Mild Traumatic Brain Injury in Children

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KEYWORDS

• Pediatric • mTBI • Concussion • Sport-related concussion • Return-to-play • Return-to-learn

KEY POINTS

- Children with a suspected head injury should be removed immediately from activity and monitored closely for red flag signs and symptoms, the appearance of which should necessitate further evaluation.
- Concussion, or mild traumatic brain injury, is defined as a head injury with a Glasgow Coma Scale between 13 and 15 and neuroimaging, if performed, does not demonstrate an acute abnormality.
- Initial management includes 24 to 48 hours of physical and cognitive rest. A period of strict rest beyond 48 to 72 hours may prolong recovery.
- Graded return to learn and play protocols should be followed, and children should first return to school and then to sports.
- The vast majority of children recover in 2 to 4 weeks. Only a small percentage have prolonged symptoms (>1 month).

BACKGROUND

Traumatic brain injury (TBI) encompasses a spectrum of disease that is, based on the Glasgow Coma Scale (GCS) at initial presentation (**Table 1**).[1] The annual incidence of pediatric TBI is estimated to be between 1 to 6 million cases worldwide, of which mild TBI (mTBI) accounts for the vast majority.[2] The diagnosis of mTBI is often synonymously used with concussion. Concussion, or mTBI, is defined as a head injury with a GCS between 13 and 15 and neuroimaging, if performed, does not demonstrate an acute abnormality.[3] The underlying mechanism of injury is transient rotational and/or linear acceleration of the head that induces mechanical forces on the brain, resulting in neuronal dysfunction. Although the mechanism is often a direct blow to the head, an impact to the body with a subsequent "whiplash" motion of the head

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Table 1
The Glasgow Coma Scale

Eyes (4)	Verbal (5)	Motor (6)
4 - Opens eyes spontaneously	5 - Oriented, appropriate	6 - Follows commands
3 - Opens eyes to voice	4 - Confused, conversational	5 - Localizes to pain
2 - Opens eyes to stimulation	3 - Inappropriate words	4 - Withdraws to pain
1 - Does not open eyes	2 - Incomprehensible sounds	3 - Flexor posturing
	1 - No response	2 - Extensor posturing
	1T - Intubated	1 - No movement

GCS = Eyes + Verbal + Motor.
A GCS of 15 is the maximum. A GCS of 3 is the minimum.
Produced with data from Teasdale and Jennett, 1974.[1]

and neck may also transmit the necessary forces for a symptomatic mTBI.[3,4] Twenty-nine percent of pediatric mTBIs are diagnosed in the outpatient setting,[5] and an outpatient provider's early diagnosis and implementation of graded return to school and sport guidelines are fundamental keys to management.[6]

DISCUSSION

Prevalence and Incidence

Pediatric TBI is a global phenomenon, with mTBI constituting more than 80% of cases.[2] More children are affected with mTBI than adults, largely owing to different activity and behaviors of children and adolescents. For example, in the United States, there are 35 million child athletes, compared with 400,000 and 20,000 athletes at the collegiate and professional levels, respectively.[7] When pediatric mTBI is assessed by mechanism of injury in the United States, the predominant mechanism changes according to age group. For children under the age of 4, falls are the predominant mechanism of injury (70%). For children 5 to 14 years old, falls and being struck by an object are equally frequent (35%). For teenagers and young adults aged 15 to 24 years, falls, being struck by an object, motor vehicle collision, and assault comprise 20% of injuries each.[8] Although commonly associated with sports, pediatric mTBI can result from many different mechanisms of injury.

Because sport-related concussion (SRC) comprises a significant portion of pediatric mTBI (70%), it warrants further scrutiny.[9] Sport- and recreation-related TBI equates to approximately 283,000 injured children annually in the United States, and its incidence is increasing, particularly in the adolescent age group.[5] Contact sports are the most common etiology with football at the top of the list.[9–11] In general, the incidence of SRC is higher for males than females.[12] However, when analyzed on a high school, gender-stratified, sport-by-sport basis in the United States, the highest rate of concussions were witnessed in men's football followed by women's soccer, men's ice hockey, men's lacrosse, and women's basketball.[11] One systematic international review that included both high school-aged and younger children indicated that rugby presented the highest rate of concussion, followed by hockey and American football.[13] Although the epidemiologic study of high school sports injuries has improved immensely through the national High School Reporting Information Online registry,[11] youth sports before the high school years have not been extensively studied owing to a lack of available documentation.[14] One study about American youth football showed that 33,000 TBI-related visits to the emergency room are for children aged 5 to 14 year old, which equates to 12% of all sport-related TBI across all age groups.[9]

However, more comprehensive analyses focused on elementary and middle school-aged children are needed. In the setting of the surge in SRC research and news media coverage in recent years, the rates of concussion diagnoses have generally increased,[5] but the rate of recurrent concussions and practice-related concussions has generally decreased.[11] The reassuring downtrend suggests heightened awareness of the condition by health care providers, athletic coaches, and organizational leaders and implementation of best practice prevention and treatment recommendations for children who are at risk for or sustain an SRC.

