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Self-Perceived Balance Disability/Handicap in the Presence of Bilateral Peripheral Vestibular System Impairment

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Abstract

The purpose of this report was to characterize the self-perceived balance disability/handicap of patients with bilateral reductions and bilateral complete losses of peripheral vestibular system function. Data from 72 patients whose electronystagmography and rotational examinations suggested normal, unilateral, or bilateral reductions in peripheral vestibular system function were used in the first investigation. Patients also completed a Dizziness Handicap Inventory (DHI). Results demonstrated significant group differences for DHI total and physical subscale scores. There were significant differences between normal and bilateral weakness groups for the total DHI score and between normal and unilateral and normal and bilateral weakness groups for the physical subscale score. In a second investigation, an item analysis of the DHI is presented for five patients with bilateral complete losses of peripheral vestibular system function. Results show that, predictably, these patients have difficulty engaging in activities requiring an intact vestibulocular reflex (e.g., physical activities such as sports, household chores).

Key Words: Disability, dizziness, handicap, vestibular

Abbreviations: BFT = Balance Function Test, DHI = Dizziness Handicap Inventory, maximum SPV = maximum slow-phase eye velocity, VOR = vestibulocular reflex

Bilateral reductions or bilateral complete losses of peripheral vestibular system function can be caused by end organ disease (e.g., autoimmune inner ear disease, Cogan's syndrome). However, more often, bilateral reduction or complete loss of peripheral vestibular system function is caused by chemical agents that are toxic to the sensory epithelium of the vestibular labyrinth. These medications include the common aminoglycoside antibiotics streptomycin and gentamycin (Ballantyne, 1984; Minor, 1998) and anticancer agents such as cisplatin (Black et al, 1982; Kitsigianis et al, 1988).

It has been our empirical observation that bilateral impairment of peripheral vestibular system function effects a significant impact on the ability of a patient to conduct activities of daily living. The bilateral peripheral vestibular system impairment is associated with either a reduction in the efficiency of or complete loss of the vestibulocular reflex (VOR). It is this reflex that enables us to fix our gaze on a point during ambulation or during movements of the head and head and body. To date, no one has validated these observations, despite the existence of a psychometrically sound measure of self-perceived balance handicap/disability (Jacobson and Newman, 1990) and the empirical observation that patients with bilateral peripheral vestibular system impairments experience difficulties carrying out activities of daily living.

The purpose of this report is to characterize the self-perceived balance disability/handicap of patients with bilateral reductions and bilateral complete losses of peripheral vestibular system function. To this end, balance function test (BFT) data are reported from groups of individuals with normal studies and studies indicating significant unilateral and bilateral reductions in peripheral vestibular system function. Also

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reported are data obtained from a smaller sample of five patients who presented to our laboratory with complete bilateral loss of peripheral vestibular system function. In particular, we report the responses of all patients to items contained on a disorder-specific index of self-perceived balance disability-handicap, the Dizziness Handicap Inventory (DHI) (Jacobson and Newman, 1990; Jacobson et al, 1991; Newman and Jacobson, 1993a, b).

INVESTIGATION 1

Method

Subjects were 72 patients evaluated for balance function from May 30, 1998 to June 30, 1999. Of this sample, 22 patients (mean age = 51.59 years, SD = 19.52 years, 12 male) were identified as having a normal BFT. Additionally, 29 patients (mean age = 49.83 years, SD = 16.37 years, 13 male) were classified as unilateral weakness on the basis of BFT findings. Finally, 21 patients (mean age = 56.48 years, SD = 18.00 years, 12 male) were classified as having a bilateral weakness on the basis of BFT results.

All patients underwent, at minimum, electronystagmography (ENG) and rotary chair testing and completed a DHI. The DHI is a 25-item, self-perceived disability/handicap scale designed to assess the effect that dizziness and unsteadiness have on quality of life (Jacobson and Newman, 1990; Jacobson et al, 1991; Newman and Jacobson, 1993a, b). Items comprising the DHI have been grouped into three subscales that are designed to evaluate the effect that dizziness and unsteadiness have on emotional, functional, and physical aspects of daily living. The 25 statements may be answered with either "yes" (scored as 4 points), "sometimes" (scored as 2 points), or "no" (scored as 0 points) responses. Accordingly, the minimum score is 0 points (representing no self-perceived disability/handicap) and the maximum score is 100 points (representing maximum self-perceived handicap).

