The Journal of International Advanced Otology

J Int Adv Otol 2023; 19(3): 234-241 • DOI: 10.5152/iao.2023.22969

Original Article

Large Variability of Head Angulation During the Epley Maneuver: Use of a Head-Mounted Guidance System with Visual Feedback to Improve Outcomes

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Cite this article as: Bhandari R, Bhandari A, Kingma H, van de Berg R. Large variability of head angulation during the epley maneuver: Use of a head-mounted guidance system with visual feedback to improve outcomes. *J Int Adv Otol.* 2023;19(3):234-241.

BACKGROUND: The aim of this study was to show the variability in head angulation during the canalolith repositioning maneuvers to treat benign paroxysmal positional vertigo and to describe a head-mounted benign paroxysmal positional vertigo guidance system to measure the head orientation.

METHODS: A guidance system for benign paroxysmal positional vertigo was developed by NeuroEquilibrium Diagnostic Systems to measure head orientation and provide visual feedback and instructions to examiners during various maneuvers for benign paroxysmal positional vertigo. Twenty-five experienced examiners and 25 healthy volunteers (aged 21-35 years) were recruited. Each examiner applied the Epley maneuver twice in 1 volunteer: without and with the use visual feedback from a guidance system. Head orientation in both procedures was measured and compared.

RESULTS: The trained examiners demonstrated a large variability in head orientation during the Epley maneuver, which was reduced by using the benign paroxysmal positional vertigo guidance system. There was a variability of 39-65° in head orientation measured without the guidance system. The use of the guidance system reduced the variation range to a sixfold decrease in variability.

CONCLUSION: There is a large variability in head orientation when performing repositioning maneuvers, which could compromise the efficacy of benign paroxysmal positional vertigo treatment. Treatment for benign paroxysmal positional vertigo can be optimized by reducing this variability with a benign paroxysmal positional vertigo guidance system. It might also be a useful tool for teaching.

KEYWORDS: BPPV, Epley maneuver, guidance system, head angulation

INTRODUCTION

Dizziness as a primary complaint accounts for 5.6 million clinic visits in the United States annually, and 17%-42% of patients with vertigo ultimately receive a diagnosis of benign paroxysmal positional vertigo (BPPV).[1,2] BPPV has an incidence of 10.7 to 64 per 100 000 population and a lifetime prevalence of 2.4%.[1,3] Though BPPV is one of the most common causes of vertigo, only 8% of BPPV patients receive effective treatment.[4,5] The time between the first symptoms and appropriate treatment can extend to several weeks.[6]

Benign paroxysmal positional vertigo is usually a self-limiting condition, and the vertigo typically lasts for less than a minute. However, patients often experience debilitating symptoms. The impact on the quality of life of undiagnosed and untreated BPPV may be far from "benign," as patients with BPPV are at increased risk for falls and impairment in daily activities.[7] As BPPV is more common in older individuals, the associated risks increase multi-fold.[7]

Benign paroxysmal positional vertigo is caused by the displacement of otoconial debris from the utricle to the semicircular canals. The debris makes the canal sensitive to gravity[6] and by that, dizziness occurs during certain head movements that change the orientation of the head relative to the gravity vector. Clinical guideline statements for BPPV state that the positional tests for BPPV

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Received: November 06, 2022 • **Accepted:** March 14, 2023 • **Publication Date:** May 31, 2023
Available online at www.advancedotology.org

like the Dix-Hallpike[8] and Supine Roll tests are simple procedures to diagnose the presence and type of BPPV.[9]

Despite its significant prevalence and health impact, considerable practice variations exist in managing BPPV across disciplines.[10] Numerous randomized controlled trials demonstrated that canalith repositioning maneuvers (CRM) are highly effective in treating BPPV.[10] For each involved canal, the appropriate repositioning maneuver should be performed. For posterior canal BPPV, maneuvers like Epley[11] are recommended; for horizontal canal BPPV, maneuvers like the Roll,[12] or forced prolonged positioning[9] are recommended. For anterior canal BPPV, the Yacovino[13] and modified Yacovino maneuver[14] are recommended.

Despite the established efficacy of the repositioning maneuvers, various studies confirmed their underuse,[15-17] and only 10% of BPPV patients are treated with CRM.[1,2] Furthermore, it is estimated that over 65% of patients with BPPV undergo potentially unnecessary diagnostic testing or therapeutic interventions.[17] Early and effective treatment could significantly improve the quality of life, save repeated visits to the Primary Care Physician, and reduce medical costs due to unnecessary tests such as head CTs and referrals to specialists in tertiary care.[15,16] Although BPPV may resolve spontaneously without treatment, up to 50% of cases may take longer than 3 months to resolve. Therefore, CRM is the preferred treatment option.[18,19]

In the literature, the reported success rate of the CRM to treat BPPV is high (50-89.9%).[16,17] However, these studies were mainly conducted in well-controlled settings in centers with expertise in BPPV. Therefore, the reported success rate of canalolith repositioning maneuvers (CRM) in the literature might overestimate their success in routine clinical practice. After all, it is not unlikely that CRMs are less effective in the hands of less experienced professionals. One of the reasons why CRMs might fail is the inability to identify the affected canal correctly. Once identified, accurate head angulation is desired to bring the affected canal aligned with gravity to facilitate the correct repositioning.[20-23]

There is not much literature on studies that assess whether the maneuvers were appropriately used and accurately performed.[7,16,17] The aim of this study was to investigate the variability in head angulation during the canalith repositioning maneuvers (CRMs) to treat BPPV. It was hypothesized that obtained head angulations significantly varied between examiners and that a head-mounted BPPV guidance system to measure head orientation would significantly improve the accuracy of head angulations during CRMs.