Evaluation

Appropriate treatment for mTBI is contingent on early recognition of the condition. Although frequently performed, imaging is not required to diagnose an mTBI. The diagnosis relies largely on clinical acumen by assimilating a patient's history of present illness, a comprehensive review of systems, and thorough physical examination. There are numerous available assessment tools to aid in diagnosis, such as the Sport Concussion Assessment Tool (SCAT), now in its fifth edition,[15] and the associated Child SCAT5 (for use from age 5–12 years).[16] These tools may be used on the sideline or in the clinic to support or refute the diagnosis of concussion. The instrument includes brief neurologic, neurocognitive and symptom evaluations.[17] Symptom burdens are commonly assessed (both on the SCAT5 and independently) using the Post-Concussion Symptom Scale (PCSS). Although these basic tools may provide decisional support, they are neither essential nor definitive for diagnosing mTBI.[18] The PCSS is helpful for classifying mTBI symptoms into symptom domains (**Fig. 1**),

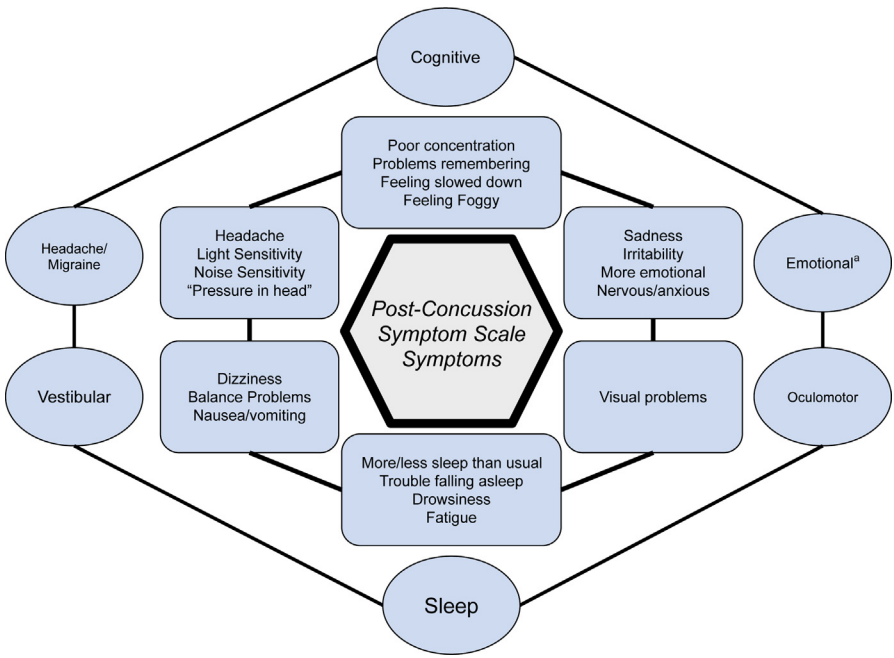

Fig. 1. Mapping symptoms from the PCSS to concussion subtypes. Inner ring includes symptoms from the PCSS mapped to major concussion subtypes (outer ring) based on classifications in Lumba-Brown et al. 2019.[20] [a]Note: The "emotional" symptom domain often used interchangeably with "mood/anxiety" domain.

which include headaches, cognitive changes, mood/emotional changes, oculomotor difficulty, vestibular issues, sleep aberration, and cervical strain.[19,20] The constellation of reported symptoms varies from patient to patient, but headaches, fatigue, and sleepiness are most common (**Table 2**).[18] Although symptoms vary, there are key features that should trigger further workup in the emergency room or transfer to a higher level of care at a designated pediatric trauma center. These red flag symptoms include worsening confusion, increasing drowsiness, refractory headaches, asymmetric pupils, focal neurologic deficit, refractory vomiting, seizures, and loss of consciousness (**Box 1**).[21,22] Patients demonstrating these signs and symptoms warrant an imaging workup and should not be managed in the outpatient setting. A thorough understanding of normal versus red flag symptoms after mTBI is critical to providing safe and effective care for these patients.

