CHAPTER 1.

CONCUSSION CLASSIFICATION: ONGOING CONTROVERSY

Robert Cantu, MA, MD, FACS, FACSM

Chairman Department of Surgery, Chief Neurosurgery Service, Director Services of Sport Medicine, Emerson Hospital, Concord, MA, Co-director Neurologic Sport Injury Center, Brigham and Women's Hospital, Boston, MA.

Abstract: The major objective of this chapter is to elaborate on the importance of comprehensive assessment and development of a robust grading system to identify concussion and to predict athletes at risk for brain re-injury due to premature return to sport participation. There is a growing body of knowledge accumulating in the literature and in clinical practice indicating the danger of long-term residual dysfunctions in athletes suffering from even single mild traumatic brain injury. It should be noted that several position statements elaborated by the mutual effort of numerous prominent leaders in this field have been recently proposed. These documents in general, and my contribution to this book, in specific, may assist team physicians, athletic trainers and coaches in providing optimal care for athletes who have sustained a concussion. So, possible long-terms abnormalities should not be overlooked while assessing brain injured athletes at the site of injury and monitoring these athletes during their course of recovery. Overall, to accomplish this goal, the medical professionals should have knowledge of and be involved with epidemiology, pathophysiology, evaluation/and treatment, post game-day evaluation/and treatment, diagnostic imaging, management principles, return-to-play criteria, complications of concussion, and prevention. Most importantly, one must understand that an athlete, while still symptomatic at either rest or exertion should not be allowed to return to competition. No athlete who has experienced loss of consciousness or amnesia should be allowed to go back into the event that same day. The general tenor is ***"if in doubt, sit them out"***. Additional factor that need to be considered is the athlete's total concussion history; including the number and the severity of those prior concussions. Moreover, the temporal proximity of concussions and the severity of the blow causing the concussion need to be assessed. Minor blows causing serious concussions should make a physician more hesitant to return an athlete to competition. The exact mechanisms of both short term_and long lasting abnormalities in the brain's functional, behavioral, cognitive abilities and many other overseen abnormalities as a result of concussion in athletes still remains to be elucidated. This chapter is complementary to other chapters in this book to fully realize the ongoing controversies and problems with evaluation and treatment of sport-related traumatic brain injuries.

Keywords: Concussion; Grading scales; Return-to-play guidelines.

1. INTRODUCTION

This chapter in essence outlines my presentation at the Conference "Concussion in Athletics: Ongoing Controversy". It was a pleasure to be at Penn State University and to speak at this conference. I knew this conference had been in the preparation stages for over a year and we were absolutely thrilled that this room was packed with enthusiastic minds wanting to know more about concussion. I believe it is particularly important to realize that in regard to the area of concussion there is much more beyond our current understanding that we still have to learn. Thus, the present body of our knowledge is still evolving.

Concussion is derived from the Latin word *concussus*, which means to shake violently. Initially, it was thought to produce only a temporary disturbance of the brain functions due to neuronal, or neuroelectrical changes without any gross structural damage. We now know that structural damage with loss of brain cells does occur with some concussion cases. There is so much that we do not know about the subject and I encourage any of you that have an interest in the area of mild traumatic brain injury (MTBI) to read the head injury chapter of the text I edited *Neurologic Athletic Head and Spine Injuries* in 2002. Other sources include the July 2001 issue of the *Clinical Journal of Sports Medicine*, and the October 2001 issue of the *Journal of Athletic Training*. The NATA writing group which was chaired by Dr. Kevin Guskiewicz and Margot Petukian lead to an excellent document which appeared in the *Journal of Athletic Training*. Publications of merit in this area include the 2001 Vienna and 2004 Prague Concussion Consensus statements that have been jointly published in three sports medicine journals. Finally I recommend the forthcoming American College of Sports Medicine Team Physician Concussion Statement which will be published in 2006 in *Medicine, Science, Sports and Exercise*.

Sections in these numerous publications on when to refer an athlete to neurological professionals or when to disqualify an athlete are important. When should we tell an athlete that enough is enough and they should not ever go back to a particular sport? This is still an open question. There were also sections in these publications on concussion among young athletes. We do feel that the immature brain is possibly at greater risk for concussion than the mature brain. I really appreciate that a special chapter in this book is devoted to pediatric concussion.

A couple years after the first Diana conference, a second International conference on concussion in sport was convened, in Prague, Czechoslovakia. After this conference, the sponsoring group, The International Ice Hockey Federation and FIFA has demanded that the consensus statement be elaborated. There are numerous individuals who have contributed to this elaborated statement. However, I am not personally convinced that this

revised statement is necessarily as good as the first one because it tended to try to get in to some areas where we really did not have enough prospective data to be certain that the recommendations would hold up over time. Specifically, a new concussion classification system was proposed using statements like "simple versus complex concussion". Personally, I am not aware of any "simple concussion" cases. Judging from the literature and my personal experience, all concussions are "complex" in one way or another. What appears simple can become something much more complicated in a few days post-concussion. Overall, I believe that this new position statement is confusing and may even be misleading for medical practitioners who deal with concussed individuals on a daily basis.

More recently, the American College of Sports Medicine has put together a team of experts in the field of people who study concussion in athletes. This particular group has representatives from different organizations such as the American Academy of Family Physicians, the American Academy of Orthopedic Surgeons, College of Sports Medicine, the American Medical Society for Sports Medicine, the Orthopedic Society for Sports Medicine and the Osteopathic Academy of Sports Medicine and other different professional groups. The set of documents was elaborated focusing on what was felt the team physician and quote unquote the medical team should know about the subject of treating concussion. These are the most comprehensive works that were elaborated on the issue of mild traumatic brain injury in athletics.

