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Review

Mild traumatic brain injury

Geoffrey Ling[1,2,3,5,*], Peter Abdelmalik[2], Jamie Grimes[3] and James Ecklund[3,4,5]

[1]Department of Neurosciences Research, Inova Fairfax Hospital, 3190 Fairview Park Drive, Suite 550, Falls Church, VA 22042; [2]Department of Neuro Critical Care, Johns Hopkins Medical Institutions, 1800 Orleans St. Baltimore, MD 21287; [3]Department of Neurology, Uniformed Services University of the Health Sciences (USUHS), 4301 Jones Bridge Road, Bethesda, Maryland 20814; [4]School of Medicine, Virginia Commonwealth University, Gateway Building, 1200 E. Marshall St., Richmond, Virginia 23284; [5]Department of Neurosurgery, Inova Fairfax Hospital, 8503 Arlington Blvd., Suite 200, Fairfax, VA 22031, USA.

ABSTRACT

Mild traumatic brain injury or concussion is a very common condition, occurring with increasing frequency. In the U.S., approximately 1.7 million traumatic brain injury (TBI) patients seek medical care, and worldwide there are about 10 million cases per year. However, it is likely these numbers grossly underestimate the burden of disease and the actual cases are much higher. The media, the U.S. Department of Defense, and medical providers have heightened public awareness regarding concussion. A variety of clinical tools have been developed to identify concussion at the point of injury. Clinical practice guidelines have been introduced. Although treatment remains supportive, with proper care, the prognosis for a full recovery from concussion is excellent.

KEYWORDS: traumatic brain injury (TBI), concussion, chronic traumatic encephalopathy (CTE), diagnosis.

INTRODUCTION

Mild traumatic brain injury or concussion is a very common condition. Mild TBI refers to the grade and type of injury sustained by a patient. Concussion is the clinical syndrome. In practice in the U.S., both terms are used interchangeably [1]. Of the 3 grades of TBI, mild is the most common. Although its name is benign, concussion is not. Sufferers can be profoundly impacted with symptoms lasting months and, occasionally, years.

Until recently, mild TBI was underappreciated by both the medical community and lay public. Over the past decade, there has been increased awareness that concussion is a serious injury and that a formal approach must be taken to diagnose and treat patients. This awareness first stemmed from the wars in Iraq and Afghanistan, where TBI became known as the signature wound of war, and was followed by concussion concerns in professional athletes.

The media has served to raise awareness of the importance of concussion, encourage objective diagnostic approaches and find effective treatments, and the medical profession has responded to their call to action. Medical providers are conducting epidemiologic studies, developing diagnostic criteria, and updating guidelines for treating concussion.

Background

Traumatic brain injury (TBI) is a serious and common affliction. Mild TBI, or concussion, is an injury to the brain that results in temporary loss of normal brain function, usually due to a blow to the head. A concussion can be present without any external signs of head trauma or loss of

*Corresponding author: Geoffrey.Ling@Inova.org

consciousness. The American Association of Neurological Surgeons defines concussion as a clinical syndrome characterized by immediate and transient alteration in brain function, including alteration of mental status and level of consciousness, resulting from mechanical force or trauma [1].

Mild TBI or concussion is especially common. In the U.S., the Centers for Disease Control and Prevention (CDC) reports that each year there are about 1.7 million TBI patients who presented to medical care [2]. Worldwide, the WHO reports about 10 million cases per year [3]. However, it is widely accepted that these are both gross underestimations of the burden of disease. It is likely that more accurate numbers are many-fold higher. From the existing data, it is certain that TBI is increasing. Again, according to the CDC, in 2001, the rate of TBI presentation to an emergency department was 521/100,000 patients. By 2010, the rate increased by 37% to 715.7 visits/100,000. In both 2001 and 2010, about 85% of these patients were managed as outpatients, suggesting that these were mild TBI or concussion cases. Thus, by a very large margin, concussion remains the predominant TBI [4].

A self-reported NPR-Truven Health Analytics Health Poll conducted in March 2016 found that 23 percent of people surveyed said they had suffered a concussion at some point in their lives, and more than three-quarters had sought medical treatment for concussion [5].

Both the medical and lay communities have traditionally underappreciated mild head injury. Now, however, the recognition that concussion can have long-term pathological sequelae has resulted in concussion laws. All 50 states in the U.S. and the District of Columbia have concussion laws [6]. Although each may have unique elements, all of them share 3 common elements. First, players who may have suffered concussion must be immediately removed from play. Second, the player may not return to play until written authorization is obtained from a licensed health care provider. The athlete, coach and parents do not have the authority to make the return-to-play determination. Third, the organization responsible for play must make educational resources available to coaches, parents and athletes.