This study assessed how trained technicians performed the maneuvers. This was done by measuring the head angle at each step and comparing the difference between the angle achieved with the angle advised. This would shed more light on the variability of head positioning during the maneuvers.

METHODS

Study Design

This study was performed at the Vertigo and Ear Clinic, Jaipur, India. Twenty-five experienced examiners and 25 healthy volunteers (aged 21-35 years) were recruited. Each examiner applied the Epley maneuver twice in 1 volunteer: without and with the use of visual feedback from a guidance system (details in Supplementary material). The examiner performed the Epley maneuver during the first maneuver while the guidance system measured head orientation. However, the examiner was blinded to the results. During the second maneuver, the examiner performed the Epley maneuver while the guidance system measured head orientation, but it also provided visual feedback and instructions to the examiner about the head orientation. The head orientations at each step of the Epley maneuver, with and without the tracker, were measured and compared.

The study design included only the Epley maneuver of the right side to eliminate any confounding effects of side variability. The maneuver was always performed first without feedback from the tracking device to ensure that there was no learning effect from the device on the performance of the maneuver the second time.[24]

Inclusion and Exclusion Criteria

The examiners included laboratory technicians with a minimum of 6 months of training in testing vestibular patients. In addition, the study included healthy volunteers with (1) no history of dizziness, vertigo, motion sickness, or migraine and (2) no restriction of head movements.

Benign Paroxysmal Positional Vertigo Guidance System

A guidance system for BPPV was developed by NeuroEquilibrium Diagnostic Systems Private Limited, Jaipur, India (see Supplementary materials, Figures 1-6, Video 1). The objective of the guidance system was to measure head orientation and provide visual feedback and instructions to examiners during various maneuvers for BPPV.

Each step of the BPPV maneuver (in this study: the Epley maneuver) is displayed on a screen, using a 3D model of the human body (including the orientation of the inner ear). The head position is also shown on the screen to provide accurate information to the examiner about the relative orientation of the inner ear. A headband with custom-made sensors (the “tracker”) measured head orientation. The tracker comprises a 9-axis absolute orientation sensor, integrating a triaxial 14-bit accelerometer, a triaxial 16-bit gyroscope, and a triaxial geomagnetic sensor integrated with a microprocessor. Next, the device is placed on the head with the patient in the initial position. The “align” button is pressed in the software, which allows the device to know the initial position of patient’s head. The device then self-calibrates.

The desired head position for each step of the BPPV maneuver is demonstrated by the 3D model on the screen of the guidance system,. The examiner needs to precisely match the orientation of the patient's head with that of the 3D model at every step of the maneuver, with a tolerance of 4° peak to peak head angle. To keep a low 2-sided tolerance level, 4° was chosen as the cut-off point. The examiner can only continue the maneuver if the appropriate head orientation is obtained. A green light is displayed once the predetermined 3D head orientation is reached. The software then displays the text instructions for the next step. In other words, the patient's head position needs to be matched with that of the 3D model at each step until the complete maneuver is successfully