So, what is the nature of the controversy surrounding concussion? What is the big problem with concussion? The problem with concussion is that with the exception of the unconscious athlete or someone who is severely dazed, it is often very difficult to identify who has sustained a concussion and who has not. Concussion is unlike orthopedic injuries in which the sign of injury is external and easily observed; with concussion there are few, if any obvious external symptom at least at the site of injury.

With concussion more than 90% of cases do not involve loss of consciousness and the most mild forms of concussion can be extremely difficult to detect especially at a distance. Thus, the loss of consciousness should not be a major classification symptom of concussion. The task specifically given to me by Dr. Slobounov was to elaborate on different classification systems and some of the controversy they have generated.

2. GRADING SYSTEMS

From a chronological standpoint, the first grading system of concussion that was used in any great detail was the Nelson grading system, which was published in Physician and Sports Medicine in 1984. Beside Dr. Nelson, there was some pretty "heavy horsepower" in this group, Dr. John Jane. He

is a current editor of the Journal of Neurosurgery. This was a five-levels concussion grading system going from 0-4; the most mild being an individual who had a headache or some difficulties concentrating after a blow to the head but did not sustain any loss of consciousness or evidence of amnesia. More severe grades involved amnesia and/or progressive periods of loss of consciousness. If one was unconscious for less than one minute the subject was given a grade of 3 and if one was unconscious for more than one minute the grade given was a 4 (see Table 1).

Table 1. Nelson grading system for concussion.

Grade 0	Head struck or moved rapidly; not stunned or dazed initially; subsequently complains of headache and difficulty in concentrating
Grade 1	Stunned or dazed initially; no loss of consciousness or amnesia; sensorium clears in less than 1 minute2
Grade 2	Headache; cloudy sensorium longer than 1 minute in duration; no loss of consciousness; may have tinnitus or amnesia; may be irritable, hyperexcitable, confused, or dizzy
Grade 3	Loss of consciousness less than 1 minute in duration; no coma (arousable with noxious stimuli);demonstrates grade 2 symptoms during recovery
Grade 4	Loss of consciousness for more than 1 minutes; no coma; demonstrates grade 2 symptoms during recovery

From:Nelson WE, Jane JA, Gieck JH. Minor head injury in sports: a new system of classification and management. Physician Sportsmed. 1984;12(3):103-107.

What is important historically about this grading system is that it was focused on primarily whether or not there is loss of consciousness and its duration and/or whether or not there was amnesia. At the time this grading system was proposed there were no prospective studies of concussion and very little objective data upon which to propose a grading system. It was really the best that was available at its time.

A year later an experimental grading system proposed by Ommaya and colleagues was published based on experimental studies using primate animals (See Table 2). In reality, the last three grades in this scheme should be considered more similar to the state of a coma rather than a concussion. Therefore although it is called a concussion grading system it is really a grading system of different degrees of diffuse axonal injury. The first three grades of this six-tier system were later adopted by a Colorado Grading System. In the mild grade concussion assessment there is no amnesia. If there is amnesia, it becomes a Grade 2, if there is brief loss of consciousness,

it becomes a Grade 3. This is historically what was used in the Colorado Grading System as shown in Table 4.

Table 2. Ommaya grading system

Grade 1	Confusion without amnesia (stunned)
Grade 2	Amnesia without coma.
Grade 3	Coma lasting less than 6 hours (includes classic cerebral concussion, minor and moderate head injuries)
Grade 4	Coma lasting 6-24 hours (severe head injuries)
Grade 5	Comas lasting more than 24 hours (sever head injuries)
Grade 6	Coma, death within 24 hours (fatal injuries)

From: Ommaya AK. Biomechanics of Head Injury: Experimental Aspects . In Nahum AM, Melvin J (eds): Biomedics of Trauma. Appleton & Lange, 1985, pp 245-269

As you can see from Table 2, the grade two in the Ommaya's system is characterized by presence of amnesia without any loss of consciousness. Although, any loss of consciousness is indicative of grade three. Since this system was developed based on animal studies, it was comparatively easier to know the length of time the subjects were unconscious. In fact, this grade 3 loss of consciousness could be observed in any animal model of experimental concussions. However, it is impossible to know if concussed animal had amnesia, tenderness or lightheadedness.

A year later, without any prospective studies, we came out with a grading system that weighed heavily on whether or not the individual was unconscious and whether or not the individual had post-traumatic amnesia (Cantu, 1986). This grading system has subsequently been changed. For historical reasons, it is appropriate to look at it, but be aware that the current body of knowledge has surpassed what was known at the advent of that scale. According to grade one, way back in 1986, there should not be loss of consciousness and/or post-traumatic amnesia within thirty minutes post-injury. And if the loss of consciousness occurred and this was lasted less than five minutes, then one could consider the presence of grade two concussions. If post-traumatic amnesia is greater than thirty minutes, but less than twenty-four hours, this may also be indicative of grade two concussion. Finally, a grade three is assigned to the patient if loss of consciousness is exhibited for more than five minutes or post-traumatic amnesia persists for more than twenty-four hours. This classification scale has been revised since, as we have learned over the last 15 years, there are almost no mild concussions on athletic fields that last longer than a minute. It is very rare that concussed athletes experience loss of consciousness for more that five minutes. In great majority of concussion cases people are

unconscious for a few seconds. We probably missed a lot of concussion cases where athletes were unconscious briefly. The time frame in which athletes usually lose consciousness is on the order of five minutes or less.

Table 3. Cantu grading system

Grade 1	No loss of consciousness; posttraumatic amnesia less than 30 minutes.
Grade 2	Loss of consciousness less than 5 minutes in duration or posttraumatic amnesia lasting longer than30 minutes but less than 24 hours in duration.
Grade 3	Loss of consciousness for more than 5 minutes or posttraumatic amnesia for more than 24 hours.

