Chapter 43

VESTIBULAR TRAUMA

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INTRODUCTION

The sense of balance is a vital combat sense. Even minor impairments in balance function can severely impact mission accomplishment, increase the risk to the fighting unit, and strain critical manpower. Therefore, diagnosing and treating balance disorders in a battlefield scenario are critical to the operational mission. Unfortunately, vestibular disorders are among the most common disorders seen in modern combat.[1] Although isolated balance disorders can occur, balance disorders in combat are most often associated with head injury. Balance disorders can arise from blunt head injury, blast head injury, or mixed (blast/blunt) head injury.[2–9]

Traumatic brain injury (TBI) and the circumstances of blast injury have been covered elsewhere in this book. This chapter will focus largely on the diagnosis and treatment of balance disorders seen on the battlefield and in association with head injury.

Proper diagnosis of balance disorders associated with operational scenarios is critical for a variety of reasons. First, as stated earlier, balance disorders are a major operational issue. Second, balance disorders significantly affect the quality of life after return from deployment. Third, balance disorders can worsen if they are untreated. The last point is particularly important. Until recently, the assumption was that

TABLE 43-1

CLASSES OF DIZZINESS SEEN AFTER OPERATIONAL TRAUMA

Disorder	Characteristics	Testing	Additional Information
Posttraumatic benign positional vertigo	Episodic positional dizziness/vertigo	Positive Dix-Hallpike Test	Just like traditional BPV
Posttraumatic exertional dizziness	Dizziness with exertion After exertion—blunt During exertion—blast	History	
Posttraumatic migraine-associated dizziness	Episodic dizziness that varies in quality and length often temporally associated with migraine headache	No specific tests	Seen after blunt or blast trauma
Posttraumatic spatial disorientation	Constant unsteadiness worse when standing still or moving quickly	Difficulty in quiet stance	May have headaches Seen mainly after blunt trauma
Postblast dizziness	Constant headache associated with constant feeling of unsteadiness	Rotary chair findings being studied	Seen after blast trauma
Postblast dizziness with vertigo	Same as above with episodes of vertigo	Rotary chair findings being studied Will have asymmetry on caloric testing and in chair	Seen after blast trauma
Superior canal dehiscence	Episodic dizziness with elevation changes, autophony, and low-frequency conductive hearing loss	VEMP appearing at lower intensity than normal Temporal bone CT scan	
Meniere's disease	Episodes of vertigo with ear pressure and tinnitus	ECoG, but specificity and sensitivity are poor	Can have significant hearing loss
Perilymph fistula	Sudden-onset significant hearing loss and vertigo after trauma	Fistula test, but specificity and sensitivity are poor	Can present with mild dizziness alone

BPV: benign positional vertigo; CT: computed tomography; ECoG: electrocochleography; VEMP: vestibular-evoked myogenic potential vestibular balance disorders seen in association with head trauma would improve and normalize over time. Although a certain percentage of these disorders do follow this pattern, a significant percentage deteriorates over time, thus becoming more troublesome to the patient and more difficult to treat. To minimize the impact of and maximize the recovery from operational vestibular disorders, it is critical to understand the diagnosis and treatment of these disorders. Table 43-1 shows the most common classes of dizziness seen after operational trauma. The role of the CT (computed tomography) scan for semicircular canal dehiscence and imaging of other trauma lesions is covered elsewhere in the text.

DIAGNOSIS OF BALANCE DISORDERS

Initial screening by the otolaryngologist and vestibular physical therapy team includes a history and systems review. Vestibular trauma identified in a war theater is frequently due to exposure to head trauma. Patients usually report a variety of symptoms. Dizziness with subsequent unsteadiness is the most common symptom followed by headaches.[1] Patients also report

- vertigo,
- tinnitus,
- hearing loss,
- neurocognitive issues, and
- sleep disorders.

If a patient reports vertigo and pathological nystagmus with positional changes, benign paroxysmal positional vertigo (BPPV) is suspected and a Dix-Hallpike maneuver will be performed during the vestibular physical therapy evaluation.

