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The patient signed an informed consent allowing for the use of medical information and photographs for this report and received information on the institution's policies regarding the Health Insurance Portability and Accountability Act.

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ABSTRACT

Background & Purpose: Benign Paroxysmal Positional Vertigo (BPPV), the most common vestibular disorder, is treated via a canalith repositioning maneuver (CRM), often providing rapid and lasting resolution of symptoms. However, 31% to 61% of patients experience residual dizziness (RD) post-treatment. For these cases, known as BPPV treatment failures, vestibular rehabilitation (VR) is recommended. Limited evidence exists for the specifics of treatment. This report documents VR of an older patient following BPPV treatment failure.

Case Description: The patient was a 77 year-old male referred to outpatient physical therapy with a diagnosis of peripheral vertigo. He reported unsteadiness and dizziness during gait and sit to stand transfers. A positive Dix-Hallpike test indicated posterior canal BPPV. Despite a successful CRM, his symptoms persisted. A VR program consisting of static balance, dynamic gait, and gaze stabilization was implemented to decrease RD, improve functional mobility, and reduce fall risk.

Outcomes: The patient demonstrated improvements in all outcome measures: the Dizziness Handicap Index score (58/100 to 30/100); the Mini Balance Evaluation Systems Test (20/26 to 24/26); condition 4 of the Modified Clinical Test of Sensory Integration on Balance (6.3s to 30s); vestibular ocular reflex (VOR) testing (3/10 to 0/10 dizziness); and strength testing of the lower extremities (increased ½ to 1 manual muscle testing grade throughout).

Discussion: A VR program implementing gaze stabilization, static balance and dynamic gait training appeared to be successful in treating this patient with BPPV treatment failure. This case report suggests that improvements in functional mobility, balance, and VOR function may be possible in patients with RD. Future research should investigate effective interventions for older patients with BPPV treatment failure.

Word count: 268

BACKGROUND and PURPOSE

Good balance requires the integration of sensory information from multiple systems, including one that resides within the inner ear: the vestibular system. The vestibular portion of the inner ear, the labyrinth, contains two types of sensory structures: semicircular canals and otolith organs. The three canals (posterior, anterior, and horizontal) respond to angular velocity of the head while the otolith organs respond to gravity and linear acceleration of the head.

Within the otolith organs are crystals of calcium carbonate, or otoconia, which can become dislodged and enter the canals causing a specific type of vestibular dysfunction known as Benign Paroxysmal Positional Vertigo (BPPV).[1] BPPV is the most common vestibular disorder.[2] Of the 5.6 million patients in the United States with a primary complaint of dizziness, up to 42% ultimately receive a diagnosis of BPPV. Idiopathic BPPV is more common, although approximately 30% of cases are secondary to conditions such as Meniere's disease, vestibular neuritis, head trauma, migraine, surgery, or prolonged bed rest.[3] BPPV becomes more common in older age, with a prevalence of 3.4% in individuals over the age of 60. It has devastating consequences in the elderly population including increased risk for falls, depression, and impaired activities of daily living.[4]

Patients with BPPV experience brief, episodic vertigo during rapid head movements and specific head positions.[1] Symptoms of BPPV typically include dizziness, nausea, and nystagmus. The Dix-Hallpike test (DHT) is the gold standard for diagnosing the condition.[4,6,13] Treatment for BPPV involves a canalith repositioning maneuver (CRM), which often provides rapid and long-lasting resolution of symptoms.[5] The Epley maneuver (see Appendix 1) is the CRM used for posterior canal BPPV, which accounts for 85-95% of cases.[4] It is 83% to 93% effective upon first attempt.[6] Horizontal (lateral) canal BPPV accounts for 5-15% of cases, is

diagnosed via the lateral roll test, and is treated via the *barbeque roll* CRM.[1] Other rare forms of BPPV include anterior canal, multicanal, and bilateral multicanal.[4]

Despite a successful CRM, 31% to 61% of patients with BPPV experience persistent imbalance without positional vertigo, known as residual dizziness (RD).[5] These BPPV cases are classified as treatment failures.[4] RD typically lasts days to weeks and is more common in the elderly, although the main causal factor is duration of vertigo.[5] The cause of RD remains unclear, although it may be related to incomplete central adaptation following a CRM.[5] BPPV treatment failure may also be due to a coexisting vestibular condition (eg. vestibular neuritis, Meniere's disease) or a central lesion.[4]

Vestibular rehabilitation (VR) is recommended for patients with RD to target specific balance deficits and reduce the risk of falls.[4] Although VR generally includes exercises for adaptation, habituation, substitution, balance and gait training, limited evidence exists regarding the proper dosage and specifics of treatment.[7] A greater understanding is needed of how VR is used to address impairments of patients with vestibular dysfunction. The purpose of this case study was to document the outcomes of VR in an older patient following BPPV treatment failure.

CASE DESCRIPTION

Patient History & Systems Review

The patient gave written consent for the use of his medical information in this case report. The patient was a 77-year old male who was a retired teacher and lived at home with his wife. His extensive past medical history included hypertension, Lyme disease (treated with subsequent negative enzyme-linked immunosorbent assays), bilateral hallux valgus, depression and anxiety. A 28-year history of type 2 diabetes mellitus included complications such as peripheral

neuropathy, right second toe amputation, retinopathy, right eye vitectomy, and glaucoma (bilateral cataracts surgery performed one week prior to initial evaluation [IE]). Several of these conditions were managed with medication (see Appendix 2). Results of the systems review are included in Appendix 3.

The patient was referred to outpatient VR by his primary care physician (PCP) with a medical diagnosis of *peripheral vertigo*. His primary complaints were feelings of unsteadiness and dizziness, especially during gait and sit to stand transfers. An episode of sinus congestion preceded a gradual onset of these symptoms over the past several months. Previously independent with ambulation, he reported occasional reliance on a walking stick and sometimes used walls or furniture for support. The patient's goals for physical therapy included wanting to "feel like I'm not going to fall." He reported one fall several years ago, but no recent falls. Two years prior he sought VR for dizziness and was ultimately referred to his PCP to address issues with blood sugar and blood pressure. At the time of this episode of care, the patient felt those issues were resolved.

CLINICAL IMPRESSION 1

The patient was referred to VR due to dizziness and imbalance during ambulation and quick positional changes. Information gathered from the history and systems review was consistent with the referring diagnosis of peripheral vertigo. Differential diagnoses included BPPV, unilateral vestibular hypofunction, bilateral vestibular hypofunction, and central vertigo. Blood pressure and blood sugar appeared stable at this time and not responsible for his current complaint. Nonetheless, blood pressure readings would be taken to rule out orthostatic hypotension. In addition, the plan for a thorough vestibular examination included cervical range of motion (ROM), the vertebral artery test, the DHT, an ocular motor exam, and a balance

assessment. The patient was a good candidate for this case report because of his complex medical history and motivation to participate in therapy.

EXAMINATION

Tests and Measures

The results of all tests and measures may be found in Tables 1 and 2. The DHT (see Appendix 4) was performed bilaterally to assess for posterior canal BPPV.[8] The right side was positive for nystagmus and vertigo while the left side was positive for dizziness, but no nystagmus. The lateral canals were not evaluated during the initial examination due to the low likelihood of multicanal involvement.

The vestibular ocular reflex (VOR) was assessed via the head-thrust test[9] (see Appendix 5) and the head-shaking nystagmus test[10] (see Appendix 6), both of which were negative. The VOR x1 exercise (see Figure 3a) was performed to further evaluate VOR function. The patient was asked to rate his dizziness on a scale of zero (*no dizziness*) to 10 (*maximal dizziness*). At baseline in seated, the patient rated his dizziness at zero. For the VOR x1 near exercise, the patient rated his dizziness at two to three out of 10 with horizontal movements and at one to two out of 10 with vertical movements. For the VOR x1 far exercise, the patient reported diplopia with horizontal movements and diplopia plus one to two out of 10 dizziness with vertical movements.

Visual tracking was examined using smooth pursuit eye movements (see Appendix 7) and cancellation of the VOR (see Appendix 8).[1] Smooth pursuit eye movements were impaired with a jump in mid-range moving from right to left. VOR cancellation was unimpaired, although there was a slight left delay.

The vestibular exam also included saccadic eye movements (see Appendix 9), which were unimpaired.[1] Both spontaneous and gaze-holding nystagmus were absent, although mild nystagmus was noted with left end range gaze. Cervicogenic dizziness is a controversial diagnosis because it lacks diagnostic testing; however, it is typically associated with neck pain.[11] Cervical ROM was within normal limits and pain-free.

Cardiopulmonary function was assessed with the vertebral artery test and blood pressure measurements taken in both sitting and standing. No symptoms were provoked with either test and blood pressure readings were within normal limits.

Additional Tests and Measures for RD

Additional tests and measures were performed once it was apparent that the patient's symptoms were persistent despite a successful Epley maneuver. These included: the Mini Balance Evaluation Systems Test[12] (Mini-BESTest, Appendix 10) and the Modified Clinical Test of Sensory Integration on Balance[13] (mCTSIB, Appendix 11) to assess balance; the Dizziness Handicap Index[14] (DHI, Appendix 12), a self-reported questionnaire; and strength testing of the lower extremities via manual muscle testing (MMT). These outcome measures were performed four weeks after IE and again upon discharge to determine improvements in functional ability.

A visual inspection of the patient's feet during week seven revealed deformities, including bilateral hallux valgus and a right second toe amputation. Sharp-dull discrimination testing revealed diminished sensation in both feet.

CLINICAL IMPRESSION 2

The examination data confirmed the initial impression of peripheral vertigo. A central lesion was deemed unlikely based on the direction of nystagmus during the DHT and the absence of nystagmus during other tests.[4] Other potential causes of the patient's symptoms, including

postural hypotension and cervicogenic dizziness, were also ruled out from the examination data. A diagnosis of peripheral vertigo was supported by the results of the mCTSIB, which revealed impaired postural control, particularly in condition four where visual and somatosensory cues are removed and balance is maintained solely with vestibular function. Further balance deficits were revealed via the Mini-BESTest, especially with anticipatory postural control and dynamic gait. Despite a negative head thrust test, head shaking nystagmus test, and VOR cancellation test, dizziness was provoked with the VOR x1 exercise, indicating some degree of VOR dysfunction. Functional impairment was demonstrated via the DHI, with a score of 58/100 indicating moderate perceived level of handicap due to dizziness.[14]

An up-beating torsional nystagmus during the DHT indicated a diagnosis of right posterior canal BPPV.[4] This was an unexpected finding since the patient's symptoms were atypical for BPPV. This raised the possibility that he suffered from more than one vestibular disorder. Research has shown that some patients develop BPPV secondary to a disorder of the inner ear.[15] As a result, the patient was given a broad physical therapy diagnosis of *other peripheral vertigo* (ICD-10 code H81.3). He received a medical diagnosis of *vertigo.* The patient continued to be appropriate for the case due to his complex medical history and atypical presentation of BPPV.

The patient was expected to make gains from VR to improve balance, reduce dizziness, and decrease fall risk. Despite positive prognostic indicators including high motivation, family support, and high prior level of function, his prognosis was deemed fair. Although most patients with idiopathic BPPV experience a full and rapid recovery, secondary BPPV has a less favorable prognosis. For example, in a study of 22 patients with BPPV secondary to vestibular neuritis, the condition responded less effectively to treatment and was more likely to recur.[16] Furthermore, progress towards the patient's goals was expected to be slow due to his advanced

age and multiple comorbidities. His deficits remained within the scope of VR and thus, referrals were not indicated.