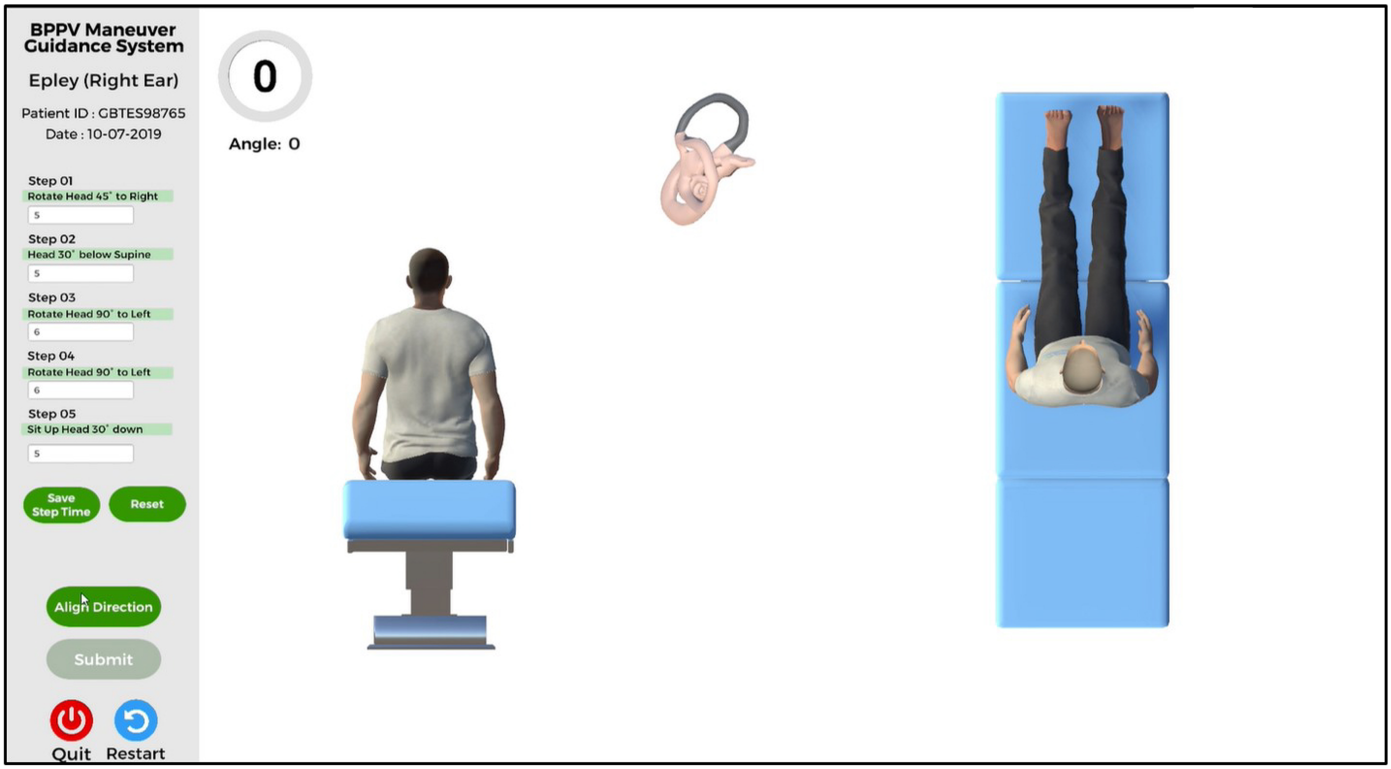


Figure 1. Screen display of the steps of the Epley maneuver with the movement of the 3D model and respective labyrinth orientation.

performed. The system is configured with a waiting period of 30 seconds between each step of the maneuver. This waiting period ensures that the debris reaches the desired position in the canal before proceeding to the next step. This waiting time can be modified by the examiner.

The steps and predetermined (desired) head orientations for the Epley maneuver on the right side included:

Starting position – Subject sitting on the examination table with face forward.

