Introduction

Of the numerous tools available for assessing patients with imbalance, the most clinically effective one is an accurate clinical history i.e., the patient’s past and presenting symptoms. Once the symptoms have been established, then one can select the appropriate laboratory studies which when interpreted in conjunction with that history should offer information relative to site-of-lesion, narrow the etiological possibilities, and provide information relative to the functional impact of the problem. The functional information provided by CDP plays a key role in contributing to treatment design, particularly to a Vestibular and Balance Rehabilitation Therapy (VBRT) protocol and in monitoring the patient’s progress. In fact, when Stewart and colleagues examined the cost effectiveness of the diagnostic evaluation of the dizzy patient within the context of this model, CDP proved to be the most cost-effective test of balance. This finding is enhanced by the role of CDP in differentiating between true and exaggerated abnormal symptoms. Other prospective studies involving patients with idiopathic Parkinson’s disease have shown that CDP impairment information can be of significant value in identifying patients likely to benefit from surgical, deep brain stimulation, and medication treatments.

Because the ability to maintain ones balance and to perform the general activities associated with daily living in a safe and effective manner depends on the interaction between multiple sensory and motor systems any attempt to assess balance “function” must take into account those interactions, the brain’s ability to adapt to changes in those interactions as well as the relative role of cognitive processing on the same. It is on this basis that recent advancements in CDP have focused on the assessment of changes in visual acuity and the maintenance of balance during active head movements.

Role of Gaze and Postural Stabilization in Balance Control

The gaze and postural stabilization systems are physiologically distinct because they rely on information from different senses, motor reactions of different groups of muscles, and different neural pathways. The two systems are, however, interdependent because gaze stability is not possible unless the body on which the head
and eyes ride is also stable; and because accurate vision, which is dependent on gaze stability, is a critical sensory input to postural control.\textsuperscript{11,12}

Because the gaze and postural systems are physiologically distinct, the performance characteristics of the two can be affected differently by a common pathology; for example, a vestibular neuronitis. And because both are heavily influenced by the brain’s unique adaptive responses to pathology, patients with similar pathologies experience a wide variety of gaze and postural symptoms and resultant functional limitations.\textsuperscript{6,12,23} This disparity of symptoms and functional limitations is why it is critical to assess both postural control and gaze stability to identify the most effective rehabilitation approach to a given patient.

Videonystagmography (VNG), rotary chair, and the vestibular autorotation test (VAT) quantify the relationship between motion induced activation of the peripheral vestibular system and the eye movements that result. Because neural connections between the vestibular receptors and the eye muscles are relatively “hard wired,” the amplitude, frequency, and direction of eye movement responses to controlled body and head movement provide good indications of the integrity of the vestibular receptors and their associated neural pathways. Hence, the general reference to these protocols as vestibular function tests—the most often stated purpose of which is to quantify the location and characteristics of pathological changes within the vestibular system to provide site-of-lesion information.

In contrast to the above, the relationship between head movement, gaze, and visual acuity is much more complex. This is because the control of gaze and visual acuity is dependent on the interaction of three components.\textsuperscript{1}

1. The vestibulo-ocular reflex (VOR), which reflexively drives eye movements that are equal and opposite to those of the head.
2. The smooth pursuit system which relies on visual input to smoothly follow a desired visual target.
3. The saccadic eye movement system, which also relies on visual inputs to generate rapid eye movements to “catch-up” to a visual target which is moving beyond the limit of smooth pursuit.

The key to maintaining stable gaze and good visual acuity then is the proper coordination of these three components.

The VOR system works in the absence of vision and at higher head movement velocities, while the smooth pursuit system uses visual inputs to follow slower moving objects. When both the VOR and smooth pursuit systems fail to maintain gaze on a visual target, rapid saccadic movements redirect gaze in the desired target direction. Adaptive interactions among the three components also enable subjects with deficits in one system to at least partially compensate by relying more heavily on the others.