Clinical Impression After Additional Tests And Measures

When the patient's symptoms persisted despite a negative follow-up DHT, additional tests and measures were performed and his plan of care (POC) was updated. Despite an unclear etiology, the patient was still expected to benefit from a comprehensive vestibular program that targeted his deficits. He was seen for 30-45 minutes, twice weekly for eight weeks. He then took a five-week vacation and returned for a final visit before discharge (see Figure 1 for timeline). Outcome measures were to be reassessed at eight weeks (prior to his vacation) and at discharge. Short-term and long-term goals were established upon IE, with new goals created at four weeks to incorporate additional outcome measures (see Table 3).

INTERVENTIONS

Coordination, Communication, Documentation

Paper documentation was completed during the patient's IE, daily treatments, and discharge. In addition, progress notes were completed after the patient's eighth and fourteenth visits. Changes to the POC were completed as needed and documented accordingly. The patient's care was coordinated among three therapists via written and in-person communication. IE and discharge documentation, as well as progress notes, were faxed to the patient's PCP.

Patient-related Instructions

Please see Table 4.

Procedural Interventions

Initially, procedural interventions were limited to patient education and the Epley maneuver. When the patient's symptoms persisted, interventions to address specific impairments were added including gaze stabilization, static balance, and dynamic gait exercises (see Table 5 for a timeline of the interventions). A 2015 Cochrane review indicated that while there is strong evidence supporting the use of VR, the evidence for dosage and specifics is still limited.[7] Overall, the patient demonstrated excellent compliance with his home exercise program (HEP) and attendance with appointments.

Epley Maneuver

The Epley maneuver, the gold standard treatment for posterior canal BPPV, was performed upon IE due to a positive DHT.[4] It involves moving the patient's head through a specific sequence of positions, which moves misplaced otoconia from the affected canal back into the vestibule, thus eliminating the source of vertigo. At the patient's second visit, a negative DHT confirmed the resolution of BPPV, and thus, a subsequent Epley Maneuver was deemed unnecessary.

Gaze stabilization

The objective of each gaze stabilization exercise was to maintain fixation on a stable or moving target while increasing symptoms by two points on a ten-point scale. Therefore, duration of each gaze stabilization exercise was based on the patient's reported symptoms. The exercise was also stopped if the therapist observed erratic head movements, excessive blinking, or unfocused eyes. Symptoms returned to baseline before moving on to the next exercise. When an exercise failed to provoke symptoms, it was either progressed or discontinued.

The most common VR exercise is VOR x1 (see Figure 3a).[18] The VOR x2 exercise is similar, except the image and the patient's head move in opposite directions. For both exercises,

the patient was instructed to move his head at a speed on the edge of blurred vision. This blurring, or "retinal slip," is read as an error signal by the brain, which attempts to minimize it by increasing the gain of the vestibular responses. Thus, by challenging the brain to reduce the error signal, vestibular adaptation is promoted.[1]

Repeated attempts were made to progress the VOR exercises by increasing the patient's speed of head movements, however, he had difficulty following this cue. Speed was therefore kept relatively constant and the exercise was progressed in other ways. Initially performed seated, the VOR x1 exercise was progressed to standing on level surfaces, then standing on unlevel surfaces (e.g. foam, grass), and finally during ambulation. Duration was increased from 15 seconds to 60 seconds.

Other gaze stabilization exercises included "nose to knee" and "ball circles" (see Figure 3b-c). Ball circles were eventually discontinued due to shoulder pain. A RBB1 Champion Sports basketball (Champion Sports, Marlboro NJ) was used for ball circles and dynamic gait.

Static balance

Static balance exercises with altered visual and proprioceptive inputs increased the patient's reliance on his vestibular system. A randomized controlled study of 26 patients with BPPV illustrated that for patients who receive treatment for BPPV (i.e. CRM), balance training is important for improving balance and functional gait ability.[19] One exercise required the patient maintain standing balance on unlevel surfaces such as an Aeromat Elite Balance Block (Aeromat Fitness Products, Fremont CA) and a tilt board. These interventions were selected based on the patient's performance on items of the MiniBESTest. Finally, random perturbations were applied by the therapist to the patient's upper body while he attempted to maintain standing balance. The patient was cued to minimize hip movements in order to emphasize ankle

strategy. Some static balance exercises were progressed to eyes closed to remove visual input, although many were sufficiently challenging with eyes open.

Dynamic gait

Because the patient's primary complaint was feeling imbalanced during gait, especially with quick head movements, a focus of treatment was on dynamic gait. A gait belt and close to contact guarding was provided during all gait exercises. One exercise consisted of horizontal and vertical head turns during walking (see Figure 4a-b). To progress the exercise, verbal cues of "up," "down," "left," "right" were given at random. During a similar task, the patient moved a ball left and right during ambulation, following the ball with his eyes and head (see Figure 4c). Other dynamic gait exercises included "high steps," side steps, tandem gait, and "sneaky steps" (see Figure 4d-f). Tandem gait was progressed by decreasing step width.

To reduce dual task interference noted during the MiniBESTest, the patient performed simple cognitive tasks during ambulation (e.g. counting backwards by threes). For people with vestibular impairments, less attentional resources are available during gait.[20] Other dynamic gait exercises included walking with eyes closed as the patient had difficulty maintaining balance with occluded vision during the mCTSIB. As the patient progressed, outdoor ambulation was introduced. This involved ambulating over grass and pavement, up and down inclines, negotiating obstacles, and turning. This provided an opportunity to assess the safety of adding outdoor ambulation to the patient's HEP.

Strengthening

The most important musculature for postural stability includes tibialis anterior (dorsiflexion), gastrocnemius (plantarflexion), hamstrings (knee flexion), and quadriceps (knee extension); but in older adults, adductor and abductor strength becomes critical for maintaining

lateral postural stability.[21] Strength deficits were identified via MMT, and thus, lower extremity strengthening was added to the patient's HEP. This included toe and heel raises, hip abduction, hip extension, hip flexion (i.e. marching), hamstring curls, and mini squats. The patient was instructed to progress from one to three sets of ten repetitions and from bilateral hand support to unilateral single finger support. The exercises were thus progressed to incorporate single leg balance.

OUTCOMES

Upon discharge, the patient met all of his physical therapy goals (see Table 3). Outcome measure results may be found in Table 2 and Figure 2. A DHT was performed at the patient's second visit and repeated at week eight; both tests were negative bilaterally. A lateral roll test performed at week eight was also negative. A decreased DHI score reflected functional gains and improved subjective feelings of dizziness. Additionally, sit to stand transfers no longer provoked symptoms. Improvements with VOR function enabled the patient to perform all VOR exercises without symptoms, although he reported mild diplopia during VOR x1 far. Improvements with the mCTSIB and MiniBESTest reflected gains with static and dynamic balance. Qualitative improvements observed during the MiniBESTest included increased stability with head turns during ambulation and decreased dual task interference. In addition, the patient demonstrated lower extremity strength gains, improving by a half to full MMT grade throughout. Functionally, the patient reported at discharge no recent loss of balance episodes. He demonstrated safe and proper form with his HEP and agreed to continue it after discharge.

The patient returned from his five-week vacation and was discharged at that time due to the results of his outcome measures and reported lack of dizziness. During the final visit,

however, the patient reported recent unexplained weight loss, bruising, and fatigue. He made plans to follow-up with his PCP regarding these concerns.

DISCUSSION

This case report accomplished the stated purpose of describing the VR of a geriatric patient with RD after BPPV treatment. Based on evidence and clinical reasoning, the POC addressed the patient's specific impairments. During eight weeks of outpatient VR, the patient demonstrated gains in VOR function, static and dynamic balance, gait, and LE strength. These improvements translated to functional gains as evidenced by a measurably improved DHI score. These results are consistent with the evidence that a patient-centered VR program incorporating gaze stabilization and balance training may improve dizziness and functional mobility.[1] His recovery, although supported by his motivation and compliance, was somewhat limited by his multiple comorbidities. Treatment time for BPPV is generally longer for patients with significant comorbidities.[18] Alcoholism, for example, of which the patient had a history, may result in cerebellar lesions that mimic symptoms of peripheral vestibular loss including gait instability and nystagmus.[22] In addition, the patient's diabetic-related vision deficits may have contributed to his persistent diplopia with the VOR exercises.

A clear etiology of the patient's RD ultimately remained elusive. Although the possibility of a concurrent vestibular condition could not be ruled out, several studies suggest this would be an unlikely cause of RD.[1] Rather, evidence suggests that older age may contribute to RD, perhaps increasing the recovery time of the otoliths.[1] In fact, RD after BPPV is considered common among the elderly.[5] The patient's anxiety was also likely a factor; evidence shows a significant correlation between RD and anxiety.[5]

Faced with an increasingly aged population, physical therapists are likely to encounter more cases of RD. Future research is warranted to guide therapists in treating these complex patients. Specific VR interventions and parameters should be evaluated to optimize outcomes in this population. This type of research will also have the broader impact of addressing fall risk in the elderly, of which, vestibular dysfunction is a leading cause.[1]

This case presents implications for clinical practice, including the importance of promptly identifying and treating patients with RD after BPPV treatment failure. Although BPPV is commonly considered a straightforward condition to treat, this report demonstrates that this is not always the case. As previously noted, 31 to 61% of patients with BPPV develop RD after a successful CRM.[5] Proper follow-up with these patients is essential to insure RD is not complicating their recovery. For patients with BPPV treatment failure, it is important that therapists screen for possible causes including concurrent vestibular conditions and central lesions.[4,16] Furthermore, this case report suggests that some patients deemed as BPPV treatment failures may still benefit from a comprehensive and customized VR program.

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TABLES and FIGURES

Table 1. Results of Tests and Measures at Initial Evaluation

Tests & Measures	Results	Psychometrics
Vertebral artery test	Negative	N/A
Blood pressure	Seated: 137/67 mmHg Standing: 135/70 mmHg	N/A
Spontaneous nystagmus	Negative	N/A
Gaze-holding nystagmus	Negative, mild nystagmus noted at end-range on left	N/A
Smooth pursuit	Jump in mid-range moving from right to left	N/A
Saccades	Negative	N/A
VOR cancellation	Negative, left delay	N/A
Head-shaking nystagmus	Negative	46% sensitivity 75% specificity[10]
Head thrust test	Negative	39% sensitivity 95% specificity[9]
Cervical AROM	WFL, pain-free	N/A
Sharp – dull discrimination	Impaired sensation B feet	N/A

VOR= vestibule-ocular reflex, AROM= active range of motion, WFL= within functional limits, B= bilateral

