Rehabilitation Strategies for Prolonged Recovery in Pediatric and Adolescent Concussion

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Most pediatric and adolescent concussion patients will heal within 1 month. However, 10% to 20% of adolescent concussions will take longer than 1 month to heal. In this subgroup, prolonged symptoms might include vestibular system deficits, residual neck muscle whiplash injury, exercise intolerance/dysautonomia, and memory issues. At this stage in recovery, these problems respond better to “active rehabilitation” via specific targeted strategies rather than to strict rest. During follow-up office visits, a careful history and physical exam can elicit specific deficits.
and help customize a rehabilitation program to maximize recovery.

Some novel therapies available for use by general pediatricians are targeted rehabilitative therapies for concussion with atypical prolonged recovery; vestibular therapy with balance and oculomotor exercises; aerobic rehabilitation for subsymptom threshold exercise; and speech therapy for working memory and executive functioning (see Sidebar).

**VESTIBULAR SYSTEM INTEGRATION DYSFUNCTION**

An examination assessing the integration of postural control is essential in post-concussion patients and has been described in the companion article in this issue by Master and Grady (see “Office-Based Management of Pediatric and Adolescent Concussion). Vestibular and other therapies may be done by specifically trained occupational, physical, or speech therapists working individually or together as part of a multidisciplinary rehabilitative team. The goal of this article is to introduce these general concepts to the practicing pediatrician.

The vestibular system combines with the visual and somatosensory systems to provide postural control to maintain a sense of vertical orientation and equilibrium relative to gravity. This interaction can be complex and may present with one or multiple deficits on physiological rehabilitation. When these systems are not coordinated, patients often complain of headaches, dizziness, visual blurring/double vision, and balance problems. Practical complaints include symptoms with reading (horizontal deficits), symptoms when looking up at the board and down at the desk during note taking (vertical deficits), or symptoms while running and trying to focus on a target such as a ball or goal (gaze stabilization).

**Vestibular System**

The vestibular system is both a sensory and motor system. The semicircular canals provide sensory information regarding head acceleration and angular head movement. The utricle and saccule, collectively known as the otoliths, provide afferent information on linear motion and acceleration, as well as static tilt of the head. The vestibulo-ocular reflex and vestibulo-spinal reflex are the motor components of the vestibular system, providing gaze stabilization and body stabilization during head movement, respectively. Gaze stabilization functions akin to “the steady-cam” feature of the brain, and allows the athlete to maintain a stable visual picture while engaging in activity that involves vertical or horizontal “bouncing” such as running, jumping, or cutting.

Vestibular rehabilitation is a specific treatment approach designed to reduce or eliminate a patient’s dizziness, improve and restore balance, and increase physical activity levels. Vestibular rehabilitation is essential for restoring deficits in the vestibulo-ocular reflex (VOR) and vestibulo-spinal reflex (VSR). Improving gaze stability and postural stability will help the patient’s complaint of blurry vision, dizziness, headache, and imbalance. Vestibular rehabilitation has been shown to be effective for patients with peripheral vestibular disorders, migraine headache, and cervicogenic dizziness. Vision therapy that is part of vestibular rehabilitation includes a series of oculomotor exercises that guide patients through a progressive routine of sets and repetitions of convergence-divergence, smooth pursuit, and saccadic movement. The oculomotor exercises progress based on the patient’s tolerance and provocation of symptoms. Variables of speed, support surface, and conflicting visual background are introduced to challenge the patient.

**Somatosensory System**

The somatosensory system, which includes joint mechanoreceptors and muscle spindles, provides sensory information to the brain. Information includes the position and motion of joints, length and tension of muscles, and the condition of the support surface (level/angled, smooth/rocky, steady, etc.) upon which they are standing.

**Musculoskeletal System in Vestibular Dysfunction**

Manual physical therapy for the cervical spine is used to address physical impairments in range of motion (ROM) and muscle tightness that are thought to contribute to symptoms of headache, dizziness, and neck pain. Manual physical therapy has been shown to be effective in patients with cervicogenic headache and cervicogenic dizziness.

**Vestibular Therapy Evaluation**

**Symptom/Functional Scales**
The patient’s symptoms are graded using a verbal analog scale (VAS): a score of 0 indicates no symptoms and a score of 10 is the worst symptoms. A VAS can be used for the symptoms of dizziness, headache, and cervical pain, among others. The Sport Concussion Assessment Tool (SCAT2) symptom scale can also be used to quantify the number and severity of symptoms.\(^2\)

**Oculomotor System**

The oculomotor system consists of smooth pursuit and saccadic eye movements as well as vergence of the eyes. Remarkable findings in oculomotor testing include non-smooth eye movement, over- or under-shooting a target, convergence insufficiency (greater than 6 cm from tip of nose to object), and convergence spasm. While testing, the examiner should ask the patient if symptoms are aggravated or reproduced with specific testing.