The ENG examination included standard examinations of ocular motility, positional and positioning testing, and either monothermal (Jacobson and Means, 1985; Jacobson et al, 1995) or alternate binaural bithermal caloric testing (Jacobson and Newman, 1993a, b). Additionally, patients underwent rotary chair testing for frequencies between and including 0.01 to 0.32 Hz (Jacobson and Newman, 1991).

Rotational testing was conducted with a Neurokinetics, Model 1010 rotary chair system. Bitemporal electroculographic recordings were conducted while each patient was rotated at 0.01, 0.02, 0.04, 0.08, 0.16, and 0.32 Hz (maximum velocity, 50 degrees/sec). Performance parameters of the VOR, including VOR gain, phase, and symmetry, were measured.

A patient classified as normal for purposes of this investigation showed no evidence of spontaneous or positioning-provoked nystagmus (i.e., a negative Dix-Hallpike positioning examination) and demonstrated normal ocular motility testing and a normal caloric examination (i.e., normal monothermal or bithermal caloric examinations). Further, for patients to be classified as normal, they had to demonstrate a normal rotational examination. Accordingly, measures of VOR gain, phase, and symmetry for frequencies from 0.01 to 0.32 all were required to be within laboratory normal limits.

A patient could be classified in the unilateral weakness group only if he/she demonstrated a statistically significant unilateral weakness (side-to-side asymmetry in maximum slow-phase eye velocity [SPV] exceeding 20%). On rotary chair testing, these individuals often demonstrated a phase lead at 0.01 Hz, and, if evaluated soon after an attack of vertigo, demonstrated an asymmetry in SPV. These individuals could demonstrate positional or motion-induced positioning nystagmus. Further, patients placed in the unilateral weakness group could show spontaneous nystagmus and associated directional preponderance on caloric testing in addition to the unilateral weakness.

A patient could be placed in the bilateral weakness group only if he/she demonstrated a total SPV response (i.e., the sum total of maximum SPV for all four caloric irrigations) of less than 22 degrees/sec (Jacobson and Newman, 1993b). Ice water irrigations were conducted in instances where no caloric response was elicited to standard 30- and 44-degree water caloric stimuli or when no nystagmus was noted during rotational testing. In order for an individual to be classified as bilateral weakness, he/she had to demonstrate significantly reduced VOR gains for all rotational frequencies (i.e., 0.01–0.32 Hz) in addition to the bilateral reductions in caloric-induced nystagmus velocities.

A one-way analysis of variance was conducted separately for each of the three subscales and total DHI scores to determine whether self-perceived balance disability/handicap differed by patient group. For each of these

analyses, the dependent variable was the subscale (e.g., functional, emotional, or physical subscales) or total DHI score. The grouping variable was the patient classification (i.e., BFT normal, unilateral weakness, or bilateral weakness).

Results

The results of these analyses showed that no significant group differences were observed for either the emotional ($F = 1.74$, $df = 2,69$, $p = .18$) or functional subscale scores ($F = 2.19$, $df = 2,69$, $p = .12$). However, significant group differences were observed for the physical subscale ($F = 5.95$, $df = 2,69$, $p = .004$). Post hoc testing (Tukey) showed that the statistically significant group differences occurred between both normal and unilateral weakness and normal and bilateral weakness groups for the physical subscale scores ($p = .03$ and $p = .005$, respectively; Table 1). Additionally, significant group differences were observed for the total DHI score ($F = 3.52$, $df = 2,69$, $p = .03$). Post hoc analyses (Tukey) showed that statistically significant group differences occurred only between the normal and bilateral weakness groups ($p = .03$; see Table 1).

Attempts were made to correlate low- and high-frequency VOR gains derived from rotational testing with the total DHI score. That is, we were interested in knowing whether, for example, higher gains at the uppermost rotary chair frequencies were associated with lesser degrees of self-perceived balance handicap. Accordingly, the VOR gains at 0.01 and 0.32 Hz (i.e., the lowest and highest rotary chair frequencies tested) and the total DHI scores across the patient sample were placed in a correlation matrix (Pearson correlation). The results are shown graphically in Figures 1 and 2. The findings showed a nonsignificant correlation between total DHI score and VOR gain at 0.01 Hz ($r = -.22$, $p = .06$; see Fig. 1) and a significant negative correlation between the total DHI score and VOR gain at 0.32 Hz ($r = -.38$, $p = .001$; see Fig. 2). That is, as the VOR gain at 0.32 Hz decreased, the total DHI score increased.