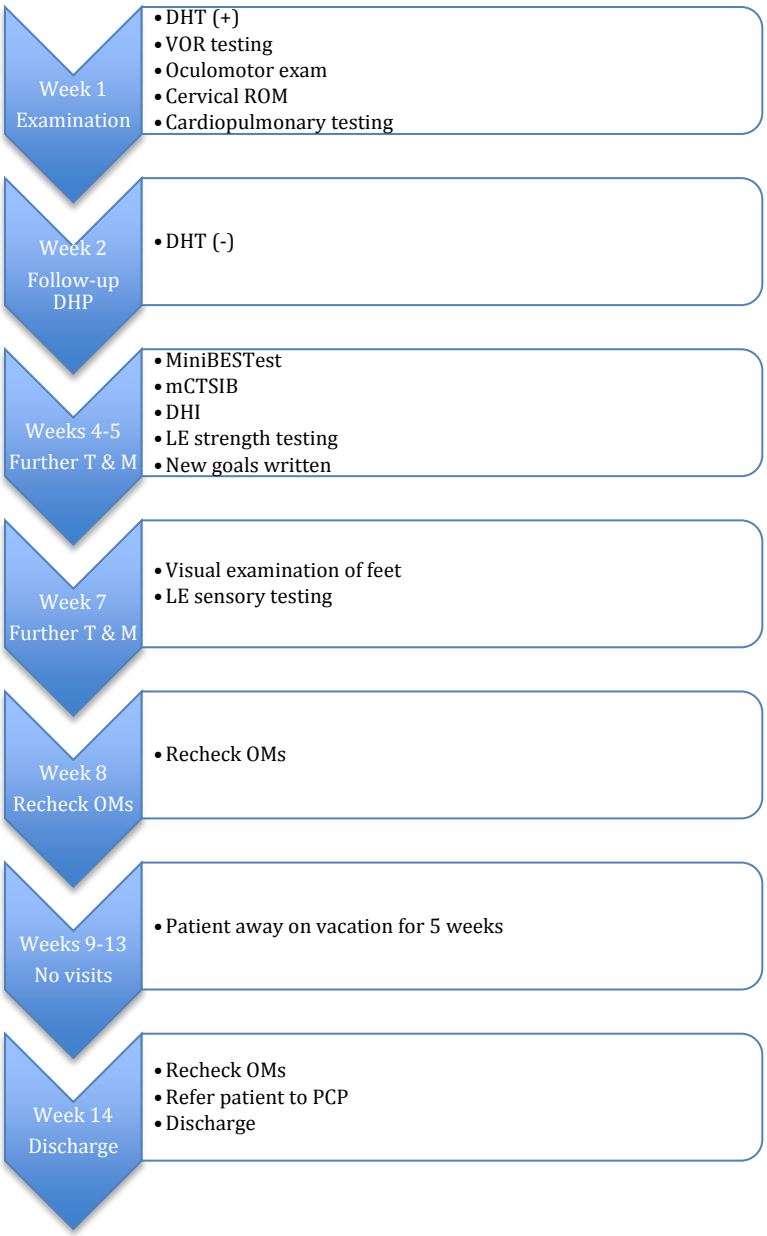

Figure 1. Timeline of Tests and Measures

DHT= Dix Hall-pike test, (+) = positive test result, VOR= vestibular ocular reflex, ROM= range of motion, (-)= negative test result, T & M= tests and measures, Mini-BESTest= The Mini Balance Evaluation Systems Test, mCTSIB= Modified Clinical Test of Sensory Integration on Balance, DHI= Dizziness Handicap Inventory, LE= lower extremity, OMs= outcome measures, PCP= primary care physician

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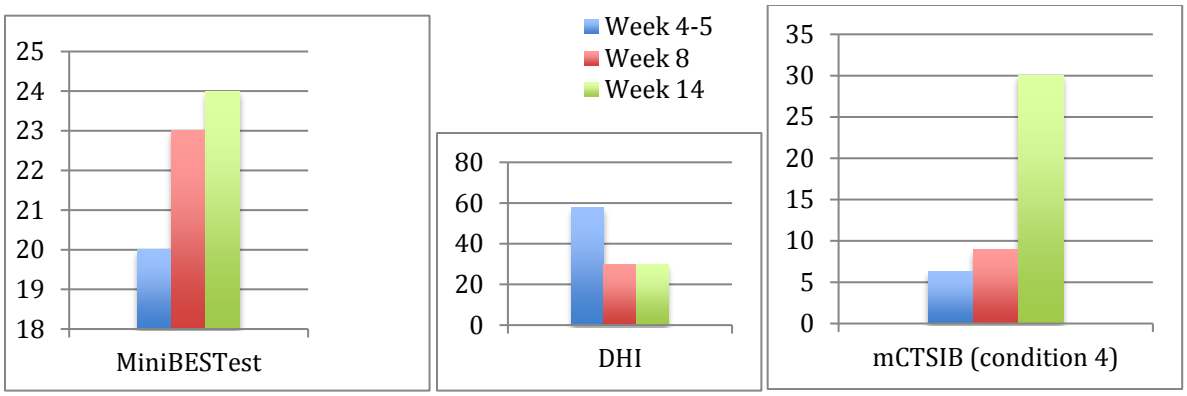
Table 2. Comparison of Outcome Measure Results at Initial Evaluation, Week 8 and Discharge

	Initial Evaluation	**Week 8 / Visit 14**	**Discharge Week 14 / Visit 16**	**Psychometrics**
VOR x1 near	Horizontal: increase in symptoms (2-3/10) Vertical: increase in symptoms (1-2/10)	Horizontal & vertical: x 30 sec with no symptoms	Horizontal: x 30 sec with no symptoms, no diplopia Vertical: x 30 sec with no symptoms	N/A
VOR x1 far	Horizontal: diplopia Vertical: diplopia, increase in symptoms (1-2/10)	Horizontal: diplopia after 20 sec Vertical: no symptoms	Horizontal: x 9 with diplopia; x 5 with diplopia; no symptoms during either trial Vertical: x 30 sec with mild diplopia that self-corrected during the trial	N/A
Dix-Hallpike Test	Right: positive for nystagmus and vertigo (3-4/10) Left: positive for dizziness, no nystagmus *Performed at 2nd visit* Right: negative Left: no nystagmus, 5 sec of dizziness, mild dizziness sitting up	Right: negative Left: negative	Not performed due to prior negative test results	82% sensitivity and 71% specificity for posterior canal BPPV[8]
Tests performed 4-5 weeks after initial evaluation				