A brief review of the visual complaints in patients with peripheral vestibular losses illustrates the need for complementary clinical information provided by vestibular function and gaze impairments tests. The extent to which reduced VOR function results in oscillopsia and/or loss of acuity during daily life activities depends on
a number of additional factors including the efficacy of the smooth pursuit and saccadic systems, the patient’s activity lifestyle, and the patient’s strategies for coordinating head and gaze movements. As a result, patients with similar vestibular pathologies report different symptoms and functional limitations. Patients who limit their actions to slower and more predictable movements, for example, may use combinations of smooth pursuit and catch-up saccadic control and experience few if any gaze impairments, while patients with lifestyles requiring high velocity, unpredictable movements experience acuity and image stability problems.

While vestibular function tests can help document the location and nature of vestibular pathology, they provide little useful information relative to the functional gaze problems experienced by the individual patient. By documenting changes in visual acuity for different directions and velocities of head movement for both predictable and random movements, gaze impairment tests help quantify the extent of a patient’s functional capabilities relative to daily life activities, as well as provide information for targeting rehabilitation exercises, setting treatment goals, and monitoring outcomes. Since the main goal of rehabilitation is to maximize the patient’s ability to use compensatory mechanisms, impairment information that quantifies the combined effects of vestibular pathology and other pathological and adaptive processes, as exemplified above, is critical to treatment of both gaze and postural components of balance system problems.

Head-Shake Sensory Organization Test (HS-SOT)

The HS-SOT protocol is more difficult than the standard SOT, and the equilibrium scores of normal patients will be slightly lower on the HS-SOT than on the SOT (<30% difference). Because the HS-SOT provides additional challenges to the sensory organization of balance, it can quantify problems in patients with subtle sensory control problems that perform within normal limits on the standard SOT. The HS-SOT also provides useful objective information relative to the patient’s ability to perform tasks of daily living, many of which involve the ability to actively balance while independently moving the head and eyes.

Head movements challenge the patient by generating a vestibular stimulus in addition to that generated by the patient’s sway. To maintain balance in the absence of alternative visual and somatosensory inputs while moving the head, the brain must differentiate the sway and head-shake stimuli. Degradations in the sensitivity and accuracy of the vestibular receptors, however, can interfere with the process of signal differentiation and reduce stability during head movement. Because the vestibular system is composed of multiple, direction specific sense organs, these degradations may also be axis specific, creating instability only when head movements occur about the involved axis.

In addition to the above effects on vestibular control of balance, head-shaking places an additional task demand on the patient. Some patients with subtle sensory problems successfully perform the standard SOT by exerting conscious effort to augment their impaired automatic reactions. In these cases, the additional task demands of the HS-SOT can abnormally reduce stability by interfering with the patient’s ability to consciously augment balance responses.
Abnormal HS-SOT performance limited to a specific axis is most likely caused by reduced sensitivity and accuracy of receptors acting about that axis. Whereas, HS-SOT problems caused by attention demands would most likely be independent of the movement axis.

According to recent research, patients with caloric asymmetries of 25% or greater and normal standard SOT results performed abnormally on the HS-SOT in 79% of cases. An even larger 89% of patients with motion provoked symptoms and normal SOT results were abnormal on the HS-SOT.16)

As with the SOT, when interpreting HS-SOT results, the reader should keep in mind that the test quantifies impairments of sensory input systems, that is, the patient’s ability to make effective use of sensory inputs, and it does not determine the underlying pathology. Impairment of vestibular input, for example, may occur in the presence or absence of peripheral vestibular pathology.

Summary

The control of balance is a complex process involving multiple and interacting sensory, motor, and adaptive processes. Because the pathological processes associated with most chronic balance disorders can be medically stabilized, but not reversed, rehabilitation exercises are the most effective management approach for reducing the symptoms and functional limitations associated with balance disorders. Effective rehabilitation management requires knowledge of the underlying pathology, and the functional impairments and adaptive responses that impact performance of daily life activities. Tests that quantify balance system impairments, including both gaze and postural stabilization, provide valuable information for treatment planning and outcome documentation that complement the information provided by site-of-lesion tests.

REFERENCES


For additional references, consult the key word searchable bibliography on the web site: