TOPICS IN VESTIBULAR PHYSICAL THERAPY

VESTIBULAR REHABILITATION SIG

APTA & Academy of Neurologic Physical Therapy

MANAGEMENT OF PEDIATRIC VESTIBULAR DISORDERS

IN THIS ISSUE PAGE

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Message from the Chair

Rachel Wellons, PT, DPT*
LSU Health Sciences Center

As a Vestibular PT treating only adults, I look forward to this issue and learning more about pediatric vestibular rehabilitation. Thanks to **Margot Gray** and the authors for sharing their expertise with us.

The Vestibular SIG prides itself on listening to our members and responding to their needs. One of the common refrains I've heard from members is that they wanted a platform to talk to each other. We responded by creating a regular online networking event. Thanks to **Lisa Heusel-Gillig** for creating and running this initiative and thanks to Vestibular SIG Leadership Team members **Karen Skop**, **Anne Galgon**, and **Jake McPherson** for participating. We look forward to the next offering on Wednesday, January 31st at 8:00 pm EST.

After over 10 years of service, Social Media Chair **April Hodge** has stepped down. **April** created social media for the Vestibular SIG from nothing and it's grown to over 2,800 followers on Facebook, 2034 followers on Instagram, and 3,600 followers on Twitter. We couldn't have created this content without a team, so thanks to **Carly Lochla, DeJ'a Crippen**, and **Kim Dao** for all your hard work. **Sydney Duhe** has stepped into this role and we look forward to her using her social media prowess for the Vestibular SIG!

One of the most important duties of the Vestibular SIG is to provide education, not only to Vestibular SIG members but to the greater PT community. The Vestibular Hypofunction CPG knowledge translation team of **Holly Roberts**, **Lisa Heusel-Gillig**, **Amy Yorke, Diron Cassidy, Linda D'Silva, Liz Dannenbaum, Erin Greenler, and Connie Weglarz** has worked so hard over the past few years to create a tremendous amount of resources and educational activities to spread the word to all PTs treating individuals with vestibular hypofunction.

The Early Career PT Vestibular SIG Taskforce, headed by **Lynn Johnson** and **DeJ'a Crippen**, organizes free Facebook live educational content targeted at students, newer graduates, and those new to Vestibular Rehabilitation. Lastly, I collaborated with **Helena Esmonde**, **Heather Campbell**, **Holly Roberts**, and **Nicole Miranda** for two presentations for the Primary Care SIG (Federal Section) on basic management and triaging of patients with Vestibular Dysfunction. In the new year, I look forward to engaging more students in presenting "What is a Vestibular PT?" virtually to PT Schools and student SIG organizations.

I look forward to seeing all of you at CSM. As per usual, there's a great slate of vestibular programming. We are not doing our usual Vestibular SIG breakfast meeting but I look forward to seeing everyone at the Vestibular SIG table at the Myelin Melter on Friday, February 16th at 6:30 pm. Vestibular SIG Service and Research awards will be awarded then.

We are an organization only as strong as our leadership team and members, and our 1,896 members make us strong indeed! Thank you again to the members of the Vestibular SIG leadership team and members. We are great because of your passion, dedication, and participation.

Introduction to the Topic

Margot Gray, PT, DPT

Children and adolescents with congenital or acquired vestibular dysfunction (VD) have been shown to have more detrimental effects compared to adults.(1) Earlier studies show the prevalence of vestibular dysfunction in children between 0.5-15% with the most recent systematic and meta-analysis demonstrating up to 30%.(2-4) In this population it may be a bigger problem because vestibular impairments are easily missed due to children's inability to describe their symptoms. Vestibular dysfunction at an early age can impact gross motor development delaying the achievement of sitting, standing, and walking.(10-12) The American Psychiatric Association reports that children with vestibular impairment present with an increased frequency of falls, specifically with higher-level balance activities such as skipping, hopping, and walking on uneven surfaces.(5)

The majority of the research coming from larger regional pediatric balance clinics worldwide, demonstrates that VD in children most commonly results from benign paroxysmal vertigo of childhood (BPVC) and vestibular migraine (VM). The Committee for the Classification of Vestibular Disorders of the Bárány Society and the Migraine Classification Subgroup of the International Headache Society published a consensus statement in recent years seeking to better classify children with migraine-related dizziness.(6) The consensus statement organizes children with migraine-associated dizziness into 3 subgroups: vestibular migraine of childhood, probable vestibular migraine of childhood and recurrent vertigo of childhood. The last of the subgroups, recurrent vertigo of childhood now replaces benign paroxysmal vertigo of childhood. As a member of a multidisciplinary pediatric vestibular and balance disorders clinic, the new classification has allowed patients who did not meet past diagnostic criteria to receive medical treatment for their symptoms.

Following vestibular migraine and BPVC, somatoform, orthostatic, and post-concussion related vertigo are the most common diagnoses of VD in children.(7) Research regarding the cause of dizziness in concussion in children and adolescents has increased considerably over the past five years. Recent evidence points to benign paroxysmal positional vertigo (BPPV) being an unsuspecting cause of dizziness post-concussion in children, with the incidence of superior and anterior canal BPPV being more common in children than adults.(2,3) Growing areas of research and attention in pediatric vestibular research are in children with cerebral palsy (CP) and global developmental delay. These two pediatric populations present with difficulty with walking and balance attributed to either brain or genetic abnormalities. Children with CP have known ophthalmic and oculomotor abnormalities, and peripheral and central vestibular pathways have been investigated in recent years.(8) It is suspected that the central vestibular pathways are disrupted resulting in poor perception of vertical, balance, head control, and gaze instability with gait.(9)

A less common cause but widely researched cause of VD in children, is sensorineural hearing loss (SNHL). Up to 60% of children with SNHL and/or cochlear implant have VD impacting coordination, gross motor development, reading, and balance.(12) The shared anatomy of the hearing and vestibular components of the inner ear make both areas susceptible to long-term damage. Vestibular assessments in this population have grown widely with children and adolescents receiving testing pre- and post-cochlear implantation, further helping to insure early vestibular treatment and prevention of progressive VD.(11,12)

Children with vestibular dysfunction that go untreated will likely form maladaptive responses with balance and gaze stability activities. This is due to the short-lived nature of their symptoms and rapid compensation. They may present with fear of specific movements or positions making them refrain from

particular play or recreational activities, such as swinging or riding a bike. Early detection of VD in children helps them receive management in the form of physical and/or occupational therapy helping them to achieve activity and participation goals.

Vestibular rehabilitation in children and adolescents requires modifications for age and attentional capabilities. Gaze stabilization exercises (GSE) including x1 and x2 viewing may not be as easily completed by a 4-year-old, for example, who does not have the attention span or the ability to understand verbal instructions. Instead, pediatric clinicians will make GSE more exciting to ensure treatment effectiveness and compliance. The utilization of games, flashcards, or children's books with head movements passively or while the child is on a swing or trampoline can help to attain patient treatment goals. Oculomotor training programs are easily accessible on websites such as eyecanlearn.com, providing computer-based games and ideas for activities to complete in person or at home. Lastly, balance training in children and adolescents is a consistent part of the pediatric vestibular rehabilitation treatment plan. Incorporating sports or other activities targeting individual vestibular impairments can be an excellent way to engage children in VR while also putting a smile on their faces.

This edition of the TVPT presents three case reports of children and adolescents with vestibular disorders who were managed by vestibular-trained physical therapists. These include a case of a patient with bilateral SNHL, a case with BPPV after a concussion, and a case of central vestibular changes after an AVM and ICH. Each case presents successful physical therapy examination and treatment helping each child reach goals both in outpatient and inpatient physical therapy settings. Specifically in the case of treating children in an inpatient setting with acquired neurological injuries, incorporating vestibular rehabilitation into their plan of care can assist them in reaching their mobility goals. In the case of pediatric concussion, assessing for BPPV is essential to ensure timely and effective treatment for dizziness.

The case of vestibular areflexia in a child with bilateral SNHL presents the importance of substitution exercises and strategies to help participation in recreational and school activities that may have been avoided otherwise. As pediatric physical therapists skilled in treating children with vestibular dysfunction, we hope this edition of the TVPT highlights the necessity of assessing vestibular function in children while also sharing kid-friendly treatment strategies.

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Vestibular Rehabilitation in an Adolescent with Bilateral Peripheral Vestibular Areflexia: A Case Report

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ABSTRACT

Introduction: Children and adolescents with bilateral sensorineural hearing loss (SNHL) are at risk for vestibular dysfunction. The effects of vestibular dysfunction in this population are seen in gross motor developmental delay, difficulty with reading in school, and the inability to participate in activities at the level of their age-matched peers.(1,2) This case report seeks to describe the vestibular impairments of an adolescent with bilateral vestibular areflexia and the vestibular rehabilitation techniques used to mitigate their functional impact. **Case Description:** An 11-year-old female with bilateral profound SNHL presented to physical therapy with difficulty with balance, coordination, and reading. The patient demonstrated bilateral peripheral vestibular areflexia (abnormal video head impulse test (vHIT) and rotary chair testing), impaired standing balance (single leg balance (SLS) and modified clinical test of sensory integration of balance (m-CTSIB)), poor dynamic balance (tandem gait and functional gait assessment (FGA)), and moderate perceived level of disability (pediatric dizziness handicap inventory (p-DHI)). **Intervention:** Vestibular rehabilitation consisting of substitution exercises for balance and gaze stability was conducted one time a week in person for 10 weeks. A home exercise program was prescribed for six days a week, one to two times a day. **Outcomes:** After 10 weeks, SLS improved by 16 seconds with eyes open and 4 seconds with eyes closed, the total time for the m-CTSIB increased by 10 seconds, tandem gait progressed from 0 to 7 steps, and dynamic visual acuity (DVA) improved by three lines. Additionally, the total score on the parent-reported p-DHI improved by 20 points. Finally, the patient reported improvements in classroom activities and volleyball. **Conclusion:** This case demonstrates how bilateral peripheral vestibular areflexia can impact an adolescent's balance, gaze stability, and coordination.(1-3) The individualized treatment program focusing on substitution exercises for balance and gaze stability led to improved fine and gross motor performance and positively impacted academic and sports participation.

Introduction

The prevalence of vestibular hypofunction in children with sensorineural hearing loss (SNHL) ranges from 20-70%.(1,2) Studies completed by Cushing et al. found that 50% of children with profound bilateral SNHL had abnormalities with vestibular function testing and 35% had severe or complete loss of vestibular function.(1,2) Children with vestibular dysfunction are less likely to be able to describe their symptoms as compared to their adult counterparts. Instead, their ability to process and integrate sensory information presents functionally and in their gross motor development. (1,2) Without intervention, gross motor delay can be progressive in children with vestibular impairment and SNHL.(1,2)

Vestibular rehabilitation research in children and adolescents is limited. However, interventions for children with SNHL and bilateral peripheral vestibular hypofunction have been reported by Rine and Brasswell.(2,3) Their research, along with research in adult populations, supports the utilization of substitution exercises to improve balance and gaze stability in children with bilateral peripheral vestibular hypofunction.(2,3) This case report describes the vestibular impairments of an adolescent with bilateral peripheral vestibular

areflexia and the vestibular rehabilitation strategies used to mitigate the functional impact on academic and sports-related activities.

CASE DESCRIPTION

History

An 11-year-old female was referred by an audiologist after her vestibular testing results (Table 1) demonstrated bilateral peripheral vestibular areflexia or loss. She presented to physical therapy with difficulties related to balance, coordination, and switching her gaze from her teacher to her paper or computer. In addition to difficulty with balance, the patient reported difficulty with keeping her attention in school. The patient and her mother reported an increased incidence of loss of balance and falling in her daily life over the past two years. She wanted to start skiing this winter and be able to ride a skateboard. Her mother reported being very nervous about her daughter starting any higher-level balance activities due to her history of falling. Previously, the patient had received physical therapy intervention at an early age in a different state for balance, developmental delay, and torticollis.

The patient had MRI imaging completed at a younger age at an outside institution. MRI imaging demonstrated absent CN VIII and absent bilateral lateral SCC, normally formed posterior SCC, and hypoplastic superior SCC bilaterally and vestibules that were distended with angulated morphology.

She has a history of profound bilateral SNHL. The patient received an auditory brainstem implant (ABI) at the age of two years. She has a cochlear implant on the right ear but this was not functional. Per the patient's mother, ABI mapping impacted her ability to walk if it was not programmed in a specific way. The patient communicates via American Sign Language (ASL) and attends a school for children who are deaf and hard of hearing. An in-person ASL interpreter was present for all physical therapy treatments.

The patient also has a history of migraines that are managed by a neurologist with medications. Her mother also reported that the patient has attention deficit hyperactivity disorder (ADHD) but there were no medical records to confirm the diagnosis and the patient was not taking any medications for ADHD.

Vestibular testing was completed at Children's Hospital Colorado. The patient received a limited vestibular testing battery including videonystagmography (VNG) without calorics, vHIT, and sinusoidal harmonic acceleration (SHA) rotational chair testing. Caloric testing (with VNG) and vestibular evoked myogenic potentials were excluded due to the cost of testing for the family and suspected vestibular areflexia due to the reported absence of cranial nerve (CN) VIII and the

Table 1. Vestibular Function Testing performed by Audiology

Testing	Result
Videonystagmography	Normal oculomotor subtests. Calorics were not completed.
Video Head Impulse Test	Overall: Abnormal for all semicircular canals– low vestibulo-ocular reflex (VOR) gain and corrective saccades. Right Lateral: Low gain, overt corrective saccades. Left Lateral: Low VOR gain, overt corrective saccades. Left Anterior: Low VOR gain, covert and overt corrective saccades. Right Posterior: Low VOR gain, covert and overt corrective saccades. Right Anterior: Low VOR gain, covert corrective saccades. Left Posterior: Low VOR gain, cover and overt corrective saccades.
Rotary Chair Testing	Abnormal with low VOR gain in all evaluated frequencies: .01, .02, .04, .08, .16, .32Hz. Unable to measure phase and symmetry due to low gain.

lateral semicircular canals (SCC) bilaterally. Her test results demonstrated bilateral peripheral vestibular dysfunction (Table 1).

Examination/Outcome Measures

The patient was found to have decreased cervical range of motion, likely secondary to her history of torticollis. Right lateral cervical flexion and left cervical rotation were decreased with cervical joint and soft tissue restrictions. When her head was at neutral, cervical rotation was limited to ~40 degrees to the left and ~60 degrees to the right. When she was sitting with her normal head posture (right lateral flexion and left cervical rotation), she demonstrated increased left cervical rotation and continued to lack right cervical rotation.

Bedside oculomotor testing, including smooth pursuits, saccades, and convergence, was normal. Facial asymmetry was noted with the left eye lower than the right, likely associated with her history of torticollis.

The functional performance of gaze stabilization mechanisms were assessed with the dynamic visual acuity test using a Snellen vision chart. Head velocity was controlled with a metronome application at 2Hz. Test results revealed a five-line difference between static and dynamic visual acuity.

Balance was significantly impaired with an inability to maintain balance greater than two seconds on condition four (eyes closed, foam surface) of the m-CTSIB. The patient could not balance for more than four seconds with eyes open and one second with eyes closed with single-leg balance testing on the ground, and she could not perform tandem gait.

The FGA was used to determine the impact of obstacles and head movements on the patient's walking abilities. Initially, her total score was 23/30 with head movements with walking and walking over obstacles being the most difficult to complete.

The DHI-PC was completed initially by the patient's mother to determine the level of balance impairment and dizziness in the patient's daily life. She demonstrated a 36 on her DHI-PC indicating a moderate level of disability. Outcome measure scores are noted in Table 2.

Table 2: Physical Therapy Outcome Measures at Initial Examination, Reevaluation and Discharge

Outcome Measure	Initial	Re-evaluation	Discharge
DVA	5 lines	3 lines	2 lines
m-CTSIB	Condition 1: 30 sec Condition 2: 30 sec with increased sway Condition 3: 30 sec Condition 4: 4 sec Total: 92 sec	Condition 1: 30 sec Condition 2: 30 sec with increased sway Condition 3: 30 sec Condition 4: 11 sec Total: 101 sec	Condition 1: 30 sec Condition 2: 30 sec with increased sway Condition 3: 30 sec Condition 4: 12 sec Total: 102 sec
SLS	Eye open: 4 sec bilaterally Eyes closed: 1 sec bilaterally	Eyes open: 20 sec bilaterally, Eyes closed: 4 sec bilaterally	Eyes open: 20 sec bilaterally, Eyes closed 6 sec bilaterally
FGA Total Score	23/30	29/30	30/30
Tandem Gait	0 steps	3 steps with visual fixation	7 steps with visual fixation
DHI-PC Total Score	36	28	16
Abbreviations: DVA = dynamic visual acuity, m-CTSIB = modified Clinical Test of Sensory Interaction and Balance, SLS = single leg stance. FGA = Functional Gait Assessment, DHI-PC = Pediatric Dizziness Handicap Inventory, sec = seconds.			

Assessment

Comprehensive functional testing indicated that the patient's bilateral vestibular areflexia impacted balance and gait stability. Dynamic visual acuity (DVA) testing revealed that the patient had significant loss of dynamic visual acuity. The m-CTSIB results demonstrated that she was unable to utilize vestibular sensation for standing balance control. The patient's performance on the FGA showed that walking with head turns and over obstacles, which require integration of vestibular sensation, was the most difficult for her as she struggled to maintain her speed and accuracy. The total score of 36 on the DHI-PC indicated a relatively moderate perceived level of disability.4 Overall, the patient's vestibular testing results, history, and physical therapy examination align with the literature demonstrating impaired dynamic visual acuity, gaze stability, and balance in children with bilateral vestibular hypofunction.3,4 A comprehensive physical therapy program to address gaze stabilization, balance, and gait to optimize her ability to participate in school and recreational activities was recommended.

Intervention

The patient was seen one time a week for 10 weeks for 60-minute treatment sessions. All exercises were adapted to meet the age and attention requirements of an 11-year-old. Exercises focused on activities that she enjoyed, such as volleyball, reading, and competitive games (e.g., eye spy), which helped to improve her attention and interest in the activities.

The balance exercises focused on training somatosensory and visual systems, while at times potentially training the vestibular system to some degree. The sitting and standing exercises consisted of the patient either sitting on a physioball or t-stool statically or while playing a card game. A foam pad was used during other standing balance exercises while the patient stood with feet apart and completed throw/catch activities progressing to catching more outside of her base of support.

Using ASL as her primary method of communication while completing her exercises, in itself, made the exercises more challenging. She had to turn her head to look at her interpreter while also using her hands and arms to sign. At times, moving her hands and arms to sign would cause her to lose her balance.

The dynamic balance activities that were prescribed were volleyball-specific since she had just started her volleyball season, including hitting back and forth with the physical therapist and up in the air to herself. The patient also participated in walking exercises on a treadmill with gaze shifting exercises reading UnoTM cards and then progressing to words. The text size was initially 24-point font and was progressed to as low as 18-point font.

Initially, substitution exercises for gaze stability consisted of gaze shifting exercises and remembered targets. These were progressed to gaze stabilization during slow, passive head movements (100 degrees per second or less) with reading activities. These exercises were prescribed to centrally program eye movements or catch-up saccades to substitute for the deficient VOR. Passive head turns were completed in the clinic by the physical therapist and were guided by a metronome application.

Her home exercise program included balance exercises such as single leg and tandem balance with gaze fixation to improve balance. She also had a foam pad at home that she worked on standing with feet apart while playing eye spy games with her father. These exercises progressed to reading a book on screen while her father passively rotated her head at 100 degrees per second or less using the same metronome application that the physical therapist used in the clinic. The father was educated on how to complete the head rotations to the speed of the metronome in person. He demonstrated the ability to complete the task correctly as observed by the physical therapist before starting this as part of her home program. The exercises were to be

completed one to two times a day, six days a week. The patient and her father reported that they completed the exercises at least five days a week overall, but only three times a week for one week while the family was on vacation.

Outcomes

The patient demonstrated improvements in her DVA, standing balance, and walking (Table 2). SLS times increased dramatically with eyes open from four seconds to 20 seconds, and from two to 11 seconds with eyes closed. Balance on condition four of the m-CTSIB improved by seven seconds, the overall score increased by nine seconds. Her oscillopsia was improved as evidenced by her DVA testing demonstrating a three-line improvement and the patient's reported improvements with her ability to turn her head and read from the board to her paper in school. The patient also reported improvements with her ability to play volleyball with less instances of losing her balance and/or falling to the ground. She also reported improved accuracy of her hitting to target. The patient had attempted riding her skateboard slowly and reported improved ability to stay on the board and less falls. Although there is currently no published data for the minimal detectable change for the DHI-PC, her total score on this measure decreased dramatically by 20 points. At 10 weeks, the patient was discharged with improved balance with sport-specific and recreational activities.

Discussion

Children and adolescents with bilateral severe to profound SNHL are at risk for vestibular dysfunction. This case report demonstrates how bilateral peripheral vestibular areflexia can impact a child's DVA, balance, and ability to participate in recreational activities. Children and adolescents, like the patient reported in this case, are less likely to be able to verbalize difficulty with vision and balance as compared to adults. However, the effects of vestibular dysfunction are seen in the classroom and on the playground, especially when capacity and performance are compared with age-matched peers. Running on uneven surfaces, riding a bike, and participating in sports requiring a higher level of dynamic balance skills are all examples of activities that can be more difficult for children with vestibular dysfunction.

The patient's outcomes in this case report were consistent with previous studies demonstrating the benefits of vestibular rehabilitation for children with SNHL and vestibular hypofunction or loss.(5-8) Similar to the findings of Braswell and Rine, the patient presented with improved DVA after exercises focusing on passive head movements in the yaw and pitch plane with reading activities.(2,3) DVA improved from initial evaluation to discharge. The patient also started riding a skateboard while participating in physical therapy and reported minimal difficulties with maintaining her balance, and her mother happily reported no falls.

It is important to note the anatomy of the patient's vestibular end organs from her past MRI results. She has absent eighth cranial nerves and bilateral lateral SCC with normal posterior SCC and hypoplastic superior SCC. The positioning of the posterior and superior SCC could provide some vestibular input with cervical rotations accounting for the improvements in her DVA scores. Alternatively, the reduction in oscillopsia as measured by the DVA could also be attributed to the physical therapist's difficulty with passive cervical rotation due to stiffness in the cervical spine, the patient's inability to attain full cervical rotation and difficulty with relaxation secondary to her history of torticollis, and/or the patient's ability to learn the letters of the Snellen chart. Of note, the patient demonstrated the ability to quickly memorize the texts she read at home and in the clinic, requiring that the books be changed frequently. Also, performing DVA testing with a Snellen chart is suggested to be a less sensitive method for assessing DVA as compared to

conducting the test with an Early Treatment Diabetic Retinopathy Study eye chart.

There are several additional limitations to this case. First, this single subject case report may not apply to all children with SNHL and bilateral vestibular dysfunction, specifically children with less severe involvement. Second, numerical results for each vestibular function test were not available to the therapist, making it difficult to determine the severity of the vestibular deficits affecting each component of the end-organ. Third, a more comprehensive assessment of gross motor function, such as the Bruininks-Oseretsky Test of Motor Proficiency™ 2nd Edition assessment (BOT-2), would have also provided a clearer picture of the patient's gross motor function as compared to her age-matched peers.

Conclusion

It is important to assess for vestibular hypofunction/loss in children and adolescents with severe to profound hearing loss. Vestibular rehabilitation can be beneficial for affected children helping them to attain balance, reading, and gross motor developmental skills. Intervention strategies for this population are similar to their adult counterparts with adaptations made for the age and attention span of a child or adolescent.

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Clinical Presentation of Pediatric Mild Traumatic Brain Injury with Peripheral Vestibular Dysfunction Including Bilateral Benign Paroxysmal Positional Vertigo: A Case Report

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ABSTRACT

Introduction: Dizziness is a common complaint in pediatric patients following a concussion event. In the adult population, peripheral vestibular disorders (PVD), including traumatic benign paroxysmal positional vertigo (BPPV), are commonly associated with concussion and are well supported in medical literature. In the pediatric population, there is less awareness of the prevalence of PVD following mild head injury, including traumatic BPPV, and this has not been as well studied as in adults. **Case Description:** A 17-year-old female presented with a diagnosis of concussion and signs and symptoms consistent with PVD, including traumatic bilateral BPPV. The patient also presented with central positional nystagmus (CPN) during positional testing for BPPV requiring differentiation between central and peripheral vestibular nystagmus patterns to select the most appropriate interventions. Dysfunction of her cervical spine and decreased exercise tolerance limited her neck mobility and participation in functional activities in her home and recreationally. **Outcomes:** The patient's bilateral BPPV was resolved in the first three sessions of physical therapy using canalith repositioning maneuvers (CRM). PVD and associated symptoms resolved following treatment of impairments from her concussion including the initiation of a progressive sub-symptom exercise program, balance training, and treatment of her cervical spine dysfunction. She had a recurrence of BPPV after riding on a spinning amusement park ride that was treated successfully with one additional CRM. **Discussion:** The patient demonstrated signs and symptoms consistent with both central and peripheral vestibular disorders following mild Traumatic Brain Injury (mTBI). Conclusion: This case presentation demonstrates the need for skilled vestibular physical therapists in pediatric rehabilitation settings as dizziness is a common complaint in children and adolescents following a concussion.

Introduction

Dizziness is the second most common subjective complaint in children with concussion following headache.(1) Traumatic sources of dizziness from disorders of the peripheral vestibular system following concussion have been identified in the literature and should be considered when completing differential diagnosis for dizziness following concussion. These include temporal bone fracture, perilymphatic fistula, superior canal dehiscence, labyrinthine concussion, and traumatic BPPV.(2) Members of the care team including pediatricians, sports and rehabilitation medicine physicians, and pediatric neurologists may not be well-trained in the identification and management of PVD.(2) Pediatric physical therapists with vestibular training and experience working in both the acute care and outpatient settings are valuable members of the medical care team who can assist with early identification of vestibular pathology following concussion.

The incidence of pediatric BPPV has been previously regarded in medical literature as a rare occurrence.(3) There is a large growing body of evidence in recent years to support the prevalence of pediatric BPPV, up to 30%, associated with

traumatic brain injury and concussion.(1) There is a greater incidence of multi-canal involvement and bilateral BPPV following post-traumatic cases of BPPV when compared to idiopathic BPPV.(4) Specifically in pediatrics, horizontal (HC) and anterior canal (AC) BPPV is more common than compared to adults.(3) It is estimated that pediatric BPPV, on average, takes 19 weeks following injury to be diagnosed and managed.(2) The purpose of this case study is to highlight the physical therapy management of an adolescent patient presenting with vestibular signs and symptoms and BPPV following a traumatic head injury.

CASE DESCRIPTION

History

The patient is a 17-year-old female status post-TBI following a fall from the hood of a car while car surfing. The vehicle was estimated to be driving between 20-30 mph when the driver of the car abruptly pulled the emergency brake, launching the patient onto the road. Witnesses at the scene report the patient hit her head on the pavement and had a brief loss of consciousness. Upon arrival at the local hospital, she had a Glasgow Coma Scale (GCS) score of 13 with severe headache and nausea. Imaging, including computed tomography (CT) of the head and neck and computed tomography angiography (CTA), was completed and demonstrated multiple closed left skull fractures including temporal, parietal, and occipital. In addition, she was found to have a scalp hematoma, a small extra-axial hemorrhage with pneumocephalus, and a right-side hemotympanum (middle ear hemorrhage). Neck imaging was negative for a cervical spine fracture or vascular injury. She was placed on observation in the emergency department overnight and transferred to the Children's Hospital the next day due to ongoing concussion symptoms including severe head and neck pain with emesis.

The patient was admitted for five days for further testing and medical management. During this time, an MRI was completed revealing multifocal hemorrhagic contusions, a small epidural hematoma, and a trace subdural hemorrhage. Neurosurgery was not indicated following imaging. The MRI was negative for cervical ligament injury, and the cervical collar initially provided as a precaution was discontinued. Inpatient therapies, including physical and occupational therapy, were ordered and provided for three days. The patient was discharged home with recommendations to follow up in an outpatient concussion clinic with rehabilitation medicine.

After discharge, the patient followed up initially with her primary pediatrician who prescribed meclizine twice daily for ongoing dizziness symptoms. One month after the injury, the patient followed up with a rehabilitation medicine physician in a concussion clinic where she was referred for outpatient physical therapy for treatment of cervical whiplash, soft tissue injury, and vestibular dysfunction including suspected BPPV.

Examination

The outpatient physical therapy initial examination was completed 45 days after injury. Primary subjective complaints included frequent headaches, constant mild to moderate neck pain, episodic vertigo when rolling over in bed, disequilibrium, muffled hearing, increased fatigue, and poor concentration. The patient had just completed her last dose of meclizine the day before the PT examination.

The patient described vertigo as a sensation of spinning when getting out of bed, lasting less than 30 seconds. Other dizziness was described as a feeling of disequilibrium, such as with physical exertion or standing in the shower with her eyes closed and head tipped. The Dizziness Handicap Inventory (DHI) was selected for her subjective outcome measure, and she scored 38/56, indicating a moderate perceived handicap.

Relevant clinical findings of the cervical exam included a negative upper quarter screen with limited and painful cervical and thoracic range of

motion. Joint mobility of the upper and lower cervical spine was within normal limits however, it was painful to palpation. Thoracic spine joint mobility was restricted grossly throughout T2-T8. Cervical ligament special testing was negative for ligamentous injury and this was also confirmed by MRI completed during the patient's inpatient stay. Decreased cervical strength was found as noted by a score of 8 seconds on the deep neck flexor endurance test.

Tables 1 and 2 present the examination findings for oculomotor and vestibular function, positional tests, and functional balance and ambulation tests. Her oculomotor function was examined in room light and included the assessment of eye alignment, smooth pursuits, saccades, convergence, and spontaneous and gaze-holding nystagmus. All tests were within normal limits and without symptom provocation. Testing was also performed with infrared goggles and demonstrated second-degree right beating horizontal nystagmus. Vestibular test findings included a positive right head impulse test and a positive post-head shake nystagmus test with reported subjective dizziness following the head shake test. Functionally, her dynamic visual acuity was normal at two lines.

Positional testing for BPPV was completed using diagnostic tests of Dix-Hallpike, midline head hang, and supine roll tests. Dix-Hallpike testing demonstrated bilateral posterior canalithiasis BPPV. In the left Dix-Hallpike, the patient was found to have a combination of a paroxysmal upbeat torsional nystagmus to the left followed by persistent downbeating nystagmus. In the right Dix-Hallpike, a combination of a paroxysmal upbeat torsional

Table 1: Initial Vestibular Physical Therapy Examination and Diagnostic Hypotheses

Test	Results	Diagnostic hypotheses
Oculomotor Exam: room light		
Spontaneous nystagmus	negative	WNL
Left gaze holding	negative	WNL
Right gaze holding	negative	WNL
Upward gaze holding	negative	WNL
Oculomotor Exam: without fixation		
Spontaneous nystagmus	+ horizontal right beating	Left hypofunction
Left gaze holding	negative	WNL
Right gaze holding	+ horizontal right beating	Left hypofunction
Upward gaze holding	negative	WNL
Head shaking nystagmus	+ right beating	Left hypofunction
Vestibular Exam		
Head thrust	+ right	Right hypofunction
Dynamic visual acuity	Normal 2 lines + dizziness	Head motion induced dizziness from central vestibular dysfunction
Positional Testing for BPPV		
Dix-Hallpike Right	Paroxysmal right upbeat torsional nystagmus followed by persistent downbeat nystagmus	Right posterior canalithiasis BPPV
Dix-Hallpike Left	Paroxysmal left upbeat torsional nystagmus followed by persistent downbeat nystagmus	Left posterior canalithiasis BPPV
Midline head hang	Brief paroxysmal upbeat torsional nystagmus followed by persistent downbeat nystagmus	Unclear laterality, upbeat torsional suggestive of posterior canal
Roll Test Right	negative	WNL-absent horizontal canal BPPV
Roll Test Left	negative	WNL-absent horizontal canal BPPV

Note: BPPV = Benign Paroxysmal Positional Vertigo, WNL = within normal limits

Table 2: Functional Tests Initial and Discharges Result

Functional Tests	Initial Exam	Discharge
BESS test	31/60	15/60
Dual Task Test	Normal performance on single and dual task components	Not Tested
BCTT	Fail at 6 minutes- symptoms exacerbation	Pass at 15 minutes- 17/20 PRE, no symptoms
Dizziness Handicap Inventory	38/56	8/56

Note: BCTT = Buffalo Concussion Treadmill Test, PRE= Perceived Rate of Exertion on Borg Scale, BESS = Balance Error Scoring System

nystagmus (of unclear laterality due to brevity) followed by a persistent downbeating nystagmus.

Balance and functional testing results included a Balance Error Scoring System (BESS) total score of 31/60, normal Dual Task Assessment (assessed by physician in concussion clinic), and failure of the Buffalo Concussion Treadmill Test (BCTT) due to symptom exacerbation at 6-minute duration.(5)

A referral was placed for audiology vestibular testing due to her history of a left temporal bone fracture, right hemotympanum, reported hearing changes, and positive vestibular exam findings with suspicion of hypofunction of unclear laterality due to mixed findings on the vestibular exam. This included a second-degree right beating nystagmus indicative of a left-sided peripheral hypofunction, and a positive right head impulse, suggestive of a right-sided peripheral hypofunction.

Diagnosis/prognosis

Following the completion of the PT exam, the patient was diagnosed with bilateral posterior canalithiasis (PC)-BPPV, with suspicion of peripheral vestibular hypofunction. The observation of downbeating nystagmus in midline head hang and Dix-Hallpike positions resulted in a differential diagnosis between AC-BPPV and Central Positional Nystagmus (CPN) and the diagnosis of persistent downbeat CPN was determined. Additional diagnoses included exercise intolerance with exertional-induced dizziness and headaches, motion sensitivity with repetitive head motion, impaired static balance with impaired ability to efficiently integrate somatosensory and vestibular inputs for balance, and cervical spine dysfunction.

The patient's prognosis was good due to having no prior history of concussion or migraine headaches, strong family support, no barriers to access transport to/from physical therapy, and having an established mental health provider from prior trauma to assist with coping and anxiety.

Goals for Physical Therapy

Therapy goals during the first four weeks of physical therapy were to resolve the bilateral PC-BPPV, initiate early sub-symptom aerobic training for her home program based on heart rate threshold from BCTT, and promote normal neck mobility and function with cervical spine interventions. Establishing independence with a comprehensive home program incorporating activities for each treatment area was also prioritized early on in her care. At her four-week follow-up, additional goals to improve her postural stability and reduce her headaches were added to the treatment plan.

Intervention

The patient was seen once per week at an outpatient physical therapy clinic for the first eight weeks. A Canalith Repositioning Maneuver (CRM)

was selected to treat bilateral PC-BPPV and treatment of the right ear, the more symptomatic ear, was completed on the initial visit. Following treatment, she was educated on how to perform a self-CRM for right side PC-BPPV, and instructed to complete this several times per day as tolerated between therapy sessions. At the second follow-up session, her right PC-BPPV had resolved with resolution of vertigo symptoms and right upbeat torsional nystagmus in the right Dix-Hallpike. A left side PC-BPPV CRM was administered twice on this visit and she was instructed to continue her self-CRM for the left side as tolerated between therapy sessions. She required one additional therapy treatment with a therapist administered CRM for left PC-BPPV and one additional week of self-CRM for the complete resolution of vertigo and left upbeat torsional nystagmus in left Dix-Hallpike. The downbeating CPN persisted following the successful treatment of bilateral BPPV. The patient was non-vertiginous with this nystagmus and therefore no habituation interventions were initiated for the CPN.

To improve her cervical spine, manual therapy, range of motion, and postural strengthening exercises were initiated in the clinic and she was provided with a home program addressing each component of her cervical program. Exercise tolerance was addressed through a progressive home program, issued for 30 minutes of cardiovascular training, five days per week, with symptom tracking. Heart rate parameters were derived from the BCTT and initially set at 80% of the threshold heart rate. Each week, heart rate parameters were increased as her exertional symptoms became less responsive to physical activity.

Balance training was provided through a home program and challenges were advanced weekly. Activities included a variety of single limb and narrow base of support progressions, unstable surface training, reducing/eliminating visual cues, and incorporating head habituation activities. She utilized props such as pillows, blankets, a soccer ball, and common household objects for home training.

Gaze stabilization activities were not indicated, as her dynamic visual acuity was normal and her head movement-induced dizziness had resolved at her first four-week progress update. Dizziness symptoms resolved quickly once she stopped taking her vestibular suppressant medication, began exercising regularly, and improved her cervical motion during everyday activities and functional mobility.

Additional Medical Testing:

A referral was placed to the audiology department at the Children's Hospital for a comprehensive vestibular evaluation. She completed testing after four weeks of physical therapy intervention and resolution of bilateral PC-BPPV. Testing included videonystagmography (VNG) consisting of static positioning, calorics, head shake, subjective visual vertical, and oculomotor testing. Video Head Impulse Test (vHIT), rotary chair (RC), and Vestibular Evoked Myogenic Potential (VEMP) testing were also included in the test battery. Her DHI score at this visit was reduced to 20/56, mild perceived handicap.

Table 3 presents a summary of the vestibular testing results. This includes a normal VNG except for the presence of nystagmus in static positioning. In head right, a low-level nystagmus was present (1 deg/sec right beating and 4 deg/sec downbeating). In supine and head left, no nystagmus was present. In body right, a low-level nystagmus was present (4 deg/sec downbeating). Dix Hallpike and head hang testing positions were excluded from the VNG testing. Calorics, rotatory chair, oculomotor, and subjective visual vertical were normal. Video Head Impulse Test (vHIT) was normal except for covert saccades detected within the right posterior canal test. VEMP testing yielded some asymmetries. Cervical Vestibular Evoked Myogenic Potential (cVEMP) results were mixed bone versus air conduction which was suggestive of a middle ear

Table 3: Vestibular and Hearing Testing Results

Test	Result
vHIT	Corrective saccades right posterior canal
Calorics	WNL
VNG-pursuits, saccades, SVV, head shake, spontaneous nystagmus	WNL
VNG- static positioning	
Head right	Low-level nystagmus 1 deg/sec right beating and 4 deg/sec downbeating
Body right	Low-level nystagmus 4 deg/sec downbeating
Head left	negative
Supine	negative
Hallpike Dix	not Tested
Rotary Chair	WNL
cVEMP	Suggestive of left middle ear involvement
oVEMP	Suggestive of left weakness –36% stronger right
Tympanograms	WNL bilaterally
Hearing	WNL bilaterally

component in the left ear. Ocular Vestibular Evoked Myogenic Potential (oVEMP) results were abnormal, with a 36% stronger response for the right ear. Audiogram results included normal bilateral tympanograms and normal hearing bilaterally.
The information from vestibular testing that was completed four weeks into her physical therapy program helped determine the extent of PVD bilaterally. This was observed with the left oVEMP asymmetry and right vHIT abnormality. However, the normal RC test found that central compensation was complete for vestibular-ocular reflex (VOR) function. This was in alignment with the patient's resolution of dizziness symptoms at four weeks and normal dynamic visual acuity test. Clinically, this was useful in helping the physical therapist determine that a formal gaze stabilization program was not needed in the next phase of the treatment plan. With normal calorics, the therapist was able to provide education to the patient and her family that no permanent vestibular nerve dysfunction was found on testing, which helped reduce the patient's anxiety and improved her outlook.

Outcome

BPPV was successfully treated bilaterally using a therapist and self-administered CRM. The patient had complete resolution of vertigo and positional torsional nystagmus in all diagnostic testing positions. The persistent positional downbeating nystagmus was refractory to repositioning maneuvers and remained present for the remainder of her therapy course, however, it was non-vertiginous and did not require intervention.

After one month, the patient no longer experienced head movement-induced subjective dizziness and had pain-free and unrestricted cervical range of motion. Following further intervention for balance training, improving exercise tolerance, and postural strength training, she improved her BESS test score to 15/60 and passed the BCTT test with exhaustion (RPE 17/20) achieved without symptom provocation by her eight-week follow-up. She also reported a complete resolution of headaches. The patient was independent with a comprehensive home program for maintaining her gains in cervical postural strength and range of motion. Therapy frequency was decreased to "as needed" due to goal achievement, however, the patient was not discharged from the physical therapy program to allow her additional weeks to follow up if needed.

The patient returned to physical therapy at 12

weeks, due to a recurrence of vertigo symptoms with bed mobility after riding on a spinning amusement park ride.

She was found to have a recurrence of the left PC-BPPV, as diagnosed with the presence of a left upbeat torsional nystagmus in left Dix-Hallpike. She was treated with two therapist-administered CRMs for PC-BPPV and instructed to resume self-CRM as needed at home. Her final DHI score was 8/56. The patient did not return to physical therapy due to symptom resolution.

Discussion

The patient demonstrated signs and symptoms consistent with both central and peripheral vestibular disorders following mTBI due to concurrent trauma to the peripheral vestibular system. Suspicion for PVD by the attending rehabilitation medicine physician was identified in the concussion clinic, and a referral was made to a skilled vestibular physical therapist. Upon PT examination, the physical therapist was able to identify BPPV and additional potential signs of PVD and make further referrals to audiology and otolaryngology. Pediatric primary care was the first medical provider to evaluate the patient after discharge from her inpatient stay and provided the patient with a vestibular suppressant medication, which may have delayed central compensation from PVD.

Following the vestibular physical therapist examination, BPPV was diagnosed at 6.5 weeks from the original date of the trauma, 12.5 weeks earlier than average.(2) To further accelerate this timeline, it is recommended that once the cervical spine is cleared following head and neck trauma in the inpatient setting, the medical care team should evaluate for traumatic BPPV.(2) In this scenario, the cervical spine was cleared three days post-trauma, and BPPV could have been identified and treated as early as the inpatient therapy setting. See Table 4 for a timeline.

Table 4: Timeline for Patient Care

Time Since Onset	Patient Care
Day 0	Head Trauma, local emergency department, observation
Days 2-3	Admitted to Children's Hospital/Trauma Unit- Cervical spine cleared
Days 2-4	Received inpatient PT & OT
Day 5	Discharged to home
Day 18	Follow-up with primary pediatrician, issued meclizine BID
Day 33	Concussion clinic with Rehabilitation Medicine
Day 44	Last dose of meclizine
Day 45 (6.5 weeks)	PT initial examination, BPPV diagnosed and treated
Day 72 (10 weeks)	Vestibular testing completed with Audiology
Day 101 (14.5 weeks)	Otolaryngology clinic
Day 137 (19.5 weeks)	Discharge from physical therapy, complete symptom resolution

CPN is often associated with cerebellar and/or brainstem dysfunction and is suspected when atypical nystagmus patterns are observed with BPPV testing.(6,7) The direction of the nystagmus is most commonly downbeating in head hanging or apogeotropic in lateral supine positions.(6,7) It is estimated that CPN may account for up to 12% of patients with positional nystagmus.(6)

The differential diagnosis between CPN and BPPV can be challenging for treating physical therapists and in these clinically atypical cases, a standardized protocol is missing.(7) To assist with differential diagnosis, common characteristics of AC-BPPV were considered and compared. Typically, AC-BPPV is characterized by a variable vertical downbeating paroxysmal nystagmus and is evoked through straight-head hanging and Dix-Hallpike positioning tests.(8,9) Additional characteristics may also include an absence of a nystagmus reversal upon returning to the upright position, unclear torsional component, and provocation of serious vertiginous symptoms in positioning tests.(8,9)

For the case presentation, the directional patterns of the patient's nystagmus were comparable to AC-BPPV however no serious vertiginous symptoms were provoked. The vertical nystagmus did not habituate with repeated positioning and was persistent for as long as the head was in a hanging position, making the clinician less suspicious of AC-BPPV. To assist with the differential diagnosis of AC-BPPV versus CPN, the physical therapist administered a CRM designed to treat AC-BPPV (Yacovino).(8) The downbeating nystagmus was resistant to the Yacovino repositioning maneuver. On the contrary, the patient had complete resolution of bilateral PC-BPPV with CRM. In addition, the positive central neurologic findings on MRI provided a possible pathophysiological explanation for the presence of a CPN. This made the diagnosis of bilateral PC-BPPV with central positional downbeat nystagmus the most likely diagnosis.

Additional sources of PVD were suspected on exam with her associated trauma of the left temporal bone fracture and right hemotympanum. The patient was referred for additional vestibular testing due to positive exam findings for vestibular hypofunction including a second-degree right beating nystagmus, positive head impulse, and post-head shake nystagmus. Vestibular testing completed four weeks after the initial PT exam demonstrated some abnormal peripheral findings including VEMP and vHIT abnormalities, however calorics and RC were normal. With the termination of vestibular suppressant medication and improved tolerance to active cervical motion and regular exercise, it is suspected that central compensation of the vestibular ocular reflex occurred during the four-week time frame between the PT exam and vestibular testing, as evident by normal RC findings and absence of the second degree right beating nystagmus on VNG.

Finally, it should be noted that after resolution of BPPV, the patient had a recurrence of left side PC-BPPV after riding on a spinning amusement park ride. The recurrence rate of pediatric BPPV is shown to be up to 18%.(10)

Conclusion

Dizziness is common for children and adolescents to experience after a concussion event, and the source of dizziness should not be assumed to be exclusively from the concussion effects on the brain. Vestibular physical therapists play an important role in comprehensively evaluating dizziness following a concussion event. Children may not always reliably report their symptoms therefore it is optimal to ask detailed questions including interviewing primary caretakers regarding dizziness, complete a vestibular exam without fixation, and rule out BPPV through positional testing in all cases. A multi-disciplinary approach including collaboration between audiology and otolaryngology departments may be helpful if available in identifying PVD and to determine additional medical management if needed. Increasing education and awareness of BPPV and

pediatric vestibular disorders following a concussion event for pediatric physical therapists working in both acute care and outpatient settings can accelerate the diagnosis and management of these conditions and decrease overall recovery time.

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ANPT Meylin Melter and Business Meeting

VRSIG representatives will have a table there to discuss SIG engagements and pick up some VR SIG Swag!

When: Friday Feb 17th at 6:30pm
Check CSM website for location

Pediatric Vestibular Rehabilitation after Arteriovenous Malformation Rupture: A Case Report

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ABSTRACT

Introduction: Pediatric arteriovenous malformation (AVM), an abnormal connection between arteries and veins within the brain structure, rupture is one of the most common causes of intraparenchymal and intracerebral hemorrhage in children. They present most commonly with headaches and seizures and are confirmed via CT, MRI, or angiography. Vestibular symptoms are not included in this differential. **Case Description:** A 16-year-old male presented to inpatient physical therapy with abnormal oculomotor movements, dizziness, poor tolerance to upright positioning, and headaches after his AVM rupture. The patient was seen in acute care for physical therapy focusing on functional mobility and vestibular rehabilitation. He improved his overall functional mobility and vestibular symptoms, with no further dizziness and improved overall balance. He was referred for vestibular testing with the audiology team with normal testing results. **Outcomes:** After discharge, he was evaluated by an outpatient physical therapist with no further balance deficits. **Conclusion:** Vestibular rehabilitation demonstrates effectiveness with varying neurological conditions and an evaluation should be included as part of an inpatient physical therapist's repertoire for pediatric AVM. Inpatient physical therapists treat a variety of presentations post AVM rupture, and while improving functional mobility is typically the primary aim, vestibular rehabilitation can be effective in improving the overall functional mobility of a patient. Further research is necessary to determine the prevalence of vestibular symptoms post-AVM rupture in pediatric patients and the need for continued follow-up for physical therapy.

Introduction

An arteriovenous malformation (AVM) is an abnormal connection between arteries and veins via a network of vessels, called the nidus, that lack an intervening capillary bed.(1) The precise pathogenetic mechanisms leading to the lack of capillaries in the AVM nidus remain unclear.(1) They are considered congenital vascular lesions that can be present at any age and are rarely detected during fetal development.(2,3) Functionally important brain tissue may be displaced and thus absent within a compact AVM, or intervening normal brain tissue may be found within a loose nidus.(1) Thus, AVMs have the potential to impact a large brain area with a rupture and are the most common cause of spontaneous intraparenchymal and intracerebral hemorrhage in children.(2)

AVMs of the brain account for 1.4 - 2% of hemorrhagic strokes.(4) Children represent 3% of all AVMs and tend to rupture more frequently than adults.(5) Brain AVMs can lead to intracranial hemorrhage, seizures, headaches, and long-term disability and are the most common nontraumatic intracerebral hemorrhage in children.(1,2) When symptomatic, the most common presenting symptoms are hemorrhage and seizures.(6) Cerebral angiography is considered the gold standard of AVM architecture evaluation and is used for treatment planning.(7) Providers typically use CT or MRI as an initial evaluation as angiography is not readily available and can also evaluate symptoms that are not specific to AVM such as seizure, headache, and hemorrhage.(8)

Treatment techniques for AVM include microsurgical excision, stereotactic radiosurgery,

embolization, or a combination.(9) The overall aim of treatment is to obliterate the AVM to prevent further rupture, which can result in catastrophic neurologic outcomes.(9) There is a growing body of literature that advocates for a multimodal approach to AVM for better outcomes.(10)

Vestibular symptoms are not well documented as related to AVM. One case report described an adult male with tinnitus, no vertigo or hearing loss, and an MRI significant for AVM of the right sigmoid sinus. (11) Following endovascular obliteration of the right sigmoid AVM, he had relief of the tinnitus, but immediate, constant vertigo. He demonstrated a left-beating horizontal nystagmus that improved with visual fixation, suggesting peripheral vestibular etiology, but denied hearing loss. The authors stated that a steroid taper was started and inpatient rehabilitation was prescribed but did not describe the rehabilitation he received. At 4 weeks, the patient reported gradual improvement in vertigo with a hearing test revealing mild sensorineural hearing loss. Vestibular testing was consistent with a marked, uncompensated right peripheral vestibular end-organ lesion. After vestibular rehabilitation, and compensation over an undescribed period of months, the patient had no residual vertigo or pulsatile tinnitus.(11)

This case report aims to highlight a pediatric AVM rupture resulting in an intraparenchymal hemorrhage (IPH) and presenting with vestibular deficits. The patient was treated with vestibular rehabilitation and demonstrated improvement in symptoms and normal testing results on a comprehensive vestibular battery.

CASE DESCRIPTION

History

The patient was a 16-year-old male with a right IPH, who presented to the emergency room for headaches, nausea, and vomiting and was subsequently admitted. Before admission, the patient had no significant medical history, he was a full-time high school student and competitive soccer player. A CT was performed on arrival which demonstrated a right frontal AVM with supply of the middle cerebral and anterior cerebral arteries.

Table 1: Timeline of the Inpatient episode of care

Days Admitted	Medical Procedure	Physical Therapy
0 - Admission	CT scan	No
1		No
2	Angiogram - diagnostic cerebral angio performed - demonstrated AVM with possible associated venous aneurysm	No
3	MRI	No
4		Yes - Evaluation
5-9		Yes- daily
10	Attempted embolization, failed due to medical complexity	No - In procedure
11	Resection of AVM and right craniotomy	No - In procedure
12	Intubated, sedated post op	No - Flat bed rest
13		No - Education to raise head of bed
14		Yes - Resumed out of bed mobility
15-16		Yes- daily
17		No - Fatigue
18–20		Yes- daily
21		Yes - Discharge from PT and hospital

Neurosurgery did not perform an intervention until 11 days after admission. At that time, they performed a right frontal craniotomy and microscopic resection of the AVM. A timeline of hospital stay events is presented in Table 1.

Examination

Physical therapy evaluation occurred on day 4 of the hospital admission. He demonstrated the following impairments: dizziness with all transitional movements, slow speed of oculomotor movements with ocular range of motion screen, directional changing nystagmus with right and left gaze, decreased strength on his left side, decreased tolerance to upright positioning, poor coordination that was worse on the left side, and dysdiadochokinesia. Refer to Table 2 for in-depth measures of his functional mobility and vestibular screen.

Evaluation/Plan of Care

The patient's presentation was consistent with central vestibular impairment, with suspected left-sided coordination impairment, and decreased strength on the left side of his body. Due to the severity of impairments, the plan of care included daily physical therapy to improve functional mobility and vestibular rehabilitation to facilitate the patient's return home at the highest functional capacity possible.

Table 2: Physical Therapy Evaluation Measures

Examination measure	Result
Bed Mobility	Stand by assist with rolling to right side, maximal assist with sidelying to sitting through hooklying, poor initiation, minimal assist with sitting to supine through hooklying; maximal assist with scooting
Sitting Balance	Contact guard to minimal assist with static sitting, reporting continued dizziness
Standing Balance	Moderate assist for static stand; deferred gait due to significant dizziness, fatigue, decreased alertness
Transfers	Maximal assist for sit to stand, moderate assist for stand to sit
Oculomotor	Smooth pursuit: Difficulty tracking in superior and inferior quadrants, but able to perform task with significantly decreased speed. Saccades: (vertical, horizontal, left/right, diagonal) Very slow saccades, Gaze holding: directional changing nystagmus with right and left gaze *Dizziness provoked with each evaluation, breaks were given in between to allow for dizziness to subside
Tactile/Proprioceptive	Light touch: Intact light touch to right side, impaired light touch through left side upper and lower body Left inattention Proprioception and coordination: dysmetria noted on left thumb opposition greater than right side; dysmetria more significant on left finger/nose, dysmetria for heel/shin bilaterally. Dysdiadochokinesia for bilateral feet. *In general, decreased attention paid to left side, required cueing to utilize left hand to stabilize with sitting, or for ADL task at evaluation
Vestibular	Central: noted gaze shifting nystagmus during saccades, poor postural responses and delays with transitional movements, including posterior lean in standing and seated positions Peripheral: unable to confirm due to deferment of head impulse test on evaluation because of strong dizziness symptoms with other testing; *did eventually demonstrate delay bilaterally on day 4 of treatment once able to perform examination*

Interventions/Outcomes

On evaluation, the focus was to improve his tolerance to transitional movements and ability to stay in an upright position for a prolonged time. This involved providing the family with guidance on ensuring the patient remains seated upright in the chair for 30 minutes to an hour, three times a day, with nursing support for transfers. An additional focus was to begin mobilizing the patient to manage his dizziness and habituate his body to movement.

Visual fixation was introduced on day two with transitional movements, particularly with bed mobility. He was instructed to focus on a target in the direction he was moving towards, and was cued to "use his eyes as his guide". Once he was statically seated or standing, he could shift his eyes to what he needed, for example reaching for a cup or looking in the mirror. He also began ambulating for a short distance, 10 feet, and therapists reinforced the importance of staying up in his chair outside of therapy times. He progressed to a minimal assist level with transfers, gait, and standing. The patient required frequent verbal cues throughout sessions, especially with visual fixation, due to observed cognitive deficits. Deficits included poor short-term recall, impulsivity, difficulty processing novel information, and comprehension of multi-step commands. His parents were heavily involved in his care and were provided with significant education regarding the therapy plan of care to progress his functional mobility and upright tolerance.

During day three of treatment, he continued to demonstrate limitations with his fatigue, nausea, and dizziness. The session focused on upright tolerance while fully supported in the bedside chair, as well as functional tasks such as ambulation to and from the bathroom, standing at the sink, and seated dressing with occupational therapy as a co-treatment.

On day four, a head impulse test was performed and the patient demonstrated a lag bilaterally. He benefited from increased use of his somatosensory system through grounding, focusing on his feet in seated and standing positions, in addition to visual fixation with functional mobility tasks to manage his dizziness. He was instructed to use a dizziness scale with activities ranging from 1-10, with one being no dizziness and 10 being the most dizzy. He reported a 1/10 with repeated saccade testing, though continued to present with direction-changing nystagmus. The patient was now ambulating with standby to contact guard assist, and began dynamic balance activities including dribbling, head turns while in a static standing position, tandem gait for 6 feet, and throwing and catching a basketball. Additionally, he performed static standing while engaging in a visual scanning activity through a game. Throughout these activities, he required seated rest breaks, with an increase in nausea. He also began level 1 gaze stabilization exercises (see Table 3) and gaze shifting exercises. Level 1 gaze stabilization involved the patient being seated comfortably and fully supported while focusing on a target one foot away from him. He then had to look to his left and right sides, as if shaking his head, "no," for ten seconds, at a slow speed of movement and within a range of motion that did not exacerbate his dizziness. He was then to repeat this for three sets, five times per day. Gaze-shifting exercises were performed at the same frequency as the level 1 exercise.

Days five and six continued to focus on out-of-bed mobility, including ambulation in the hallways, progressing from 40 to 150 feet by day six. He was able to stand with contact guard assist for three minutes before requiring a rest break, and seated balance progressed to close stand-by assist for 15 minutes prior to demonstrating increased fatigue and dizziness.

Surgery was performed which included an embolization and craniotomy. Following his surgery, physical therapy was not provided for two days due to flat bed rest precautions on post-op day one and slowly working on upright tolerance through slowly raising the head of the bed on post-op day two. On days three and four post-operatively, PT was initiated and he required minimal to moderate assistance for

Table 3: Levels 1-3 Gaze Stabilization

Level	Description
One	Performed seated, focus on target 1 foot in front, turn head side to side while keeping eyes focused on target. Slow speed of head to ensure dizziness no greater than 2-3 points higher than when starting exercise, on a 1-10 self-report scale. Practice for 10-15 seconds, 5 times a day.
Two	Performed in standing or seated position. As the head turns right, the target moves left, as eyes move left, and vice versa. Also performed standing on tilt board or bosu, as body tilts right, target moves left and eyes move left, and vice versa. Slow speed of head and body movement to ensure dizziness no greater than 2-3 points higher than when starting exercise, on a 1-10 self-report scale. Practiced for 20-30 seconds, 5 times a day.
Three	Utilized busy visual surface, patient still focusing on a target, however, initiated squats, as target moved in horizontal and vertical planes. performed with squatted down, target moved vertically, as patient rose, target moved down. Patient was instructed to squat with a bias towards right and left weight shift, with the target moving opposite of squat. Repeated for 30 seconds, 8 repetitions, 4 in each plane.

for functional mobility and was limited by fatigue and increased nausea. By day five he was still limited by fatigue, though was able to ambulate with handheld to minimal assist for 40 feet. He continued to demonstrate direction-changing nystagmus and a positive head impulse test. The patient reported improvement with visual fixation and grounding. Therapists were unable to see him on day six post-operatively due to fatigue after utilizing a bedside commode with nursing.

On day seven post-op he continued to report 3-5/10 dizziness on a self-report scale but demonstrated improvement with smooth pursuit and saccades. Improvements included less reported dizziness, as well as decreased amplitude of observed nystagmus during saccade testing, and increased speed of ocular movements during smooth pursuit. He was able to perform tandem stance with right leg posterior for five seconds and left leg posteriorly for ten seconds before a loss of balance. The physical therapist continued to reinforce the importance of out-of-bed mobility with family, ambulating in halls, and performing visual exercises. The Dynamic Gait Index (DGI) was attempted but was limited by dizziness with testing.

Level 2 gaze stabilization exercises (see Table 3) were initiated on post-op day eight with standing on a bosu and tilt board, separately, while performing weight shifts and staring at a target, with minimal assist. Squatting while on the bosu and tilt board with minimal assist was also added. He performed head turns while walking to and from the therapy gym, requiring stand-by to contact guard assist. Given the patient was a competitive soccer player, he performed dynamic balance exercises by passing the soccer ball to his father, with minimal assistance.

By day nine, his ambulation had improved to stand-by assist, though he continued to demonstrate slight path deviation with head turns. He demonstrated significant improvements in standing endurance, performing dynamic standing activities for 12 minutes including ladder drills, passing the soccer ball with standby to minimal assist before requiring a break. Dizziness improved with rest breaks.

On day ten he demonstrated no loss of balance with gait and was independently ambulating for 25 minutes without a rest break. The patient performed a therapeutic exercise program including bridges, clamshells, short arc quads, and progressed to level 3 gaze stabilization. His level 3 gaze stabilization (see

Table 4: Physical Therapy Outcome Measures

DNT = Did not test

Test	Test 1 (Pre-surgery, 6th visit)	Test 2 (Inpatient Discharge)	Test 3 (Outpatient Evaluation)
Dynamic Gait Index	10	16	*DNT*
Single Leg Stance	*DNT*	Left: 46 seconds Right: 26 seconds	>30 seconds each leg
Tandem Stance	*DNT*	Left lead: 24 seconds Right lead: 30 seconds	**eyes closed* Left lead: 15 seconds Right lead: 19 seconds
Tandem walk	*DNT*	*DNT*	No difficulty walking forward or backward

Table 3) included squatting while focusing on a target with head turns on a busy visual surface. He performed the DGI, tandem stance, and single-leg stance with improvements. Dizziness levels were 2-3/10 throughout the session. No further inpatient physical therapy was recommended at this time, however, parents were educated to follow up with outpatient physical therapy with a focus on return to soccer. It was also recommended that the patient schedule an outpatient vestibular evaluation with audiology to assess for any further vestibular impairments that might impede his return to soccer.

Outcome

During his 21-day hospital stay, he received 13 days of physical therapy sessions. On day 21, he received a final physical therapy session, demonstrated safety with mobilizing, and was discharged to home.

Three weeks after his inpatient discharge, he received a comprehensive vestibular evaluation with our audiology team (see Table 5). The results demonstrated a normal vestibular evaluation without concern for peripheral or central vestibular dysfunction. This included normal vestibular evoked myogenic potentials, videonystagmography, video head impulse test, and rotational chair testing. He was seen in outpatient physical therapy two months after discharge with no further concerns from a physical therapy perspective. He demonstrated improvement in his coordination, strength, and balance. Refer to Table 4 for all outcome measures.