Another important contributor to the emerging awareness is the Department of Defense (DoD). While moderate and severe traumatic brain injuries are readily apparent, concussions had previously been deemed insignificant and often overlooked due to the less obvious symptoms. During the Global War on Terror, the DoD initiated an important epidemiologic effort, the Armed Forces Health Surveillance (AFHS). From Operation Iraqi Freedom (OIF) and Operation Enduring Freedom in Afghanistan (OEF), data revealed the high prevalence of TBI, of which concussion predominated [7]. Because of this, the DoD issued a general order (DTM-09-033) that required every service member who was involved in an incident in which they might have suffered a mild TBI be screened for concussion [8]. Importantly, the burden of responsibility for TBI screening was placed on commanders, not patients. This ensured that all potential TBI victims would be identified. If screening revealed a risk of concussion then referral to an advanced health care provider for further work-up was mandated. Furthermore, the service member could not return to duty until cleared to do so by the advanced health care provider. The military also instituted a comprehensive “system of care” in the war theater. Concussion care centers were established in the war zone with combat units. Each center was staffed by an occupational therapist and was co-located with both medical and combat stress personnel. In this way, concussion patients could receive focused, comprehensive concussion therapy as quickly as possible. Additionally, these care centers provided an expectation of early return to duty, and eliminated the need for injured service members to be evacuated out of theater.

Etiology

Concussion is caused by several injury mechanisms [2, 4]. The most common cause is due to falls. Falling accounts for about 50% of TBI suffered by young children (0-14 years old) and over 60% among adults aged 65 years and older, followed by motor vehicle accidents, and sports-related injury. Assault is a less prevalent cause, contributing to about 10% of TBI. In the military, explosive blast has been shown to be a cause of concussion [9, 10].

The mechanism of injury begins with the head moving faster than the brain [11, 12]. Because the brain resides in a fluid-filled bony skull, it will move slower than the head. When the head comes to an abrupt stop, the still moving brain will strike the inner table of the skull. If the brain rebounds, it can also strike the opposite side of the inner skull table, resulting in a coup-contrecoup injury, causing an additional contusion. If the head is focally struck as with a club, the brain will still strike the skull's inner table, and develop a contusion at the site of impact. This will lead to a cascade of secondary injury processes, which include excitatory amino acid release, calcium flux and activation of neuro-inflammatory mediators [13].

In a mild injury, these secondary injury processes are limited. Cerebral edema, tissue necrosis and apoptosis and brain herniation are not associated with mild injury. After an isolated mild injury, there typically are no long-term neurological and neuropathological sequelae. With proper treatment and avoidance of reinjury, the majority of patients will have resolution of their clinical symptoms within a few days.

With repeated concussion, there is the risk of chronic effects such as prolonged post-concussive syndrome and early onset dementia. Athletes with repeated concussions had a higher incidence of post-concussive syndrome lasting more than a year than athletes with fewer concussions [14]. In addition, repeated concussions are thought to contribute to the risk of developing chronic traumatic encephalopathy (CTE), a neuro-degenerative brain disease associated with multiple concussions and TBIs [15]. This is a condition where, following multiple concussions over many years, a tauopathy can develop in brains of affected patients. McKee and co-workers have shown that this can occur in professional athletes, military personnel and others [16-18]. A recent study suggests CTE shows up in the brains of football players more often than previously indicated. CTE was discovered in 110 out of 111 NFL player brains [19]. The majority of CTE cases have been seen in either war veterans or people who played contact sports, particularly American football. CTE causes the brain to accumulate tau protein, which interferes with neuropathways and leads to a variety of clinical symptoms including memory loss, confusion, impaired judgment, aggression, depression, and sometimes suicidal behavior.

Clinically, CTE is associated with early onset dementia. What is not known is what the prevalence in at-risk populations is and what are the critical risk factors that cause some patients to develop CTE and others not. Because CTE develops over time, symptoms may take years to manifest. CTE can only be formally diagnosed with an autopsy; however, researchers are attempting to develop accurate testing for living subjects, which would enable interventions that could potentially slow CTE progression.

Second Impact Syndrome (SIS) is a condition where a second concussion occurs before a first concussion has properly healed, causing rapid and severe brain swelling. Second impact syndrome can result from even a very mild concussion that occurs days or weeks after the initial concussion [20, 21]. The second injury does not necessarily have to be to the head; SIS has been reported in athletes injured elsewhere such as a blow to the chest. When SIS occurs, the patient initially appears well but within a few moments collapse and becomes comatose with dilated pupils and impaired ventilation [22]. Neuroimaging reveals diffuse cerebral edema, often with brain herniation [22]. The pathophysiology of SIS is thought to be loss of cerebral autoregulation [23]. The initial TBI causes this dysregulation, which when unresolved, allows a systemic change in blood pressure and flow to initiate diffuse cerebral hyperemia. This in turn causes diffuse cerebral edema and increased intracranial pressure (ICP), which leads to neurological collapse. The clinical outcome in these patients is dire. Most will either die or not regain independent living. Thus, it is best for concussed patients to avoid a second injury before they fully recover.