Patient self-reporting instruments administered by vestibular physical therapy include the Dizziness Handicap Inventory (DHI; Table 43-2), which measures a patient's self-perceived handicap as a result of vestibular disorders. The test is valid and reliable (test-retest reliability: $r = 0.97$). The DHI provides quantification of the patient's perception of disequilibrium and its impact on daily activities. It is useful to establish subjective improvement and provides insight into quality of life. The DHI consists of 25 questions, subgrouped into functional, emotional, and physical components. It is scored on a scale of 0 to 100, with higher scores indicating a greater degree of disability.[10]

Another commonly used self-report measure is the Activities-specific Balance Confidence (ABC) Scale (Exhibit 43-1) that measures patient confidence in performing activities of daily living without falling. There are 16 questions, each of which is scored on a scale of 0% to 100%, with a higher score indicating a greater degree of self-confidence in one's balance. The ABC is widely used to assess the impact of an individual's perceived balance deficits on performance of everyday activities. The ABC Scale was found to be internally consistent and demonstrated good test-retest reliability, as well as convergent and criterion validities.[11] Testing vestibular function generally can be divided into testing performed in the audiovestibular laboratory and testing performed in the physical therapy department.

AUDIOVESTIBULAR LABORATORY MEASURES

Clinical evaluation by an otolaryngologist or audiologist includes the following:

- audiogram,
- tympanogram/otoscopy,
- distortion product otoacoustic emission testing,
- electronystagmogram for central vestibular oculomotor functions, and
- electronystagmogram for peripheral vestibular oculomotor functions.

Additional rotary chair testing examines a variety of balance reflexes and, if properly administered, can yield information about otolithic function. Vestibular-evoked myogenic potentials also examine otolith function. (A detailed description of the test methodologies goes beyond the scope of this chapter.)

VESTIBULAR MEASURES AND EVALUATION

Special Tests for Benign Positional Vertigo

The Dix-Hallpike maneuver is a diagnostic, clinical provocation test that attempts to reproduce positional vertigo with associated nystagmus. A positive test is indicative of posterior canal BPPV (also known as posterior canal BPPV).[12] This instrument is used as part of a vestibular examination for imbalance, dizziness, and vertigo. It should be used with clients who have a history of repeated episodes of vertigo with changes

TABLE 43-2

DIZZINESS HANDICAP INVENTORY*

Items	**4**	**3**	**2**	**0**	
	All	**Most**	**Some**	**Never**	**Condition**
Does looking up increase your problem?					**P**
Does walking down the aisles of the commissary or PX without a cart increase your problem?					**P**
Does performing more ambitious activities like sports, dancing, or military common duties/tasks increase your problem?					**P**
Do quick head movements increase your problem?					**P**
Does turning over in bed increase your problem?					**P**
Does walking on uneven terrain increase your problem?					**P**
Does bending over increase your problem?					**P**
Because of your problem, do you restrict your travel for duty or recreation?					**F**
Because of your problem, do you have difficulty getting into or out of bed?					**F**
Does your problem significantly restrict your participation in social activities?					**F**
Because of your problem, do you have difficulty reading?					**F**
Because of your problem, do you have someone accompany you when you leave quarters?					**F**
Because of your problem, is it difficult for you to take care of yourself (bathe, dress, prepare a meal)?					**F**
Because of your problem, is it difficult for you to walk around your quarters in the dark?					**F**
Because of your problem, do you avoid driving your vehicle during the daytime?					**F**
Because of your problem, is it difficult for you to go for a walk by yourself?					**F**
Because of your problem, is it difficult for you to walk up and down stairs?					**F**
Because of your problem, do you avoid driving your vehicle in the dark?					**F**
Does your problem interfere with your job or your military duties?					**F**
Because of your problem, is it difficult for you to concentrate?					**E**
Because of your problem, do you feel frustrated?					**E**
Because of your problem, are you afraid to stay home alone?					**E**
Because of your problem, are you afraid people think you are intoxicated?					**E**
Has your problem placed stress on your relationships with members of your family or friends?					**E**
Because of your problem, are you depressed?					**E**

All	**Most**	**Some**	**Never**	**Total**
(×4) =	(×3) =	(×2) =	(×0) =	
(×4) =	(×3) =	(×2) =	(×0) =	
(×4) =	(×3) =	(×2) =	(×0) =	

E: emotional; F: functional; P: physical; PX: Post Exchange
*Scores >10 points should be referred to balance specialists for further evaluation.
Data source: Jacobson GP, Newman CW. The development of the Dizziness Handicap Inventory. *Arch Otolaryngol Head Neck Surg*. 1990;116:424–427.

