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TRAUMATIC BRAIN INJURY (A VALADKA, SECTION EDITOR)

Diagnosis and Management of Mild Traumatic Brain Injury

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Abstract

Purpose of Review This article summarizes the current literature on the acute and outpatient assessment, management, and treatment of mild traumatic brain injury (mTBI).

Recent Findings Emerging research indicates that there are different clinical profiles, or patterns of symptoms and deficits, that can occur due to mTBI. Advancements in assessment tools allows for improved detection of mTBI and delineation of the clinical profile after injury. Experts advocate for the development of an individualized treatment plan for specific symptoms and deficits from mTBI, rather than a "one-size-fits-all" approach to managing the injury.

Summary This review provides a summary of the emerging literature for the evaluation and management of mTBI in the acute and outpatient settings.

Keywords Mild traumatic brain injury · Concussion · Clinical profiles · Acute management · Outpatient management · Assessment

Introduction

Mild traumatic brain injury (mTBI), also known as concussion, is a growing public health concern [1, 2]. Nearly three million visits are made to the emergency department (ED) for traumatic brain injury (TBI) over the course of a year [3], and 70–90% of the TBIs treated in the hospital setting are classified as mild [4]. The most common causes of mTBIs are falls and motor vehicle accidents (MVAs) [4], but the prevalence of sport-related injuries seen in the trauma setting continues to rise. Between 1997 and 2007, the number of ED visits for sport-related mTBI more than doubled among children and adolescents [5]. Given the increased prevalence of mTBI in the trauma setting, it is important for frontline practitioners to be knowledgeable regarding this injury.

The scientific understanding and treatment of mTBI have evolved considerably over the past decade [6]. Improvements in the assessment tools for detecting and evaluating mTBI allow for better identification of the injury [7, 8] and for the development of an individualized treatment plan tailored to address the specific symptoms and deficits experienced by a patient. A "one-size-fits-all" approach to treatment or prescription of strict rest beyond the first 48 h of the injury is no longer considered the standard of care [6, 9•, 10•, 11, 12]. Emerging research indicates that there are different clinical profiles, or subtypes, that occur in mTBI [10•, 11, 12], and experts advocate for a targeted approach [13•] to treatment to address the different recovery patterns exhibited following the injury.

Injury Overview

Definition

The World Health Organization (WHO) defines mTBI as "an acute brain injury resulting from mechanical energy to the head from external physical forces" (pg 115) [14]. Table 1 lists the operational criteria for the diagnosis of the injury.

Blunt or blast trauma to the head and whiplash injuries that translate a traumatic force to the brain are encompassed within

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Table 1 Criteria for the diagnosis of mTBI

Presence of one or more of the following signs or symptoms	- Loss of consciousness (LOC) for 30 min or less
	- Posttraumatic amnesia (PTA) for 24 h or less
	- Disorientation
	- Confusion
	- Transient neurological abnormality
Glasgow Coma Scale (GCS) score	- GCS Score of 13–15 after 30 min post-injury or upon presentation to a healthcare system
Symptoms not due to other medical conditions	- Symptoms are not due to drugs, alcohol, medications, other injuries or treatment of other injuries, other medical or mental health disorders, or penetrating craniocerebral injury

the definition of mTBI [2, 14]. Traditional markers of head injury (i.e., loss of consciousness (LOC), posttraumatic amnesia (PTA)) are not reliable predictors of severity of mTBI [15–20], and fewer than 20% of the mTBIs are accompanied by a LOC [16, 17]. Transient neurological abnormalities that may occur after injury include various physical (e.g., headache, seizure), sleep, cognitive, and emotional symptoms. Some of the most commonly reported symptoms are listed in Table 2.