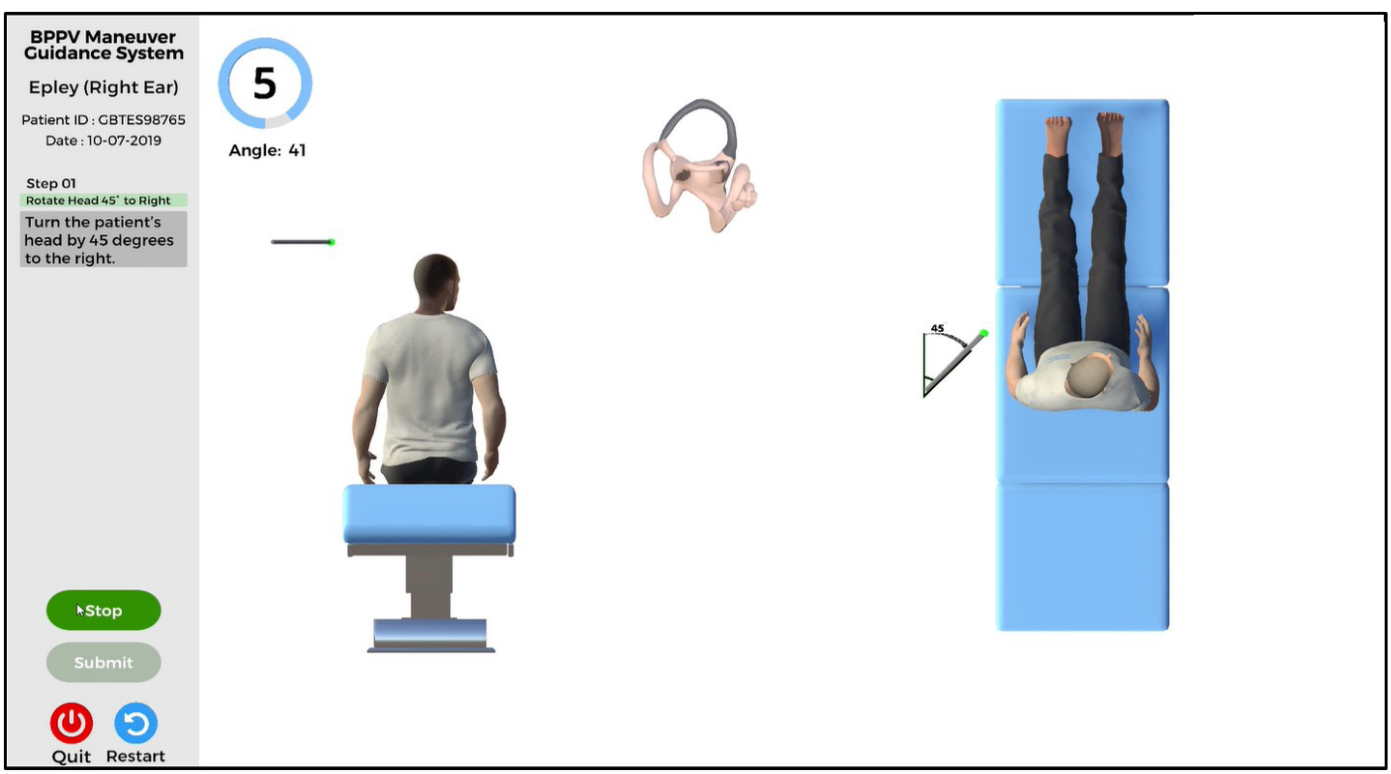


Figure 2. Screen display of the first step of the Epley maneuver to turn head to the right by 45°.

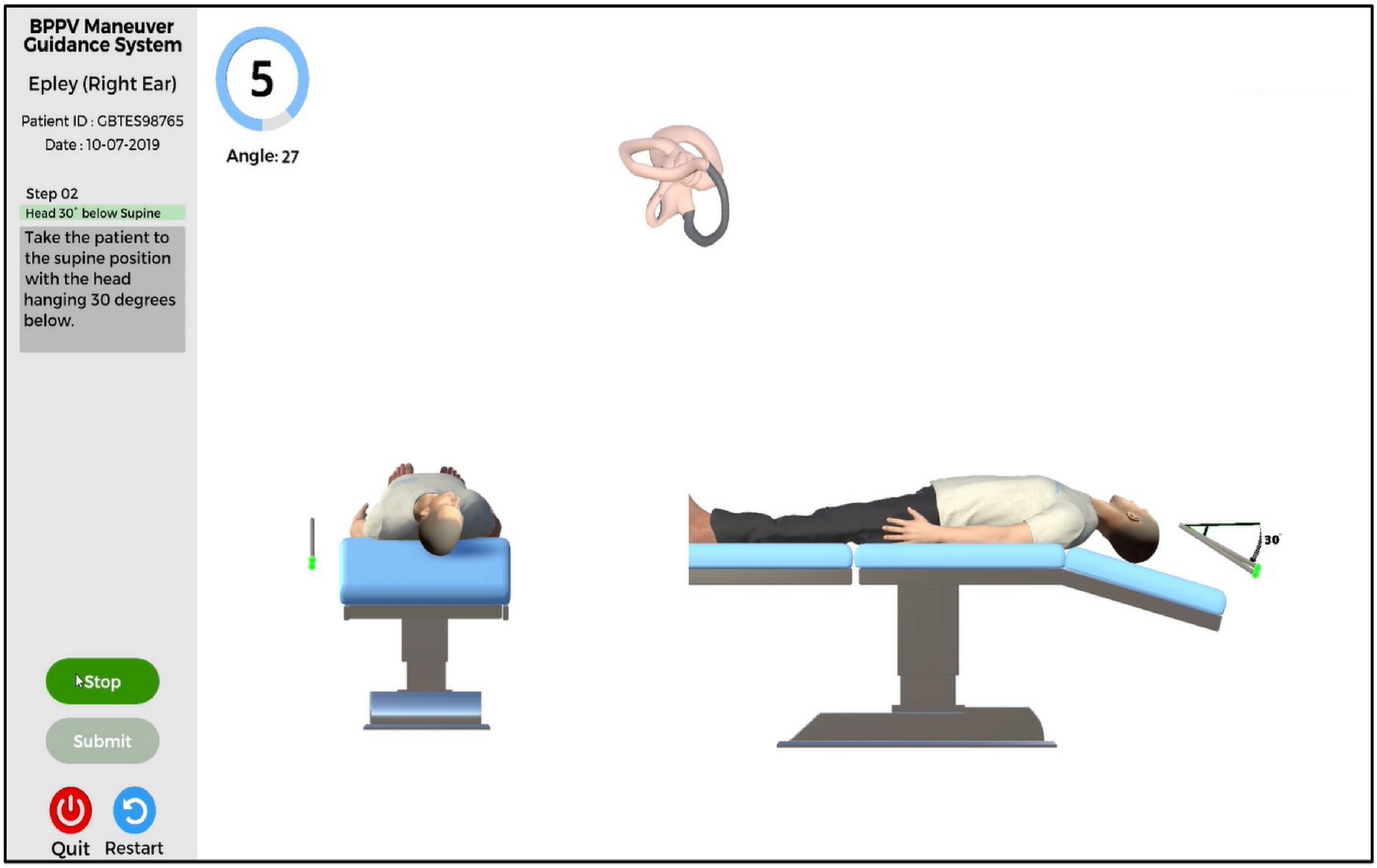


Figure 3. Screen display of the second step of the Epley maneuver to hyperextend the neck by 30º.