in head position relative to gravity.[13] A positive test occurs due to the abnormal presence of otoconia in one of the semicircular canals. Vertigo is caused by movement of otoconia when the involved canal is placed in a gravity-dependent position. Although the incidence of BPPV is not increased by exposure to blast, it is possible to have BPPV occur at the same time a service member is having blast-related symptoms, especially if the service member has a history of BPPV. Only 4% of blast injuries are coincident with BPPV.[1]

EXHIBIT 43-1

THE ACTIVITIES-SPECIFIC BALANCE CONFIDENCE SCALE

For *each* of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
No confidence								Completely confident		

"How confident are you that you will *not* lose your balance or become unsteady when you:

1. … walk around the house? ______%
2. … walk up or down stairs? ______%
3. … bend over and pick up a boot from the front of a closet floor? ______%
4. … reach for a small can off of a shelf at eye level? ______%
5. … stand up on tiptoes and reach for something above your head? ______%
6. … stand on a chair and reach for something? ______%
7. … sweep the floor? ______%
8. … walk outside the house to a car parked in the driveway? ______%
9. … get into or out of a car? ______%
10. … walk across the parking lot to the PX (Post Exchange)? ______%
11. … walk up or down a ramp? ______%
12. … walk in a crowded mall where people walk rapidly past you? ______%
13. … are bumped into by people as you walk through the mall? ______%
14. … step on or off of an escalator while you are holding onto the railing? ______%
15. … step on or off of an escalator while holding onto parcels and therefore cannot hold onto the railing? ______%
16. … walk outside on oil-slick sidewalks? ______%

Cranial Nerve Examination

An oculomotor examination should be conducted to assess cranial nerve integrity and angular vestibuloocular reflex (VOR). This examination encompasses cranial nerves III, IV, VI, and VIII. It also includes an evaluation of smooth pursuit. The inability to perform smooth pursuit may indicate central nervous system involvement.

Vestibuloocular Reflex Testing

The Head Impulse Test is a clinical test that assesses the integrity of the VOR. It would be used in a patient with suspected vestibular hypofunction. The Head Impulse Test is considered positive when—after a small, high-speed movement of the head—a refixation saccade is noted.[14] A client with a vestibular hypofunction may use a refixation saccade after the head is moved toward the side of the hypofunction. With bilateral hypofunction, a refixation saccade with the right and left tests may be seen. Individuals with normal vestibular function do not use corrective saccades after the Head Impulse Test; their eyes stay fixed on the target (ie, examiner's nose). The Head Impulse Test is only positive in vestibular loss or hypofunction, not in cerebellar stroke or migraine. It is important that the test is correctly delivered as a high-acceleration, moderate velocity, low-amplitude head rotation with the subject maintaining gaze on a fixed target. If delivered only in the right and left directions, this tests the horizontal semicircular canals and the superior branch of the vestibular nerve.

The Head-shaking Nystagmus Test (administered with Frenzel lenses) is a clinical test that assesses for dynamic asymmetry in the VOR. The examiner rotates or "shakes" the client's head back and forth 20 times in 10 seconds (2 Hz) in approximately 45 degrees of rotation to either side. When the head movements stop, nystagmus that beats toward the more active (intact) side or away from the side of a unilateral peripheral vestibular lesion indicates a positive response.[15]

The clinical Dynamic Visual Acuity Test (DVAT) is a procedural test that measures stabilization of eye gaze with active head movement. It is a performance measure of the VOR.[16] It would be used in a patient with suspected vestibular hypofunction.

Gaze Stabilization Test

The Dynamic inVision System (Neurocom, Inc, Clackmas, OR) may be effectively used to assess visual function. This system assesses gaze stability, perception time, target acquisition, and target tracking. It requires the use of head movement while visualizing letters and tracking moving targets. Neuroanatomically, this represents an assessment of the horizontal semicircular canals, the vestibular nerve, and the vestibular and oculomotor pathways. Vestibular therapy at the Naval Medical Center San Diego has adopted a set of visually based vestibular/visual/cognitive interaction tests to guide the selection of objective outcome measures for blast-exposed patients to a customized vestibular physical therapy program.[17] This test battery is performed in a darkened room with an effective viewing distance of 10 feet. Individuals give a verbal response that is recorded by the test operator.

