a GCS score of 6 (severe) but with an LOC of only a few hours (moderate). In recognition of the heterogeneity of TBI, numerous attempts have been made to classify concussions according to severity grading systems (Esselman and Uomoto 1995; Slobounov, 2008). For a historical review of concussion grading systems, see Slobounov (2008). The development of concussion grading systems has been primarily spurred by the sports medicine field, given the need to provide rapid sideline assessment and triage of concussed athletes (Hunt and Asplund 2010). Although no concussion grading system is universally accepted, three systems have gained widespread usage in the late 1990s based on four criteria (Slobounov 2008), although their use varies among professions (see Table 2.3).

The Colorado Medical Society's grading system classified concussions based on presence of amnesia and LOC (Colorado Medical Society 1991). A concussion resulting in confusion without amnesia and no LOC is classified as Grade 1, whereas a concussion resulting in confusion with amnesia and no LOC is Grade 2. Under this system, any LOC results in a grade 3 concussion. The American Academy of Neurology (AAN) (1997) grading system primarily distinguished concussion grades based on presence of LOC and resolution of concussion symptoms or mental status abnormalities. As in the Colorado Medical Society's grading system, the AAN system considers any concussion with an LOC to be grade 3. Grades 1 and 2 are distinguished by the resolution of acute symptoms or mental status abnormalities (i.e., within 15 min for Grade 1 and lasting longer than 15 min for Grade 2). Cantu (2001) updated his previous grading system using data from prospective studies. This grading system extended previous attempts by including length of postconcussion symptoms, based on empirical evidence that postconcussion symptoms and PTA predict poor performance on neuropsychological tests (Cantu 2001). Absence of LOC and brief PTA and postconcussion symptoms are classified as Grade 1 or mild concussion. Brief LOC, PTA up to 24 h, and postconcussion symptoms up to 7 days is classified as Grade 2 or moderate concussion. LOC longer than 1 min, PTA longer than 1 day, and postconcussion symptoms longer than 7 days is classified as a Grade 3 or severe concussion.

A more recent distinction has been made between simple and complex concussions, depending mainly on duration of postconcussive symptoms. Introduced as a result of the 2nd International Conference on Concussion in Sport held in 2004 (McCrory et al. 2005), simple concussion was defined as an injury that resolves within 10 days, whereas complex concussion was defined as an injury with persistent symptoms (i.e., more than 10 days), convulsive convulsions, prolonged LOC, or prolonged cognitive impairment. This classification system has been criticized based on the fact that determining whether or not a concussion is simple or complex is a retrospective clinical judgment that does not assist practitioners in determining injury severity at the time of injury (Makdissi 2009). Indeed, the simple vs complex concussion classification system was abandoned in favor of just calling the injury a concussion at the 3rd International Conference on Concussion in Sport held in 2008 (McCrory et al. 2009), although the panel agreed that the majority of concussions show symptom resolution within 10 days (i.e., simple concussion).

2.4 Nosological Issues

Problems with the definition and classification of concussion have plagued efforts to conduct sound empirical research, resulting in controversy and misunderstanding amongst clinicians and families. No discussion of the nosology of concussion is complete without a discussion of the issues that drive these controversies.

2.4.1 Severity Ratings

The classic measure of head injury severity is the GCS, which is used to distinguish mild brain injuries, such as concussion, from more severe forms of TBI. One problem with the GCS is that it cannot readily be completed retrospectively (Ruff and Jurica 1999), because the symptoms assessed with the GCS typically are exhibited during the first few hours following the injury. This is a particular problem for mTBI, because a GCS score is often not recorded or available immediately postinjury in this population (Tator 2009; DeMatteo et al. 2010). An additional concern regarding the GCS is that it is often administered at different time points, leading to problems deciding which GCS score to use for documenting severity (Yeates 2010). Over time, duration of PTA has gained favor as a measure of TBI severity; however, PTA is not universally accepted as the best indicator of severity (Cantu 2001). For example, PTA is often assessed retrospectively and can be influenced by the patient's initial confusion around the time of injury (Esselman and Uomoto 1995). In addition, a patient's account of memories surrounding the injury can reflect what they have been told happened rather than events that they actually recall. Finally, few standardized measures of PTA are available. As mentioned previously, presence of LOC is often used to define and classify concussions. Evidence has emerged suggesting that LOC

does not correlate well with concussion outcomes, leading one group to conclude that LOC not be used to measure severity of concussions (Cantu 2006). Recent research has documented a correlation between duration of postconcussion symptoms and neuropsychological test performance, resulting in increased attention to postconcussion symptoms in rating concussion severity (Cantu 2001).