Cantu RC. Guidelines for return to contact sports after a cerebral concussion. Phys Sportsmed 1986;14:76-79. Used with permission of McGraw-Hill, Inc.

In 1986, I proposed the Cantu Grading System which relied on the presence or absence of loss of consciousness and the duration of post traumatic amnesia. The most mild, Grade 1, was assigned to cases in which there was no loss of consciousness and post traumatic amnesia was brief, usually under 30 minutes. In the intermediate Grade 2, there could be loss of consciousness of less than 5 minutes duration, post traumatic amnesia greater than 30 minutes and less than 24 hours. In Grade 3 there was loss of consciousness for more than 5 minutes or post traumatic amnesia for greater than 24 hours. This grading system is still popular among medical practitioners.

Now I will focus on another system, the Colorado Grading System, which will be briefly discussed, though I will not spend too much time on it. According to this system, the presence of confusion without amnesia is an indication of Grade 1. The presence of confusion with amnesia is an indication of Grade 2. Any sign of loss of consciousness (LOC) is a grade three concussion, suggesting that if patient did not loss consciousness at the time of injury, there was mild rather than a severe concussion. However, we should not forget the cases including Steve Youngs, Meryl Hodges, Al Tune, Pat LaFontaine and numerous other professional athletes who have never been rendered unconscious at the time of injury, though had to retire because of persistent and long lasting post-concussive symptoms. I think it is inappropriate to consider these cases within the category of moderate grade, yet it costs these people their career. I would say it is a severe concussion if it causes somebody to give up their favorite sport. To reiterate, the loss of consciousness at the time of injury should NOT be considered as a primary predictor of concussion grade.

Table 4. Colorado medical society grading system for concussion

Grade 1.	Confusion without amnesia; no loss of consciousness
Grade 2.	Confusion with amnesia; no loss of consciousness
Grade 3.	Loss of consciousness

From Report of the Sports Medicine Committee. Guidelines for management of concussion in sports. Colorado Medical Society, 1990 (revised May 1991). Class III

In 1989 Barry Jordan who has made significant contributions in the concussion field especially as it relates to boxers proposed his own grading system which is a bit of a hybrid of what had preceded it. It is shown in Table 5. According to this classification system, confusion without amnesia and no loss of consciousness should be considered as grade one. This is fact quite similar to multiple other proposed classification systems of concussion. The presence of confusion with amnesia lasting less than 24 hours with no loss of consciousness is an indication of grade two.

Table 5. Jordan grading system for concussion

Grade 1	Confusion without amnesia; no loss of consciousness
Grade 2	Confusion with amnesia lasting less than 24 hours; no loss of consciousness
Grade 3	Loss of consciousness with an altered level of consciousness not exceeding 2-3 minutes; posttraumatic amnesia lasting more than 24 hours
Grade4	Loss of consciousness with an altered level of consciousness exceeding 2-3 minutes.

From: Jordan BJ, Tsairis PT, Warren RF (eds): Head Injury in Sports. In Sports Neurology. Aspen Publications, 1989, p 227.

This system is also pretty similar to a Myers Grade 2 concussion classification characterized by confusion with amnesia, but without loss of consciousness (LOC). When loss of consciousness with altered levels of consciousness not exceeding two to three minutes, or post-traumatic amnesia lasting more than twenty four hours is present, this should be considered as Grade 3. The Grade 4 assumes the loss of consciousness for a longer period of time (usually more than few minutes). Thus the hallmarks of concussion are presence of post-traumatic amnesia and loss of consciousness. Both loss

of consciousness and its duration are important determinants in terms of assessment of concussion grade.

In 1991 Joe Torg, who is much better known for his cervical spine axial load compression injuries causing quadriplegia, proposed a six-tiered grading system for concussion. This system was published in the textbook titled *Athletic Injuries to the Head, Face and Neck.* The major themes of this system can be found in Table 6. It should be noted that head injuries were only partly discussed and very major part of the book did indeed deal with the cervical spine and neck injuries. As it relates to concussion, his grading system has chiefly focused on short-term confusion and presence of amnesia at the time of injury or shortly after the incidence. He also introduced the "bell rung" term, referring to possible noise sensitivity following mild traumatic brain injury. It is important to note, that duration of transient loss of consciousness was also considered as important feature in this classification system.

Table 6. Torg grading system for concussion

Grade 1	"Bell rung"; short-term confusion; unsteady gait; dazed appearance; no amnesia
Grade 2	Posttraumatic amnesia only; vertigo; no loss of consciousness
Grade 3	Posttraumatic retrograde amnesia; vertigo; no loss of consciousness
Grade 4	Immediate transient loss of consciousness
Grade 5	Paralytic coma; cardiorespiratory arrest
Grade 6	Death

From: Torg JS. Athletic Injuries to the Head, Neck, and Face. St. Louis, MO:Mosby-Year Book; 1991, p226.

As can been seen from Table 6, the most prominent symptoms of mild grades of concussion include some confusion, but no amnesia. Within **Grade 2**, there was presence of some post-traumatic amnesia. By definition, Torg referred post-traumatic *antrograde amnesia* as synonymous with post-traumatic amnesia. In other words, difficulties with cognitive abilities must be present from the moment of concussion and further on as concussion progressed. According to this system anterograde amnesia was considered in conjunction with loss of consciousness (LOC).