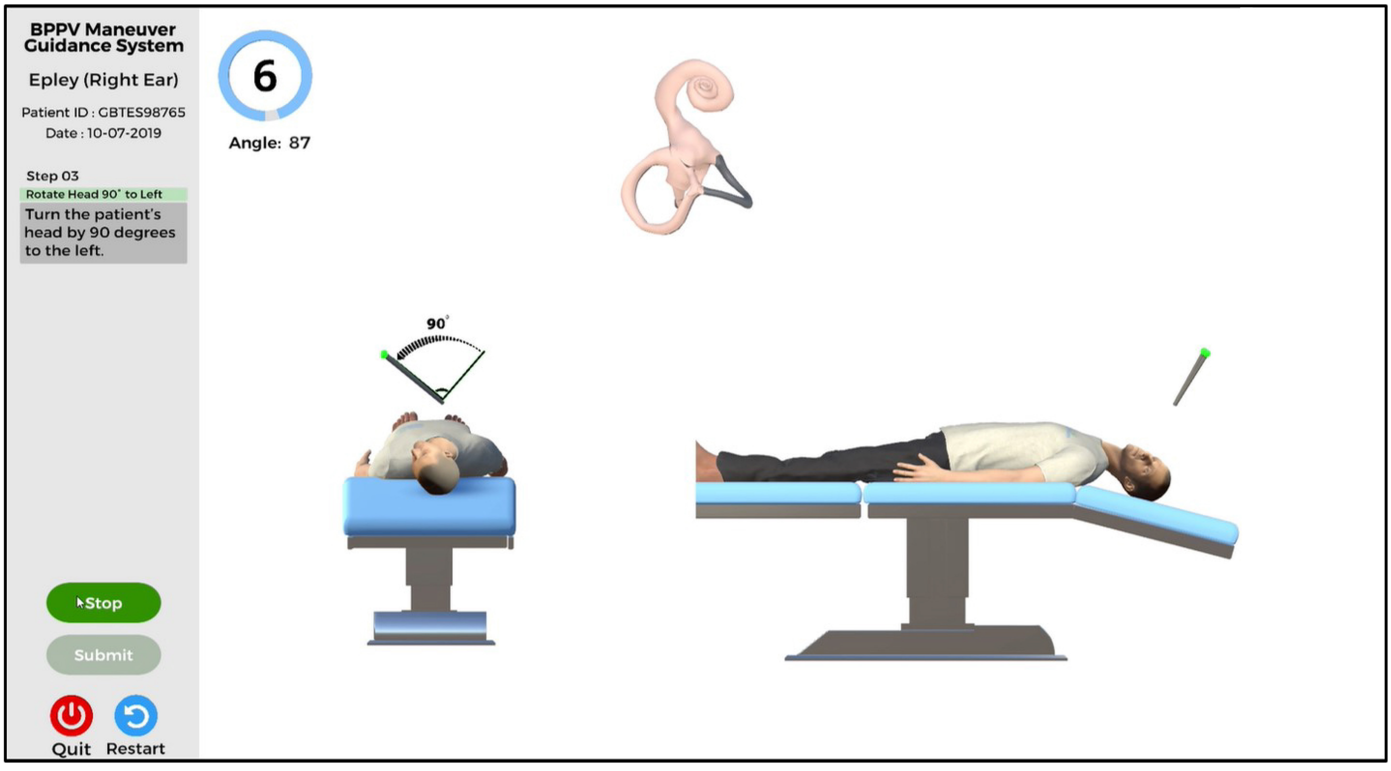


Figure 4. Screen display of the third step of the Epley maneuver.