Red flag symptoms are a clear indication for neuroimaging; however, opinions have varied over the years as to indications for neuroimaging for patients without red flag symptoms. Recent high-quality research as well as recommendations from the Centers for Disease Control and Prevention (CDC) have helped to clarify this issue. In 2009, the Pediatric Emergency Care Applied Research Network group published validated guidelines that identified children who present with GCS 14 or 15 and are at low risk for clinically important TBI.[23] The appropriate identification of this low-risk subgroup of pediatric patients with mTBI enabled evidence-based recommendations to guide providers in safely deferring an imaging workup. Children with clinically important TBI were defined for the purposes of the study as death from TBI, neurosurgical intervention, intubation after 24 hours from time of injury, or hospital admission longer than 2 nights. The criteria were stratified according to children who were younger or older than 2 years of age, and the sensitivities were 100% and 97% for each age group, respectively. Salient data for infants and toddlers (<2 years old) included mental status, presence and location of a scalp hematoma, loss of consciousness, mechanism of injury, palpable skull fracture, and acting at baseline per the child's parents. For children 2 years and older, relevant information included mental status, loss of consciousness, vomiting, mechanism of injury, signs of basilar skull fracture, and headache severity. Their validated algorithm is depicted in **Fig. 2**.[23] This study has

Table 2
Signs and symptoms of concussion in sport

Clinical Domain	Presentation
Somatic	Headache, nausea, vertigo or dizziness, photophobia, phonophobia, tinnitus, difficulty focusing with vision, postural lightheadedness, anosmia, fatigue
Cognitive	Mental fog, memory difficulty, difficulty concentrating, word-finding difficulty
Behavioral	Mood lability, irritability, hypersomnia, insomnia, anxiety, depression, personality changes
Physical signs	Loss of consciousness, amnesia, neurologic deficit
Sleep/wake disturbance	Somnolence, drowsiness
Balance impairment	Gait unsteadiness

From Ahluwalia et al. 2020[21]; used with permission.

Box 1
Concussion red flag symptoms

Unequal pupils

Progressive headache

Progressive nausea/vomiting

Prolonged or delayed loss of consciousness

Focal neurologic deficit (1-sided facial droop, weakness, numbness)

Significantly altered mental status

Progressive alteration in behavior or mental status

Delayed seizure

From Ahluwalia et al.,[21] 2020; used with permission.

since been reviewed as Level B evidence and integrated into the CDC guidelines for evaluation of pediatric mTBI.[21]

Once the decision is made to pursue neuroimaging, the computed tomography (CT) scan is considered the gold standard in pediatric mTBI evaluation. This imaging modality carries the risks of ionizing radiation, high doses of which have been known to be associated with delayed malignancy. The long-standing concern about early exposure to ionizing radiation has prompted assessments of the usefulness of MRI in the evaluation of TBI, particularly with the advent of rapid sequence MRIs.[24] Standard brain MRIs have higher sensitivity in detecting intracranial structural abnormalities, which adds to their appeal.[25] Yet, MRI usefulness has historically been limited owing to length of scan, common need for sedation in pediatrics, and high cost. The advent of rapid sequence MRI decreased the time of the standard scan from 65 minutes to 5 to 15 minutes to improve its usefulness in the acute setting[26,27]; however, the shortened study time also undermines the ability to detect less obvious abnormalities. The major issue cited against using MRI in acute TBI evaluation, rapid sequence or otherwise, is the lower sensitivity it displays in assessing bony anatomy.[27] The sensitivity of the MRI for skull fracture detection is comparable to that of a skull radiograph whose sensitivity of 63% for single fractures obviates its usefulness.[21,28] Therefore, CT scan remains the preferred imaging modality by health care providers and the CDC owing to its expediency and accuracy, despite the risk of ionizing radiation.[21] In general, CT scans are readily available, and newer generations of scanners have lower doses of radiation, as well.

In addition to the SCAT,[15–17] a number of adjuncts have been developed to assist in diagnosing concussion.[29–31] The usefulness of most of these tools is typically beyond the scope of the average pediatric outpatient provider's clinic and more relevant to sideline staff (eg, athletic trainers) and the detailed interviews of concussion clinics and practicing neuropsychologists. The PCSS has been demonstrated to be useful in tracking symptoms over time and defining the need for symptom-specific therapies should long-term problems persist.[19,20] Given the variable complexity in clinical adjuncts, outpatient providers should routinely rely on the patient's reported clinical history of head trauma and symptomatology to make their diagnosis.[19,20]