Table 2 Commonly reported symptoms from mTBI

Symptoms
Headache
Nausea
Vomiting
Balance problems
Dizziness
Fatigue
Trouble falling asleep
Sleeping more than usual
Sleeping less than usual
Drowsiness
Sensitivity to light
Sensitivity to noise
Irritability
Sadness
Feeling more emotional
Numbness or tingling
Feeling slowed down
Feeling mentally "foggy"
Difficulty concentrating
Difficulty remembering
Visual problems

Pathophysiology

Conventional neuroimaging (e.g., computed tomography [CT] scanning, magnetic resonance imaging [MRI]) for traumatic brain injury (TBI) is often unremarkable in patients with mTBI [21–23]. Patients with evidence of structural abnormalities on neuroimaging (e.g., subdural hematoma, contusion) and who meet criteria for mTBI are classified as having a *complicated* mTBI and exhibit a recovery pattern more similar to patients with a moderate TBI. In contrast, injuries with no evidence of a structural abnormality are classified as *uncomplicated* mTBIs [24, 25]. Patients with unremarkable imaging can still experience significant functional impairment and adverse symptomology from the neurometabolic crisis that occurs after this injury [22, 23, 26].

The traumatic force to the brain in mTBI results in the stretching and distortion of neuronal membranes that allows for indiscriminate ionic fluctuations disruptive to cell homeostasis. Restoration of this neurometabolic crisis requires a considerable amount of energy, and these physiological changes may render the brain more vulnerable to further cellular injury [22, 23]. An insult to the brain while in this metabolic crisis may have potentially catastrophic outcomes, such as in the case of second-impact syndrome (SIS). It is speculated that additional injury to the brain while in this vulnerable state can result in inflammation and cerebral edema that is rare, but can be fatal when it occurs [27, 28].

Recovery Time

Most mTBIs resolve within weeks to months of injury [6, 10•, 29, 30]. The recovery timeframe for mTBI is classified into three phases: acute (within 72 h post-injury), subacute (after 72 h to 3 months post-injury), and persistent/chronic (3 months and greater post-injury) [8]. Most adolescent athletes require 3–4 weeks to recover from a sport-related mTBI [10•, 31, 32]. Athletes experiencing symptoms beyond 4 weeks of injury are classified as having a prolonged or complicated recovery [6] and meet criteria for "Postconcussion Syndrome [33]." In comparison, the recovery time in adult mTBIs is typically 1 to 3 months, but some adults may experience symptoms for up to 12 months or longer [1, 30].

Emerging research has identified risk factors that predispose patients to exhibit a prolonged recovery from injury [11, 34]. Demographic characteristics including younger age [29, 35], female sex [35–37], and a history of prior mTBIs [34, 38, 39] have all been identified as risk factors for longer recovery time. Patients with certain preinjury health conditions may also be at risk for a complicated recovery after injury. One of the most robust predictors of postconcussion syndrome is a history of a mental health condition [4, 40–42]. Studies suggest that the preinjury mental health condition is more predictive of ongoing symptomology than the mTBI itself [40, 42]. Other health-related risk factors that may render individuals more vulnerable to mTBI include a history of migraine headaches [43, 44], neurodevelopmental conditions (e.g., attention deficit-hyperactivity disorder, learning disability) [45–47], and/or motion sickness [48]. It is speculated that preinjury neurological and psychological vulnerabilities may decompensate after sustaining a mTBI, resulting in an exacerbation of a preinjury condition and functional impairment [11, 41, 48].

The initial signs and symptoms evidenced within the acute phase of injury also provide important information on prognosis. As aforementioned, the presence of traditional markers of TBI (e.g., LOC or PTA) are not reliable predictors of recovery time from mTBI [15, 16, 18, 19, 49]. Recent research indicates that other reported symptoms or deficits may provide better insight into the underlying neural pathways disrupted by metabolic crisis. For instance, immediate reports of dizziness and mental fogginess are indicators of central vestibular dysfunction and predictive of prolonged recovery time [17, 20]; in sport-related injuries, athletes with positive findings on vestibular-oculomotor screening are expected to take longer to recover [48, 50], and these athletes may require physical therapy for rehabilitation of the vestibular system [51–53]. Additional symptom profiles that are associated with longer recovery time include the presence of posttraumatic migraine [54–56], mood changes/posttraumatic stress [57–59], sleep dysregulation [60–62], and oculomotor abnormalities [48, 63]. Each of these signs and symptoms reported after injury must be considered within a biopsychosocial context. For instance, involvement in litigation or the potential for secondary gain surrounding the injury is one of the strongest predictors of persistent disability from mTBI [1, 64]. Overall, there are several potential risk factors that may impact recovery time, and a consideration of these risk factors may help to identify patients at risk of a prolonged recovery.