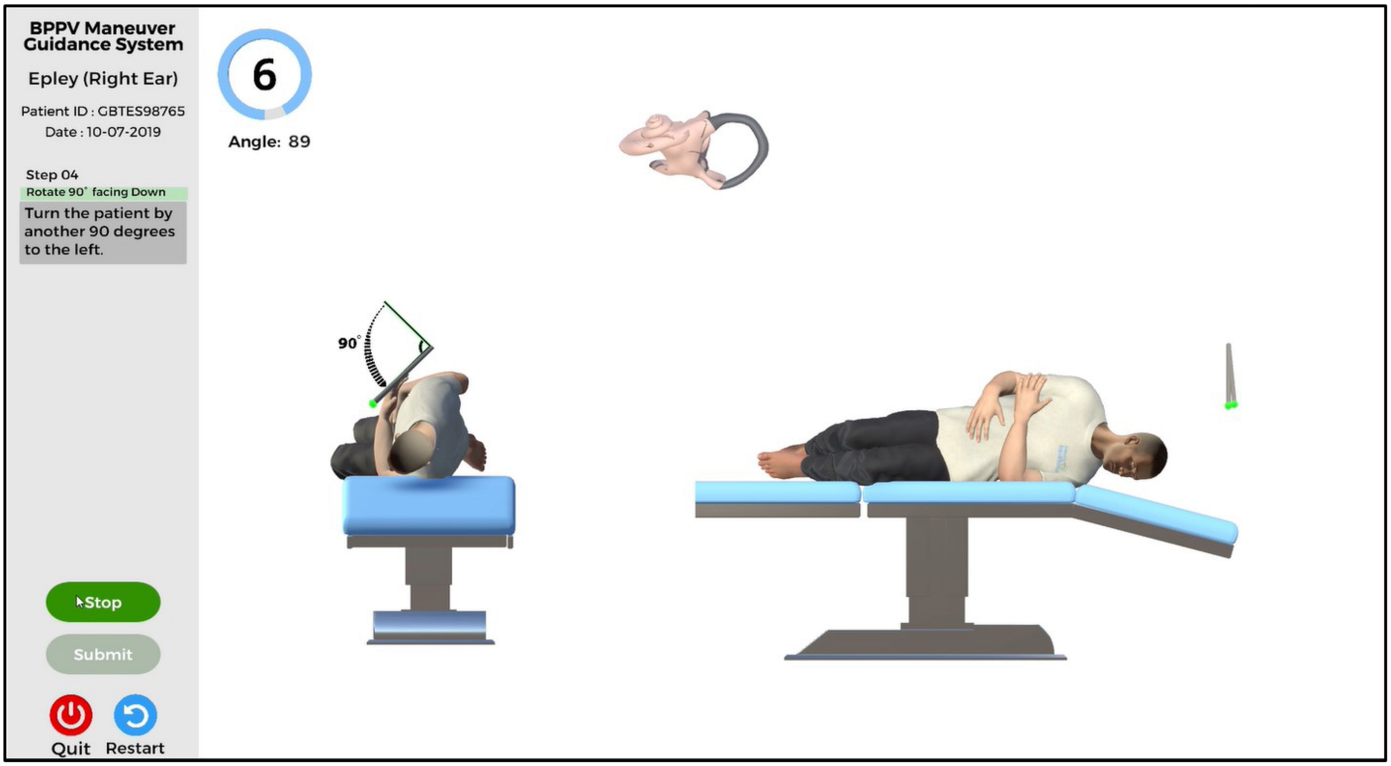


Figure 5. Head is turned by another 90°.

Step 1: Head is turned 45° to the right.
Step 2: Subject taken to lying down position with head 30° below horizontal and head turned 45° to the right.
Step 3: Head turned 90° to the left with the head 30° below horizontal.
Step 4: Head turned another 90° to the left.
Step 5: Subject brought back to sitting position with face forward.

Angles of the head were measured in 1 dimension at predetermined angles of 45°, 30°, 90° and a further 90° at steps 1-4. This was to ensure that the study design was simple and user-friendly.

