After concussion occurs, a complex neurophysiological cascade is initiated resulting in the disruption of axonal and membrane function, including ionic flux with widespread neurotransmitter release, cerebral blood flow (CBF) alterations, and synaptic dysfunction. This results in an injury of transient neurological dysfunction, as evidenced by the clinical syndrome of concussion.

The “metabolic mismatch” of decreased cerebral blood flow and increased glucose requirement is thought to be a potential cause of central nervous system vulnerability and the presence of associated symptoms.

Approximately 90 percent of adults experience clinical recovery from concussion within seven to 21 days, while up to 10 percent progress to post-concussion syndrome, a symptom complex that includes persistent dizziness, fatigue, irritability, anxiety, insomnia, loss of concentration, memory impairment, and noise sensitivity.

Prolonged recovery courses are more common in the pediatric population, with 15 percent still reporting post-concussive symptoms 90 days after injury. Neurocognitive dysfunction is concurrent with persistent post-concussive symptoms, as adolescents perform below average on measures of memory, verbal ability, and executive function.

FACTORS INFLUENCING RECOVERY

Many factors potentially influence recovery from concussion, including age, history of prior concussion, and preexisting comorbidities. Youth with a history of one or more concussions within the 12 months prior to sustaining a new injury experience poorer recovery outcomes, suggesting a period of vulnerability in which previously injured youths are at higher risk of a refractory recovery course.

In patients with migraine, depression, anxiety, attention deficit disorder, sleep disturbances, and other mood disorders, concussion may exacerbate those symptoms and make them more refractory to treatment. Mental health issues have also been reported as a long-term consequence of traumatic brain injury. Recent reports suggest depression rates of up to 20 percent within one year following mild TBI. It is not clear if concussive injury worsens a comorbid condition, impairs compensation in individuals with an underlying comorbidity, or a combination of both; however, a better understanding of how these factors may affect concussion risk and outcome is becoming an essential aspect of management.

SIMILARITIES TO MIGRAINE

Multiple studies also suggest that post-traumatic migraine characteristics following concussion are associated with cognitive impairments and prolonged symptoms, further highlighting the considerable overlap of typical post-concussive symptoms and those commonly described in migraine. Most recently, Kontos et al reported that patients with PTM had a 7.3 times and 2.6 times increased risk of a protracted recovery than those with no headache or headache without migrainous symptoms, respectively.

Previous research raises the possibility of a common molecular pathophysiological cause of migraines and post-traumatic headache. Mild head trauma can activate trigeminal nociception, similar to that seen in migraine. This, in turn, results in the sequential activation of second- and third-order neurons within the brain stem, hypothalamus, and thalamus, leading to cortical spreading depression. The upper cervical sensory nerve roots that converge on the trigeminal nucleus caudalis may also contribute to the activation process, as inciting trauma results in forced flexion and extension of the cervical spine.

TAKE HOME TIP

While the treatment of concussion has improved significantly in the past decade, the management of this unique injury remains an imperfect art. Emerging clinical evaluation techniques, neuroimaging technologies, interventions, and prevention strategies are all essential to providing superior care and performing meaningful research.
POSTTRAUMATIC HEADACHE TREATMENT

With regard to persistent post-traumatic headache (formerly chronic post-traumatic headache), there is legitimate concern that duration of symptoms may impact the efficacy of future treatment attempts. For this reason, some have proposed an earlier and more aggressive treatment paradigm with regard to post-traumatic headache (PTH); however, there is little evidence on its medical management. Generally, treatment is approached as the primary headache disorder it most closely resembles in phenotype. The majority of PTHs exhibit migraine or probable migraine characteristics, although similarities to all primary headache types have been noted. A multidisciplinary approach is recommended in the management of PTH due to the spectrum of associated symptoms and presentations.