Last, it is important to note that, despite a substantial amount of research devoted to mTBI serum biomarkers, there is no current evidence or guidelines to suggest the use of serum biomarkers for mTBI.[3,21,32]

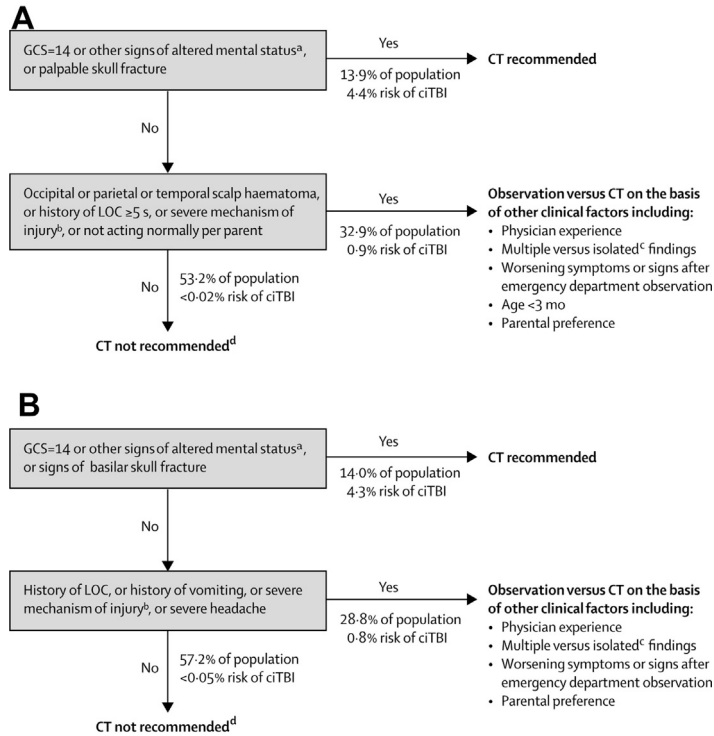

Fig. 2. Algorithm for determining the need for neuroimaging after head injury in children with GCS scores of 14 to 15. (*A*) Suggested CT algorithm for children younger than 2 years. (*B*) Suggested CT algorithm for children older than 2 years. ciTBI, clinically important traumatic brain injury; LOC, loss of consciousness. [a]Other signs of altered mental status: agitation, somnolence, repetitive questioning, or slow response to verbal communication. [b]Severe mechanism of injury: motor vehicle crash with patient ejection, death of another passenger, or rollover; pedestrian or bicyclist without helmet struck by a motorized vehicle; falls of more than 0.9 m (3 feet) (or >1.5 m [5 feet] for *B*); or head struck by a high-impact object. [c]Patients with certain isolated findings (ie, with no other findings suggestive of TBI), such as isolated LOC, isolated headache, isolated vomiting, and certain types of isolated scalp hematomas in infants older than 3 months, have a risk of ciTBI substantially lower than 1%. [d]Risk of ciTBI exceedingly low, generally lower than risk of CT-induced malignancies. Therefore, CT scans are not indicated for most patients in this group. (*From* Kupperman et al., Pediatric Emergency Care Applied Research Network (PECARN). Identification of children at very low risk of clinically-important brain injuries after head trauma: a prospective cohort study. Lancet. 2009 Oct 3;374(9696):1160-70. doi: 10.1016/S0140-6736(09)61558-0. Epub 2009 Sep 14. Erratum in: Lancet. 2014 Jan 25;383(9914):308. Reproduced with permission of Elsevier, Inc.)

Approach

Initial physical and cognitive rest

Once the diagnosis of a concussion or mTBI has been made, management and treatment is largely supportive, hinging on appropriate counseling with regard to rest and activity. Immediately after the postinjury evaluation, physical and cognitive rest for 1 to 3 days remains a mainstay of management consistent across mTBI guidelines.[32] Most important, children with a suspected concussion should not be returned to activity on the same day as injury.[3,32] Historically, the slight risk of second impact syndrome, or diffuse cerebral edema related to 2 head impact injuries in close temporal proximity,

drove these recommendations.[33] Recent evidence has suggested that those who continue to participate in activity after a concussion, especially in sports, actually may suffer longer recovery times and ultimately miss more days of activity.[34] At present, all 50 states have passed legislation forbidding the return to organized physical education class or sports until cleared by a provider trained in concussion management (although the required credentials vary state to state).[3,35] At the earliest, this clearance can be obtained 24 hours after the injury.