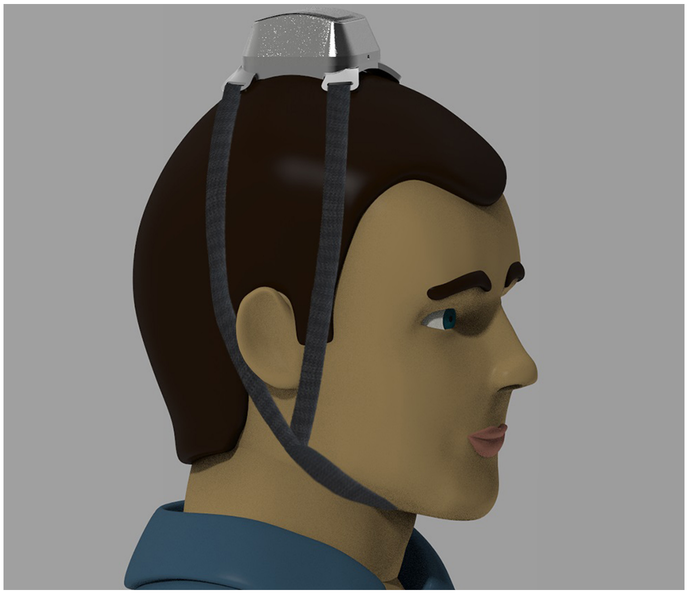


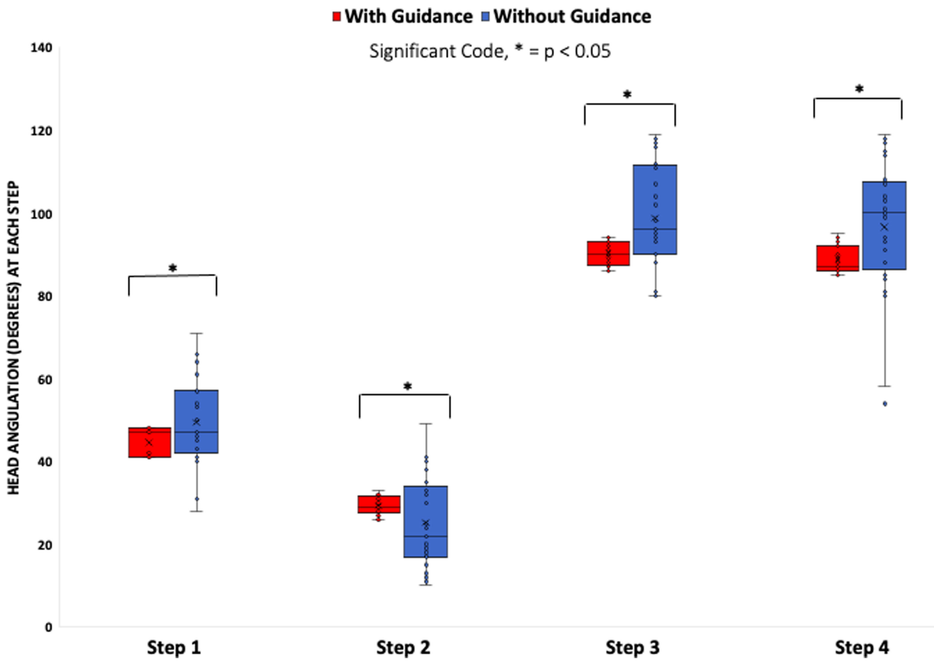
Figure 6. Guidance system placed on subject's head.

Figure 1 shows the information displayed on the screen while performing an Epley maneuver of the right posterior semicircular canal in the starting position with the face forward. On the left side of the screen, each step of the maneuver is displayed, together with the patient details. On the right side of the screen, the top view of the 3D model is seen. This view helps ensure the correct head orientation of the actual executed step. The center of the screen shows the 3 semicircular canals. The movement of these canals is synchronized with the head movement. This enables visualization of the orientation of the affected canal when the head is moved at the desired angle. Additionally, a timer at the center of the screen shows the time that the head should be held in that position. The examiner can use a button on the screen to restart or quit the maneuver.

Figure 2 shows the instructions to turn the head by 45°. The yellow light shows the present head position and the blue light indicates the target head position. The light becomes green when the subject reaches the desired head position.

In the next step, the subject is brought to the head hanging position with the head taken 30° below the horizontal (Figure 3). Once the subject's head matches the position of the 3D model, the next step is displayed.

The next step is to turn the head by 90° to the left (Figure 4). This step brings the posterior canal into the vertical plane allowing the debris to be repositioned further ahead in the canal under the effect of gravity. In the next step, the subject is turned another 90° (Figure 5) and finally returned to the sitting position. As the recording has been done on healthy volunteers, the time between each step has been reduced to 5 seconds.



Graph 1. Head orientation for each step of the Epley maneuver. Each set represents each step (steps 1, 2, 3, and 4) consecutively, without (blue boxes) and with (red boxes) using visual feedback of the guidance system (n = 25 examiners) and the dotted line beside representing the desired angulation at each step. The asterisk at steps 2, 3, and 4 shows the different angulations obtained with and without the guidance system. The boxes represent the interquartile ranges, the top of the box denotes the upper quartile, the line passing through the box denotes the median quartile, and the lower part of the box denotes the lower quartile. The upper and lower whiskers represent the extreme lines (values that vary outside the upper and the lower quartiles). Outliers are represented by blue dots. The asterisk inside the box represents the mean.

Figure 6 shows the guidance system and its placement on the head.

Video 1 demonstrates how the tracking device guides the clinician during each step.

In the present study, the Epley's maneuver was performed on healthy volunteers, and the examiners held the head in that position for about 5 seconds and then went to the next step. The videos in the Supplementary materials show this short interval between steps to make the video more user-friendly. The final head angle at each step was measured.

Statistical Analysis

The head orientations achieved by the examiner at each step of the maneuver (measured by the tracker) were compared to the predetermined head orientations in 2 conditions – without and with visual feedback from the guidance system. The difference in angulations of each step and cumulatively of the procedure were calculated and statistically analyzed. Descriptive statistics were performed with the statistical software Statistical Package for Social Sciences (SPSS) version 21.0 (IBM SPSS Corp.; Armonk, NY, USA) to calculate and compare the 2 means. The data were found to be not normally distributed on the Kolmogorov–Smirnov test. The Friedman and Mann–Whitney *U* tests were used to detect the differences between dependent and independent variables within and between groups pre- and postintervention, respectively. The non-parametric Wilcoxon signed-rank test was used to find the differences among the groups before and after the intervention. Post hoc analysis with Wilcoxon signed-rank test was used to see whether significant differences occurred at 95% CIs ($P \leq .05$).

To find out the actual difference that occurred in each group postintervention, post hoc analysis with Wilcoxon signed-rank test was used. All results were considered significant at $P < .05$.