On the other hand, retrograde amnesia, if it was present without LOC may be indication of Grade 3. Grade 3 may also be assigned if any sign of LOC was present at the time of injury. Grades 5 and 6 are really not concussion any more. These cases should be considered severe brain injuries rather than mild traumatic brain injuries (i.e., concussion). Here, two basis categories are considered (i.e., amnesia and LOC). Loss of

consciousness, regardless how long it was present at the site of injury was considered as severe brain injury.

One year later, Bill Roberts who is a primary care sports medicine specialist in Minnesota and a Past President of the American College of Sports Medicine, proposed his grading system which can be found in Table 7. Both, loss of consciousness and post-traumatic amnesia were critical indices of this system. Lack of symptoms such as LOC or amnesia and presence of other symptoms less than 10 minutes was classified as either what you call "Bell Ringer" or grade zero. Grade 1 was when post-traumatic amnesia was less than thirty minutes, but more than ten minutes with no loss of consciousness. Grade 2 was loss of consciousness less than five minutes, and post-traumatic amnesia present greater than thirty minutes. The more severe one was loss of consciousness greater than five minutes and post-traumatic amnesia greater than twenty four hours. So, Dr. Roberts and I probably shared some of the same thoughts that originally proposed in 1986.

Table 7. Roberts grading system of concussion

Bell Ringer.	No loss of consciousness; no posttraumatic amnesia; symptoms less than 10 minutes
Grade 1.	No loss of consciousness; posttraumatic amnesia less than 30 minutes; symptoms greater than 10 minutes
Grade 2.	Loss of consciousness less than 5 minutes; posttraumatic amnesia greater than 30 minutes
Grade 3.	Loss of consciousness greater than 5 minutes; posttraumatic amnesia greater than 24 hours

From: Roberts WO. Who plays? Who sits? Managing concussion on the sidelines. Phys Sportsmed 1992; 20:66-76.

The same individuals that wrote the Colorado Grading System subsequently came up with the American Academy of Neurology Grading System which was published in *Neurology* in 1997. It is basically similar to the Colorado Grading System except that there were some time limits placed on the Grade 1 concussions which by definition was transient confusion with no loss of consciousness and symptoms all resolving within 15 minutes. If they did not resolve within 15 minutes it became a Grade 2. Grade 3 was any loss of consciousness no matter how brief.

Based on recent work that we had done, with Kevin Guskiewicz, Mark Lovell and Mickey Kohn as well as with the founder of Hiplounder, Dave Erlounder, we came up with a revision of our original grading system. We fully realized that five minutes of being unconscious is not what happens on

athletic fields. A one minute duration of symptoms became the cut-off point between a moderate and a severe concussion provided that there was a loss of consciousness. Moreover, all post concussion symptoms, not just LOC, should be considered important features of concussion that may be used as classifiers. They are all important in terms of managing individuals with brain injury because we do not want people return to play while they still have post concussion symptoms. Also, the symptoms such as post-traumatic amnesia, headaches, balance problems lasted less than thirty minutes were considered as primary classifiers of Grade 1.

Table 8. ANN practice parameter (Kelly and Rosenberg) grading system.

Grade 1	Transient confusion; no loss of consciousness; concussion symptoms or mental status abnormalities on examination resolve in less than 15 minutes
Grade 2	Transient confusion; no loss of consciousness; concussion symptoms or mental status abnormalities on examination last more than 15minutes
Grade 3	Any loss of consciousness; either brief (seconds) or prolonged (minutes)

From: Kelly JP, Rosenberg JM. The diagnosis and management of concussion in sports. Neurology 1997; 48:575-580

Starting with the work of Lovell as well as that of Erlanger, subsequent prospective studies as have the Vienna and Prague consensus statements and American College of Sports Medicine Team Physician Statement on concussion, all refute the notion that brief loss of consciousness represents a serious concussion.

Table 9. Data driven Cantu revised concussion grading system

Grade 1	No LOC* PTA‡/PCSS‡‡ < 30 min (Mild)
Grade 2	LOC <1 min or PTA > 30 min <24hrs, other (Moderate), PCSS >30 min <7days
Grade 3	LOC ≥ 1 min or PTA ≥ 24 hrs, PCSS > 7 days (Severe)

*Loss of consciousness
‡Post-traumatic amnesia (anterograde/retrograde)
‡‡Post-concussion sign/symptoms
Cantu, RC Post-tramatic (retrograde and anterograde) amnesia: pathophysiology and implications in grading and safe return to play. J of Athletic Training 36(3)244-248, 2001

The final grading system that I wish to discuss and the one which is based on prospective studies is the Data Driven Cantu Revised Concussion Grading Guidelines. This current grading system was published in the *Journal of Athletic Training* in 2001 and shown in Table 9. This is the only concussion grading scale where all post concussion symptoms are taken into consideration with extra weight given to post traumatic amnesia. In that grading scale the most mild grade involves no loss of consciousness, brief post traumatic amnesia and/or other post concussion symptoms, all of which are under 30 minutes of duration. The intermediate grade involves brief loss of consciousness of less than one minute, post traumatic amnesia greater than 30 minutes but less than 24 hours, or other post concussion symptoms greater than 30 minutes but less than one week. Finally the Grade III under that guideline involves loss of consciousness greater than one minute or post-traumatic amnesia greater than 24 hours and/or other post concussion symptoms greater than seven days. I would urge people neither grade their concussed athletes nor treat these athletes until information until all the symptoms have cleared. There is a growing agreement between professionals that the duration of the post concussion symptoms is a very significant component of how severe the head injury an athlete experienced. Again, in the previous grading systems the emphasis was given to presence and duration of post-traumatic amnesia and loss of consciousness. We believe that all concussion symptoms should be carefully considered and included in classification model of concussion in athletics. These post concussion symptoms can be found in the Post Concussion Signs and Symptoms Checklist in Table 10.

