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ORIGINAL ARTICLE

Helping Patients Understand Their Dizziness: Assessment of a Three-Dimensional Printed Vestibular Model

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Abstract To assess the improvement in patient understanding with use of a three-dimensional printed vestibular model as a teaching tool and to evaluate the effects of educational approach on dizziness-related disabilities. Single center randomized controlled trial set in the Otolaryngology ambulatory care clinic located at a tertiary care, teaching institution in Shreveport, Louisiana. Patients with a current or suspected diagnosis of benign paroxysmal positional vertigo who met inclusion criteria were randomized to either the three-dimensional model group or the control group. Each group received the same education session about dizziness, with the three-dimensional model being used as a visual aid in the experimental group. The control group received only verbal education. Outcome measures included patient understanding of benign paroxysmal positional vertigo etiology, comfort level with symptom prevention, anxiety related to vertigo symptoms, and how likely the patient was to recommend the teaching session to another individual suffering from vertigo. Pre-session and post-session surveys were administered to all patients to assess outcome measures. Eight patients were enrolled in the experimental group, and eight patients were enrolled in the control group. On post-survey data, the experimental group reported increased understanding of symptom etiology ($p = 0.0289$), increased comfort level with preventing symptoms ($p = 0.2999$), a larger decrease in symptom related anxiety ($p = 0.0453$) and were more likely to recommend the education session ($p = 0.2807$) compared to the control group. Three-dimensional printed vestibular model demonstrates promise for patient education and reducing related anxiety.

Keywords 3-D printing · Vestibular model · Dizziness · Vertigo

Introduction

Large population-based studies have found the lifetime prevalence of dizziness to be 30% in the adult population with 15–20% adults affected annually [1]. The spectrum of dizziness etiology is broad and can be multifactorial, which makes pinpointing the source challenging. Regardless of the underlying pathophysiology, increase in dizziness severity has been correlated with lower patient quality of life (QOL) [2].

Vertigo due to vestibular dysfunction is a relatively benign cause of dizziness. However, patients can feel that the condition is unmanageable for a variety of reasons such as diagnosis uncertainty, intense spatial disorientation causing unsteadiness, or the unpredictable nature of symptom onset, duration, and frequency. As a result, anxiety often ensues. Restrictive behaviors are adapted due to fear of these events. Limiting activities to avoid potential triggers further contributes to psychiatric comorbidity along with delaying recovery [3–5].

It has been observed that improved patient education in those with chronic disease increases compliance and results in better health outcomes [6]. Studies have shown that visual aids can be highly effective tools utilized to improve patient

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decision making as well as change patient attitudes [7]. Wake et al. completed a study that demonstrated utilization of three-dimensional (3-D) printed models as visual aids resulted in better patient understanding along with increased patient comfort regarding treatment plans [8].

Since the element of uncertainty may contribute to vertigo related symptoms in patients, the authors speculate that vestibular dysfunction education with the use of a 3-D printed vestibular apparatus model will decrease anxiety centered around dizzy spells, as well as empower and motivate patients to seek resolution of symptoms. The aim of this study was to assess the potential for improvements in patient education of vertigo through use of a 3-D printed vestibular model as a visual aid and teaching tool.

Methods

This study received approval from the Louisiana State University Health Sciences Center Institutional Review Board (ID Number: STUDY00001442). This study is a single center, randomized controlled trial. Inclusion criteria for the study were: age above 18 years; patients with a current or suspected diagnosis of benign paroxysmal positional vertigo (BPPV). Patients with dementia, intellectual disabilities precluding educational sessions, severe hearing loss precluding proper and complete education sessions, suspected neurocardiogenic dizziness, diagnosed neurocardiac dizziness, and prisoners were excluded from the study. Children under the age of 18 years and pregnant women were also excluded from the study.