Acute Evaluation

Detection

Immediate signs and symptoms that indicate a potential head injury has occurred are provided in Table 3. This list of indicators was developed by the medical personnel of the National Football League (NFL) [65] for assisting sports healthcare professionals in the identification of head injury from the sideline. Extensive protocols for detecting mTBI are critical in contact sports due to the risk of secondary insult and potentially catastrophic outcome if an athlete takes a blow to the head while actively concussed [27, 28]. Some clinical markers of head injury are apparent based purely on observation, while others require questioning or assessment of the individual [65]. The Centers for Disease Control and Prevention [66] recommends an evaluation in the ED if any emergent neurological signs or symptoms are present.

Table 3 Indicators of a potential mTBI adopted from the Head, Neck and Spine Committee of the National Football League [65]

Indicator of potential head injury	Observable sign versus reported symptom of injury
LOC	Observable sign
Disorientation	Observable sign
Seizure	Observable sign
Incoordination/imbalance	Observable sign
Confusion	Observable sign
Dazed	Observable sign
Posttraumatic amnesia	Requires questioning
Headache	Requires questioning
Clutching head	Observable sign
Physically slow	Observable sign
Dizziness	Requires questioning
Vomiting	Observable sign
Nausea	Requires questioning
Light or noise sensitivity	Requires questioning
Feeling off balance	Requires questioning
Tinnitus	Requires questioning
Feeling mentally slow or foggy	Requires questioning
Visual disturbances (e.g., blurred or double vision)	Requires questioning

Emergent Neurological Disease

Ruling out emergent neurological sequelae is the first priority in considering a diagnosis of mTBI. The National Institutes of Health (NIH) recommends that the evaluation of TBI during acute hospitalization include a clinical interview, physical/neurological examination, imaging, functional assessments, and evaluation of vital signs, laboratory tests, and biomarkers. However, traditional neurodiagnostic testing is often unremarkable in uncomplicated mTBI [21–23]. Current guidelines recommend imaging be restricted to patients exhibiting high-risk neurological signs [26, 67] due to the radiation exposure [68], cost, and time [69] required for imaging. Researchers have developed protocols, such as the Canadian CT Head Rule, to empirically assist practitioners for deciding when to refer patients for a CT scan [26]. Once emergent neurological sequelae are dismissed, a diagnosis of mTBI may be considered.

Acute Assessment

Acute assessment of mTBI is largely based on a targeted clinical interview and functional assessment tools. Information gathered during the clinical interview includes details on the mechanism of injury, documentation of markers of injury/symptoms, and identification of potential risk factors for a complicated recovery. Table 4 provides an overview of a potential clinical interview.

Functional assessment tools are empirically established measures of skills and behaviors utilized in daily life. Performance on functional assessment tools has been shown to predict recovery and prognosis following mTBI [17, 50, 70]. It is recommended that a combination of both objective and subjective measures be included in the assessment [7, 8]. Standardized evaluation tools recommended by the NIH [7, 8] include neuropsychological testing, vestibular/oculomotor screening, and symptom report inventories (i.e., sleep quality, emotional functioning, TBI-related symptoms, quality of life). Scores on these measures can assist in determining diagnosis and prognosis [70–73], as well as establish the clinical profile from the injury, functional deficits, and appropriate treatment.