Table 10. Post Concussion Signs/Symptoms Checklist

Bell rung	**Memory deficits**
Depression	**Nausea**
Dinged	**Nervousness**
Dizziness	**Numbness/tingling**
Drowsiness	**Poor balance**
Excess sleep	**Poor coordination**
Fatigue	**Poor concentration**
Feel "in a fog"	**Easy distraction**
Feel "slow down"	**Ringing in the ear(s)**
Headache	**Sadness**
Inappropriate emotions	**Light intolerance**
Personality change	**Noise intolerance**
Irritability	**Anxiety**
LOC	**Confusion**
Loss of orientation	**Stupor**

Note: A PCSS checklist is used not only for the initial evaluation but for each subsequent follow-up assessment which is periodically repeated until all PCSS have cleared at rest and exertion.

It should be stressed again that there are a number of other grading systems that might be considered from both historical and conceptual perspectives. Just a few are discussed above, emphasize overall, the existing lack of consistency as well as the controversies in assessing athletes suffering from traumatic brain injury. More sophisticated scientific data driven assessment scales and numerical categories of concussion need to be elaborated in the future.

2.1. Post-traumatic Amnesia

Apart from loss of consciousness, the most distinctive feature of concussion is the occurrence of traumatic amnesia. The traumatic amnesia may be used to describe an assortment of memory deficits. There are two types of post-traumatic amnesia: retrograde and anterograde amnesias. Although, there was some tendency to ignore the differences between these two types of post-traumatic amnesia. Retrograde amnesia is memory deficits prior to traumatic injury. Specifically, retrograde amnesia is the total loss of the ability to recall events that have occurred prior to brain injury. Athletes usually are unable to recall such things as the name of the stadium they played in, name of opponents they played against, color of the uniform they were wearing, etc. On the other hand, anterograde amnesia is characterized by memory deficits following the traumatic brain injury. The duration of anterograde amnesia has often been found to be a generally accurate guide to the severity of the head trauma. The retrograde amnesia may progressively shrink during the post-traumatic recovery. Eventually, bouts of amnesia may last for only few seconds. It is important to stress, though, that post-traumatic amnesia is quite different from and should not be confused with post-traumatic loss of consciousness (LOC).

Retrograde Amnesia

"Partial or total loss of ability to recall events that have occurred during the period immediately preceding brain injury"

From: Cartidge NEF, Shaw DA: Head Injuries p 53 London 1981, WB Saunders

The testing of retrograde amnesia can be done according the format shown in Table 11. The testing of retrograde amnesia should be predominantly done at the side line following traumatic brain injury. Thus,

proper assessment of memory deficits and associated cognitive dysfunctions should provide a basis for classification of severity of concussion.

Table 11. On site assessment of retrograde amnesia in athletics

- **Score prior period**
- **Score at time of hit**
- **Name of stadium**
- **Name of opponent**
- **Components colors**
- **Details of the hit, the play, etc.**

The duration of posttraumatic amnesia is considered a clinical indicator of the severity of the injury.*

From: Cartidge NEF, Shaw DA; Head Injury, London 1981. WB Saunders

Anterograde amnesia is really what you are testing using computerized test batteries. This type of amnesia is related to deficits in forming new memoryies episodes. A concussive blow received in close proximity to a particular event results in memory loss of this event. It is known that memory initially encoded in a short–term labile active state and is therefore especially vulnerable to elimination by disturbing events such as a concussion. To test for anterograde amnesia at the time of incidence, it is recommended having an athlete repeat six digits and count forward and backward few times. Also, anterograde amnesia is usually accompanied by decreased attention. Inaccurate perception of events is another symptom accompanying anterograde amnesia present right after a concussive blow. Detailed neuropsychological testing will definitely pick up these dissociated cognitive deficits. There are other manual sheets available in the clinical practice that can be used to assess these neuropsychological functions in order to properly manage concussion. The testing of anterograde amnesia can be done according to following format shown in Table 12.

Table 12. On site assessment of retrograde amnesia in athletics

- **Repeat months of year backward starting with present month**
- **Repeat days of week backward starting with current day**
- **Repeat six digits forward and then backward**
- **Repeat four dissimilar objects immediately and at 2 minutes**

2.3. Loss of consciousness (LOC)

First of all, it is important to note that consciousness remains an elusive concept due to the difficulty of defining what has been regarded for many years as a subjective experience, therefore irrelevant for scientific study (Tassi & Muzet, 2001). According to these authors, consciousness, vigilance, arousal and alertness may involve different functional entities, which are probably not linked by single monotonous function. Consciousness at its different levels may essentially refer to awareness and the building up of mental representations with or without the possibility of patients' verbal responses. Clearly, verbal responses should not be used to assess the state of consciousness. On the other hand, vigilance may reflect the attentional capacities and mental resources at every moment. Arousal is, according to these authors, the only state immediately dependent on physiological status. Finally, alertness may reflect a subjective feeling of well-being related to the level of arousal and vigilance. In the following discussion, the very general concept of consciousness reflecting the subject' awareness and alertness will be used while defining consciousness and loss of consciousness (LOC). Sudden temporary loss of awareness is the most characteristic and enigmatic symptom of concussion (Shaw, 2002). According to Plum & Posner (1980), the maintenance of consciousness is dependent upon a complex interaction between brainstem, thalamus, hypothalamus and cortical activity. Conversely, loss of consciousness will occur following diffuse bilateral impairment of cortical activity.

With regard to the issue of loss of consciousness in terms of the grading of concussion, there are now a number of papers that have prospectively studied concussion. The central message from these papers clearly shows that a brief loss of consciousness is not necessarily associated with concussion severity. Previous assumptions that a concussion was present only when individuals remained unconscious for a a long amount of time are just not right.