Written consent was obtained from patients included in the study. Simple randomization using random number tables was used and patients were randomized to the experimental or control group. Standardized educational information covering basic vestibular apparatus anatomy and physiology, otolith displacement resulting in vestibular dysfunction, the Dix-Hallpike maneuver as a diagnostic tool, and the Epley maneuver as an otolith repositioning tool was provided to each patient. The experimental group received the teaching session along with the 3-D printed vestibular model for visual aid. The 3-D model (Fig. 1) was printed by the fourth author (SA) and assembled by the second author (SH) using the free, downloadable model design "Fluid-Filled Vestibular Apparatus for Vertigo Education" by Vestibular First, Philadelphia, PA (https://vestibularfirst.com/how-to-make-a-fluid-filled-vestibular-apparatus/). The control group received verbal education alone. Pre-session survey data consisting of 11 questions (supplemental document 1) and post-session survey data (supplemental document 2) consisting of 9 questions were obtained. Severity of symptoms was reported on a 10-point scale. All other survey responses were reported on a 4-point scale correlating to

Fig. 1 3-D printed model of the vestibular apparatus with tubing containing mineral oil and colored gemstones to simulate physiologic otolith movement with positional changes

answer choices. Outcome measures included the following: patient understanding of BPPV etiology, comfort level with symptom prevention, anxiety related to vertigo symptoms, and how likely the patient was to recommend the teaching session to another individual suffering from vertigo. Responses to pre-session survey question numbers 1, 2, 6, 7, 8, 11 and post-session survey question numbers 1, 2, 7, and 8 were analyzed. Data was statistically analyzed with a student's t-test.

Results

Among the 16 patients enrolled in the study, 8 were enrolled in the experimental group and 8 in the control group. The 3-D model group was 87.5% female and had a mean age of 49.4 ± 15.0 years. The control group was 62.5% female and had a mean age of 43.3 ± 12.9 years.

The average symptom severity was 5.25 in the 3-D model group and 6.125 in the control group with a p-value of 0.4603. The average frequency of symptoms was 2 in the 3-D model group and 2.75 in the control group with a p-value of 0.1489. The mean increase in comfort level with symptom prevention was 1.125 in the 3-D model group and 0.5 in the control group with a p-value of 0.2999. The mean decrease in anxiety related to symptoms was 1 in the 3-D model group and 0.13 in the control group with a p-value of 0.0453 (Fig. 2.). Increase in patient understanding was 3 in the 3-D model group and 1.625 in the control group with a

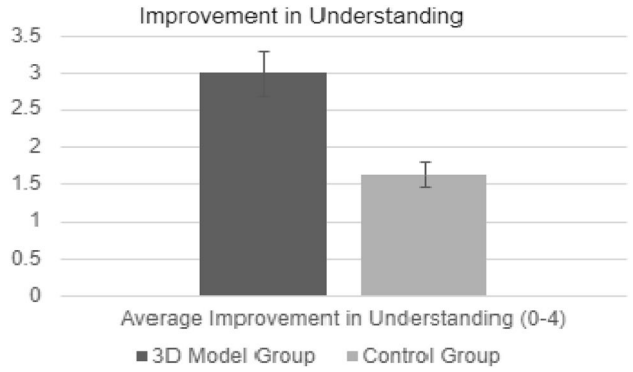

Fig. 2 The 3-D model group displayed a significant improvement in understanding symptom etiology when compared to the control group after receiving educational sessions. The *P*-value was 0.0289

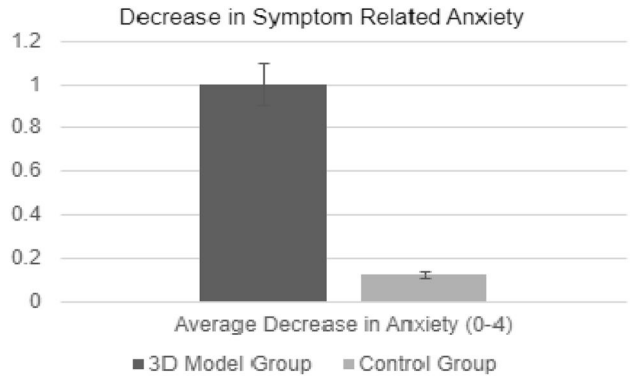

Fig. 3 The 3-D control group displayed a significant decrease in anxiety related to symptoms when compared to the control group after receiving educational sessions. The *P*-value was 0.0453

p-value of 0.0289 (Fig. 3). The average recommendation of the educational session to someone experiencing vertigo was 3.25 in the 3-D model group and 2.625 in the control group with a *p*-value of 0.2807.