For acute treatment, NSAIDs, simple analgesics, and triptans are the usual first-line options depending upon the symptomatology. Clinicians should be aware of potential medication overuse headaches with frequent use of these agents. Prescription drug formulations containing narcotics, butalbital, or benzodiazepines are generally not endorsed due to the risk of abuse and habituation. Prophylactic therapy typically includes an approach similar to migraine and/or tension-type headache treatment. This includes a standardized approach with beta-blockers, antidepressants, or anti-epileptic drugs. Clinicians, however, should be mindful when using beta-blockers in conditioned athletes, given the risk of exercise intolerance. Antiepileptics, such as topiramate, should also be used with caution given their propensity for perceived cognitive slowing—a common complaint in patients after concussion.

Medical management of collegiate and professional athletes also requires strict adherence to various governing bodies and their respective regulations. Most organizations utilize the World Anti-Doping Association’s (WADA) guidelines, which are the most regimented. Others, including the National Football League, Major League Baseball, and the National Collegiate Athletic Association, have similar policies. Prohibited substances vary.

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Other Medical Management Options

Patients manifesting symptoms of depression or anxiety can be treated with selective serotonin reuptake inhibitors, tricyclic antidepressants, or referred to a psychiatrist for further care. Post-concussive complaints such as cognitive fatigue, memory difficulties, and concentration challenges have been addressed using methylphenidate with mixed results. Amantadine has also been used for cognitive and behavioral symptoms with varying results. It is possible that some of the inconsistencies of these medications relate to the fact that some studies included patients with moderate to severe TBI. Additional studies dedicated to only post-concussive injuries may yield more conclusive results.

Computerized Neuropsychological Testing

Computerized neuropsychological testing now provides a more practical means of evaluating transient cognitive dysfunction. With computer-based assessment, large groups of individuals can be assessed in a brief period of time with decreased staffing, labor, and finances. There is limited evidence, however, suggesting the use of neuropsychological testing helps prevent recurrent concussion, catastrophic injury, or long-term complications. In fact, Randolph et al. postulate with undue use of such testing, the risk of “premature” return to play and increased likelihood of further injury occurs. Therefore, such testing should be used only as part of a comprehensive concussion management strategy and should not be used as a single determinant.

Return to Play

The return to play (RTP) decision after a concussion can be one of the most difficult challenges facing a team physician. Previous guidelines suggested that return to physical activ-
ity may occur when all symptoms have cleared and results of a comprehensive neurological and cognitive evaluation of the athlete are normal. These recommendations were based largely on the premise that premature exercise after mild TBI may be counterproductive by exacerbating post-concussive symptomatology, thereby impeding the restorative process. We are, however, seeing a paradigm shift in physical activity recommendations following injury. With regard to sport-related injury there has been significant discussion of when it is best for an athlete to begin physical exertion after concussion. The widely held practice of “rest until asymptomatic” once a concussion is diagnosed is being shown to not always be the best approach. While some evidence shows that early exacerbation of symptoms after injury can have a negative effect, prolonged periods of inactivity can also create difficulties in patients with TBI, including fatigue, reactive depression, and generalized deconditioning. Thus, clinical experience and careful consideration of each individual situation are required to appropriately determine when to reinstate activity in the post-injury population.

Furthermore, current guidelines do not fully delineate management of athletes with persistent symptoms. A fundamental cause of symptom persistence post-concussion is thought due to physiological dysfunction, including altered autonomic function and impaired cerebral autoregulation. Aerobic exercise may help concussion-related physiological dysfunction through increased parasympathetic activity, reduced sympathetic activation, and improved cerebral blood flow. Leddy et al have proposed that symptom-limited exercise testing and progressive subsymptom threshold aerobic exercise training are safe and may assist in the recovery of physiological homeostasis. Clearly, much of the RTP protocol remains controversial and incomplete.