Joe Maroon and Mark Lovell were the first who raised this concern in studying individuals that were briefly concussed. Concussion both in athletic and non-athletic events may be present within any even brief loss of consciousness. Specifically, one group of subjects who were unconscious and another without LOC at the time of brain injury were tested using standard neuropsychological test batteries. No differences in terms of cognitive scores were observed between these two groups of subjects. It can be inferred that LOC did not significantly influence the degree of cognitive deficits later on in recovery process. Neither the severity of concussion nor the rate of recovery following the concussion correlated with duration of LOC at the time of concussive blow. However, athletes who experienced retrograde and/or anterograde amnesia between 24 hours and forty-eight

hours following concussion scored poorly on neuropsychological tests. Overall, it was clearly shown that loss of consciousness did not predict any measurable neuropsychological deficit.

Erlanger and his group (2003) presented similar findings regarding the LOC as an index of severity of concussion. The study attempted to correlate subjects' memory complaints with that of poor scores on neuropsychological tests. Again, this study demonstrated that loss of consciousness was uncorrelated with severity of brain injury. Moreover and quite surprisingly, even a history of a prior concussion was not correlated with overall duration of symptoms and numbers of symptoms.

Erlanger and his group conducted a second study in which group of concussed individuals were tested. Similar to their first study, there was no correlation found between LOC and severity of concussion. However, most of the concussed individuals reported memory deficits. The amount and duration of memory deficits were the most significant classifiers and predictors of concussion severity. This is really not a great surprise because what is being studied in those neuropsychological test patterns is predominately anterograde memory function. Another research group from the Pittsburg area (Lovell et al., 2003) also found statistical differences between athletes suffering Grade 1 versus Grade 2 and Grade 3 concussion in memory levels at four and seven days post-injury. In this series of studies no correlation was found between LOC and severity of concussion.

Dr. Guskiewicz and his group (2001) in their NCAA study had a significant pool of subjects with brain injury that showed numerous cognitive and behavioral deficits at seven days post-injury. There were some cases in which concussed athletes surprisingly performed poorly at 90 days post-injury. This infers that residual cognitive and behavioral abnormalities may be present even after other clinical symptoms are resolved. Thus, athletes who may be "clinically asymptomatic" may experience long-term cognitive deficiencies. The type of memory symptoms and duration of these symptoms as related to severity of concussion are summarized in the following table 13.

Table 13. Concussion Severity – Symptom Type by Duration of Symptoms

Symptoms/signs	*yes/no*	*Number*	*P*
Concussion Resolution Index	yes	24	.005
Impairment Score	no	20	.002
Memory Complains at 24-48 hours follow-up	yes	15	.003

Dizziness at Side-line	yes	37	.144
Irritability at 24-48 hours follow-up	yes	13	.377

Adjusted R Squared = .449

Cognitive impairment and memory complaints at 24-48 hour follow-up predicted duration of symptoms. LOC and a history of concussion were not associated with overall duration of symptoms. Analysis includes all symptoms significantly correlated with duration of symptoms.

From: Erlanger, Kaushik, Cantu, Barth, Broshek, and Freeman J Neurosurg 2003

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3. SECOND IMPACT SYNDROME

In the interest of space, I am not going to fully cover the topic of *second impact syndrome*, as this is extremely significant phenomenon which deserves special consideration. However, I would like to stress that *second impact syndrome* is a real occurrence that we should be aware of. There has been some discussion and inconsistent opinions among medical practitioners in terms of definition of this severe phenomenon. . When first described by Schneider, he did not call it *second impact syndrome*. It has been called by a variety of names such as cumulative brain trauma or multiple close head injury. *Second impact syndrome*, repetitive brain injury, or cumulative syndrome, despite variations in the terminology, is the most common cause of fatality in athletics. I personally frequently refer to this condition as second impact syndrome partly because it was proposed by Saunders and Harvall in a JAMA article back in 1984 and first described by Schneider. Basically, this term can be defined as the case in which an individual still has post-concussive symptoms but is allowed to return to sport participation, at which time he or she may be subjected to a second head injury. As a result, a very catastrophic thing may occur, including the loss of regulations. This is most often is fatal in children.

What Saunders and Harbaugh called the *second impact syndrome* of catastrophic head injury in 1984 was first described by Schneider in 1973.

We continue to see this severe head trauma every year. Surgically, we can see it in its pure form without any sign of subdural hematoma. There are at least five cases that I am personally aware of and have been involved with. In all of these cases, there was only a small amount of subdural blood, so technically, this injury was called a subdural hematoma. However, these injuries were actually massive brain swellings. As a result, there was

complete loss of regulation and all consequences associated with it. This type of damage is now termed *Second Impact Syndrome*. The usual time course and development of second impact syndrome can be illustrated in the following Table 14.