Mini-BESTest	Anticipatory: 3/6 Reactive: 6/6 Sensory orientation: 4/4 Dynamic gait: 7/10 Total score: 20/26*	Anticipatory: 4/6 Reactive: 6/6 Sensory orientation: 3/4 Dynamic gait: 10/10 Total score: 23/26	Anticipatory: 4/6 Reactive: 6/6 Sensory orientation: 4/4 Dynamic gait: 10/10 Total score: 24/26	Excellent test-retest reliability (ICC =0.94-0.99) and excellent validity when compared to the mean global rating of change score in rehabilitation (r = 0.72, CI 0.61-0.81). For balance disorders, MCID = 4 points (out of 28 total).[12]
mCTSIB	Condition 1: 30 sec, minimal sway Condition 2: 30 sec, moderate sway Condition 3: 30 sec, moderate sway Condition 4: 6.3 sec, fall	Condition 1: 30 sec, minimal sway Condition 2: 30 sec, mild sway Condition 3: 30 sec, mild sway Condition 4: 8.9 sec, fall	Condition 1: 30 sec, minimal sway Condition 2: 30 sec, mild sway Condition 3: 30 sec, minimal sway Condition 4: 30 sec, mild sway	Condition 4 has a sensitivity of 95% and a specificity of 90% when compared to the Sensory Organization Test.[13]
LE MMT	B hip flexion: 4/5 B hip IR, ER, abd, add: 4+/5 B hip extension: 4/5 B knee flexion & extension: 4/5 B ankle PF, DF, inv, ev: 4+/5	R hip flexion: 4/5 All other motions: 4+/5	B hip flexion: 4+/5 All other motions: 5/5	Good intratester reliability (r = 0.63-0.98), but intertester reliability is more varied. Agreement between testers within half a grade was 50-97%.[24]
DHI	Total score: 58/100	Total score: 30/100	Total score: 30/100	Excellent test-retest reliability (r = 0.97) and high internal consistency reliability (r = 0.89).[1] For vestibular dysfunction, MCID = 18 points.[14]
Lateral roll test	Not performed	Negative bilaterally	Not performed	Recommendation from multiple taskforces for use with BPPV: Reasonable to use, but limited study in target group.[25]

VOR= vestibular ocular reflex, sec= seconds, Mini-BESTest= The Mini Balance Evaluation Systems Test, *One test item was omitted due to lack of equipment; thus, total score is out of 26 rather than 28 point, MCID= minimal clinically important difference, mCTSIB= Modified Clinical Test of Sensory Integration on Balance, sec= seconds, LE= lower extremity, MMT= manual muscle testing, B= bilateral, IR= internal rotation, ER= external rotation, abd= abduction, add= adduction, PF= plantarflexion, DF= dorsiflexion, inv= inversion, ev= eversion, DHI= Dizziness Handicap Inventory.



(a) (b) (c)

Figure 2. Results of Outcome Measures Over Time

a. MiniBESTest= Mini Balance Evaluations Systems Test. b. DHI=Dizziness Handicap Inventory, c. mCTSIB= Modified Clinical Test of Sensory Integration and Balance.

Table 3. Physical Therapy Short and Long Term Goals

	Goal	At discharge
Short term: In 3 visits	Patient will be able to perform horizontal and vertical VOR exercises with no greater than 2/10 increase in symptoms.	Met
	Patient will be able to perform sit to stand transfers with no greater than 2/10 increase in symptoms.	Met
Long term: In 5 visits	Patient will be able to perform sit to stand transfers with no increase in symptoms.	Met
	Patient will achieve a negative Dix-Hallpike test to the left and right.	Met
Additional goals: In 10 visits	Patient will be able to maintain standing balance through all mCTSIB conditions.	Met
	Patient will score 24/26 on the MiniBESTest indicating a decrease in symptoms.	Met
	Patient will score 30/100 on the DHI indicating a decrease in symptoms.	Met

VOR= vestibular ocular reflex, mCTSIB= Modified Clinical Test of Sensory Integration and Balance, MiniBESTest= Mini Balance Evaluations Systems Test, DHI=Dizziness Handicap Inventory. Additional goals were established at patient's 10th visit.

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Table 4. Patient-related Instructions

Topic	Instructions
BPPV & vestibular rehabilitation	• Educated about the pathology, symptoms, and treatment of BPPV. • Following the Epley maneuver: advised to avoid excessive cervical flexion and extension, and rapid head turns for the remainder of the day. • Provided with educational handouts on BPPV and vestibular rehabilitation.[17]
Plan of care	• Communicated the frequency and duration of visits and the anticipated time course of recovery. • Explained the multisensory integration of the balance system, how the patient's various deficits were contributing to his symptoms, and how they were being addressed via the prescribed interventions. • Provided performance feedback using objective data.
Home exercise program	• Educated on the importance of mildly provoking symptoms during each exercise (ie. 2/10 increase in dizziness). • Reviewed exercises frequently so they could be progressed when they no longer provoked symptoms. • Provided maintenance exercise program at discharge to facilitate self-management of symptoms.
Functional mobility	• Educated on safe outdoor ambulation: walking sticks, caution on uneven surfaces, stop before turning head to cross the street. • Advised on proper footwear to optimize proprioceptive input and balance. • Taught proper lifting techniques to minimize dizziness and back strain.