INVESTIGATION 2

Method

Subjects were five patients (mean age = 57.60 years, SD = 12.12 years, 4 males) seen at the balance laboratory at Henry Ford Hospital during 1998 and 1999. All patients were evaluated for intractable dizziness and unsteadiness. All five subjects were seen following the administration of aminoglycoside antibiotics (i.e., always gentamicin, sometimes in combination with other aminoglycoside antibiotics or vancomycin). Four of five patients were evaluated within 4 months of treatment. Three patients were treated for sepsis related to hemodialysis. One patient was treated for osteomyelitis and one was treated for peritonitis that occurred as a result of an esophageal perforation. These data collected from this set of patients were not used in the first investigation.

The patients underwent pure-tone audiometric testing, and the results are summarized in Table 2. No audiometric tests were available prior to treatment, and, accordingly, it was not possible to determine whether the medications that were vestibulotoxic resulted in new hearing losses or a worsening of preexisting hearing losses. That is, these patients were not evaluated in the context of either a cochleotoxicity or vestibulotoxicity monitoring protocol but, instead, were evaluated when they complained to their physicians of dizziness or unsteadiness.

Subjects in this sample underwent bithermal caloric testing using techniques described in Investigation 1 or ice water testing when no

Table 1 DHI Subscale and Total Scores (SD) for Patients with Normal Balance Function Tests and Those with Evidence of Significant Unilateral or Bilateral Vestibular System Impairments

	*Emotional Subscale**	*Functional Subscale†*	*Physical Subscale‡*	*Total Score§*
Normal	11.64 (8.45)	10.54 (7.86)	8.09 (7.39)	30.27 (20.98)
Unilateral	12.21 (8.11)	13.93 (8.44)	13.65 (8.02)	39.79 (21.15)
Bilateral	18.28 (20.61)	15.81 (8.87)	15.61 (6.85)	49.71 (30.00)

*Minimum 30 points, maximum 32 points; †minimum 0 points, maximum 36 points; ‡minimum 0 points, maximum 32 points; §minimum 0 points, maximum 100 points.

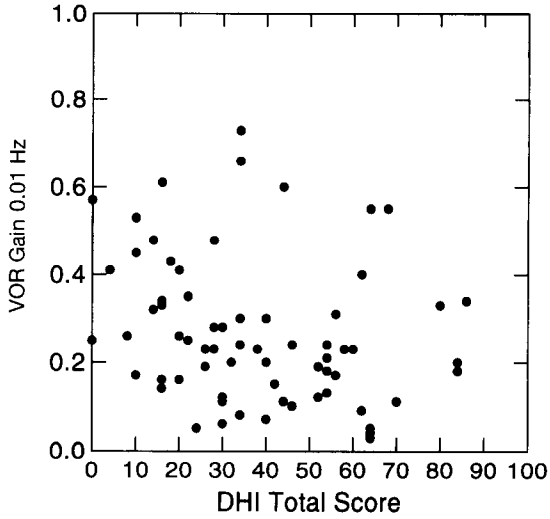

Figure 1 Scatterplot of total DHI scores plotted against VOR gains at 0.01 Hz for the 72 subjects in Investigation 1 (r = –.22, p = .06).

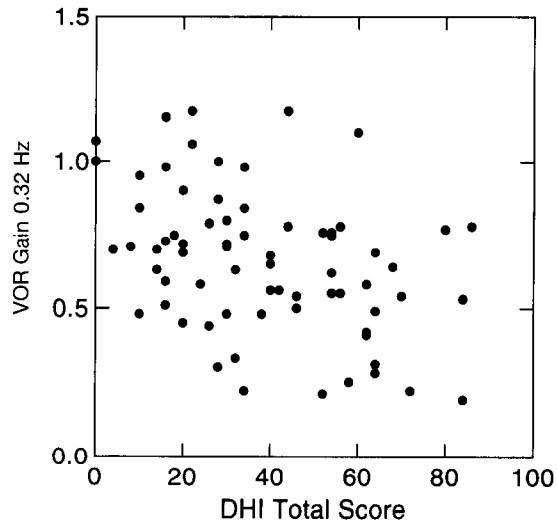

Figure 2 Scatterplot of total DHI scores plotted against VOR gains at 0.32 Hz for the 72 subjects in Investigation 1 (r = –.38, p = .001).

nystagmus was observed during rotational testing. In this regard, all subjects underwent rotary chair testing for chair frequencies from 0.01 to 0.32 Hz. Finally, all subjects completed a DHI.