Acute Treatment

Recommending strict rest (i.e., no cognitive or physical activity) beyond 24 to 48 h of injury is no longer considered an acceptable treatment for mTBI [6]. Results of a randomized controlled trial indicate that adolescents diagnosed with mTBI in the ED who were advised to engage in strict rest rather than usual care (i.e., gradual return to activity after 48 h) reported a greater severity and longer duration of postconcussion symptoms [9•]. The advantage of an activity-based rather than rest-based model during acute recovery is likely related to the benefit of activity on neuroplasticity and the physiological adaptive responses that occur shortly after neuronal injury [74]. A modified schedule of activity and maintenance of healthy lifestyle factors (e.g., hydration, adequate nutrition, routine sleep schedule, stress management, low risk/light physical activity) in the acute phase of injury may assist in the mitigation of symptoms such as headache and sleep disruption and promote recovery [75–77]. Every acute evaluation should include education and normalization of expected symptoms after mTBI, as well as referral to a specialist for outpatient management of the injury [78, 79].

Table 4 Clinical interview

Demographic information	Age, sex, socioeconomic status, occupation
Personal and family medical history	TBI history, migraine history, oculomotor history, etc.
Personal and family mental health history	History of anxiety or depression, substance use, psychosocial stressors, etc.
History of disease/injury event	Time, place, cause and mechanism of injury, complicating factors (e.g., second insult, cervical injury), classification of TBI severity

Outpatient Evaluation

The primary advantage of specialty evaluation and management of mTBI in the outpatient setting is the development of an individualized treatment plan. Through comprehensive, multimodal assessment and follow-up care, the symptom pattern, also referred to as the clinical profile, and potential functional impairments that ensue after injury can be identified and appropriately treated. Emerging clinical profiles include post-traumatic migraine, vestibular, oculomotor, anxiety/mood, and cognitive fatigue [11]. Each of these profiles requires different types of treatment. Expert consensus across multiple health disciplines (e.g., neuropsychology, neurosurgery, neurology, physical medicine and rehabilitation, physical therapy) advocates for an active, patient-centered treatment plan to benefit the recovery of patients, rather than a one-size-fits-all approach to treating this injury [13]. To develop an individualized treatment plan, the outpatient evaluation should include a clinical interview, functional assessment tools, and identification of the clinical profile.

Clinical Interview

Table 4 provides the general outline for information obtained as part of every clinical interview. In the outpatient setting, it is also important to establish any treatments that were already attempted, results of imaging and/or laboratory tests, nature and trajectory of symptoms, and current functional activities that are limited or affected by the injury. All information obtained in the clinical interview should be verified with medical records when possible. Given the multitude of risk factors associated with a prolonged recovery from this injury, reported symptoms and deficits must be considered within a biopsychosocial context. This includes focusing on risk factors in the medical or mental health history, injury characteristics, and psychosocial/environmental circumstances that put the patient at risk for a complicated recovery. Subjective information gleaned from the clinical interview should be compared to objective assessments when possible.

Functional Assessment Tools

Traditional neurodiagnostic testing is often not sensitive to the neurometabolic disruption that occurs after mTBI, and therefore, the outpatient evaluation of the injury is primarily conducted with empirically established functional assessment tools [7, 8]. International guidelines recommend that a comprehensive evaluation includes both objective and subjective measures of function [6]. Assessment tools must have the capability of being serially administered and provide reliable change indices to track whether meaningful recovery has occurred between time points. Standard evaluation of mTBI based on NIH guidelines [7, 8] includes the following assessment modalities: neurocognitive testing, symptom inventories, and vestibular/oculomotor screening. Table 5 provides a brief description of the specific types of testing included within each of these assessment modalities.