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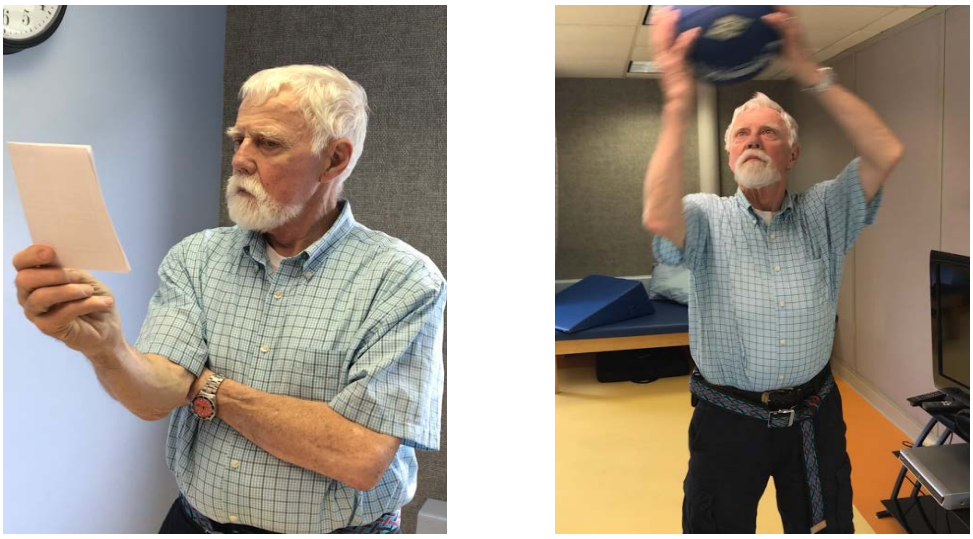
Table 5. Timeline of Physical Therapy Interventions

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 14
Gaze stabilization		-Seated V1 near H & V x 15-30 sec -Seated V1 far H & V x 15 sec -Nose to knee x 5-10 sec -V2 x 2 sets of 5 sec -Standing V1 far H & V x 15 sec	-Standing V1 H & V x 30 sec -Standing V1 far H & V x 30 sec -Nose to knee x 20 sec -V2 x 15 sec -Ball circles CW x 10 reps, CCW x 10 reps	-Standing V1 far V x 70 sec, H x 10 sec -Standing V1 near H & V x 50 sec	-Standing V1 far V x 60 sec, H x 30 sec -Standing V1 near H & V x 45 sec	-Standing V1 far H & V x 60 sec -Standing V1 near H & V x 60 sec -Standing V1outdoors near & far H x 30 sec	-Standing V1 on foam far H x 2 set of 30 sec -V1 during gait H & V 20 ft x 2		
Static balance				-Standing with perturbations	-Standing on foam with EC x 10, 20, 20, 30 sec -Standing on tilt board with heels up and EO x 5, 30 sec -SLS with EO for 2-5 sec x 5 reps bilaterally	-Standing on foam with EC x 30, 30 sec - Standing on tiltboard with heels up and EO 2 x 30 sec -SLS with EO 5 x 2-5 sec bilaterally	-SLS with EO for 2-8 sec x 6 reps -Standing on foam with EO x 30 sec -Standing on foam with EC x 30, 30, 45 sec		
Dynamic gait		-Gait with head turns 2 x 40 ft	-Gait with random head turns 2 x 40 ft		-High steps 2 x 40 ft -Sneaky steps	-Gait outdoors x about 200 ft	-Gait with head turns 2 to 4 x 40 ft		

			-Gait with ball and head turns 4 x 40 ft -Gait with EC 4 x 40 ft		2 x 40 ft -Side steps 2 x 40 ft -Gait with random head turns 2 x 40 ft		-Tandem gait 2 x 40 ft -High steps 2 x 40 ft -DT gait 4 x 40 ft		
Other	-Epley maneuver to the right							- no treatment performed due to reassessment of outcome measures	no treatment erformed due to eassessment of utcome neasures
HEP		-V1 near & far, H & V, seated and standing -Nose to knee x 5 sec -V2	-Continued	-Discontinued V2 and nose to knee	-Added SLS x 30 sec	-Added LE strengthening	-Reviewed LE strengthening	-Continue V1 far and LE strengthening	

V1= VOR x1 exercise, near= 24 inches, H= oscillating horizontal head turns, V= oscillating vertical head turns, sec= seconds, far= 10 feet, V2= VOR x2 exercise, CW= clockwise, CCW= counterclockwise, EC= eyes closed, EO= eyes open, SLS= single leg stance, ft= feet, DT= dual task, HEP= home exercise program, LE= lower extremities



(a) (b)

Figure 3. Gaze stabilization exercises

a. VOR X1 exercise: The patient holds a card printed with an "X" stationary at arm's length distance (approximately 24 inches). He moves his head side to side by approximately 30 degrees while keeping the "X" in focus. This exercise is performed with both vertical and horizontal head movements at two different distances, 24 inches (i.e. *near*) and 10 feet (i.e. *far*).

b. Ball circles: The patient stands and holds a basketball at arm's length distance, moving it clockwise and then counterclockwise. Patient is instructed to move head and eyes with the ball.

c. Nose to knee [not pictured]: The patient is seated, looking straight ahead to start. He moves his nose down towards one knee, returns to an upright position, and then brings his nose down to his opposite knee. Each time he returns to the upright position, his gaze returns to looking straight ahead.

(a) (b) (c)

(d) (e) (f)

Figure 4. Dynamic gait interventions

a & b. Gait with horizontal and vertical head turns: While walking, patient receives cues to turn head "left" or "right," (a) and "up" or "down" (b).

c. Gait with ball and head turns: Patient walks while moving basketball left and right continuously. Patient is instructed to move head and eyes with the ball.

d. "High steps" gait: Patient walks with exaggerated hip flexion.

e. Tandem gait: Patient walks toe-to-heel as if on a tightrope.

f. "Sneaky steps" gait: Patient takes large, diagonal steps resembling lunges

507 **APPENDICIES**
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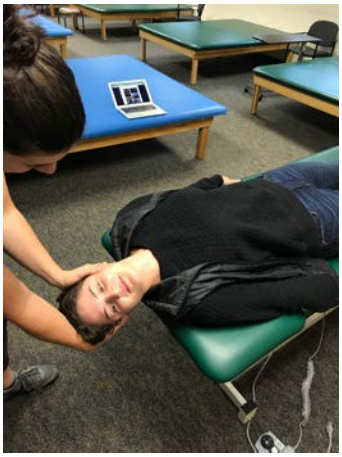
Appendix 1. Stepwise sequence of the Epley maneuver[4]

1. The patient is seated with the head turned 45 degrees toward the affected side (i.e. toward the ear that was positive on the Dix-Hallpike test). (a)
2. The patient is rapidly moved to supine with the head held in 20 degrees of cervical extension. Hold for 20 seconds. (b)
3. The patient's head is turned 90 degrees toward the unaffected side. Hold for 20 seconds. (c)
4. The patient's head is turned another 90 degrees, placing the patient in a nearly facedown position. The patient's body may move partially out of the supine position, as needed. Hold for 20-30 seconds. (d)
5. The patient is returned to a seated position.