Once symptoms have stabilized or improved after the initial period of rest, children may gradually resume normal daily activity as tolerated. Notably, extensive rest may paradoxically lead to more symptoms and a longer recovery.[36] Thus, typical initial recommendations include cognitive rest for 1 to 2 days and return to school as symptoms are tolerated, followed by a graded return to full school and activity.[3,37,38] Children and adolescents should return to school first then sport,[6] but can also proceed nearly in parallel.

Graded return to learn

Typically, children and adolescents can return to some level of academics in 2 to 5 days.[37] A graduated return-to-learn progression commences once the individual has resumed typically daily activities without increasing symptoms such as reading and screen time.[3] The progression described within the most recent Concussion in Sport Group Consensus Guidelines is presented in **Table 3**.[3]

Adolescents (ie, high school students) may take longer to return to school than younger children and are simultaneously more concerned about negative academic effects.[6,39] Accommodations are necessary for 17% to 73%[37] of students and those with medical letters from providers are more likely to get these.[40] Thus, providing the patient with a letter to the school describing symptoms, expected required short-term accommodations, and/or absence excuse is an important aspect of care that can improve the return to learning process and communication between health care providers and schools.[21,37] A template for such a letter is available from the CDC Heads Up website (https://www.cdc.gov/headsup/providers/discharge-materials.html).

Graded return to play

Following a graded return-to-play (or sport) protocol is most applicable for those children and adolescents aiming to return to an organized sport; however, much of the concept can be applied to all children and adolescents simply looking to return to activities. The progression described within the most recent Concussion in Sport Group Consensus Guidelines is presented in **Table 4**.[3] The CDC recognizes a similar graded approach.[21] Each step requires 24 hours and therefore at least 6 days are required between injury and return to normal gameplay. If symptoms recur at a given stage, the

Table 3
Stages of return to learn

Stage	Activity
Stage 1 (activities at home)	Typical activities as tolerated in 5- to 15-minute intervals
Stage 2 (school activities)	Cognitive activities, such as homework, outside of the classroom
Stage 3 (return to school part time)	Partial school day or full day with increased breaks Introduction of schoolwork should be gradual
Stage 4 (return to school full time)	Gradually increased school activities until return to normal school day

From McCrory et al. 2017.[3] Reproduced by permission of BMJ Publishing Group Ltd.

Table 4
Stages of return to play

Stage	Activity
Stage 1 (symptom limited activity)	Slow return and exposure to work/school activity
Stage 2 (light aerobic exercise)	Increase in heart rate by walking or stationary cycling
Stage 3 (sport-specific exercise)	Increase movement; note, this cannot include activities in which head impact is possible
Stage 4 (noncontact training drills)	Increase in coordination, thinking tasks, and overall exercise In this stage, resistance training may begin
Stage 5 (full contact practice)	Assess functional skills If medically cleared, the athlete may return to baseline training regimen
Stage 6 (return to sport)	Resume normal play, no restrictions

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athlete should repeat the previous step. For those children and adolescents not involved in organized sports and who be potentially less motivated to participate in the graduated activity protocol, it is important to note that earlier return to aerobic exercise is increasingly recognized to be associated with a faster recovery.[41–43]

When to refer: specialty concussion clinic

Current guidelines suggest waiting 1 month before referral to a specialty concussion center for children and adolescents.[3,21,32] However, for those with a substantial symptom burden, risk factors for prolonged recovery (discussed elsewhere in this article), or those unable to progress with return to activity, earlier referral should be considered.[32,44] Despite these guidelines, evidence is mounting for early referral (<1 week from symptom onset) and its association with quicker recovery, so a lower threshold for referral may be beneficial.[44–46] A concussion or mTBI clinic provides comprehensive care by a multidisciplinary team that typically includes sports medicine physicians, physiotherapists, behavioral health specialists, and others.[32] The reasons for referral and the recommended timing for referrals are presented in **Table 5**.

When to refer: therapy

Physical therapy should be considered if the child is struggling to progress through graduated return to activity at 1 to 2 weeks. For competitive athletes and those highly motivated to return to activity, early subthreshold aerobic activity starting around 72 hours after injury, has been shown to improve recovery by about 4 days in a randomized controlled trial.[41] Determining a patient's exercise threshold requires a physical therapy consultation for exercise tolerance testing.[41,47] If athletes are able to complete exercise tolerance testing without worsening of their symptoms, this factor may indicate physiologic recovery from the concussion, whereas those who demonstrate worsening of symptoms may benefit from a subthreshold aerobic exercise regimen.[48] Exercise tolerance testing, subthreshold aerobic exercise, and multimodal physical therapy have been shown to be safe both in acute injuries (<72 hours after injury) and for those who have persistent symptoms.[41,47,49–52]