Neurocognitive Testing Neurocognitive testing provides information on cognition to predict functional impairment. Aspects of cognition that are included within batteries for mTBI include measures of attention, learning, memory, language, visual spatial skills, fine motor skills, executive functioning, and intelligence/premorbid estimation [7, 8]. Results of neurocognitive testing are often interpreted by a neuropsychologist trained in conceptualizing cognitive patterns [80]. These patterns of impairment can be linked to specific neural networks affected by mTBI [81] and provide insight into a patient's ability to function in the school or occupational setting. Computerized neurocognitive testing has become a widely utilized tool for measuring outcome after mTBI [6, 82], because it provides an objective measurement and because of its feasibility of use [83–86]. Patients who are reportedly symptom free may still demonstrate deficits on cognitive testing [86–89]. Performance on neurocognitive testing within the first 7–14 days of injury improves the ability to predict whether a patient will have a simple or complicated recovery [49, 72]. Effort and symptom validity testing are particularly important in situations in which there may be secondary gain associated with the injury [90, 91].

Symptom Inventories Symptom inventories provide a method of quantitatively capturing the nature and severity of symptoms and functional impairments experienced by the patient.

Table 5 Assessment modalities

Modality	Description of assessment tools
Neurocognitive testing	Computerized neurocognitive testing, paper-and-pencil neurocognitive testing, mental status examination, effort/validity testing.
Symptom inventories	Questionnaires of behavioral function, psychological function, postconcussion/TBI-related symptoms, substance abuse, quality of life, and sleep quality.
Vestibular and oculomotor screening	Screening of postural stability (balance), central vestibular function (vestibular-ocular reflexes, visual motion sensitivity), and oculomotor function (near point of convergence, smooth pursuits, saccades).

Endorsement of a high symptom burden in the acute phase of injury is a robust predictor of prolonged recovery from the injury [49, 70, 92]. Given that mTBI can result in a constellation of physical, cognitive, sleep, and mood symptoms, it is important to have a comprehensive understanding of the symptoms that are most bothersome to the patient. The pattern of symptoms endorsed can provide valuable information into the clinical profile of the injury [10•, 11, 12, 56].

Vestibular and Oculomotor Screening The vestibular system is a complex sensory system that allows for central maintenance of balance and the stabilization of vision with movement. Patients with central vestibular problems after mTBI often report symptoms that are consistent with the sensation of motion sickness (e.g., dizziness, vertigo, lightheadedness, unstable vision, nausea, imbalance) [52, 73, 93–95]. Two aspects of the vestibular system that warrant screening after suspected head injury include testing of balance/postural stability and vestibular-oculomotor function. Balance testing is more useful in the acute phase of injury as balance problems appear to resolve within the first 72 h of injury [96, 97], while a positive finding on vestibular-ocular motor screening in the acute phase of injury is predictive of prolonged recovery time [50, 52, 73, 93].

Screening for oculomotor impairment after mTBI is also recommended as part of the neuromotor exam. The oculomotor system coordinates eye movements to focus vision. Between 24 and 48% of the patients evaluated within 1 month of injury will demonstrate posttraumatic oculomotor abnormalities [63, 71, 98], and these patients exhibit a prolonged recovery from the injury [48]. Patients with oculomotor dysfunction may experience difficulties in environments or with activities that involve a heavy demand on the visual system (e.g., reading in school, working on a computer screen).

Clinical Profiles

Information obtained through the clinical interview and standardized evaluation allows for the conceptualization of the clinical profile of this injury. Emerging research indicates that different clinical profiles and patterns of symptoms can occur after mTBI, and each profile warrants different types of treatment. These profiles are not considered mutually exclusive in that an individual can experience overlapping symptoms from multiple profiles. Identified clinical profiles include posttraumatic migraine, vestibular, oculomotor, anxiety/mood, and cognitive fatigue. The description of each of these clinical profiles provides a theoretical framework for conceptualizing and recognizing the nuanced differences in outcomes from mTBI [10•, 11, 12]. Individuals with preinjury vulnerabilities may be more at risk for the development of certain clinical profiles (e.g., a patient with a preinjury history of migraines develops a posttraumatic migraine secondary to the mTBI)

[11, 41, 48]. The research on these clinical profiles is in its infancy, but preliminary findings support the notion that certain preinjury characteristics increase the risk of posttraumatic complications from mTBI, and specific deficits after mTBI necessitate targeted treatments [51, 52, 93]. The literature on mTBI continues to evolve, and further delineation of methods for identifying, evaluating, and treating these clinical profiles is warranted.