Results

ENG Examination

For this sample, the largest total caloric response (i.e., sum of the maximum SPVs for all four caloric irrigations) was 14 degrees/sec. Indeed, four of the five subjects (80%) failed to demonstrate nystagmus on any of the four caloric irrigations. Only one of these four subjects generated nystagmus (< 6 degrees/sec) to ice water stimulation.

Rotary Chair Testing

The group mean VOR gain data obtained for rotary chair testing are shown in Table 3. It can be observed that the low gains for each of the frequencies support the contention that, in this sample, there was little, if any, measurable nystagmus recorded during rotational testing. Accordingly, phase and symmetry measures are not reported in Table 3.

Dizziness Handicap Inventory

The group mean subscale and total scores on the DHI are shown in Table 4. It may be observed that, on average, the DHI total score was 71 points, representing significant self-perceived dizziness handicap. An item analysis of the DHI for this small sample is shown in Table 5. Displayed in this table are items from the DHI where subjects as a group scored <2 points (mostly "no" responses) >4 points (mostly "yes" responses).

The result of this analysis suggests that our patients with bilateral loss of vestibular system function did not have difficulty concen-

Table 2 Mean Audiometric Test Results (SDs) for the Five Patients with Bilateral Complete Loss of Peripheral Vestibular System Function

	Frequency (Hz)							
	250	*500*	*1000*	*2000*	*3000*	*4000*	*6000*	*8000*
Left ear dB HL	22.50	20.00	27.50	35.00	38.33	41.25	42.50	48.75
	(11.90)	(13.54)	(14.43)	(13.54)	(29.30)	(25.94)	(24.66)	(33.26)
Right ear dB HL	23.75	22.55	30.00	33.75	45.00	41.25	38.75	50.00
	(6.29)	(8.66)	(12.25)	(8.54)	(21.79)	(22.87)	(22.87)	(31.36)

Table 3 VOR Gain at Each of the Five Frequencies for the Sample of Patients with Bilateral Complete Loss of Vestibular System Function and Normal Upper and Lower Limits

	Frequency				
	0.01	*0.04*	*0.08*	*0.16*	*0.32*
Patient sample mean	0.11	0.13	0.13	0.24	0.23
Patient sample SD	0.07	0.06	0.04	0.06	0.03
Normal upper limit (mean + 2 SD)	0.46	1.0	1.0	1.01	1.01
Normal group lower limit (mean – 2 SD)	0.14	0.34	0.45	0.45	0.45

trating or reading, which does not require head movement and hence does not require the VOR. Additionally, these patients, as a group, were not afraid to be at home unattended. In this regard, it is likely that home may represent a "safe haven" for these patients. Additionally, as might be expected, physical activities not requiring an intact VOR did not cause an exacerbation of symptoms. These activities included turning over in bed, which, for most, is done in darkness.

Patients with complete bilateral losses reported many problems contributing to their self-perceived handicap including a sense of frustration with their problem, a fear of leaving home alone, a fear that others would interpret their unsteadiness of gait to represent a state of intoxication, and restrictions in their ability to walk by themselves or to travel for business or leisure (i.e., a general loss of independence). Additionally, patients reported problems with many activities requiring the visual image to remain fixed on the retina during movement (e.g., household chores, physical activities such as sports, walking down the aisle of a supermarket).

DISCUSSION

The purpose of the present investigations was to characterize the self-perceived balance disability/handicap of patients with bilateral peripheral vestibular system impairments. The results of these investigations have shown that the self-perceived balance handicap experienced by patients with bilateral reductions in peripheral vestibular system function is significantly greater than that experienced by patients with balance complaints who demonstrate normal balance function tests but is not greater than patients with unilateral vestibular system impairments. Patients with complete losses of peripheral vestibular system function (i.e., the subgroup of five patients) experienced self-perceived balance handicap that qualitatively exceeded that of patients who demonstrated bilateral weaknesses on caloric testing and bilateral gain reductions across frequencies 0.01 to 0.32 Hz during rotational testing. Indeed, mean scores for the two groups differed by 21 points (i.e., mean total DHI score for bilateral reduction group = 49.71 points and for bilateral complete loss group = 70.80 points).