- Smooth pursuit testing is performed by having the patient follow a slowly moving target (see Figure 1). The target is held about 20 to 24 inches away from the patient and is moved 30° in all directions (ie, horizontal, vertical, and diagonal).
- Saccades are tested by having the patient look back and forth between two stationary targets (see Figure 2). The targets are held about 20 to 24 inches away from the patient. Patients perform saccadic eye movements in the horizontal, vertical, and diagonal planes.
- Vestibular therapists may employ the King-Devick test as an alternate means of documenting saccades.\(^7\) In this test, a series of numbers is listed on a card. The patient is timed while reading the numbers on each card. Post-injury, these times are prolonged (from baseline if available) and improve with symptom-resolution, and if needed, vestibulo-ocular rehabilitation.
- Vergence is tested by assessing convergence first (see Figure 3) followed
Patients with prolonged concussion symptoms frequently complain of early fatigue with physical or mental activity.

by divergence (see Figure 4). The examiner’s finger/pen is held in the mid-sagittal plane and slowly moved toward the patient’s nose. The patient attempts to maintain focus on the inward moving target. The point at which the patient reports double vision is measured from the tip of the nose. Normal convergence is less than 6 cm from the tip of the nose (a measuring tape can be placed at the tip of the patient’s nose). Divergence is then tested by slowly moving the target away from the tip of the patient’s nose. The patient should be able to maintain focus on the diverging target.

- Ocular alignment can be assessed using the cover-uncover test. The presence of exophoria, esophoria, hyperphoria, and hypophoria may be determined with the cover-uncover test. Clinically, it appears that a pre-existing compensated ocular misalignment may be unmasked by concussive injury and is associated with protracted recovery.
- Pupil reaction should be assessed with a light pen. Dilated pupils that react to light are common in patients with autonomic dysfunction. This may be observed on physical exam or reported by parents only when the child/adolescent is more symptomatic following physical or mental activity.

**Vestibular System**

Gaze stability involving the vestibulo-ocular system can be assessed with the patient visually fixing on an object while nodding or shaking their head to see if symptoms are provoked.

**Central Nervous System**

- Gait is assessed to detect deficits in dynamic balance. Frequently, the gait appears normal and deficits are detected only when testing is made more challenging. Gait and balance can be easily assessed in the office using heel-toe walking. Check gait by starting with heel to toe walking forward with the eyes open. Progress to heel to toe walking backwards first with eyes open then with eyes closed. More deficits will be detected as the degree of difficulty increases. Usually decreased cadence and postural sway are noted as common deficits. In severe cases, marked deviation from a midline path, stumbling, or wide based gait may be seen.8
- The Romberg test can be used to evaluate static balance. The Balance Error Scoring System (BESS test) can also be used. The modified version of the BESS is part of the SCAT2.9 Postural control has been shown to be impaired in patients with concussion.10-12
- Coordination is assessed with fingertip to nose testing. Speed deficits are common early in the concussion but frank dysmetria is an unusual finding.

**Cardiovascular System**

Resting heart rate should be recorded. Elevated resting heart rates can be present post-concussion, which may indicate autonomic nervous system dysfunction.13 If symptoms worsen with heart rate elevations above a specific number, then therapy should be adjusted to keep the heart rate below this threshold.

**Musculoskeletal System**

- Assessment of the musculoskeletal system focuses on posture and cervical range of motion (ROM). The patient’s posture should be assessed for forward head position, rounded shoulders, excessive thoracic kyphosis, and static head tilt positions. The examiner can gain an appreciation for any muscular imbalance that may negatively impact cervical muscle strength and stabilization. Static head tilt positions may provide subtle cues to vestibular system involvement or compensation for ocular malalignment.

- The patient is asked to perform cervical ROM in the directions of flexion, extension, rotation, and sidebending. Reproduction of the patient’s symptoms is noted. The cervical muscles (upper trapzius, levator scapula, sternocleidomas-toid, cervical paraspinals, and sub-occipital muscles) are palpated for tension, length, and reproduction of symptoms. If there is a component of unrebhabilitated cervical spine whiplash injury, then cervical spine physical therapy can be added to the rehab prescription.

**EXERCISE INTOLERANCE/ DYSAUTONOMIA**

Patients with prolonged concussion symptoms frequently complain of early fatigue with physical or mental activity, sensitivity to light and noise, sleep disturbance and light headedness/dizziness when going from a seated to standing position. Literature showing that some of these symptoms may have a physiological basis has begun to emerge. In a recent study by Maugans and colleagues,13 36% of patients between 11 to 15 years of age still had reduced cerebral blood flow up to 4 weeks post-injury. Leddy and colleagues14 have proposed that these prolonged symptoms are a result of impaired autonomic function and that a gradual return-to-exercise protocol can be used to treat these symptoms. Leddy and colleagues15 have further demonstrated that in adult patients with prolonged symptoms, a subsymptom threshold aerobic exercise rehabilitation program improved clinical outcomes.15 They designed a treadmill stress test utilizing a modified Balke Protocol, described in the Buffalo Concussion Treadmill Test (BCTT).16 The BCTT is used to systematically determine a patient’s tolerance to aerobic activity and forms
the basis for a progressive exercise regimen based upon the heart rate achieved on the test. The BCTT has been shown to be safe and reliable in patients with prolonged symptoms and helps to restore physical conditioning and return patients safely to sport within 4 to 12 weeks. A similar rehabilitation program has been established for younger children with prolonged symptoms after sustaining a sports-related concussion; it combines gradual, closely monitored physical conditioning, general coordination exercises, visualization, education, and motivation activities.

