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Spring 2011

Aging and the Vestibular System

Dizziness is the most common outpatient complaint among patients 75 years and older and accounted for 2.5% of all emergency room visits nation-wide from 1995-2004 (Ishiyama 2009). Correct diagnosis of the cause of dizziness is important for successful treatment but can be difficult to determine given the many systems that influence balance and dizziness. These systems include the peripheral vestibular system, central nervous system including the vestibular nucleus and cerebellum, vision, cardiovascular system, cervical spine and proprioception (Ishiyama 2009 & Herdman 2007). Further, issues such as polypharmacy, co-morbidities such as peripheral neuropathy and orthostatic hypotension, vitamin deficiency such as B12, postural changes and decreased activity can all contribute to a patient’s complaints of dizziness. In this way, diagnosing and treating vertigo is multifactorial.

Dizziness is often associated with falls in the elderly. The Ishiyama (2009) article reveals that each year, 30% of community ambulators fall at least once with 10-20% having recurrent falls. A retrospective study of people over the age of 70 revealed that participants who had one or more falls in the last year presented with decreased vestibular function during rotatory vestibular testing whereas participants who had no falls presented with no vestibular abnormalities (Ishiyama 2009). Another study revealed that 40% of patients who presented to the emergency room after falling reported symptoms of vertigo (Ishiyama 2009).

There are several types of vestibular dysfunction that affect the geriatric population. Some examples are vestibular neuritis, labyrinthitis, Ménière’s disease, vestibular hypofunction, tumors and benign paroxysmal positional vertigo (BPPV). BPPV is the most common cause of dizziness in the geriatric population with an incidence of 10% in people 80 years and older (Ishiyama 2009). The consequences of BPPV are life-changing for older patients with one study reporting 24% of patients giving up driving and 18% not leaving their home as a result of dizziness (Ishiyama 2009). Another study revealed that 61% of geriatric patients who did not initially report dizziness during a routine medical visit complained of dizziness once asked specific questions during examination (Ishiyama 2009). Further, 9% of those patients presented with BPPV when tested (Ishiyama 2009).

Given the incidence and consequences of BPPV and other vestibular dysfunctions in the elderly, it is important to understand the anatomy and physiology of the vestibular system and examine how the system changes with age. The peripheral vestibular system is composed of the bony and membranous labyrinths that lie within the inner ear and are surrounded by the temporal bone, cochlea and middle ear (Herdman 2007). The bony labyrinth is composed of the cochlea, vestibule and semicircular canals (SCC) and is filled with perilymphatic fluid (Herdman 2007). There are three SCCs: horizontal, anterior and posterior. One end of each SCC is wide and forms an ampulla (Herdman 2007).

The membranous labyrinth sits within the bony labyrinth and is supported by the perilymphatic fluid (Herdman 2007). It includes the membranous portions of the SCCs and the saccule and utricle, the two otolith organs (Herdman 2007). The membranous labyrinth contains endolymphatic fluid that is similar to intracellular fluid in electrolyte ratio (high postassium to sodium) (Herdman 2007).

Hair cells within the ampullae, utricle and saccule sense head movement and convert motion into neural firing with information traveling to the vestibular nerve (Herdman 2007). The hair cells of the ampullae sit on a cluster of nerve fibers, blood vessels and the crista ampullaris, which is covered by the cupula (Herdman 2007). The cupula is associated with angular head motion and moves with changes in endolymphatic pressure (Herdman 2007). The hair cells of the utricle and the saccule are called maculae and are innervated by afferent neurons located in the Scarpa's ganglion, close to the ampullae (Herdman 2007). Otolithic membranes are similar to the cupulae but are denser due to the presence of calcium carbonate crystals called otoconia (Herdman 2007). The maculae are sensitive to gravity and linear acceleration due to the density of the otolithic membranes (Herdman 2007).

BPPV occurs when otoconia break loose from the utricle and flow freely in the endolymph of the canal or attach to the cupula, creating movement of the endolymph and changing the firing rate of the neurons (Herdman 2007). This gives the patient a sensation of vertigo and the clinician observes nystagmus when the patient's head is moved in the position that provokes the involved canal. Cupulolithiasis results when otoconia attach to the cupula and canalithiasis results when the otoconia float freely in the endolymph of the canal (Herdman 2007). Canalithiasis is much more common than cupulolithiasis and the posterior SCC is the most commonly affected canal with 76% of patients presenting with BPPV in the posterior canal (Herdman 2007).