Vestibular therapy is appropriate for the vestibular subtype of concussion, which is characterized by dizziness, nausea, vertigo, disequilibrium, and fogginess.[19] On physical examination, these children may demonstrate abnormal vestibular ocular reflexes, visual motion sensitivity, nystagmus, imbalance, and gait dysfunction.[19,53] The

Table 5
Where, when, and why to refer

Referral to	Reason to Refer	When	Purpose
Multidisciplinary concussion clinic[a]	1. High initial symptom burden 2. Risk factors for prolonged recovery (ADHD, prior concussions, headache or psychiatric history etc.) 3. Prolonged symptoms (>1 mo) 4. When considering additional therapy referrals to centralize care	1/2. Within 1–2 wk if high risk 3. At 1 mo if symptoms persistent and no high risk factors 4. If considering physical, vestibular or vision therapy	1/2/3/4. Connect patient with multidisciplinary care team for more comprehensive concussion care
Physical therapy	1. Patient is struggling to progress through graduated activity protocols 2. Highly motivated or competitive athletes for consideration of subthreshold aerobic activity programs 3. Exercise tolerance testing	1. Failure to progress activity within 1–2 wk of injury 2. Within 72 h for early subthreshold aerobic activity programs 3. If athlete suspected recovered but mild symptoms persist	1. Provide structure and regimen to break recovery plateaus 2. Attempt to minimize physiologic recovery time 3. Exercise tolerance testing may determine physiologic recovery
Vestibular therapy and vision therapy	1. Vestibular concussion subtype (see Fig. 1) 2. Oculomotor signs or symptoms (double vision/blurry vision)	1/2. Symptoms persist >2 wk or highly symptomatic	1/2. Specific intervention for vestibular and vision symptoms, prevent prolonged disability
Neurology	1. Persistent headache	1. >2 wk of new or worsened headache after injury	1. Focused headache treatment
Psychiatry	1. High emotional PCSS subscores (see Fig. 1) 2. Worsened psychiatric symptoms in those with family or personal psychiatric histories	1/2. 1–2 wk after injury if symptoms persisting or worsening	1/2. Focused psychiatric care, consideration of pharmaceutical interventions
Neuropsychology	1. Persistent cognitive symptoms	1. Symptoms > 1 mo	1. Formal neuropsychological testing to identify areas for cognitive therapy 2. Results may aid in clinical decision-making

Abbreviation: ADHD, attention deficit hyperactivity disorder.

[a] Referral to a multidisciplinary concussion clinic is recommended as the first stop to centralize care and referrals to other specialists with experience in brain injury rehabilitation.

presence of these signs and symptoms substantially increase the risk of prolonged recovery[53] and suggest the need for vestibular therapy. Vestibular therapy may be conducted by either physical or occupational therapists, is patient specific, and can include targeted gaze stability training, graded exposure to visually stimulating environments, or dynamic balance treatment.[54] There is some limited evidence that earlier treatment may be beneficial and short interval follow-up to assess for persistent vestibular complaint is useful to make a timely referral.[55–58]

Similarly, vision therapy is helpful for patients with significant vision complaints, including persistent light sensitivity, blurry vision, and diplopia, which are associated with double the risk of a prolonged recovery.[59,60] Vision therapy could be computer based or conducted in person by a therapist. Specific exercises vary, but aim to retrain the oculomotor system by addressing fixation, accommodation, version, vergence, pursuit, or even with reading protocols.[60,61] Vision rehabilitation may be performed in conjunction with vestibular therapy or may involve optical modifications such as prisms, tinted lenses, or filters.[59] There is limited evidence for vision therapy in pediatric mTBI, and evaluation within the concussion clinic should precede a direct referral to neuro-ophthalmology for these complaints.

When to refer: neurology, psychiatry, and neuropsychology

The most common pediatric concussion/mTBI subtype is headache/migraine.[19,62] About 10% of children continue to have persistent headaches at 2 weeks after an mTBI, and 8% continue to have headaches at 3 months.[63] Those patients who continue to have persistent headaches often have a personal or family history of migraine or other headaches requiring treatment.[62,64,65] Referral to neurology for persistent headache is recommended at 2 weeks after injury at the earliest given the majority of patients have resolution at this point. Empirically re-imaging a patient for continued headache or other persistent symptoms 2 weeks or more after injury is low yield and cost ineffective.[66] New or acutely worsening symptoms and new neurologic deficits several days to weeks after concussion should be evaluated as potentially unrelated and require the standard clinical and imaging evaluation.