The test battery includes the following:

- static visual acuity,
- perception time,
- target acquisition,
- target following,
- dynamic visual acuity (DVA), and
- Gaze Stabilization Test (GST).

Perception time is measured by calculating the time in milliseconds; a randomly presented optotype must be on the screen before accurate recognition. Target acquisition is the time (in milliseconds) required for generating a saccade from the center of the screen to a new optotype positioned up, down, to the right, or to the left of center. Target following is a functional measure of smooth pursuit speed (degrees/second), wherein the subject could accurately track a symbol moving horizontally or vertically at constant velocity. DVA is measured as the logarithm of the minimum angle of resolution from the Snellen chart optotype scale. DVA tests reflect the change in function from stable acuity to dynamic acuity during horizontal or vertical head motion. GST is the speed (degrees/second) with which the subject can accurately hold a target and maintain recognition while performing active horizontal or vertical head motion.

Historically, computerized dynamic posturography and Dynamic Gait Index (DGI) are useful outcome measures for individuals with vestibular deficits. However, their utility is hampered by ceiling effects in a young, well-trained balance disorder population. The visual vestibular-based interaction tests have proven to be the most sensitive measure of vestibular function posttrauma. Although each test in this battery provides valuable information, the vertical GST is the last measure to improve in our military patient populations. This likely indicates that recovery of vestibular function is frequency and velocity dependent, and intimately related to the prior establishment of gaze stabilization. The details of findings in specific groups of patients are presented elsewhere.

Gait Analysis

Physical therapy gait analyses tools include the DGI or Functional Gait Assessment (FGA). The FGA measures gait tasks that incorporate head movement, a narrow base of support, and changing speeds.[18,19] Although similar to the DGI, the FGA also includes more challenging tasks that make it ideal for avoiding the ceiling effect found with the DGI when testing higher functioning patients. The FGA also has an identified fall risk cutoff of 22/30, which is helpful for assessing lower level TBI patients.[19]

The High-Level Mobility Assessment Tool (HiMAT) is a tool specifically designed to measure high-level balance and mobility in people with TBI. It is used to quantify high-level mobility outcomes of 15 tasks, including walking, bounding, running, ascending stairs, and descending stairs. The HiMAT is suitable for any TBI patients who have goals that require a level of mobility beyond independent level walking and balance. Therefore, it is beneficial to use the HiMAT to screen military active duty service members who are required to pass a service-specific physical fitness test in order to be found fit for full duty. Content was generated from a review of existing mobility scales and by surveying expert opinion.[20]

Cerebellar Tests

The clinician can choose from among an array of standard cerebellar tests. Two choices are (1) rapid alternating movements and/or (2) finger-to-nose/past-pointing. In past-pointing, the patient is instructed to extend the arms and place the index finger of one hand on the index finger of the examiner, or on a static target, such as a mark on a table. The eyes are then closed, the arm raised above the head, and then quickly returned to the perceived starting position. The procedure should be repeated several times with the eyes remaining closed. Normal patients will return the fingers to the starting position with little lateral deviation, whereas an abnormal result would be represented by the hands drifting away from the target as the trunk rotates. Consistent rotation to one side may indicate peripheral dysfunction on the side toward which the patient deviates, whereas less consistent deviation may indicate a compensated or peripheral weakness. Reported sensitivities for past-pointing performance range from 20% to 50%, and reported specificities range from 76% to 100%.[21,22]

Integration of Multisensory Input for Balance

The Romberg and Sharpened Romberg Test challenges the vestibular system by providing decreased somatosensory and visual inputs for balance. The *Romberg test* is performed by having the patient stand with feet next to each other, first with eyes open, then with eyes closed. The *Sharpened Romberg test* is performed by having the patient stand with the heel of one foot to the toe of the other with eyes open, then closed. These tests may also be performed on foam. A loss of balance during a Romberg test on foam may be presumed to indicate bilateral vestibular loss.

Computerized dynamic posturography is useful to assess integration of multisensory input for balance. Tests available include the following:

- the Sensory Organization Test,
- the Head-shaking Sensory Organization Test,
- the Motor Control Test, and
- the Adaptation Test.