**COGNITIVE REST**

Despite cognitive rest being a cornerstone of concussion management, few studies have evaluated this specific intervention. The recommendation is based on the premise of suspected reduction of cerebral blood flow (CBF) after acute injury. In patients with potentially compromised CBF, decreased cognitive exertion aims to reduce cerebral metabolic demand. In the acute time period following injury, activities that require concentration and attention may exacerbate symptoms and further complicate recovery. These include activities such as texting, video games, computer usage, and schoolwork. Concussed students may benefit from excused absences or reduced academic loads. Attempting to maintain academic work while symptomatic may cause symptoms to worsen and could also threaten academic performance. Excused absences, lighter homework, frequent breaks during the day, and increased time

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for testing or homework are just several examples of the temporary accommodations that may be indicated. Once the athlete is symptom free they can gradually transition to normal school hours and demands.

**COGNITIVE REHABILITATION**

Cognitive rehabilitation is used by some in an attempt to restore cognitive deficits following concussion. While such cognitive therapy may provide psychological support and guidance, there is also emerging evidence of its effectiveness in improving post-concussive cognitive recovery. Despite conflicting evidence, some studies suggest that certain aspects of cognitive performance may be enhanced by focused rehabilitation. Given the typical transient duration of such clinical deficits after injury, the routine use of cognitive rehabilitation in the management of sports-related concussion is of unclear benefit. However, there may be cases of prolonged recovery in which its use is appropriate.

**VESTIBULAR THERAPY**

Vestibular rehabilitation aids in the treatment of balance dysfunction due to migraine, cervicogenic dizziness, and other peripheral vestibular disorders. Benign paroxysmal positional vertigo (BPPV), vestibulo-ocular reflex (VOR) impairment, motion sensitivity, and balance dysfunction due to migraine, cervicogenic dizziness, and other peripheral vestibular disorders. Benign paroxysmal positional vertigo (BPPV), vestibulo-ocular reflex (VOR) impairment, motion sensitivity, and balance dysfunction can occur post-concussion. Some researchers believe that patients with these complaints may represent unique clinical subtypes of sports-related concussion. Targeted therapies and treatments for these vestibular phenotypes are useful in preventing unnecessary delays in recovery.
OTHER NON-PHARMACOLOGICAL THERAPIES

Timely referral to a neuropsychologist with concussion related experience can be very helpful for those patients finding it difficult to cope with the more emotional and cognitive symptoms such as mood swings, memory issues, irritability, anxiety/panic attacks and depression. Cognitive behavioral therapy, meditation, biofeedback, and psychotherapy can all be utilized. 38 When post-concussion symptoms remain refractory and interfere with daily activities, referral to a multidisciplinary concussion clinic is indicated.

POTENTIAL ROLE OF BIOMARKERS

According to the National Institutes of Health, biomarkers are defined as a characteristic that can be objectively evaluated and measured as a reliable indicator of a normal biological process, pathogenic process, or pharmacologic response to an intervention. A strong biomarker candidate for concussion should be able to detect either injury to structural changes of cellular elements, leakage of specific brain-related proteins into peripheral circulation and cerebral spinal fluid, or a subtle change in neurological function. 39 Researchers hope to ultimately detect concussion on a cellular level by measuring specific proteins that are released during axonal injury, such as tau, S-100 calcium-binding protein β, glial fibrillary acidic protein, and neuron-specific enolase. These biomarkers may ultimately provide practitioners an objective means to detect cerebral dysfunction at onset, recognize the window of vulnerability post-concussion, aid in return-to-play decision making, and possibly identify those individuals at risk of long-term cognitive problems, 40 however, their routine usage is currently not recommended in the management of sports-related concussion.

CONCLUSION

While the treatment of concussion has improved significantly in the past decade, the management of this unique injury remains an imperfect art. Emerging clinical evaluation techniques, neuroimaging technologies, interventions, and prevention strategies are all essential to providing superior care and performing meaningful research. There is clearly a great need for further research exploring the treatment and long-term ramifications of this injury. This evolving field of neuroscience will ultimately provide the opportunity to offer far more effective therapeutic options to our athletic and non-athletic patients alike.