Table 4 Mean DHI Subscale and Total Scores (and Minimum/Maximum Possible Scores) for the Subsample of Patients with Complete Bilateral Loss of Peripheral Vestibular System Function

	*Functional**	*Emotional†*	*Physical‡*	*Total§*
Mean	23.2	25.6	22	70.80
SD	8.32	3.29	6.32	9.55

*Minimum 30 points, maximum 32 points; †minimum 0 points, maximum 36 points; ‡minimum 0 points, maximum 32 points; §minimum 0 points, maximum 100 points.

The term "bilateral reduction" requires clarification. Bilateral loss of caloric responses does not ensure that patients are devoid of peripheral vestibular system function. Like the auditory system, the vestibular system responds to motion across a frequency spectrum. Detection (i.e., transduction) of very low frequency motion (e.g., 0.003 Hz) is equivalent to detection of slow, listing movements of the head and body when standing still. Physiologic frequencies are those associated with locomotion (i.e., walking, running) or quick head turns and are associated with frequencies above 1 Hz. In common practice, we assess the function of the lowest frequencies with bithermal caloric testing (i.e., the SPV envelope of a caloric response is roughly equivalent to a frequency of 0.003 Hz; Hess et al, 1996). It is only by using rotational test techniques (i.e., sinusoidal rotation and vestibular autorotation testing; O'Leary and Davis, 1990) that we are able to assess the response of the vestibular system to frequencies that fall within

Table 5 Summary of Item Analysis of DHI for Five Patients with Bilateral Complete Loss of Peripheral Vestibular System Function

Responses to items <2 points (i.e., negative responses)
P1 = Does looking up increase your problem?
P13 = Does turning over in bed increase your problem?
E20* = Because of your problem, are you afraid to stay home alone?
Responses to items >3 points (i.e., affirmative responses)
E2* = Because of your problem, do you feel frustrated?
F3 = Because of your problem, do you restrict your travel for business or recreation?
P4 = Does walking down the aisle of a supermarket increase your problem?
P8 = Does performing more ambitious chores like sports, dancing, and household chores such as sweeping or putting dishes away increase your problem?
E9* = Because of your problem, are you afraid to leave your home without having someone accompany you?
P11* = Do quick movements of your head increase your problem?
F12 = Because of your problem, do you avoid heights?
F14* = Because of your problem, is it difficult for you to do strenuous housework or yardwork?
E15 = Because of your problem, are you afraid people may think that you are intoxicated?
P16* = Because of your problem, is it difficult for you to go for a walk by yourself?
E21* = Because of your problem, do you feel handicapped?
F24 = Does your problem interfere with your job or household responsibilities?
P25 = Does bending over increase your problem?

*Items for which there was unanimity of response (i.e., all respondents stated yes or no).

the physiologic range. It is noteworthy that unlike what occurs with the auditory end organ, vestibular end organ disease affects low-frequency function first. Accordingly, the first effects of end organ disease can be detected through the use of the conventional caloric examination. It is not uncommon for patients with losses of low-frequency function to have bilaterally preserved high-frequency peripheral vestibular system function in the same manner that it is possible for patients with high-frequency sensorineural hearing loss to have preserved low-frequency auditory function.

Unilateral reduction or unilateral complete loss of peripheral vestibular system function is associated, initially, with true vertigo that lasts for hours and dissipates over a period of days. Within weeks, the neurologically intact patient with permanent unilateral peripheral vestibular system impairment is able to function normally and only is reminded of the permanent impairment during quick movements of the head or head and body. It is during the period immediately after the injury and the weeks following that the central vestibular system including the centrifugal connections between midline cerebellar structures and the vestibular nuclei "rebalances" centrally the peripheral imbalance (see Curthoys and Halmagyi, 1996). We have described this process in the context of recovery nystagmus (Jacobson et al, 1998).