Ethical Considerations

All the study participants gave written informed consent for the study. No ethical committee approval was required as the study was conducted on healthy individuals, and the burden and risks of performing 2 Epley maneuvers were considered very low.[6,9]

Results

The head orientation achieved at each step of the maneuver was compared to the predetermined head orientation in 2 conditions – without feedback from the guidance system and with feedback from the system. Graph 1 demonstrates that during each step of the Epley maneuver, the head orientation of the volunteers was significantly closer to the predetermined head orientation when using the guidance system as compared to without using the guidance system. Furthermore, head orientation between both conditions significantly differed for each step of the maneuver (step 1: $Z = -2.222$, $P = .026$; step 2: $Z = -2.044$, $P = .041$; step 3: $Z = -2.769$, $P = .006$; step 4: $Z = -2.705$, $P = .007$).

The width of the box plots also illustrates that by using the guidance system, much lower variabilities of head orientation were found for each step of the maneuver. For example, a sixfold decrease in variability was demonstrated: with the guidance system, ±3°-4° degrees of variability was seen at each step. However, without the guidance system, a variability of ±17°-26° was seen at step 1, ±19°-20° at step 2, ±10°-29° at step 3, and ±25°-29° at step 4 was seen.

The class of evidence in this study is class IV.

DISCUSSION

The aim of this study was to investigate the variability in head angulation during canalith repositioning maneuvers (CRMs) to treat BPPV. It was hypothesized that obtained head angulations significantly varied between examiners and that a head-mounted BPPV guidance system to measure head orientation would significantly improve the accuracy of head angulations during CRMs.

This study showed that trained examiners demonstrate a large variability in head orientation (39°-65°) during the Epley maneuver. Furthermore, it was found that using a guidance system, which provides visual feedback of head orientation during BPPV maneuvers, significantly improves the accuracy of head orientation during the Epley maneuver. These are significant findings since previous literature suggests that correct head orientation might improve treatment efficacy.[20,21,25-27] After all, patients with reduced neck mobility (leading to incorrect head orientation) have a higher failure rate of liberatory maneuvers.[25,28]

Clinicians who do not perform CRMs in their routine practice have been shown to be reluctant to perform the repositioning maneuver in BPPV patients.[18] This could be related to previous unpleasant experiences with performing the maneuvers or not being able to remember the steps of the maneuvers.[28,29] The guidance system could help clinicians accurately perform repositioning maneuvers by providing a visual feedback system along with tracking the head position.[22,23] In this way, the use of a guidance system might improve care for patients with BPPV. We also hypothesize that this guidance tool can also help physicians in emergency rooms in properly treating BPPV after a correct diagnosis is made.[22,23]

Additionally, the guidance system could be used as a teaching tool for medical students and practitioners to learn how to perform the maneuver correctly. It could also be used as a tool to guide the paramedical staff at remote locations to carry out the BPPV maneuvers accurately.

Limitations

The BPPV guidance tracker's position on the head, as presented here, is not calibrated relative to the orientation of the semicircular canals in an individual patient. This could, in theory, be done for each individual patient using imaging techniques. But such a procedure is costly, time-consuming, and not very practical in daily practice. Furthermore, the orientation of the semicircular canals varies up to about 20° in humans.[30] Despite this drawback of possible misalignment, the accuracy of maneuvering with the guidance system is well below the natural variance of canal orientation and, therefore, substantially allows a better angulation of the canals in the maneuvers in the general population. The movement of the debris as a function of time is based on a physics model describing the "standardized average" debris movement as a function of the canal orientation relative to gravity.[20,22,26,27] The time taken for the debris to move to the most dependent position at each step of the maneuver depends on various factors like endolymph viscosity, friction, and debris size, which are not taken into account here. However, a waiting period of predetermined time interval at each step of the maneuver would be sufficient to offset these variables.

This study has been performed on healthy volunteers. Further clinical trials should be done to validate the results.

CONCLUSION

This study demonstrated that the use of a guidance system that provides visual feedback on head orientation during BPPV maneuvers significantly improves the accuracy of head orientation during the Epley maneuver. This guidance system could be used as a clinical to improve the treatment efficacy of BPPV maneuvers.

Ethics Committee Approval: N/A.

Informed Consent: Written informed consent was obtained from all participants who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – R.B., A.B.; Design – R.B., A.B.; Supervision – H.K., R.vB.; Funding -N/A; Materials – N/A; Data Collection and/or Processing – R.B., A.B.; Analysis and/or Interpretation – R.B., A.B., H.K., R.vB.; Literature Review – A.B., R.B.; Writing – A.B., R.B.; Critical Review – H.K., R.vB.

Declaration of Interests: Rajneesh Bhandari and Anita Bhandari are Directors at NeuroEquilibrium Diagnostic Systems Private Limited, India. All other authors do not have any competing interests.

Funding: The authors declare that this study had received no financial support.

Video 1: Tracking device that guides the clinician during each step.

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