The increased incidence of BPPV with age is a result of several factors. The otoconia in the utricle and saccule lose density and degenerate over time (Ishiyama 2009). This degeneration has been observed in the otoconia of both aging humans and rats. The otoconia become irregularly shaped, fragmented and of varying sizes (lshiyama 2009). These changes allow the otoconia to displace more easily, causing the person to have an increased risk of BPPV (Ishiyama 2009). Higher rates of BPPV in the elderly have also been correlated with osteopenia and osteoporosis, diabetes, mild head trauma and giant cell arteritis (Herdman 2007). Research has also shown that geriatric patients with undiagnosed BPPV present with a higher incidence of falls, trouble with activities of daily living (ADL) and a history of depression (Ishiyama 2009 & Herdman 2007).

Although BPPV is the most prevalent cause of dizziness in the elderly, it is not a normal part of aging. However, the decrease in hair cells and vestibular afferents with age slow vestibular functioning (Chang et al 2010 & Herdman 2007). The SCCs have receptors whose feedback produce compensatory oculomotor and postural responses called the vestibulo-ocular reflex (VOR) and vestibulospinal reflex (VSR) (Herdman 2007). In a healthy young person, ocular motion provoked by head movement is equal and opposite, producing a VOR gain of 1 and allowing a person to fixate his/her eyes on a target while moving his/her head (Herdman 2007). The decrease in hair cells and neurons with age reduces the VOR gain and lessens visual compensation associated with head movement, especially with high velocity motion and may cause poor visual acuity with quick head movement (Herdman 2007). This condition is part of the natural slowing of sensory-motor processing with age but does not imply that dizziness is a normal part of aging (Furman et al 2010).

One other factor that should be considered with regard to vestibular changes in the geriatric population is the use of ototoxic medications such as Vincristine and DCM, both chemotherapy medications, and antibiotics such as Streptomycin and Gentamicin (Hain 2003). Gentamicin has been found to damage the vestibular afferents and saccule maculae in guinea pigs (Chang et al 2010). Although use of ototoxic drugs is not directly related to the aging process of the vestibular system, living longer increases exposure to them and bilateral vestibular hypofunction is a common consequence of the use of ototoxic medications in geriatric patients (Herdman 2007).

Once a vestibular impairment is correctly identified, patients respond well to vestibular rehabilitation. The Ishiyama (2009) article reports that age does not influence the success of physical therapy intervention but that both young and old patients who presented with similar vestibular disorders exhibited a similar decrease in the incidence of falls after appropriate intervention. From a clinical standpoint, this may be true of falls related to vestibular disorders such as BPPV, which can be treated and resolved quickly, but may not be true of other vestibular problems. As previously stated, dizziness and imbalance are complicated because they implicate many body systems beyond the vestibular—central, visual, musculoskeletal and cardiovascular—all of which are affected by aging.

Dizzy patients want to get better yesterday. Due to the severity of symptoms including vertigo, nausea and vomiting and the resulting high risk of falls and injury, it is important to determine the best physical therapy intervention to treat the vestibular dysfunction. Since BPPV is the most common cause of dizziness in the elderly with posterior canalithiasis being 76% of cases (Herdman 2007), it is important to determine the most appropriate intervention to treat it.

BPPV is diagnosed through the Dix-Hallpike Test or Side-Lying Test and posterior canalithiasis is characterized by (1) a brief delay in the start of vertigo when the patient's head is moved into the provoking position, (2) complaints of vertigo concurrent with nystagmus that is upbeating with torsion towards the affected ear and (3) vertigo and nystagmus ending in less than 1 minute (Herdman 2007). Once identified, this type of BPPV can be resolved in one treatment in 85% of cases (Herdman 2007). So what *is* the best treatment?

Herdman (2007) suggests three interventions for posterior canalithiasis: the canalith repositioning maneuver (CRM), the liberatory maneuver (LM) and Brandt-Daroff exercises, with the CRM being the preferred intervention. The theory behind these treatments is to reposition the free-floating otoconia back into the utricle (Herdman 2007). The primary researcher of this paper is an American Physical Therapy Association Vestibular Competency-trained physical therapist. She has treated geriatric patients presenting with canalithiasis with the CRM and given post-repositioning instructions to sit up as much as possible and to avoid quick head motions and sleeping on the affected side for 24 hours. She has also prescribed Brandt-Daroff exercises as a follow-up home exercise program (HEP). Although these treatments have been successful, does the evidence support this practice? If not, how should her practice change?