A total, complete, bilateral loss of peripheral vestibular system function results in a reduction or loss of the VOR. Without a functioning VOR, it is not possible for the brain to maintain gaze on a fixed point as the head or head and body are in motion. Accordingly, patients with loss of bilateral peripheral vestibular system function have stereotypical complaints. Patients commonly complain of oscillopsia (i.e., a jiggling or "bobbling" of the visual field as the patient is in motion). Quick movements of the head are associated with saccadic gaze readjustments instead of smooth compensatory eye movements, which impair clear vision. For these reasons, patients with bilateral total loss of peripheral vestibular function often stop driving for fear of causing an accident. Also, patients with bilateral complete vestibular system losses may appear ataxic when walking as a result of the loss of the VOR. These patients rely on visual and proprioceptive information in order to maintain postural control during ambulation. At night, in darkness, patients with bilateral loss of vestibular system function are at particular risk for falls since they have only one functioning sense (proprioception) to help them remain upright. For these reasons, patients with retinal disease and/or diabetic neuropathies are at particular risk for falls when ambulating during the day and especially at night. Unfortunately, these patients usually are elderly and prone to hip and upper limb fractures that are associated with significant morbidity. It is critical that once bilateral impairment has been identified, these patients should be counseled about the importance of

using night lights and firm support surfaces (as opposed to heavily cushioned carpets) in their homes.

It is interesting that the result of the correlational analysis suggested a statistically significant but only mild-moderate relationship between a physiologic measure of vestibular system function (i.e., VOR gain at 0.32 Hz) and a subjective measure of self-perceived balance disability/handicap (i.e., the DHI total score). In fact, fully 85 percent of the variance associated with self-perceived balance disability/handicap could not be explained on the basis of the magnitude of VOR gain at 0.32 Hz. Such disagreement between measures of impairment and disability/handicap has been reported for hearing loss. That is, correlations between degree of hearing impairment (i.e., speech frequency and high-frequency pure-tone threshold averages) and hearing disability/handicap (i.e., estimated from the use of the Hearing Handicap Inventory for Adults) range from 0.33 to 0.34 (Newman et al, 1990). Many factors play a role in the determination of the effect an impairment has on the magnitude of an associated disability. These factors include individual coping abilities, life stressors, support systems, and general physical health (i.e., the presence of coexisting medical conditions).

There are a number of common causes of bilateral vestibular system disease that include exposure to aminoglycoside antibiotics such as gentamicin, tobramycin, and streptomycin (Ballantyne, 1984; Minor, 1998) and exposure to anticancer agents such as cisplatin (Black et al, 1982; Kitsigianis et al, 1988). The aminoglycoside antibiotics as a group are commonly used for the treatment of gram-negative infections (Hashino et al, 1997). Gentamicin is administered intramuscularly or subcutaneously and approximately 50 percent is excreted by the kidneys within 24 hours in patients with intact renal function (Hess, 1996). For this reason, patients with impaired renal function are at particular risk for profound ototoxic side effects. In addition to impaired renal function, factors that have been identified that place individuals at specific risk for vestibulotoxic side effects include individual tolerance, hyperthermia, concomitant use of other ototoxic medications (i.e., synergistic effects), the dosing strategy, and the age of the patient (Hess, 1996).

The monitoring of auditory function during treatment with cochleotoxic medications has become commonplace in most tertiary and quaternary care centers. Guidelines for accomplishing the monitoring task have been published by the American Speech-Language-Hearing Association (ASHA, 1994). Accordingly, there is no dispute as to the importance of preserving auditory function, the importance of hearing, or the effect that hearing loss has on the ability of a person to lead a normal life. Less emphasis has been placed on the development of methods and procedures for monitoring peripheral vestibular system function during treatment of patients with potentially vestibulotoxic medications. The results of the present investigation suggest that monitoring modalities (e.g., rotational testing, vestibular autorotation testing) and protocols are needed to help decrease that morbidity associated with the effects of vestibulotoxic medications.

It is worth noting that, with appropriate rehabilitative interventions, patients with bilateral incomplete losses of peripheral vestibular system function can perform tasks of everyday living (e.g., driving a car, walking, running, etc.). This is possible because the loss of the ability of the peripheral vestibular system to detect low-frequency stimuli has a minimal effect on frequencies of head movement associated with normal daily activities. Additionally, even patients with complete peripheral vestibular system losses can learn to compensate for loss of the VOR in many situations through vestibular rehabilitation. These rehabilitative techniques have been described in detail by Shepard et al (1993) and Herdman (1996) and in the context of complete and incomplete loss of peripheral vestibular system function will be the subject of a future report.

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