Discussion

Per the literature, even with hemorrhagic presentation, there is a favorable, final functional status after surgical intervention for AVM, but it is likely not the sole determinant of long-term outcome. (12) While one review from Singapore only describes surgical interventions, they reported that 86.2% of patients did not have a recurrence of AVM.(12) They additionally reported that if the patient has a higher Glasgow Coma Scale score, that leads to increased favorable outcomes.(12)

As there is limited documentation of vestibular impairments in pediatric patients with AVM, this case contributes to evidence regarding the need to assess this aspect of their presentation. The patient described in this case had a different area impacted by the AVM compared to the case report in the literature of an adult male, both demonstrated vestibular symptoms and impairments.(11) However, our patient had no further vestibular impairment per an audiology vestibular battery, whereas the other case had lasting deficits including mild symmetric bilateral sensorineural hearing loss and right peripheral vestibular end-organ lesion.(11) In addition this case does not describe what rehabilitation took place.(11) Another adult patient detailed in a case report by Khalil et al., reports a 25-year-old who demonstrated an AVM rupture with cerebellar hemispheric hemorrhage with IVH, and severe ataxia. (13)

He gradually demonstrated functional improvement but after a prolonged period of 8 years.(13) Again, besides surgical intervention, including EVD placement immediately following rupture, no further rehabilitation is described.(13)

Due to the patient in this case report demonstrating significant difficulty with transitional movements, we focused primarily on habituating him with increased practice to out-of-bed mobility and sitting and standing upright. He was instructed to compensate by focusing on a visual target during these transitional movements to decrease the amount of visual stimuli. He demonstrated intermittent success with visual fixation and grounding, likely limited by his cognitive status.

Once he reported decreased dizziness with transitional movements, then the focus of intervention progressed to out-of-room mobility, including increasing his distance with ambulation. Level one gaze stabilization was initiated early in his care to improve his habituation and prepare for increased mobility. As his dizziness and fatigue improved, he progressed through level two and three gaze stabilization, as well as dynamic standing balance practice to improve his postural responses. He demonstrated a brief setback after his surgery however, he recovered fairly quickly and was able to return home on post-op day 10.

Although a standard balance outcome measure could not be performed due to his initial presentation, he was able to perform the DGI at the midpoint of his hospital stay and at discharge. He demonstrated a significantly improved DGI score between tests.(14) Additionally, he demonstrated improved single-leg stance on each leg from his final score on inpatient, to when he was evaluated on outpatient, two months later. He could not achieve 30 seconds with eyes closed with single leg stance or tandem stance, but this was still a great improvement compared to his inpatient times. From a functional mobility perspective, he was minimal to maximal assist upon evaluation, and by his outpatient evaluation, was completely independent. There is evidence to support that acute inpatient rehabilitation with patients with all types of AVMs, across treatment modalities, demonstrates improved outcomes, but there is no in-depth description of using vestibular rehabilitation strategies in patients with AVM.(15)

Another thing to consider is that this patient was a previously highly competitive soccer player. This was incorporated into the plan of care and also used as motivation to increase participation. There is limited documentation that surrounds safety with back to sport following AVM rupture. One case report documents an 18-year-old male who presented with AVM rupture and subsequent IPH to the right thalamus, lateral ventricles, and third and fourth ventricles.(16) This article also does not describe vestibular impairments, besides headaches, and does not describe his specific rehabilitation post-AVM. The authors describe allowing him back to sport once neurosurgery and radiology agreed his scans were stable with no changes after 17 months. The patient in this article received clearance to return to soccer 9 months after a stable arteriogram.(16)

Despite an increased chance of favorable outcomes, there is a higher risk of lifetime rupture with pediatric AVM compared to adults.(12) Continued neuroimaging is important to detect recurrence, with consistent long-term follow-up until adulthood.(12) The natural history of AVMs in a pediatric population is still not fully studied or understood.(2) While children have a higher survival rate compared to adults, they are at risk for long-standing neurological, cognitive, and adaptive behavior impairments, which can impact their lives from a social and independence perspective. (17,18) As such, the patient in this case had continual follow-up with neuropsychology and speech therapy. Since he is connected to services within a larger hospital system, it is relatively easy for him to be referred to physical therapy, should further deficits arise. While his vestibular outcomes, based on audiology lab

testing, were normal, he may benefit from ongoing sports physical therapy to assist with his return to sport, but as of October 2023, he was not currently in outpatient physical therapy.

Conclusion

Physical therapists have an integral role in the early detection of vestibular signs and symptoms. Increased severity of AVM rupture, particularly through IPH or IVH has a higher risk of significant symptoms such as weakness, impaired balance, decreased endurance, poor motor control, ataxia, and headache. This case report demonstrates that vestibular testing should be included as part of an inpatient evaluation. Based on the findings of the evaluation, a vestibular rehabilitation program should be incorporated into the plan of care, as patients with AVM rupture may demonstrate vestibular impairments. Further research is indicated regarding the effectiveness of vestibular rehabilitation for a variety of AVM presentations, as well as any ongoing impairments months to years after the first presentation.

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Table 5: Vestibular Function Test Results

Videonystagmography (VNG)	
Spontaneous Nystagmus	With and Without fixation: no nystagmus
Oculomotor	Gaze: Normal Saccades: Normal Smooth Pursuit: Normal Optokinetic Nystagmus: Normal
High-Frequency Headshake	No nystagmus
Static Positioning	All positions: No nystagmus (Head right-Head center (supine)-Head left)
Rotational Chair	
Sinusoidal Harmonic Acceleration (Top mount binocular recording) Frequencies evaluated: 0.01, 0.02, 0.04, 0.16, 0.32 Hz	Gain: In normative range for all frequencies tested Phase: In normative range for all frequencies tested Symmetry: In normative range for all frequencies tested
SHA with VOR suppression	Frequency evaluated: 0.16 Hz - Suppression: 89% which is normal
Subjective Visual Vertical	Test type: Static - Patient average response: 1.9 to the right, which is normal
Video Head Impulse Test	
Lateral	Right/left gain: Normal - Right/left corrective saccades: Not detected
Left anterior, right posterior	Left anterior gain: Normal - corrective saccades: Not detected Right posterior gain: Normal - corrective saccades: Not detected
Right anterior, left posterior	Right anterior gain: Normal - corrective saccades: Not detected Left anterior gain: Normal - corrective saccades: Not detected
Vestibular Evoked Myogenic Potential	
Cervical Vestibular Evoked Myogenic Potential	Stimuli: Air conduction High intensity level tested: 97 dBnHL - Right Ear: Present/Left Ear: Present Asymmetry ratio: 18% stronger response for the right ear, which is normal
Ocular Vestibular Evoked Myogenic Potential	Stimuli: Air conduction High intensity level tested: 97 dBnHL - Right Ear: Present/Left Ear: Present Asymmetry ratio: 5% stronger response for the left ear, which is normal

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Are you interested in writing a literature review? Do you have an interesting clinical case?

The TVPT Editors are interested in sharing your clinical experience and can provide mentorship to help you contribute.

Contact: Anne Galgon at galgonanne56@gmail.com

CSM 2024 Preview

Victoria Gaugis, PT, DPT*
VA Outpatient Clinic, Terre Haute, IN

The most significant physical therapy event will be held at the Boston Convention and Exposition Center in Boston, Massachusetts, February 15-17,2024. This year's list of presenters promises continued exploration and advancements in physical therapy.

Check out the APTA website for updates and exciting events at CSM 2024. Please review the list below for the current slate of speakers:

Thursday 8-10AM
Recognizing and Rehabilitating Central Vestibular Dysfunction in People Living With Neurodegenerative Diseases
Presented By: Colin R. Grove, PT, DPT, MS, PhD, Leland E. Dibble, PT, ATC, PhD, FAPTA and Brooke Nicole Klatt, PT, DPT, PhD

Thursday 11AM-1PM
Motor Versus Sensory Dysfunction for Balance Control After Mild Traumatic Brain Injury: Implications for Rehabilitation
Presented By: Laurie Anne King, PT, PhD, Kody Campbell, Peter C Fino, PhD and Jennifer Louise Wilhelm, PT, DPT

A Call for Physical Therapy Action on Hearing Loss, Balance Problems, and Falls Risk
Presented By: Jennifer Lynn Kelly, PT and Anat Vilnai Lubetzky, PT, PhD

Thursday 3-5 PM
Vestibular Disorders and Falls: Recognizing, Examining, and Intervening in Older Adults
Presented By: Susan L. Whitney, PT, DPT, ATC, FAPTA, Pamela Marie Dunlap, PT, DPT, PhD and Brooke Nicole Klatt, PT, DPT, PhD

Friday, 3-5 PM
Scientific Rationale, Findings, and Newest in Management of Special Cases of Benign Paroxysmal Positional Vertigo
Presented By: Susan L. Whitney, PT, DPT, ATC, FAPTA, Barry Seemungal and Regan Harrell, PT, DPT

Advances in Management of Posterior Canal BPPV: Canalithiasis Long and Short Arm, Cupulolithiasis, Jam
Presented By: Janet Odry Helminski, PT, PhD and Tammie Jo Ostrowski, PT

Saturday 8-10 AM
Spinning Out of Control: A Deep Dive Into Chronic Dizziness and Dysautonomia
Presented By: Janene M. Holmberg, PT, DPT, Clayton Daniel Powers, PT, DPT and Nicole Andre Miranda, PT, DPT

Saturday 11 AM-1 PM
Spin Doctors — Best Practice Dizziness Care in the Emergency Department
Presented By: Rebekah Lynne Griffith, PT, DPT, Helena Esmonde, PT, DPT and Kaitlyn Marie Johnstone, PT, DPT

Saturday 3-5 PM
The Assessment and Treatment of Benign Paroxysmal Positional Vertigo in the Home Setting
Presented By: Elena Christine Newland, PT, DPT, Jessica Lauren Visintainer, PT, DPT and Rachel Shimko, PT, DPT

Poster Presentations

Thursday

People with Hearing or Vestibular Loss Tend to Exercise Less Compared to Normal Hearing Peers.
Liraz Arie, PT, DPT, Maura Cosetti, Jennifer Lynn Kelly, PT, Katherine Scigliano, Brittani Morris, PT, DPT, Hao Tang, Daphna Harel and Anat Vilnai Lubetzky, PT, PhD

Assessing the Effectiveness of Head-Held Virtual Reality Vestibular Physical Therapy: A Case Series
Alexander Au Dien, PT, DPT, Elliot J. Gann, PT, DPT, Jeffrey Sharon, MD, Natalie Gabrielle Anzures, PT, DPT and Madison Isaak

Concurrent Headshake and Postural Training Using Virtual Reality Improves Eye Movement Velocity: Preliminary Data
Kwadwo Osei Appiah-Kubi, PT, MSPT, PhD, Heather M. Shattuck, PT, DPT, Jaime B. Bicknell, PT, DPT, Evan Laing, BS, MS, Yonellie Jean, PT, Julianne Adegoriolu, PT, DPT, Ananda Cann, PT, DPT and Emmanuel Asante-Asamani, BS, MS, PhD