This system provides a challenge of balance with equipment and software under different conditions. The sensory organization test looks at age- and height-referenced responses to sway in the sagittal plane. It may uncover inappropriate responses to inaccurate sensory responses in the service member postvestibular trauma. The Motor Control Test looks at balance dysfunction and impaired reactive latencies. It may show delayed motor responses to unpredictable perturbations.

Cervical Proprioception

Cervicogenic dizziness is a common result of vestibular trauma. If the cervical spine is affected by a blast injury, for example, then information being transmitted to the brain may be distorted, or blood flow in the basilar artery may be disrupted.[23] Assessment of cervical proprioception may show that the patient is unable to orient his/her head to vertical without visual input. Cervical proprioception contributes to ocular motor and postural function.[24] Consequently, it is important that, in the presence of postural dysfunction, cervical proprioceptive deficits be corrected through physical therapy intervention.

TREATMENT MODALITIES

The treatment of choice for most operationally related balance disorders is vestibular rehabilitation. The details of rehabilitation are described below. Three special cases are discussed: (1) superior canal dehiscence, (2) Meniere's disease, and (3) traumatic perilymph fistula. Although these three disorders require rehabilitation, they each have specific treatment modalities in addition to rehabilitation.

Superior Canal Dehiscence

A small percentage of individuals who present to our clinic have superior canal dehiscence. This disorder is characterized by vertigo/dizziness that is produced with elevation changes and/or load noises and a mild, low-frequency conductive hearing loss.[25–27] The disorder is caused by an opening in the bone over the superior semicircular canal that produces a third mobile window in the inner ear. This extra mobile window changes fluid flow through the inner ear, thus producing the tell-tale auditory and vestibular issues associated with the disorder. The condition is diagnosed by symptoms, a CT scan showing the dehiscence, and a vestibular-evoked myogenic potential that arises at an abnormally low sound level. The treatment of choice is surgical repair, if the symptoms are troublesome to the patient. The details of the surgical procedure go beyond the scope of this chapter. There are a number of possible surgical options, but the goal of each of these is to correct the defect and/or to occlude the troublesome balance canal. Surgery should always be accompanied by vestibular rehabilitation. The details of this rehabilitation are discussed below.

Meniere's Disease

Meniere's disease is not a disorder seen acutely in combat, but can develop over time. Meniere's disease is an inner ear condition wherein individuals suffer from episodic vertigo with fullness and tinnitus in the involved ear. The vertigo episodes last minute to hours and are often heralded by an increase in the tinnitus and/or fullness in the involved ear. There is also a low-frequency sensorineural hearing loss in the involved ear. The pathological condition thought to be responsible for (or at least associated with) Meniere's disease is endolymphatic hydrops, which results from excess fluid in the endolymph compartment of the inner ear. Although there are many potential etiologies of this pathological condition, trauma has long been recognized as a cause.[28] In fact, both blunt and blast TBIs are associated with up to a 15% incidence of Meniere's disease, with the blast patients tending to progress more quickly than the blunt patients. The diagnosis of this disorder is made primarily based on history, along with exclusion of other causes. An electrocochleography test is a helpful adjuvant in the diagnosis of this disorder. The electrocochleography test is useful when the test is positive (expanded SP/AP [summating potential/action potential] ratio) and is less helpful when the test is negative. The treatment algorithm for Meniere's disease is complex and controversial. Currently, treatment starts with dietary modification, medicines, and rehabilitation. If patients fail that treatment, more aggressive treatment ensues.

Perilymph Fistula

No balance disorder is more controversial than perilymph fistula (PLF). What is known is that a PLF occurs when the oval or round window is torn and fluid leaks from the inner ear into the middle ear. Although enough fluid leakage can certainly cause deafness and significant vertigo, it is very rare to see this combination of symptoms (immediate deafness and severe vertigo) in an acute or even subacute combat situation. Many individuals now believe that PLF can present with less severe hearing loss and less severe dizziness or even with less severe dizziness alone.[29] They argue that smaller leaks could produce fewer symptoms. Unfortunately, there is no gold standard for the diagnosis of a PLF, except direct observation of the leak during an operative case. A positive fistula test (dizziness and eye deviation with positive and then negative pressure on the eardrum via pneumatic otoscope) is helpful, but lacks specificity and sensitivity. Currently, we consider individuals as having a definitive fistula if they have sudden-onset dizziness and hearing loss after a traumatic event (including blunt, blast, or barotrauma). These individuals are treated with bedrest and, if there is no improvement (or if the hearing loss is severe initially), the individuals undergo a middle ear exploration wherein the leak is packed (or if the leak is not seen, usually both the oval and round windows are packed). In addition, these people do require rehabilitation after the procedure. It may turn out that, in the future, individuals with a different set of circumstances will be considered as possibly having a PLF, but only after this subject has been studied more.