In 1997, the American Academy of Neurology issued clinical practice guidelines with recommendations that concussed athletes delay return to play until fully recovered with longer periods away from play if additional concussions were sustained in the same season [24]. In 2013, the American Academy of Neurology updated these clinical practice guidelines [25]. The new

guidelines recommend that players be removed from play and do not return until after being evaluated and cleared to do so by an appropriately licensed health care provider. Typically, the patient will need to be symptom free and not taking any medications for concussion-related symptoms.

Diagnosis

There are challenges in getting an accurate diagnosis and treatment, especially when there is no documented or observed loss of consciousness, although there does not need to be a loss of consciousness for a brain injury to occur. Patients who are suspected of having suffered a concussion should be immediately removed from play or work. A licensed health care provider should evaluate such patients as soon as possible.

The Zurich Conference identified 4 common features to concussion [26]. The first is that concussion may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an "impulsive" force transmitted to the head. The second is that concussion typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, symptoms and signs may be prolonged and take many minutes to hours to fully resolve. Third, concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality related to the injury is seen on routine clinical neuroimaging (CT or MRI) due to the subtle nature of mild brain injury. Fourth, concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. For example, a patient may have disorientation, loss of awareness or either or both anterograde and retrograde amnesia. Resolution of the clinical and cognitive symptoms typically follows a sequential course, which may also be prolonged.

Concussion is a blow to the head that leads to an acute encephalopathy. This can be a brief loss of consciousness, amnesia or alteration in orientation and awareness, typically lasting just a few minutes or less. Unlike more severe forms of TBI, patients should not have an acute focal neurological deficit or neuroimaging (CT or MRI) abnormality related to injury or seizure. Individuals who have alternating periods of lucidity and disorientation or prolonged altered consciousness should be evaluated for ongoing seizures. Patients should also not have suffered a skull fracture. Routine clinical neuroimaging with CT or MRI will not reveal abnormalities associated with injury. Newer radiographic modalities, such as diffusion tensor imaging (DTI), may provide evidence of injury but these are not yet widely clinically available and will require additional validation before routine clinical use can be recommended [27]. Likewise, Positron-emission tomography (PET) has high sensitivity, yet is associated with high costs and ionizing radiation exposure.

Typically, concussed patients are diagnosed based on history consistent with TBI and symptoms such as headache and dizziness. At the time of presentation to the licensed health care provider, the patient's general physical and neurological, mental status and cognitive examinations are usually normal. Thus, taking a detailed history, especially from witnesses, and a detailed review of symptoms are often critical to making the correct diagnosis.

Screening of at-risk patients is another important aspect of concussion diagnosis. A validated screening tool allows rapid point-of-injury assessment of persons who have been involved in an event that places them at risk of having suffered a concussion. Asking a patient if he/she is concussed is insufficient. As patients are potentially suffering from a TBI, it is unreasonable to expect that they would have insight into their condition. Screening helps to objectively identify at-risk patients to allow the appropriate decision whether or not to remove them from further play or work. This reduces the risk of reinjury and SIS.

A number of clinical tools are available to help determine quickly who is at risk of having suffered a mild TBI. The Standardized Assessment of Concussion (SAC) [28] tests 4 critical domains: concentration, orientation, immediate recall and memory. Initially, it was used in football players as a rapid assessment tool. Since then, it has been applied to other at-risk patients. The U.S. military

developed a clinical tool, the military acute concussion evaluation (MACE), which incorporates the SAC but also includes patient history and physical exam [29]. The MACE was deployed with military first providers in both OIF and OEF. In the case of the MACE, patients who score 24 or less (out of a possible 30) are referred to an advanced medical provider for a more detailed neurological assessment. In the civilian sector, the third International Conference on Concussion in Sports (also known as the Zurich meeting) introduced a screening tool known as the sports concussion assessment tool (SCAT3) [30]. It is very similar to the MACE but also includes a test of balance and coordination. A pediatric version of SCAT3 is also now available [30]. The SAC, SCAT3 and MACE are not diagnostic tools but are designed and meant for screening. A licensed health care provider must make the diagnosis.

Treatment

There is currently no specific neuro rescue or neuro prophylaxis medication that is FDA-approved for a clinical indication of improving TBI outcome. Treatment is supportive and focuses mainly on ameliorating symptoms.