Neuroimaging has also been used to assist with classifying concussions. Although traditional imaging methods may not be sensitive enough to document potential structural lesions in concussions, the use of CT scans has shown impressive sensitivity and negative predictive value in defining mTBI, meaning that CT scan can be useful in identifying more severe injuries that require medical intervention (Matz 2003). Neuroimaging has also been used to demonstrate that more complicated concussions (i.e., with positive imaging findings) are more similar to moderate TBI than are concussions without imaging findings (Williams et al. 1990). Children with neuroimaging abnormalities following mild TBI have been shown to display more postconcussion disorder symptoms than those without neuroimaging abnormalities (Taylor et al. 2010) and to show poorer neuropsychological outcomes (Levin et al. 2008). More modern neuroimaging procedures that assess brain structure (i.e., diffusion tensor imaging, susceptibility weighted imaging) or function (e.g., functional MRI, magnetic source imaging (MSI), positron emission tomography, and single-photon emission CT) may hold promise in the assessment of concussions and mTBI (Ashwal 2010; Hunt and Asplund 2010; Mendez et al. 2005), but standards for clinical procedures in individual cases have yet to be developed at this time. Several recent studies have provided some support for the use of advanced imaging techniques in predicting neurobehavioral outcomes following mTBI (Levin et al. 2004; Newsome et al. 2008), but this remains experimental.

2.4.2 Grading Systems

Although grading systems were once popular in the sports medicine literature to make return to play decisions, their use has not gained wide acceptance in other clinical settings. First, empirical evidence for the majority of these grading systems is lacking (Anderson et al. 2006). In most medical settings, the criteria used in the grading systems cannot be practically gathered. For example, the AAN grading system requires documenting the duration of concussion symptoms and mental status abnormalities immediately following injury. This can be accomplished on the athletic field where team physicians and athletic trainers are available immediately after the injury and can monitor the athlete's functioning postacutely. In the context of nonsports-related concussions, however, the patient often does not receive immediate medical attention to document acute mental status abnormalities and the exact time of injury is sometimes not available to assist with documenting duration of symptoms. Finally, the majority of concussion grading systems are based on factors such as LOC and PTA, which often cannot be reliably documented in concussion populations.

2.4.3 Concussion Versus Mild TBI

As indicated in the definition section of this chapter, a major controversy exists regarding the distinction, if any, between concussion and mTBI. Is concussion the same as mTBI or do they represent different conditions? Is concussion simply a variant of mTBI? How does concussion fit into the broader TBI spectrum? A comparison of the ACRM and WHO definitions (see Table 2.1) and the TBI severity spectrum (see Table 2.2) suggests that, based on length of PTA, some injuries that ACRM and WHO define as “mild” would be considered “moderate TBI” using traditional severity ratings. This definitional confusion needs to be resolved to advance empirical and clinical understanding of concussions.

2.4.4 Complicated mTBI

Many authors and clinicians have used the term “complicated mTBI” to distinguish mild head injuries (or concussions) that result in positive neuroimaging findings. Research has provided evidence in support of the distinction, finding that individuals with complicated mTBI are more similar to those with moderate TBI in regards to measures of neurobehavioral and neuropsychological outcomes (Levin et al. 2008; Taylor et al. 2010; Williams et al. 1990). An alternative approach would be to label any injury with neuroimaging evidence of parenchymal injury as moderate TBI. This issue needs further empirical attention, especially in pediatric populations.

2.4.5 Young Children with Concussion

The vast majority of research on concussion and mTBI has been conducted with adolescents and young adults. This leaves a major gap in our understanding of the clinical presentation and sequelae of these injuries in young children (Kirkwood et al. 2006). Fortunately several investigators have begun to examine concussions in this population (Mittenberg et al. 1997; Thiessen and Woolridge 2006; Yeates et al. 1999, 2009; Yeates and Taylor 2005). Several controversial issues have emerged in research and clinical endeavors with pediatric concussion. Assessing injury severity in infants and young children can be difficult when relying on traditionally adult measures such as GCS and PTA (Yeates 2010). The GCS relies on verbal and motor components that may not be developmentally appropriate for young children. Attempts have been made to adapt the GCS to younger populations (see Durham et al. 2000). Measuring PTA in young children often relies on report from either parents or medical staff because young children may not be able to reliably provide self-report of memories around the time of injury. Objective measures of PTA have been developed, such as the Children’s Orientation and Amnesia Test (COAT, Ewing-Cobbs et al. 1990), although assessing PTA in preschool children

is problematic. Specific grading systems have not been developed for pediatric concussion, and it is unclear if pediatric concussions should be classified differently than adolescent and adult concussions.

2.5 Summary

Increased attention has been given to concussions in both research and clinical settings in the past two decades. Despite this increased attention, a consensus has not been reached regarding an exact definition of the term concussion or the classification of concussion severity. Numerous controversies exist with regard to methods of assessing severity of TBI (i.e., LOC, PTA, GCS, etc.) and systems of grading severity within concussion itself (i.e., grading systems). We cannot clearly differentiate a concussion from an mTBI, and it is unclear whether or not an injury can be classified as a concussion if parenchymal injury is present. Most empirical studies have been conducted with adolescents and young adults, leading to a large gap in our knowledge of how to define and classify concussions in infants, preschoolers, and school age children. An emerging body of research is now available about this population; however, more research is needed to guide clinical activities with these groups.

2.6 Key Points

Several definitions exist for concussion, but no consensus has been reached.
There are no specific classification systems for pediatric concussion.
There is no consensus regarding the distinction between concussion and mTBI.
There is an emerging literature regarding pediatric concussion and mTBI, but numerous nosological controversies remain.

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