Sleep Quality Is Associated with Patient-Reported Outcome Measures Among Persons with Vestibular Disorders
Pamela Marie Dunlap, PT, DPT, PhD, Fai A. Alradady, PT, MSPT, Claudia M Costa, Patrick Joseph Sparto, PT, PhD, FAPTA, Joseph M Furman, MD, PhD and Susan L. Whitney, PT, DPT, ATC, FAPTA

The Adoption of the Video Head Impulse Test (vHIT) in a Physical Therapy Practice
Anne K. Galgon, PT, MPT, PhD, Rebecca Ann Bliss, PT, DPT, DHSc, Zachary W. Moyer, PT, Nicole Girgis, Nikki Palma and Olivia Zakaria, PT, DPT

The Impact of Vestibular Education for the Inpatient Rehabilitation Therapist: A Qualitative Case Study
Heather Witt, PT, Natalie Pope and Nathan Forrest Johnson, PT, DPT, PhD

Management of Central Vestibular and Oculomotor Impairments in an Individual with a Chronic Stroke
Zachary Knox, PT, DPT

The Importance of Performing Vestibular Assessments on Patients Following TBI: A Retrospective Study
Heather Witt, PT, Lauren Rose Noe, SPT, Madelynn Hancock, SPT, Jennifer Brockman Cline, SPT, Kaitlin Mullaney, SPT, Stephen Porter and Nathan Forrest Johnson, PT, DPT, PhD

Eye-Gaze Accuracy of Vestibulo-Ocular Exercises at Different Head Speeds
Fai A. Alradady, PT, MSPT, Pedram Hovareshti, Brooke Nicole Klatt, PT, DPT, PhD and Susan L. Whitney, PT, DPT, ATC, FAPTA

Identification and Treatment of Decompensated Vestibular Hypofunction in an Older Adult
Derek Joseph Fanto, PT, DPT

Impact of Care Process Training on Outcomes in Patients with Bppv, Pppd, & Vestibular Hypofunction.
Janene M. Holmberg, PT, DPT, Mark David Stephens, PT, DPT and Jennifer Clarke Terry, PT

Vestibular Habituation Improves Chemotherapy Induced Motion Sensitivity in Stage III Breast Cancer: A Case Report
Matthew Todd Martin, PT, DPT

Prevalence and Predictors of Benign Paroxysmal Positional Vertigo (BPPV) in Persons with Non-Specific Balance Disorders
Christina Marie Garrity, PT, DPT, Kurt Jackson, PT, MPT, PhD, Meghan Brown, SPT, Kara Gnau, SPT and Shannon Nicole Thiel, SPT

Young Adults with History of Concussion Have Difficulty Performing the Balance Error Scoring System (BESS)
Antonia Bartolotta, SPT, Sara Marie Deprey, PT, DPT, MS, PhD and Victoria Caroline Kowalewski, PT, DPT, PhD

Normative Values for Instrumented Gaze Stabilization Test and Dynamic Visual Acuity Test Following Fatigue
Kathryn Renee Lewis, PT, DPT, Cathey P. Norton, PT, DPT, Holly Marie Cauthen, PT, DPT and Nancy Sue Darr, PT, DSc

Central Vestibular and Oculomotor Rehabilitation Following an Acute Pontine Stroke: A Case Report
Jessica Jacobs, PT, DPT, PhD and Zachary Knox, PT, DPT

Modifications to Benign Paroxysmal Positional Vertigo Testing and Intervention in the Acute Rehabilitation Setting: A Case Series
Caroline Ko, PT, DPT, Debra Clooney, PT, DPT and Angela Michelle Link, PT, DPT

Using a "Reverse" Semont Maneuver for Anterior Canal Benign Paroxysmal Positional Vertigo: A Case Report
Bonni Kinne, PT, MSPT, DHSc

Vestibular Rehabilitation Delivered through Telehealth in Persistent Postural Perceptual Dizziness: A Case Study
Rosemary Lackey Babcock, PT, DPT, Emma Probus, SPT, Reid Whiting, SPT, Jennifer Tucker and Morris Casano Beato, PT, DPT

Influencing Quality of Life in an Individual with Chronic, Unremitting Central Vertigo. a Case Study.
Corinne Woodbine, PT, DPT, Geoff Willard, PT, DPT, NCS, CSRS and Hannah Elizabeth Foster, PT, DPT

Promis Outcomes: Higher Odds of Adverse Mental Health When Physical Function Is Impaired
Christopher C. McConnell, PT, DPT

Case Report: Diagnosis and Treatment of Visual Midline Shift Syndrome Using Computer-Assisted Rehabilitation Environment.
Celeste Martina Delap, PT, DPT

Effectiveness of Forced Prolonged Position for Geotropic Horizontal Canal Bppv: A Systematic Review
Bonni Kinne, PT, MSPT, DHSc, Haley Jeanne Anderson, SPT, Blair Cremerius, SPT and Sylvia Mirai Staltmanis, SPT

Virtual Reality Assessment of Binocular Alignment in Acute Vestibular Patients
Daniel Ludwig, PT, DPT, Michael C Schubert, PT, PhD, FAPTA, Carrie W. Hoppes, PT, DPT, ATC, PhD and Colin R. Grove, PT, DPT, MS, PhD

Comparison of Vertical and Horizontal Gaze Stabilization Mechanisms in People with Multiple Sclerosis
Colin R. Grove, PT, DPT, MS, PhD, Brian James Loyd, PT, DPT, PhD, Sophia Petrino, Leland E. Dibble, PT, ATC, PhD, FAPTA and Michael C Schubert, PT, PhD, FAPTA

Screening for Unrecognized Bppv in the Geriatric Population: Are We Asking the Right Questions?
McKenzi Goebel, PT, DPT, Geoff Willard, PT, DPT, NCS, CSRS and Hannah Elizabeth Foster, PT, DPT

Qualitative Study of Physical Therapist's Understanding of Bppv across Practice Settings
Regan Harrell, PT, DPT, Rebecca Hart, Joanna Jen and Susan L. Whitney, PT, DPT, ATC, FAPTA

Exploring the Lived Experiences and Opinions on Mindfulness Meditation for Individuals with Chronic Dizziness
Elizabeth Danielle Cornforth, PT, Katherine Sloan Schramm, PT, DPT, Erik Cruz, SPT, Mackenzie Lee Marks, SPT and Kylee Hart Wollins, SPT

Prefrontal and Vestibular Cortex Activation during Different Optic Flow Speeds
Shelby Kae Boatwright, SPT, Ashley L. Bailey, SPT, Shanyue Guan, PhD, Rui Wu, PhD, Brian Sylcott, PhD and Chia-Cheng Lin, PT, MSPT, PhD

A Novel Approach for Treatment of PC-Bppv with Limited Cervical ROM and Severe Thoracic Kyphosis
William Joseph Carroll, PT, DPT and Josh Campanella, PT, DPT

Resolution of Horizontal Canal Bppv in Multi Canal Bppv with Head Trauma: A Case Report
Jennifer Lynn Kelly, PT and Santosh Krishnamoorthy, PT, DPT, MS

Resolution of Atypical Posterior Semicircular Canal Bppv: Evidence for Putative Short-Arm Location
Daniel Ludwig, PT, DPT and Michael C Schubert, PT, PhD, FAPTA

Implementation of Behavioral Sleep Interventions in Vestibular Rehabilitation: A Case Study
Rudie Spigarelli, PT and Rupal M. Patel, PT, PhD

Managing Atypical Bppv in Conjunction with Vestibular Migraine Induced Positional Vertigo: A Case Report
Robin Joy Evans, PT, DPT and Stephanie Beth Osborn, PT, DPT, BSE

Psychomotor Skills of the Dynamic Visual Acuity Test Assessed By Wearable Technology
Karen Louise Schaubert Goodman, PT, DPT, Keith Robert Cole, PT, DPT, PhD and Ashley Warren, PT, DPT

Recovery of Turning Speed in Patients after Vestibular Schwannoma Resection
Angela Renee Weston, PT, DPT, Leland E. Dibble, PT, ATC, PhD, FAPTA, Peter C Fino, PhD, Carrie W. Hoppes, PT, DPT, ATC, PhD, Brian James Loyd, PT, DPT, PhD and Rich Lisonbee

The Computerized-Visual Vertigo Analogue Scale (cVVAS): A Novel Tool to Evaluate Visual Vertigo
Elizabeth Dannenbaum, Yunyi Liu, Thomas Ashton, Joyce Fung and Alessia Vitullo

Friday

Improving the Skill Set of Vestibularly Trained Therapists in Acute Care for Improved Staff Satisfaction
Leanne Pataky, PT, DPT, Jessica Strikwerda, PT and Allison Grunst, PT

Incremental Velocity Error As a New Treatment in Vestibular Physical Therapy (INVENTVPT): Servicemembers with mTBI
Stacy Pepitone, PT

Saturday

Undetected Vestibular Dysfunction in Cognitively Healthy Older Adults: Prevalence and Implications for Fall Risk Screening
Tanvi Bhatt, PT, PhD, Jessica Pitts, PT, Neha Mehta, PT, Mahaziver Master and Lakshmi Navaneetha Kannan

Vestibular-Focused Balance Training Enhances Quality of Life and Reduces Fall Risk in Parkinson's Disease Individuals
Mohamed El-Sayed Khallaf, PT, DPT, MSc, PhD, Hatem Jaber, PT, MPT, DSc, Mohamed Hassanin, Dina Magdy, Hend Kamal, Mohamed Mousa, Eman E. Fayed, PT and Mansoor Ahmed AlAmeri, PT, MPT, PhD

Vestibular Habituation Training for Forty Years of Chronic Migraines: A Case Study.
Kaycee Vargo, PT, DPT, Zachary E. Walston, PT, DPT and Paige C. Pizzuto, PT, DPT

Vestibular Function and Balance in Children
Emily McCarthy, PT, DPT and Victoria Gocha Marchese, PT, PhD

Effectiveness of Vestibular Rehabilitation in Children Post-Concussion: A Systematic Review
Devashish Tiwari, PT, DPT, PhD, Paige Concannon, Mairead Obyrne, Victoria Twombly and Autumn West

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The editors of the TVPT will accept literature reviews, brief research reports, clinical perspectives, conference presentation summaries, and clinical case studies. Editors will support and mentor clinicians who wish to contribute clinical experience and knowledge in this forum. The editors invite members to suggest topics and guest editors with expertise in a targeted topic.

TVPT is published biannually and is available online through the ANPT/VRSIG web page. https://www.neuropt.org/special-interest-groups/vestibular-rehabilitation/newsletters

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