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Original Paper

Research on the Integrated Repositioning Method for Benign Paroxysmal Positional Vertigo

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Abstract

Objective: *This study aims to investigate an integrated repositioning technique for treating benign paroxysmal positional vertigo (BPPV).*

Methods: *We utilized three-dimensional CT scans of the inner ear to extract the structure of the semicircular canals. Using 3D printing technology, molds were created to simulate the repositioning of otoliths within these canals. These molds were then integrated into a wearable headgear device that allows for real-time simulation and demonstration of the movement trajectories of otoliths during repositioning.*

Results: *Demonstrations with the molds confirmed that repositioning of otoliths could be effectively achieved simultaneously in both canals.*

Conclusion: The repositioning method effectively addresses the simultaneous repositioning of dislodged otoliths in the posterior and horizontal canals on a single side. This method facilitates otolith repositioning in all four semicircular canals, whether performed on the left or right side.

Keywords

Benign paroxysmal positional vertigo, precise demonstration, integrated repositioning, multi-canal repositioning

1. Introduction

Benign Paroxysmal Positional Vertigo (BPPV), also known as "otolith disease," is characterized by transient rotational dizziness precipitated by positional changes of the head that affect the movement or rotation in the inner ear's semicircular canals. This condition frequently includes characteristic nystagmus and autonomic symptoms such as nausea and vomiting[1]. BPPV typically occurs suddenly during movements like getting up, lying down, turning the head, bending over, or looking upward, with each episode generally lasting less than one minute. The classic features of BPPV include: ① recurrent, short-duration episodes; ② onset induced by changes in head position relative to gravity; ③ distinctive eye tremors[2]. The principal treatment strategy is manual repositioning, which involves relocating dislodged "otoliths" from the semicircular canals back into the utricle. While both traditional and novel repositioning methods exist, this article introduces an integrated repositioning method that allows for multiple canals to be repositioned in one or a series of maneuvers, thus obviating the need to identify and reposition different canal types of BPPV separately. This integrated method can roughly be considered a fusion of the traditional Epley and Barbecue repositioning techniques.

2. Subjects and Methods

2.1 Study Subjects

Following the "BPPV Clinical Practice Guidelines"[3] for diagnostic and therapeutic efficacy standards, typical middle-aged, otherwise healthy BPPV patients from the Dizziness Clinic at Huaibei People’s Hospital were selected for this study. The research was conducted in accordance with the Declaration of Helsinki and approved by the hospital’s ethics committee (Ethics Approval No. 2022-97). Informed consent was obtained from all participants.

2.2 Research Methods

Structures of the semicircular canals were delineated from actual human inner ear 3D CT images. Using 3D printing technology, molds that can simulate the repositioning of otoliths within these canals were produced. These canal molds are distinguished by their accurate anatomical replication, transparent canals for visibility, and embedded simulated otoliths (Figure 1). A wearable headgear device designed for assisted repositioning was also employed (Figure 2), enabling real-time simulation and demonstration of the otoliths' movement trajectories during repositioning. This approach was utilized to examine the precision of BPPV repositioning and evaluate the effectiveness of the integrated repositioning method.

Figure 1. Stereographic Mold of a Unilateral Semicircular Canal

Figure 2. Patient in Use Status

Specific steps of the integrated repositioning method are as follows: 1. The patient, facing away from the operator, sits on the repositioning bed with their head turned 45 degrees towards the affected side. 2. With the operator's assistance, the patient quickly lies back, allowing their head to hang (approximately 30 degrees backward) and remains in this position for 60 seconds until the dizziness subsides. 3. Then, the patient rotates their head 90 degrees towards the healthy side and maintains this position for another 60 seconds until the dizziness subsides. 4. The patient's body and head turn a further 90 degrees towards the healthy side, holding this position for 60 seconds until the dizziness subsides. 5. The rotation continues another 45 degrees towards the healthy side to a prone position, maintained for 60 seconds until the dizziness subsides. 6. Finally, under the operator's assistance, the patient rolls onto the healthy side and quickly sits up on the side of the bed, properly aligning their head. The entire repositioning process is accurately guided by the wearable headgear device, finely adjusting the semicircular canals and otolith positions for precise repositioning.

3. Results

The demonstration of the otolith movement trajectories provided a clear visual observation that this repositioning method can simultaneously adjust otoliths in both the horizontal and posterior canals on the affected side. Additionally, the repositioning angles align well with the gravitational influence on the otoliths, theoretically enabling precise, integrated repositioning of both canals. For example, in step 2 of the described repositioning procedure, the otoliths in both the posterior and horizontal canals on the affected side simultaneously reach the lowest point of the semicircular canals (see Figure 3). Step 6 effectively incorporates elements from the Barbecue repositioning method into the Epley method, facilitating the movement of the otoliths from the horizontal canal on the affected side into the utricle, while preventing the otoliths in the posterior canal from returning (see Figure 4). Patients reported a notable reduction in symptoms following repositioning.

Figure 3. Otoliths in both Canals Simultaneously Positioned at the Lowest Point (Indicated by the Yellow Arrows)

Figure 4. Otoliths from both Canals simultaneously Repositioned into the Utricle (Indicated by the Yellow Arrows)

4. Conclusion

Using precision-molded models for real-time dynamic demonstrations allows for the observation of otolith movement trajectories and the detection of positional deviations during the repositioning process. This enables timely and accurate adjustments to the repositioning maneuvers, refining the process and minimizing residual symptoms post-repositioning. The integrated repositioning method validated by these models adheres to the principles of BPPV repositioning and effectively achieves simultaneous repositioning of the otoliths in both the posterior and horizontal canals on the affected side. Recent studies consistently indicate that posterior semicircular canal BPPV is the most common, followed by a higher incidence in the horizontal semicircular canal, with these types accounting for the majority of clinical cases. The incidence of superior semicircular canal BPPV varies among researchers, with some even suggesting that true superior semicircular canal BPPV is virtually non-existent[4]. Therefore, achieving bilateral posterior and horizontal canal BPPV repositioning can essentially resolve all clinical BPPV cases. This method, when performed on either the left or right side, facilitates the repositioning of otoliths in all four semicircular canals. This method, similar in motion amplitude to traditional methods, is suitable for patients with typical BPPV symptoms who have no contraindications such as cerebrovascular or other serious conditions. A single operation on each side typically achieves integrated BPPV repositioning, often without the need to specifically identify the affected semicircular canal, thereby enabling multi-canal otolith repositioning. Although the integrated repositioning method has shown significant effects in a small number of patients, further validation in a larger cohort of clinical BPPV patients is required. Moreover, the presence of endolymph in the semicircular canals implies that the movement speed and vectors of the "otoliths" differ significantly from those in the 3D model, making it challenging to replicate real conditions fully during simulated repositioning. Unscreened repositioning of the affected side may exacerbate otolith displacement, increasing the complexity of repositioning, although no such cases have been observed during simulations. Otolith repositioning also serves a therapeutic role and can broadly be considered a vestibular rehabilitation technique. Changes in body position during repositioning can induce endolymph flow within the semicircular canals, stimulating the cupula and promoting information influx from both vestibular systems to the vestibular center, thereby achieving dynamic balance through self-regulation[5]. Vestibular rehabilitation has also been advocated recently as a treatment for vestibular-related diseases[6]. In summary, for treating patients with benign paroxysmal positional vertigo, the BPPV repositioning method is effective and, due to its simplicity, safety, and ease of learning, is well-suited for widespread adoption in primary healthcare settings.

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