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## Guest Editorial

# Balance and Vestibular Function

Balance impairment is the most common motor symptom across the spectrum of severity of traumatic brain injury [1]. The severity of the balance dysfunction is dependent upon the extent and location of the injury to the brain and surrounding structures. The ability to maintain balance is determined by input from visual, vestibular, sematosensory, cognitive, and emotional systems, as well as the ability to organize information from these functions for the proper motor output. It is common to have multiple system involvement after traumatic brain injury due to the nature of the injury. In addition, balance may also be affected due to other injuries incurred during the initial traumatic event such as fractures or peripheral nerve injuries. Medications used to manage medical issues may also contribute to problems with balance and can delay recovery from the injury.

Horak, Wrisley and Frank [2] developed a balance evaluation tool that organizes postural control systems in to six categories for diagnostic and treatment purposes:

1. Biomechanical Constraints. This addresses the ability to maintain center of mass over the base of support. The biomechanics necessary for postural control can be affected by decreased range of motion, strength or surface alterations of the support base. These constraints can be viewed as primary or secondary after brain injury. A primary constraint would result from motor cortex damage during the traumatic event. Secondary constraints include fracture that alters the alignment of the lower extremity or spasticity that ultimately leads to decreased range of motion at the ankles contributing to balance impairment.
2. Stability Limits/Verticality. Perception of orientation to gravity (verticality) and awareness of the limits of base of support (stability limits) is important for maintaining balance. Impairments in sensory systems or damage to the parietal cortex from brain injury may result in impaired perception of upright causing increased demands on the postural system.
3. Anticipatory postural adjustments. These are necessary to respond to postural changes produced from volitional movement. These adjustments are based on past memory of successful movement and help prepare for initial movement. When one lifts their arms in front of them, this increases the anterior load. If it weren't for the back extensors, hamstrings and gastrocs activating prior to the movement, there would be a destabilizing force forward. Damage to supplementary motor areas, the basal ganglia and brain results in impaired anticipatory responses.
4. Postural Responses. If the postural system is displaced further than planned, a postural response is needed to return the body to a state of equilibrium. Ankle, hip or stepping strategies help stabilize postural displacements from unplanned slips or pushes. These strategies can be delayed (secondary impairments due to peripheral nerve injury, primary impairment due to white matter tract disruption), weak (basal ganglia damage) or exaggerated (cerebellar damage) depending upon the area of the brain that is injured.
5. Sensory Orientation. This system identifies any increase in body sway during stance associated with altering visual or surface somatosensory information for control of standing balance. Sensory disorientation results in instability in patients

with deficits in pathways involving the vestibular system and sensory integrative areas of the temporoparietal cortex when the support surface or visual environments are moving.

6. Stability in Gait. This evaluated Stability during gait. Deficits are seen as a result of impaired coordination between spinal locomotor and brain-stem postural sensori-motor programs.

The vestibular system detects motion of the head in space and in turn generates reflexes that are crucial for our daily activities, such as stabilizing the visual axis and maintaining head and body posture. The vestibular system also provides us with our subjective sense of movement and orientation in space. The vestibular sensory organs are located in the petrous part of the temporal bone in close proximity to the cochlea, the auditory sensory organ. The vestibular system is comprised of two types of sensors: the two otolith organs (the saccule and utricle), which sense linear acceleration (i.e., gravity and translational movements), and the three semicircular canals, which sense angular acceleration in three planes. The receptor cells of the otoliths and semicircular canals send signals through the vestibular nerve fibers to the neural structures that control eye movements, posture, and balance.

This special issue of *NeuroRehabilitation* focuses on the assessment, diagnosis and treatment of balance and vestibular disorders. Drs. Khan and Chang begin with the anatomical structures and pathways of the vestibular system. The next two articles apply that anatomy and provide guidance on the assessment of balance and vestibular dysfunction. Dr. Chandrasekhar focuses on the assessment of balance and dizziness in the TBI patient providing a roadmap for assessment of these patients. Dr. Smouha presents a framework for the diagnosis and treatment of inner ear disorders, with an emphasis on problems common in neuro-rehabilitation. He differentiates vertiginous disorders based on clinical pattern and duration to reach the diagnosis. He discusses common inner ear causes of vertigo including: vestibular neuritis, Meniere's disease, benign paroxysmal positional vertigo, and bilateral vestibular loss. He also discusses common central nervous system causes of vertigo including: post concussion syndrome, cervical vertigo, vestibular migraine, cerebrovascular disease, and acoustic neuroma.

Dr. Lei-Rivera and colleagues review the clinical utility of vestibular laboratory testing and the bedside vestibular examination in patients following mild traumatic brain injury (mTBI). In addition, the validity and inter-observer reliability of functional outcome measures commonly used in individuals with mTBI is also reviewed. Dr. Lei-Rivera concludes that TBI rehabilitation services are increasingly exemplified by the needs of patients, rather than by the underlying pathology or diagnosis. Basing treatment decisions and treatment timing on laboratory, clinical, and functional testing can optimize the rehabilitation outcome.

Dr. Gay reviews studies on the interaction of physiological and cognitive processes required to maintain balance that may aide assessment and recovery of balance disturbance in patients with brain injury providing the rational for further inclusion of neurocognitive measures in the assessment of vestibular disturbance.

Dr. Cohen discusses, the relevant anatomy of vision and the components of a neuro-optometric evaluation and vision rehabilitation. He emphasizes the importance of vision and visual processing for maintaining a sense of balance and equilibrium. Drs. Shaikh and Ghasia then review the neurophysiology and pathogenesis of common disorders of saccades and gaze holding. Drs. Rine and Wiener-Vacher provide an overview of the etiology of vestibular dysfunction in children as well as the related impairments, and to describe testing methods and evidence based interventions to ameliorate the vestibular related impairments in children.

Dr. Gurley and colleagues appraise the current and accepted methods available to the skilled clinician in quantifying and treating vestibular dysfunction following concussion. Incidence and prognostic indicators are reviewed along with common barriers to recovery. Dr. Lin and Aligene pharmacologic treatment of dizziness and balance deficiencies. Commonly encountered drugs with potential to cause balance-related symptoms are also reviewed along with background on advantages of certain drugs and methods to minimize adverse effects.

This issue of *NeuroRehabilitation* concludes with an article by Drs. Aligene and Lin regarding the clinical management of vestibular and balance dysfunction in a concussed athlete. They focus on diagnosis, initial work-up, and management.

The articles in this special issue allow the reader to have a comprehensive view of the neurologic underpinnings, evaluation, and treatment of vestibular and balance disorders. A thorough history, physical and judicious use of tests should lead the clinician to the etiology of the balance or vestibular impairment and increase success in treatment. Treatment must be tailored to the patient based on diagnosis and functional impairments.

We hope you enjoy the issue.

*Guest Editors*

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