Discussion

From our review of literature this is the first study to explore the use of a 3-D printed vestibular apparatus to assess patient understanding and effects on dizziness-related disabilities. The control and 3-D model group reported similar dizziness frequency and severity, and there was no statistically significant difference found between the groups. The 3-D model group was found to have a statistically significant improvement in understanding as well as a statistically significant decrease in anxiety related to vertigo symptoms. Additionally, the 3-D model group reported a higher comfort level with symptom prevention and were more likely to recommend the educational session. These findings display the value in using 3-D printed models to expand patient education and perception.

The association between dizziness and psychiatric disturbances, particularly anxiety, is well documented [2, 9]. Psychiatric comorbidity in those suffering with dizziness is associated with increased psychosocial impairment and a decreased quality of life [9]. Interestingly, it seems that dizziness and anxiety are both implicated in exacerbating one another, irrespective of which illness manifested first [3, 10]. A pathological cycle is created when vertigo attacks are perceived as uncontrollable. Negative experiences from prior attacks can lead to overwhelming thoughts and anticipation of catastrophic dizzy spells. Subsequently, fear cultivates maladaptive coping strategies such as restricting head movements or avoiding environments with confusing positional information. This is troublesome for several reasons. With the intent of preventing symptoms, daily activities become limited, further contributing to psychiatric illness and self-perceived disability. Central compensation for vestibular dysfunction requires repetitive exposure of provoking factors to appropriately adapt. Evading precipitating situations hinders recovery and sustains vulnerability to triggering events and symptoms. With no improvement of symptoms or productive coping mechanisms in place, the anxiety-related cognition that augments restrictive behavior rationale, is facilitated. [4, 9, 11] Moreover, emotional factors influence motor function controls and can limit suitable motor compensation during dizzy episodes, exacerbating the existing handicaps and inciting an intense fear of falling [12].

Neuroanatomic connections between the vestibular nuclei and autonomic regions in the brainstem have also been proposed to be the link between anxiety and balance disturbances [13]. When treating patients with chronic subjective dizziness and anxiety, Staab and Ruckenstein reported that selective serotonin reuptake inhibitors (SSRIs) were effective in reducing dizziness and anxiety, irrespective of the inciting event. This response is thought to be from direct effects on the vestibular nuclei or indirect effects from reduction in base-line psychiatric illness. This work echoed previous studies that support psychiatric factors sustain dizziness [11, 14, 15]. Heightened autonomic arousal experienced during states of panic or anxiety produce symptoms such as lightheadedness, postural instability, and dizziness that amplify or maintain the symptoms felt with vestibular dysfunction alone. [4, 9, 16] Excessive autonomic activity indirectly causes increased muscle tension, fatigue, and poor concentration [5]. Consequences of these effects paired with extra central processing to compensate for balance disruption, make daily tasks demanding [17].

After noting that higher Hospital Anxiety and Depression Scale (HADS) scores were associated with greater handicap caused by dizziness, Cheng et. al suggested that alleviating complicating factors, such as mood disorders, has the potential

to reduce the handicap generated by dizziness [2]. Yardley et. al found that nearly half of the individuals experiencing dizziness reported handicap to some degree, and of those working and experiencing dizziness, 40% reported occupational difficulties [16]. Due to the considerable influence on everyday functioning, intervention is warranted.

Patient-oriented intervention through professional education is thought to be beneficial for health outcomes in chronically ill patients. Comprehensive information presented in a feasible manner improves patient self-care management and long-term health outcomes [18]. Moreover, insufficient health literacy has been associated with more frequent use of the healthcare system, health disparities, and worse health outcomes [19]. It has been our experience that demonstrating physiological otolith movement in the semicircular canals of the 3-D model along with verbal explanation of vestibular dysfunction eases the concern that a more sinister process is occurring. This standardized method of teaching is advantageous because it can be conducted by providers or trainees at varying levels.

Though the study was limited by a small sample size, our involvement in patient education as a means of reducing the burden of BPPV is encouraging. To better evaluate the effects of patient education with use of a 3-D vestibular model a larger, multi-center study is needed. Furthermore, assessing patient education level prior to teaching sessions and tailoring information to match the patient's education level may provide greater benefit. The authors propose that patient education has potential to help allay anxiety and subsequently ameliorate dizziness severity in individuals suffering from BPPV.

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Declarations

Conflict of interest The author declares that they have no conflict of interest.

Ethical Approval Approved by IRB, LSU Health, Shreveport.

Informed Consent Obtained from all patients participating in the study.

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