A review by Helminski et al (2010) revealed that in two randomized control trials, patients diagnosed with posterior canalithiasis who were treated with the CRM were 22 times and 37 times more likely to present with resolved BPPV after treatment than the placebo group. Patients were retested with the Dix-Hallpike 24 hours after the initial treatment and were considered to be clear if no nystagmus was observed (Helminski et al 2010). Nystagmus (as opposed to complaints of vertigo) was defined as the determining factor for BPPV because patients could have other reasons for dizziness (Helminski et al 2010). The Dix-Hallpike was performed 24 hours after the initial treatment to prevent a fatigue response (that could occur if retested earlier than 24 hours) (Helminski et al 2010).

Helminski et al (2010) also reported that some limited studies found that use of the LM to correct posterior canalithiasis was more effective than a placebo group with no significant difference in effectiveness between the LM and CRM. However, further results revealed that the CRM combined with a self-performed CRM home exercise program was the most successful intervention while use of the Brandt-Daroff exercises was the least beneficial (Helminski et al 2010). It is unclear from the review if Brand-Daroff exercises were used alone or in conjunction with the CRM.

There is a lack of evidence regarding activity restriction after the CRM or LM but the Helminski et al (2010) article reported patients who did not restrict activity after initial treatment required 1-2 additional treatments before BPPV resolved. A review by Frympas et al (2009) revealed that efficacy of the CRM was not affected by free movement or activity restriction after the initial treatment. The review did mention, however, that inability to detect a positive result of activity restriction could be related to the number of maneuvers performed in one treatment session (Frympas et al 2009). Some clinicians treated patients with one CRM and others performed multiple CRMs. The article proposes that patients who only receive one CRM may benefit from activity restrictions (Frympas et al 2009). Herdman (2007) suggests that in order to ensure that the otoconia remain in the utricle after the CRM, patients may be fitted with a soft cervical collar as a reminder to avoid head movement but then states that this is no longer the current practice.

In summary, the research reveals that the best practice for treating posterior canalithiasis is the CRM followed by self-administered CRM exercises. There is a lack of evidence to support post-repositioning activity restriction. There is also a gap in research about modifications for treating geriatric patients with posterior canalithiasis. For example, the primary researcher for this paper has found that the positions for the Dix-Hallpike and CRM are difficult for geriatric patients to tolerate. Both require that the patient long-sit and then fall back quickly back into supine with the therapist supporting the patient's head (Herdman 2007). Kyphotic posture, forward head, shortened hamstrings and overall decreased flexibility make this position difficult to get into and sustain. In the clinic or hospital, therapists can get therapy aide assistance and adjust beds or therapy tables to help the patient get into the long-sitting. Some beds can be moved into the reverse Trendelenburg position which makes it easier for the patient to fall back as well as reduces the need for neck extension to perform the CRM properly.

For this reason, the primary researcher has been performing the Side-Lying Test as opposed to the Dix-Hallpike with geriatric patients in order to prevent the need for the long-sitting position if the patient does not present with vertigo and nystagmus during testing. Similarly, the primary researcher has consistently treated geriatric patients presenting with posterior canalithiasis with one CRM as opposed to multiple maneuvers. One other modification that the primary researcher has made is with regard to geriatric patient education and safety.

Instead of teaching the self-administered CRM HEP after the CRM, the primary researcher has been prescribing the Brandt-Daroff HEP. This prevents the patient from getting into the precarious position of the CRM at home. If it is difficult for the patient to get into the position with the assist of a therapist, it is more difficult for the patient to do it alone or with the help of an elderly spouse. Further, exercises that provoke dizziness increase the risk for falls and having an elderly patient roll in the bed while dizzy puts him/her at risk for falling out of the bed. Although the Brandt-Daroff exercises have less evidence-based success they may have more clinically-safe relevance. The patient can sit on the edge of the bed with feet on the floor and legs touching the edge of the bed and move into side-lying which may be easier and safer.

So, will the primary researcher's practice change? Yes and no. Yes, in that she will no longer spend time educating patients, families and nurses about post-repositioning activity restriction. No, in that safety is first and since there are no research trials to test the safety of the self-administered CRM HEP among geriatric patients with posterior canalithiasis, she will stick with teaching the Brandt-Daroff exercises post-CRM. The most impressionable lesson that the primary researcher has learned through this paper is that the evidence must be relevant to the population it treats and this means that appropriate interventions should be tailored to ensure effectiveness and safety in the geriatric population.

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