As many as 5% to 12% of adolescents and children who suffer an mTBI may go on to develop a temporary postinjury psychiatric disorder.[67–70] A family or personal history of psychiatric disorders preceding the injury increase the subsequent risk of worsened or new psychiatric symptoms, the most common of which is personal change.[68,70] Those patients scoring high on the PCSS emotional subscore[69] and those at increased risk based on medical history who are exhibiting new or worsened psychiatric symptoms should be referred for psychiatric evaluation.

A referral to neuropsychological assessment is generally restricted to those with persistent cognitive symptoms for 1 month or more.[21,32] A neuropsychological assessment may consist of written testing with a neuropsychologist or a computerized assessment administered by a team doctor, sports medicine physician, or athletic trainer in the case of athletes with SRC. Although neuropsychological testing may aid in clinical decision-making, management decisions, such as returning to sport or school, should not be solely based on these test results.[3]

Medications

Most children require supportive care with over-the-counter medications such as acetaminophen or antiemetics in the acute injury period. Care should be taken when recommending aspirin or nonsteroidal anti-inflammatory drugs for 48 to 72 hours after injury owing theoretic increased risk of intracranial hemorrhage.[32,71] Notably,

these risks have been extrapolated from limited studies and the actual risk of hemorrhage related to these medications is low.[72]

There is limited evidence to support any specific medication regimens that may improve outcomes in pediatric mTBI.[32,63,73–75] Nonsteroidal anti-inflammatory drug and acetaminophen (Tylenol) use should be limited to 2 to 3 uses per week owing to the potential for overuse headaches.[32,63] There is limited evidence to support the use of amitriptyline for persistent headache, and this condition is best managed by a headache specialist or psychiatrist.[63,75] Melatonin has been promoted for its palliative effects for sleep disturbances and headache.[63,73] A recent randomized controlled trial of melatonin for persistent postconcussion symptoms did not find any substantial improvement in symptoms[74]; however, melatonin is low risk and low cost and may provide symptomatic relief in the more acute period. Otherwise, there is no substantial evidence for the use of other supplements or vitamins to improve mTBI symptoms or outcomes.[73,76]

Clinical Outcomes

Typical recovery

Clinical recovery from mTBI or concussion is typically defined as resolution of symptoms.[77] For children, mTBI recovery rates have been studied after a SRC. Clinical

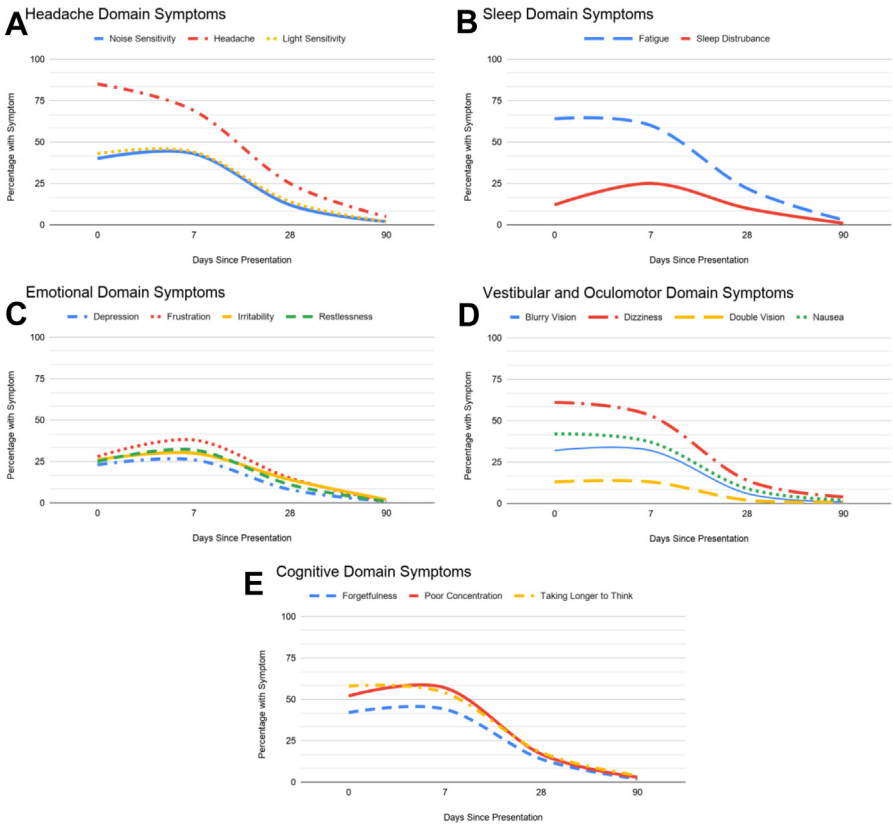

Fig. 3. (*A–E*) Resolution of various concussion symptoms by symptom domain. In general, symptoms improve dramatically between days 7 and 28. Only a small portion of patients remain symptomatic 90 days after presentation. (*Data from* Eisenberg, Meehan and Mannix. Pediatrics, 2014.[83])