Table 14. Development of second impact syndrome

- **Typically, the athlete suffers post-concussion symptoms after the first head injury;**
- **These may include visual, motor, sensory or labyrinthine symptoms and/or difficulty with thought and memory;**
- **Before these symptoms resolve – which may take days or weeks – the athlete returns to competition and receives a second blow to the head;**
- **The second blow may be remarkably minor;**
- **Perhaps involving a blow to the chest, side, or back that merely snaps the athlete's head and imparts accelerative forces to the brain;**
- **The athlete may appear stunned but usually remains on his or her feet for 15 seconds to a minute or so but seems dazed, similar to someone suffering from a grade 1 concussion without loss of consciousness;**
- **Once brain herniation and brainstem compromise occur, coma, ocular involvement, and respiratory failure precipitously ensue;**
- **This demise occurs far more rapidly than that usually seen with an epidural hematoma;**

Initially, the second impact can occur in the same contest in the mild form, but the history of previous blows may play a critical role. Here is a typical scenario of the development of second impact syndrome. The athletes may receive a second or third concussive blow within a short period of time while engaged in same sport contest. Upon getting up from their fall, they may, for a minute or two they appear stunned or dazed. In this situation, as it is difficult to observe any unusual signs or behavioral symptoms after the first couple of minutes, they may walk off the field on their own, without any aid. They may or may not come back to the field and what happens in the next three or four minutes sets apart from anything else that one may experience. There is usually no subdural blood initially at the time of a single injury. However, this is evolving process producing problems such as converting athletes with brain injury from a conscious wakeful state to unconsciousness. Then, over the next two minutes this evolving process ended up with brain herniation. What happens in *second impact syndrome* is that individuals experience rapidly transition from the state of being awake to being a little dazed, and then suddenly to being

comatose, with fixed dilated pupils and respiratory difficulty. Brain herniation occurs because of a massive increase in intracranial pressure which ensues much faster than blood clots can get bigger. If you ever had the opportunity to see it you would not want to see it twice because the brain is coming out like cheesecake.

There are different treatment protocols depending upon the injury classification, symptoms progression and resolution. These treatment protocols can be summarized in the following Table 15.

Table 15. Treatment protocol for second impact syndrome

- **On-field treatment of SIS requires rapid intubation, hyperventilation (to facilitate vasoconstriction by lowering blood carbon dioxide levels), and intravenous administration of an osmotic diuretic (such as 20% mannitol);**
- **Foley catheter is necessary to handle the osmotic diuresis;**
- **Unconscious athlete who sustains a head injury is transported with his or her neck immobilized;**
- **On-field treatment of SIS requires rapid intubation, hyperventilation (to facilitate vasoconstriction by lowering blood carbon dioxide levels), and intravenous administration of an osmotic diuretic (such as 20% mannitol);**
- **Foley catheter is necessary to handle the osmotic diuresis;**
- **Unconscious athlete who sustains a head injury is transported with his or her neck immobilized;**
- **At the hospital, a CT or MRI scan of the head may be nearly normal;**
- **May show small ventricles and obliterated perimesencephalic cisterns consistent with increased intracranial pressure;**
- **Occasionally a small thin subdural hematoma may be seen, but midline shift is greater than accounted for by subdural hematoma;**

4. RETURN-TO-PLAY AFTER CONCUSSION

Guidelines for return-to-play after a first concussion can be found in Tables 16-19 reflecting those published by myself and those published by Colorado Medical Society which are currently most widely used in clinical practice. It is important to note, however, that all these guidelines are not founded on prospective data but rather reflect personal experience and common practice. They are best estimates of a way to manage concussion in athletics. We definitely should face the reality that many athletes suffering from concussion are not recognized and properly treated. And, even if a concussion is recognized at the time of injury, premature return to play

solely based on some symptoms resolution may create further problems including a second brain injury with all these consequences including fatality. The major problem with return-to-play criteria is related to the lack of prospective experimental data on individual responses to concussion. For instance, neuropsychological data (such memory and other cognitive scores) and subjective symptoms reported by injured athletes are often uncorrelated. Moreover, symptom reports document variability in patient responses, even though they experience a similar type of concussive blow. A more complex situation is observed when athletes have experienced two or more concussive blows. Following multiple brain injuries, symptoms resolution and recovery from injury are quite individual and most often unpredictable. Therefore, it is a real challenge for medical practitioners to make a decision regarding the time at which injured athletes are ready for a safe return to sport participation.

There are many factors that should be taken into consideration before allowing an athlete to return to play after a concussion. Among these are: clinical history, number of previous concussions, severity of previous brain injuries, current results of clinical evaluation, etc. In general, if an athlete has any symptoms on the field or outside, this athlete should not be allowed to resume athletic practices, especially in contact sports. Another general rule that should be observed, is that criteria for return to sport participation in asymptomatic athletes should be the same for all sports, regardless of the degree of contact or use of protective devices. If neuropsychological evaluation is used, special caution should be exercised by medical practitioners, because the athlete's motivation, peer pressure or pressure from coaching staff may be a serious confounding factor. In fact, I am pleased that a special chapter in this book is devoted to the issue of athletes' motivation during neuropsychological assessment both at baseline (before the occurrence of any head trauma) and particularly after concussion. Finally, it cannot be assumed that an athlete is asymptomatic when he or she "feels fine" based on subjective reports, since, as I previously mentioned, subjective feeling may not be correlated with objectively obtained clinical evaluation.

Table 16. Cantu guidelines of return to play after a first concussion

Grade	**Recommendations**
1	May return to play if asymptomatic* for one week
2	May return to play if asymptomatic* for one week
3	Should not be allowed to play for at least one month. May then return to play if asymptomatic* for one week

* rest and exertion (Cantu et al., 1986).

It is common practice now that athletes suffering from brain injury should not return to sport participation until neuropsychological testing is done and this athlete is reported as asymptomatic at least one week post-injury. Recently, number of studies clearly demonstrated diagnostic value of balance testing. Several guidelines include balance testing in addition to standard neurological exams for evaluation of athletes who have sustained brain injuries. Unfortunately, there are no neuroanatomic, physiological or diagnostic neuroimaging data that can be used to precisely determine the extent of brain injury in concussion, the severity of metabolic dysfunction or the precise moment it has cleared. Normal neuroimaging data would not warrant clearance of post-concussive symptoms. Therefore, a clinical decision as to when to allow an athlete to return to play after concussion should not be made solely on the basis of results of neuroimaging tests. Rather, a clinical decision should be made based on the presence of other symptoms such as dizziness, slowness in responding to questions, evidence of difficulty concentrating, physical sluggishness, memory deficits, especially retrograde amnesia. Athletes who experience retrograde amnesia do not usually fully recover during the athletic contest. This sign is a strong predictor of injury classification.