Vestibular Physical Therapy

Vestibular physical therapy uses specific exercises designed to decrease dizziness, increase balance function, and increase general activity levels. These exercises are graded in difficulty to foster integration of the somatosensory, visual, and vestibular systems for skilled spatial orientation. Exercises to decrease dizziness may focus on compensation or exposure to specific stimulus for habituation or attenuation of the response. Balance retraining involves exercises designed to improve organization of sensory information for balance control and coordination of muscle responses. General activity exercise involves a daily aerobic exercise program of progressive walking, cycling, or swimming.

A vestibular physical therapy program consists of exercise procedures that target the following:

- VOR,
- cervicoocular reflex,
- depth perception,
- somatosensory retraining,
- dynamic gait, and
- aerobic function.

The VOR, cervicoocular reflex, and depth perception exercises are graded in difficulty, based on velocity of head and object motion, and then follow a progression of body positioning from sitting to standing to walking. The somatosenory retraining exercises are graded in difficulty by narrowing the base of support, making the surface uneven, or changing the surface from firm to soft. Large-amplitude head and trunk movements are also used to increase somatosensory input. These exercises include the proprioceptive neuromuscular facilitation techniques of slow reversal head and neck patterns, modified chopping and lifting for head and trunk in progression from supine to sitting and standing postures, and total body mass rolling activities. Various walking exercises are graded in difficulty by changing direction, performing with the eyes closed, increasing speed of ambulation, walking on soft surfaces, or navigating stairs. An aerobic exercise home program progressively increases the time, speed, or distance that the patient can tolerate.

Although the general program is integrative in nature, we have found that a top-down strategy is tolerated well by patients and produces impressive outcomes in terms of both subjective patient and objective functional metrics. The beginning status of VOR and eye-tracking functions is a vital determinant of the rate of initial progression. It is impossible to begin to master somatosensory exercise and proprioceptive neuromuscular facilitation skills without first gaining control of eye motion and eye-head coordination. As a result, a great deal of time and attention is directed, both initially and throughout therapy, to challenging the VOR and gaze control. Integration of head motion with eye motion during gaze shifts is an important precursor for performance of somatosensory exercises, proprioceptive neuromuscular facilitation tasks, and mastery of basic cardiovascular and strength exercises. Poor static and dynamic head positioning also create a strain on the neck, which may result in negative feedback on balance function through altered cervicoocular reflex or impaired interpretation of torso and limb somatosensory cues. A schema of how these exercises are applied is shown in Figure 43-1.

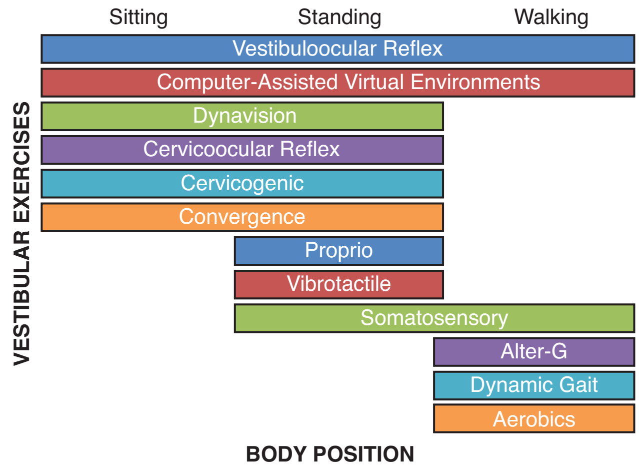

Figure 43-1. Vestibular physical therapy exercise and position progress.
Alter-G: anti-gravity treadmill

Computer-assisted rehabilitation environments (CARENs) may be a valuable tool in vestibular physical therapy across the spectrum of sitting, standing, and walking. CAREN involves using a moving platform with integrated treadmill and force plate that is referenced to a virtual scenario. Working in real time, the environment tasks the patient with visual, auditory, tactile, and vestibular sensory inputs.