Posttraumatic Migraine Headache is one of the most commonly reported symptoms after mTBI [99] and is classified as a posttraumatic migraine when the headache occurs within a week after the head trauma and is accompanied by symptoms of nausea and/or photophobia and phonophobia [100]. Migraine headaches are typically moderate or severe in intensity, have a pulsating quality, last for hours, and are aggravated by activity. Potential risk factors for this profile include a personal or family history of migraine [101]. Symptom inventories and questioning during the interview can help to determine if headaches are accompanied by nausea, photophobia, or phonophobia. Computerized test results may show a pattern of worsened verbal and visual memory scores [54]. Individuals demonstrating this profile are at risk for a prolonged recovery from mTBI [54–56] and may have difficulty tolerating daily functional activities. Treatment for this clinical profile may include employment of behavioral regulation strategies (i.e., regulated sleep, hydration, healthy diet, stress management, and cardiovascular exercise) [11, 75, 76], nutritional supplements for migraine headache [102–104], and in protracted cases pharmacological intervention [105].

Vestibular Disturbance of the central vestibular system after head trauma typically results in the sensation of motion sickness [17]. Patients may report dizziness, fogginess, nausea, lightheadedness, and feeling overwhelmed in busy or complex environments [11]. The central vestibular system coordinates neural signals for maintaining postural stability and gaze stabilization and assists in making internal estimates of motion and spatial orientation [94]. Patients with a vestibular problem may be reportedly asymptomatic at rest until initiating movement or when involved in activities involving motion (e.g., car rides, crowded environments). A potential risk factor for the development of this profile after head injury includes a preinjury history of motion sickness, such as carsickness [48]. Symptom inventories can help to detect vestibular symptoms, but a vestibular-oculomotor screening is warranted for capturing such abnormalities. Patients with this profile often experience the onset or worsening of motion sickness symptoms when engaged in exams of oculomotor function, vestibular-ocular reflexes, and visual motion sensitivity [12, 50, 73]. Treatment often requires rehabilitation of the vestibular system through a structured physical therapy plan [51–53, 93, 106], and in protracted cases that involve autonomic nervous system changes, pharmacological interventions may be warranted [107].

Oculomotor Posttraumatic vision changes from central disturbance of oculomotor control are common after TBI [71, 108]. The most common oculomotor abnormalities following a mTBI affect accommodation and convergence functions that maintain near vision [108, 109]. Symptoms that may serve as an indicator of an oculomotor deficit include reported trouble focusing eyes, blurred/double vision, frontal-based headache and/or head pressure, or fatigue/discomfort with activities with a heavy visual demand (e.g., reading, computer work) [11, 71, 110]. Oculomotor deficits can be captured by neuromotor screening tools (i.e., examination of smooth pursuits, saccades, near point of convergence, and accommodation) [73, 111–113], evaluation by a neuro-optometrist [48], or detection of a pattern of lowered performance on computerized testing [63, 71]. Further research is warranted to determine if developmental oculomotor abnormalities, such as strabismus, are associated with posttraumatic vision changes after mTBI. Oculomotor abnormalities can lead to occupational and school impairments, especially if responsibilities require prolonged use of near vision [11, 63, 114]. Recent research indicates that oculomotor abnormalities may increase the recovery time from mTBI among children [48, 50]. Treatment options may include vestibular-ocular therapy, vision therapy, and/or eyeglasses [12, 115].