Table 17. Colorado medical Society Guidelines for return to play after first concussion.

Grade	Recommendations
1	May return to play if asymptomatic* at rest and exertion after at least 20 minutes observation.
2	May return to play if asymptomatic* for 1 week.
3	Should not be allowed to play for at least 1 month. May return to play if asymptomatic* for 2 weeks.

*rest and exertion

From: Kelly JP, Nicholas JS, Filley CM, et al. Concussion in sports: Guidelines for the prevention of catastrophic outcomes. JAMA 1991;266-2867; Report of the Sports Medicine Committee for the management of concussion in sports. Colorado Medical Society, 1990 (revised May 1991). Class III

Whether an athlete has been unconscious is, of course, important in terms of the return to play decision. It is generally believed that the degree of brain injury is indicated by the depth and duration of the unconscious state. While not diminishing the importance of being rendered unconscious, it is inappropriate to make a decision of return to play solely on this symptom. I find it illogical to assess as less severe the concussion occurring

without LOC that produces post-concussive symptoms which last months or years than the concussion which results in brief LOC and a resolution of all post-concussive symptoms within a few minutes or hours.

Regarding the clinical history, medical practitioners should be aware that athletes who have had a concussion will more than likely have further concussions due to possible cumulative brain trauma. According to Dr. Guskiewicz, once a player has incurred an initial cerebral concussion, his or her chances of incurring a second one are 3 to 6 times greater than for an athlete who has never sustained a concussion. One causes for this is a premature return to play based solely on clinical symptoms resolution. A sobering reality is that the ability to process information may be reduced after a concussion, and the severity and duration of functional impairment may be greater with repeated concussions. Damaging effects of the shearing injury to nerve fibers and neurons are proportional to the degree to which the head is accelerated and that these changes may be cumulative. Taking into consideration the differential responses to single versus multiple concussions in terms of symptoms duration and symptoms resolution, special guidelines for return to play following multiple concussion were proposed.

Table 18. Cantu Guidelines for Return to Play After a Second or Third Concussion

Grade	**Second Concussion**	**Third Concussion**
1	Return to play in 2 weeks if asymptomatic	Terminate season
2	Minimum of 1 month	Terminate season
3	Terminate season; may return to play next season if asymptomatic*.	

From Cantu RC, Guidelines for return to contact sports after a cerebral concussion. Phys Sportsmed 1986;14:76-79. Used with permission of McGraw-Hill, Inc.

There is some evidence which suggests that high school athletes who suffer more than three concussions may experience more concussion symptoms. Moreover, these symptoms may be more severe and last longer. It is also important to document a history of previous concussions in terms of severity. There is definitely an interaction effect between number and severity of previous concussions that should be considered in terms of return to play criteria. A few anecdotal facts suggest that even extremely mild multiple concussions may lead to a carrier ending catastrophic injury. Brett Lingros, Al Toon, Jim Miller, Steve Young, and Merill Hodge are professional athletes whose carriers were ended by numerous mild

concussions without LOC, which produced sustained long-term post-concussion symptoms.

Table 19. Colorado Guidelines for Return to Play After a Second or Third Concussion

Grade	Second Concussion	Third Concussion
1	Terminate contest or practice play if without symptoms for at least 1 week.	Terminate season; may return to play in 3 months if without symptoms.
2	Consider terminating season may return to play in 1 month if without symptoms.	Terminate season; may return to play next season if without symptoms.
3	Terminated season; may return to play next season if without symptoms.	Terminated season; strongly discourage return to contact or collision sports.

From: Kelly JP, Nicholas JS, Filley CM, et al. Concussion in sports: Guidelines for the prevention of catastrophic outcomes. JAMA 1991;266-2867; Report of the Sports Medicine Committee for the management of concussion in sports. Colorado Medical Society, 1990 (revised May 1991). Class III

Overall, universal agreement cannot be reached in the case of concussion grading and in case of return-to-play criteria. However, there is unanimous agreement that an athlete still suffering post-concussion symptoms at rest and exertion should not return to sport participation. There can be significant pressure placed on both athletes as well as medical practitioners to return the athlete to practice and play as soon as possible after the brain injury. However, returning to play may be delayed because of concern about susceptibility to a second brain injury. Partial returning to practice may be a reasonable means of maintaining physical conditioning while awaiting full recovery. This decision should be made on individual basis.

CONCLUSION

It is important to understand that all of the guidelines agree in not returning an athlete to competition until they have a normal neurologic examination, and they are asymptomatic at rest and exertion, a neuropsychological test battery is baseline or above, and if done, a CT or MRI of the head shows no intracranial lesions that place the athlete at increased risk. Most importantly one must understand that an athlete, while

still symptomatic at either rest or exertion should not be allowed to return to competition. No athlete who has experienced loss of consciousness or amnesia should be allowed to go back into the event that same day. The general tenor is ***"if in doubt, sit them out".***

Additional factors that need to be considered include the athlete's total concussion history; including the number and the severity of those prior concussions. Moreover, the temporal proximity of concussions and the severity of the blow causing the concussion need to be assessed. Minor blows causing serious concussions should make a physician more hesitant to return an athlete to competition. The exact mechanisms of both short term and long lasting abnormalities in the brain's functional, behavioral, cognitive abilities and many other overseen abnormalities as a result of concussion in athletes still remains to be elucidated.

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