SUMMARY

Symptoms of dizziness and unsteadiness are the leading complaints of vestibular trauma as a result of conflict engagement in theater. Medical personnel benefit from recognizing and triaging the spectrum of vestibular trauma presenting to the point of care. Differential diagnosis and subsequent countermeasure intervention for distinct vestibular insults can conserve the optimal warfighter performance. Military medicine continues to address development of vestibular diagnostic and therapeutic best practices for mobile, rugged, and easy-to-use protocols.

CASE PRESENTATION

Case Study 43-1

Presentation

The patient was a 24-year-old Caucasian male on active duty in the US Navy. The mechanism of injury was a fall from 40 feet to 60 feet that resulted in multiple fractures of his skull, including a left temporal bone fracture with otic capsule sparing, hemotympanum, and dislocated ossicles. He also sustained fractures of the left mastoid, right maxilla (suboccipital region), and four left ribs, as well as a right pulmonary contusion. The patient denied any loss of consciousness, but was stunned right after the fall. Five days after the initial injury, the patient began experiencing weakness and sensory loss on the left side of his face and was diagnosed with axonal neuropathy of all three branches of cranial nerve VII. A gold weight was implanted in the left eyelid to assist with eye closure. The patient had a profound mixed hearing loss between 250 Hz and 8,000 Hz with absent acoustic reflexes in the left ear. This hearing loss was not resolved with intratympanic steroid injections. The patient underwent ossicular chain reconstructive surgery to restore the correct anatomical position and obtain normal mobility of the ossicular chain.

The patient presented to vestibular rehabilitation for evaluation 19 days after injury. The patient's chief complaints were dizziness with positional changes and head motion, unsteadiness with walking, and spatial disorientation that was worse in the dark. He also complained of persistent loss of hearing on the left and tinnitus. He also reported drooling when attempting to drink from a cup. He was taking no medications.

The patient reported that the following activities exacerbated his dizziness or unsteadiness: looking up or down, sitting to standing transitions, making head movements while walking, walking in the dark, doing aerobic exercise if not seated, making rapid head movements, hearing loud noises, and riding in a car on a bumpy road. The patient's goals for vestibular rehabilitation were to resolve his dizziness and unsteadiness during activities so that he could return to full duty status as a Navy Seal.

The clinical oculomotor examination revealed right gaze-evoked nystagmus, convergence insufficiency, saccade slowing, abnormal smooth pursuit, and a positive head thrust with head rotation to the left. Upon clinical examination, the Weber test tone lateralized to the right. Caloric testing revealed a 58% asymmetry with reduced responses in the left ear. Rotational chair testing revealed decreased gains with rotation to the left. Subjective visual vertical testing was abnormal, consistent with left utricular dysfunction.

The patient completed the DHI and the ABC Scale. Computerized dynamic posturography was performed, including the Sensory Organization Test, the Sensory Organization Test-Head Shake Test, the Motor Control Test, and the Adaptation Test. The FGA and the HiMAT were performed as clinical measures of dynamic balance. Functional assessment of the VOR was performed using the DVAT and the GST.

The patient's test results indicated abnormalities in VOR function, deficits in somatosensory integration, impaired gait, and motion sensitivity**.**

Plan of Care

Based on the initial evaluation and test data, short-term and long-term goals were established. The short-term goal (3 weeks) was to be able to walk 20 feet with head turns and without path deviation, as measured by the FGA. The long-term goal was for the patient to decrease DVAT logarithm of the minimum angle of resolution loss to no more than 0.20 in 6 weeks. The patient's self-goal was to return to full performance in his assigned position.

Intervention

The patient received vestibular physical therapy four times per week for 6 weeks, with each session lasting for 1 hour. The patient was retested at 3, 6, and 9 weeks. After 9 weeks, the GST deficits remained. Physical therapy continued for three more weeks before resolution of the GST deficits. Physical therapy interventions are listed below.

To improve gaze stability during head movements

- *×1 and ×2 viewing exercises*: The gaze stability exercises were progressed from sitting, to standing, to walking. As the patient progressed, the velocity of the head movement was increased and more visually challenging targets were utilized. The progression ended with performing exercises several stories above ground level on walkways between buildings.
- *Remembered target exercises*: The exercises were performed initially while sitting and progressed to standing with laser target acquisition tasking.