Anxiety/Mood Mood changes and emotional disturbances can occur after head trauma. Physiological alterations in limbic-cortical circuitry and neurotransmitter release from the neurometabolic crisis that ensues after mTBI resemble that of major depression and other mood disturbances [22, 23, 116, 117]. Symptoms that are indicative of emotional problems include ruminative thinking, sadness, emotional lability, difficulties initiating and maintaining sleep, panic attacks, nervousness, and hypervigilance. These individuals may demonstrate avoidant behaviors (e.g., wearing sunglasses indoors, dimming brightness on computer screens, wearing noise-canceling headphones) when attempting to return to functional activities [118–121]. Assessment of the anxiety/mood clinical profile largely resides on a thorough clinical interview, the use of symptom inventories, and a comparison of objective data to subjective symptom complaints. Inconsistencies in reported symptoms (e.g., memory problems) and performance on objective testing (e.g., neuropsychological measures of memory function) can assist in determining whether physical complaints have a psychological basis [11, 122]. A preinjury history of mental health problems is a risk factor for developing this profile and is one of the strongest predictors of postconcussion syndrome [1, 40, 42]. Treatments that have been recommended for this profile [122] in the initial phases include psychoeducation [78, 123] and a gradual return to functional activities [11, 94, 124, 125], while more protracted cases may require psychotherapy [126–128] and/or pharmacological interventions [129, 130].

Cognitive Fatigue Patients presenting with predominant complaints of cognitive difficulties (e.g., memory and attention problems) and fatigue are characterized as exhibiting a cognitive fatigue profile. Neurocognitive testing provides an objective measure of cognitive processes to elucidate this profile [11]. Further research is warranted to determine the risk factors and trajectory of recovery from this profile. Potential treatment options in protracted cases include cognitive rehabilitation [123] and pharmacological intervention [131].

Return to Functional Activities

There are several considerations that must be made prior to returning a patient with mTBI to his or her usual daily activities. The first consideration is the safety of the patient. Any activities that pose a risk of head injury are strongly discouraged given the risk of catastrophic outcome with a second insult to the head [27, 28]. For instance, in order to return an athlete to a contact sport, international criteria require that the athlete is symptom free at rest, symptom free with non-contact physical activity, and demonstrates a normal exam [6]. Occupational hazards and involvement in high-risk tasks (e.g., balance on scaffolding, operating heavy machinery, or financial investing) are also a safety concern and must be considered within the context of the assessment results and clinical profile to ensure no harm is done to the patient or others.

Another major consideration is the patient's ability to be productive and tolerate the occupational or school environment. Recommending strict rest beyond a period of 48 h postinjury is ill advised, and instead, light activity or a modified schedule may be more beneficial for recovery [9•, 74, 77, 132]. This allows the patient to gradually increase his or her tolerance of daily activities. It is not unusual for patients to experience an initial spike in symptoms when first returning to functional activities such as the school environment, and this spike in symptoms does not appear to be detrimental to recovery [133]. The use of an "exposure-recovery model," in which a patient engages in a symptom-provoking activity (exposure), and then takes a break or relaxes to allow symptoms to abate (recovery), may help to facilitate the return to activity. This model has been demonstrated to be effective in affective disorders and may particularly benefit patients at risk for mood disturbances [134, 135]. Specialty management of the injury utilizes the individualized clinical profile to determine tolerance and to guide the return to functional activities.

Conclusion

Advances in the scientific understanding of and assessment tools for mTBI have led to improvements in the evaluation, management, and treatment of this injury. Emerging research indicates that certain risk factors and clinical profiles after injury may predispose patients to experience different recovery patterns. Prescription of strict rest beyond the acute phase of injury and a "one-size-fits all" approach are no longer recommended as the standard of care. Experts advocate for an individualized treatment plan to address the specific symptoms and deficits exhibited after injury.

Compliance with Ethical Standards

Conflict of Interest Natalie Sandel has no conflicts of interest to declare. Michael Collins is the Co-Developer and Shareholder of ImPACT Applications, Inc.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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