(a)



(b)

(c)

(d)

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Appendix 2. List of Medications	
Medication	**Indication**
Aspirin	Cardioprotection
Atorvastatin	High cholesterol
Diltiazem	Hypertension
HumaLOG	Insulin medication for diabetes
Losartan	Hypertension
Timolol maleate	Eye drops for glaucoma
Fluticasone	Seasonal allergies

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Appendix 3. Results of Systems Review	
Cardiovascular/Pulmonary	Impaired- History of hypertension (normal vitals at initial evaluation)
Musculoskeletal	Impaired- Rotator cuff syndrome
Neuromuscular	Impaired- Diabetic neuropathy, impaired balance
Integumentary	Unimpaired
Communication	Unimpaired- However, patient is verbose and has some difficulty describing symptoms.
Affect, Cognition, Language, Learning Style	Unimpaired- Speaks English. Preferred learning style is kinesthetic.

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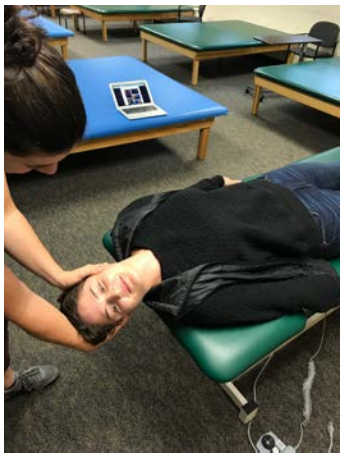
Appendix 4. Steps of the Dix-Hallpike Test [6]

1. The patient starts in a long-sitting position with head rotated 45 degrees to one side (toward the labyrinth to be tested). (a)
2. While maintaining 45 degrees of rotation, the patient is quickly and passively moved to a supine position with head extended 30 degrees beyond horizontal. (b)
3. Observe for nystagmus and ask the patient about symptoms of vertigo.
4. Repeat sequence to test opposite side.

(a)



(b)

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516 **Appendix 5. Head Thrust Test** [9]

517 The head thrust test, also known as the head impulse test, is used to examine semicircular
518 canal function. The therapist holds the patient's head, flexed 30 degrees, while the patient is
519 seated. The patient is instructed to focus on the therapist's nose while the head is passively
520 rotated with a quick, unpredictable movement 5 to 15 degrees to the left or right. A positive test
521 is when the patient's eyes move off the target and a corrective saccade is observed, indicating
522 impaired VOR function.

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524 **Appendix 6. Head-Shaking Nystagmus Test** [10]

The head-shaking nystagmus test is useful in diagnosing unilateral vestibular hypofunction. With eyes closed and head flexed 30 degrees, the patient's head is passively moved left and right at a oscillating frequency of 2 repetitions per second (2 Hz) for 20 cycles. The eyes are then opened and the therapist assesses for nystagmus. Nystagmus indicates a positive test result and possible unilateral vestibular hypofunction.

Appendix 7. Smooth Pursuit Eye Movements[1]

The patient's head remains still and he or she is instructed to track a slowly moving target (e.g. a pen) both horizontally and vertically. The presence of catch-up saccades, or *saccadic pursuit*, indicates a positive test.

Appendix 8. VOR Cancellation[1]

The patient is instructed to focus on the therapist's nose as the therapist passively moves the patient's head back and forth at 1 Hz. The therapist moves his or her head at the same speed, but in the opposite direction of the patient's head. A positive test occurs when the patient is unable to maintain focus on the target, indicating impaired VOR function.

Appendix 9. Saccades[1]

Saccadic eye movements are tested by having the patient look back and forth at two targets spaced apart. The patient's head remains stationary while the motion is repeated several times. The amplitude and velocity of the saccades are assessed. Saccades should be brisk, equal bilaterally, and no more than 10% hypometric or hypermetric.

Appendix 10. Mini Balance Evaluation Systems Test (MiniBESTest)[12]

The MiniBESTest is a shortened version of the Mini Balance Evaluation Systems Test.

The test has fourteen items scored on a three level ordinal scale. It is used to assess six different balance control systems including anticipatory, reactive, sensory orientation, and dynamic gait.

Appendix 11. Modified Clinical Test of Sensory Integration on Balance (mCTSIB)[13]

The mCTSIB is a modification of the CTSIB that eliminates the use of the visual conflict dome. Its purpose is to quantify postural control under various sensory conditions. To perform the test, the patient stands with arms across chest and feet together for the following four conditions:

- Condition 1: Stand on firm surface with the eyes open.
- Condition 2: Stand on firm surface with the eyes closed.
- Condition 3: Stand on compliant surface (foam) with the eyes open
- Condition 4: Stand on compliant surface (foam) with the eyes closed.

For each condition, the patient is timed for 30 seconds and the degree of sway is noted. If the patient is unable to maintain the position for 30 seconds, two additional attempts are provided and the three trials are averaged.

Appendix 12. Dizziness Handicap Inventory (DHI)[14]

The DHI is a patient-reported questionnaire used to measure the perceived impact of dizziness on daily activities. It contains 25 questions divided into three subgroups: functional, emotional, and physical. The minimum score is zero and the maximum score is 100. A higher score indicates a higher level of perceived disability due to dizziness.