As discussed in the article in this issue regarding the pathophysiology of concussion (“Concussion Pathophysiology: Rational for Physical and Cognitive Rest” by Matthew F. Grady, MD; Christina L. Master, MD; and Gerard A. Gioia, PhD), initiation of physical exertion too early after a concussion is associated with increased symptoms and slower recovery. However, emerging research supports the use of aerobic exercise as a treatment therapy after the acute post-concussion period has passed (ie, 3 to 4 weeks) to facilitate neurogenesis and physical reconditioning. The difficulty in the pediatric population is determining when to start aerobic (exertional) activity. Clinically, it is reasonable to consider beginning regular aerobic training in pediatric patients 4 to 6 weeks post-concussion regardless of symptoms.

The concussed patient is instructed to exercise up to the threshold of provoking worsening symptoms but not beyond. The long-term goal is at least 30 minutes of sustained aerobic activity. If symptoms prevent sustained aerobic activity, intensity must be decreased. This process can be started by physical therapists familiar with the BCTT process. Early in this process, 30 minutes of activity may only be moderate walking, but over a few months this should improve to sustained hard aerobic activity.

MEMORY DIFFICULTIES

In most patients a slow, graduated return to school is sufficient to permit recovery of school-related skills, including memory and central processing. For these individuals, return-to-school comprises their cognitive therapy. A small subset, however, may continue to struggle with more profound functional memory deficits. In this group, recovery can be aided by speech therapy that targets language-based deficits in working memory and executive function.

Patients with severe post-concussion symptoms may report difficulty remembering, concentrating, following directions, word retrieval issues, or participating in conversation with peers. Cognitive skills commonly impacted by a concussion include attention, memory, and processing speed, all of which can have a direct impact on communication and academic performance. At this stage in recovery, a comprehensive assessment of the patient’s cognitive and communication skills may be warranted. Such an evaluation is extremely helpful in academic planning for children with prolonged post-concussion symptoms and deficits.

This assessment may be conducted by a neuropsychologist and a speech-language pathologist when symptoms persist beyond 8 to 12 weeks. A neuropsychological evaluation includes an assessment of the child’s overall cognitive abilities, including cognitive processes affected by concussion, and their impact on behavior. A speech-language evaluation will focus on the child’s ability to understand and use language, as well as the impact of cognitive skills on communication. Communication may be verbal or nonverbal and includes listening, speaking, gesturing, reading, and writing in all domains of language (phonologic, morphologic, syntactic, semantic, and pragmatic). Cognition includes cognitive processes and systems (eg, attention, perception, memory, organization, executive function). Areas of function affected by cognitive impairments include behavioral self-regulation, social interaction, activities of daily living, learning and academic performance, and vocational performance. These assessments allow a comprehensive understanding of a child’s cognitive profile. If deficits are revealed during the evaluation process, speech therapy may be recommended to restore these skills to the child’s pre-injury baseline.

Speech-language therapy will include rehabilitation and compensatory strategy training to optimize recovery of cognitive-communication functioning. Goals include introduction and training of compensatory strategies for memory, language, executive functioning and other cognitive-communication skills. The speech-language pathologist or neuropsychologist can also collaborate with school personnel to establish appropriate supports and accommodations during the school re-entry process.

CONCLUSION

Recovery from a concussion occurs spontaneously for most patients. Clinically, patients who suffer a concussion and rest immediately as the initial treatment tend to recover more quickly. Those patients who physically and/or cognitively over-exert too early in the post-concussion period tend to have a prolonged recovery. These findings are consistent with research comparing immediate rest to immediate exertion.

Patients who have persistent signs and symptoms 4 weeks after injury benefit from “active rehabilitation.” Common problems include impaired balance, vestibulo-ocular dysfunction, and aerobic intolerance and memory deficits. Rehabilitation prescriptions should be customized to therapies specific to the patient’s deficits.

Patients who receive vestibular therapy are prescribed a comprehensive daily home exercise program that may include...
oculomotor, balance, and cervical spine exercises. Each patient should be encouraged to perform progressive aerobic activity based on their level of recovery. Improvements can be seen in patients as soon as 4 weeks into therapy and some patients may report improvements within a few sessions.

For the medically difficult, post-concussion patient with an atypical prolonged recovery trajectory, a multidisciplinary team approach to the overall management of protracted concussion symptoms is recommended. For patients with prolonged post-concussion symptoms, a comprehensive evaluation for possible vestibular dysfunction, oculomotor difficulties, musculoskeletal, aerobic, and speech or language impairments facilitates appropriate referral to physical, occupational, or speech therapists trained in the evaluation and management of concussion-related deficits.

REFERENCES