Patients should be informed and reassured that this condition typically fully resolves within a very short period of time. An important aspect of recovery is the expectation that full recovery is probable.

Patients should not be exposed to further risk of injury and allow sufficient time for the brain to recover. No two concussions are the same; recovery time is unique to each patient. Recovery does not mean only sleep; although adequate sleep is important but over-sleeping is not helpful. Cognitive rest, or reducing cognitively or sensory demanding mental activities such as reading, playing video games or higher-order analytical work, is an equally important aspect of recovery.

Symptoms should be treated. Non-pharmacologic approaches may be used such as encouraging good sleep practices, biofeedback and others. However, if needed, pharmacologic agents should be prescribed. Clinicians should begin with low doses of the most benign medications and titrate as necessary. For example, begin with acetaminophen for headaches or triptan if there are migraine features versus an opioid [31]. Overmedication is to be avoided. Useful treatment guides are the VA-DOD Clinical Practice Guidelines for Managing Concussion/Mild TBI and the Canadian Clinical Practice Guidelines for Mild TBI and Persistent Symptoms [32, 33].

Post-concussive syndrome (PCS) is a chronic sequela of mild TBI, where symptoms persist. Fortunately, the vast majority of concussion patients will not develop PCS. However, in some PCS at-risk groups, up to 50% of patients with concussion can develop this condition [34]. PCS results from a mild head injury [35], with a typical duration of 3-6 months post injury but may persist up to a year or more. Symptoms include memory and concentration problems, mood swings, personality changes, headache, fatigue, vertigo, insomnia and excessive drowsiness [36]. Patients with PCS should avoid activities that put them at risk for a repeated concussion. As with acute concussion, the goal of therapy is to relieve symptoms [32].

The Rivermead Post-Concussion Symptoms Questionnaire (RPQ) is a tool to quantify the severity of PCS [37]. The questionnaire may be self-administered or administered by a second party. This is a 16-symptom test for which the maximum score is 64. Each symptom receives a score from 0-4, with 4 being severe. The first 3 symptoms on the RPQ are headache, dizziness and nausea/vomiting, which are common following TBI. Because these are 3 symptoms affecting the head, they are also referred to as the RPQ3 or RPQh or RPQ head. The remaining 13 factors include fatigue, sleep disturbance, poor concentration, depression, light sensitivity and other constitutional symptoms and are collectively labeled RPQ13. The RPQ, RPQ3 and RPQ13 have been validated and are used to both document and assess PCS [38].

Females appear to be at greater risk than males for PCS. Studies conducted on emergency department patients seen acutely with mild TBI found that female gender, the presence of both retro- and anterograde amnesia, and Digit Span Forward Scores > 9 were predictive of higher risk of post-concussive syndrome at both 1 and 3 months after

injury [39, 40]. Amnesia predicts higher risk of PCS, especially if accompanied by moderate to severe headache at presentation [41, 42].

A small minority of patients can suffer very chronic PCS, lasting greater than 18 months. This condition is referred to as permanent PCS [42]. Generally, this condition manifests in older patients and is associated with more severe PCS, mild cognitive deficits and anxiety. Unfortunately, many of these patients are unable to return to work.

Return to work and play

Patients should not return to work or play until they have fully recovered from their concussion. Full recovery is when patients no longer report any symptoms, are not taking any medications and successfully pass provocative testing. Many clinicians use a multi-step process that includes provocative testing to transition concussion patients back to work [31], where once the patient is symptom-free with no activity and not taking any medications, he/she is asked to perform simple physical exercises, such as walking. If symptoms recur, then the exercise test is stopped and the patient is treated. If the symptoms do not recur, then more vigorous exercise testing, such as jogging, is done. This continues until the highest level of provocative exercise testing, such as full-contact drills, does not elicit symptoms. At this point, the patient is cleared to return to his/her premorbid level of activity.

CONCLUSION

Concussion is a common and serious disorder following traumatic injury to the brain and head. Due to increased public awareness, patients are being removed from play and/or work early to avoid re-injury. Re-injury can have severe consequences from second impact syndrome. Screening tools are now available to facilitate identification of TBI victims at the point of injury, which enables rational removal from play or work situations and, if necessary, earlier medical care. Once a patient has been identified as being at risk of having suffered a concussion, a licensed health care provider must evaluate and start appropriate treatment to relieve symptoms.

With proper care, the prognosis for a full recovery from concussion is excellent. The overwhelming majority of concussion patients will fully recover within a few days. However, some will have post-concussive syndrome, which delays recovery. Repeated concussion throughout a patient's lifetime can lead to chronic traumatic encephalopathy.

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CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest declarations to make relevant to this authored work.

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