recovery may be present at rest, but patients may experience exercise- or activity-induced relapse of symptoms.[77,78] This nuance likely underlies why most young athletes seem to demonstrate clinical recovery within 7 to 14 days but take closer to a month to return to competition.[79] Most recent studies have found that complete recovery is likely 3 to 4 weeks,[6,77,80] despite peak recovery within 1 to 2 weeks after the injury.[81] By week 4 (28 days) after an injury, approximately 80% of pediatric patients with an mTBI have recovered fully.[81,82] Specific symptoms may resolve at vary rates (**Fig. 3**).[83] Symptoms persist longer than a month in 10% to 20% of children and generally more than 1 symptom for more than 1 month is considered postconcussion syndrome (PCS).[84,85] In school-aged children, 13% are likely to be symptomatic at 3 months after injury and 2% at 1 year after injury.[86]

Risk factors for prolonged recovery

Given the potential for prolonged recovery to affect a child's quality of life, substantial scientific and investigative energies have been directed at accurately identifying those children for early intervention. Over the past 20 years, a substantial number of risk factors have been proposed, many with literature both supporting and refuting their existence.[84,87] Important preinjury factors that increase PCS risk include family[88] or personal[89–91] migraine or headache history, family or personal history of psychiatric illness.[88,92] and prior concussion history.[88,89,91] Although amnesia[93–95] and loss of consciousness[89,93,94] have been advocated as important injury-related risk factors for PCS, these injuries are likely inter-related with the broader finding that a greater initial symptom burden is strongly associated with an increased PCS risk.[93] More detailed accounting of risk factors can be found in 2 recent review articles on the subject (Iverson and colleagues[87] and Zuckerman and colleagues[84]). Further research in this area is still necessary to identify other risk factors and confirm prior finding studies on a larger scale.

SUMMARY

Mild TBI, or concussion, is a common diagnosis in the United States and around the world. Children carry the largest disease burden. Health care providers can diagnose mTBI in children with a history of head trauma who have an initial GCS of 13 to 15, and neuroimaging, if performed, is negative for acute findings. Symptoms typically resolve in days to weeks with 80% of children reporting symptom resolution by 4 weeks after injury. The core acute management includes 24 to 72 hours of physical and cognitive rest with graded return to learn and return to sport guidelines. The 10% to 20% of patients who report 1 or more symptoms extending beyond 1 month meet criteria for a diagnosis of PCS and should be referred to a multidisciplinary concussion clinic, if not already completed. Concussion clinics can create a tailored approach to the management of mTBI sequelae, with options for neuropsychiatric evaluation for academic or behavioral issues, neurology evaluation for seizures, headaches, or sleep problems, ophthalmologic evaluation for vision issues, and physical and occupational therapy. Pediatric outpatient providers are the foundation for the diagnosis and conservative symptomatic management of children with acute mTBI.

Clinics Care Points

- If any suspicion exists for a symptomatic mTBI or concussion, the child should be removed from the offending activity and monitored for symptoms.
- A prolonged period of physical and cognitive rest, that is, cocoon therapy, is not recommended and may prolong symptoms.

- Clinical recovery for most children and adolescents occurs by 4 weeks after mTBI.
- Early referrals to specialty, multidisciplinary concussion clinics should be considered for those with clear risk factors for prolonged recovery, including a history of 1 or more prior concussions and those with significant initial symptom burdens.
- For school-aged children, education accommodations are often necessary and students with medical letters are more likely to receive appropriate accommodations. Templates are available at https://www.cdc.gov/headsup/providers/discharge-materials.html
- Both physical and occupational or vestibular-ocular therapy may be helpful for those children with significant symptom burdens or no improvement in symptoms by 2 to 4 weeks.
- Referrals to neurology or other provider specializing in headache management may be considered 2 weeks after mTBI if the patient is experiencing persistent headaches or has an existing headache history.
- There is no significant evidence to support the use of any medication to improve outcomes in pediatric mTBI.

DISCLOSURE

Dr C.M. Bonfield serves as an unaffiliated neurotrauma consultant for the National Football League. The remaining authors have no financial or commercial conflicts of interest to disclose.

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