To improve convergence

- The patient stood with arms against a wall while looking at a fixed object forward of the wall. The patient's task was to maintain focus on the object while doing a push-up against the wall.
- *Active slow convergence*: The patient utilized yoke prism lenses or flip lenses as indicated by optometry when performing convergence tasking. This was practiced for 1 minute, first in a sitting position and then progressed to a standing position.
- *Active fast convergence*: Patients looked at targets far to near of varying sizes.
- The patient underwent Brock string exercises.

To improve standing balance

- Standing balance exercises were performed with the arms crossed, eyes closed, and a decreasing base of support. Performed initially with head level and then with head tilted back.
- Standing balance exercises were performed with arms crossed, eyes closed, and a decreasing base of support. Performed with active weight shift forward, backward, and side to side (without loss of balance). Each position was maintained for a short period of time before switching to the next position.

- Standing balance exercises were performed with arms crossed, eyes closed, a decreasing base of support, and a slight quarter squat.
- These exercises were progressed by changing the support surface from a firm floor to a softer, compliant surface (eg, grass, sand, or seat cushion).

To improve dynamic balance

- Walking with the head turning horizontally, vertically, and diagonally.
- Turning corners and making pivot turns while walking.
- Skipping, hopping, and lunging.
- Performing stair ascent and descent.
- These exercises were progressed from flat to uneven surfaces or stairs, with varying amounts of light, noise, and cognitive tasking.

To decrease motion sensitivity

- The patient performed the following movements to decrease the symptoms of dizziness that occurred with position changes: sit to supine, sit to bending forward, sit to standing with head turn, standing full-body diagonals, and standing pivot turns.

To decrease exertion-induced symptoms and improve aerobic conditioning

- *Aerobic exercise*: Patient exercised first on a stationary bike, then progressed to an elliptical machine, and finally to swimming (with steadily increasing demands). Progression from one activity was based on the patient's ability to perform the activity without provocation of dizziness.
- *Job-specific activities*: Given the patient's job requirements, the swimming exercises progressed from distance swims to sprints, with flip turns in daylight and in the dark. In addition, the patient attended surf clinic and used the surf kayak, stand-up paddle board, and surfboard.

The patient was also followed by audiology, where he was fit with hearing aids and taught tinnitus adaptation strategies.

Outcomes

After 9 weeks of vestibular physical therapy, the patient had met his short-term goal and had partially met his long-term goal. Table 43-3 summarizes the patient test scores on outcome measures between the initial visit and the 9-week timepoint of his vestibular rehabilitation.

TABLE 43-3

SELF-REPORT AND FUNCTIONAL GAIT MEASURES OVER 9 WEEKS OF VESTIBULAR THERAPY

Measurement	DHI	ABC	FGA	HiMAT
Income	44	54/100	24/30	
3 Weeks	30	76/100	25/30	
6 Weeks	17	93/100	28/30	52
9 Weeks	12	93/100	30/30	54

ABC: Activity-specific Balance Confidence (Scale); DHI: Dizziness Handicap Inventory; FGA: Functional Gait Assessment; HiMAT: High-Level Mobility Assessment Tool

This patient's success can be seen in the normalization of most outcome scores throughout his treatment. He did not meet his GST long-term goal of achieving 180 degrees per second in all directions, nor did his DVA for head rotation to the left return to normal levels. Standing and dynamic walking and aerobic function improved by 6 weeks. The patient was not able to return to full active duty because of permanent hearing loss, which was aided by an assistive device that could not be worn during water requirements for duty as a Navy SEAL.

Lessons Learned

Lessons learned from this case study show that, as expected, the outcome for this patient was sufficient to compensate and return to independent activities of daily living in the home and community environment. Vestibular rehabilitation did provide compensation as illustrated by objective test measure improvement as described in this chapter, and self-report of decrease in perceptual postural dizziness and unsteadiness. However, due to the highly demanding duty description of his Navy SEAL specialty, his recovery outcome was not within operational standards to return to the unit fit for full duty. New techniques of surgical intervention and rehabilitation on the horizon may be able to remediate the left ear hearing loss evident in audiology testing and left peripheral vestibular deficits evident in dynamic visual acuity testing.

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