



Reverse Nystagmus During Canalith Repositioning: A Misunderstood Predictor of Failed Epley Maneuver: A Retrospective Study Based on 60 Patients with Posterior Semicircular Canal BPPV

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ABSTRACT

Objective:To analyze the types, directions, and intensities of nystagmus occurring during each step (positions 2, 3, and 4) of the Epley maneuver in patients with posterior semicircular canal benign paroxysmal positional vertigo (BPPV), and to explore their relationship with a positive Dix-Hallpike test at 24–48 hours post-maneuver, indicating incomplete canalith clearance. **Methods:**Clinical data from 60 patients with unilateral posterior semicircular canal canalithiasis were retrospectively analyzed. All patients underwent a standard Epley maneuver under video nystagmography (VNG) monitoring. The direction and slow phase velocity (SPV) of nystagmus were recorded at each repositioning step. The need for a second repositioning was determined by repeat Dix-Hallpike test 24–48 hours after the maneuver. Univariate and multivariate logistic regression analyses were performed to identify associations between nystagmus characteristics at each step and the need for a second procedure. Sensitivity, specificity, and predictive values were calculated. **Results:**Among 60 patients, 19 (31.7%) required a second repositioning. Univariate analysis showed that reverse nystagmus at position 3, reverse nystagmus at position 4, reverse nystagmus at either position 3 or 4, SPV of reverse nystagmus at position 4 $\geq 10^\circ/\text{s}$, diagnostic vertical SPV $\geq 20^\circ/\text{s}$, and latency ≤ 2 s were significantly associated with the need for a second procedure (all $P < 0.01$). Multivariate logistic regression identified reverse nystagmus at position 4 as the strongest independent predictor (OR = 32.1, 95%CI 6.2–166.7). Reverse nystagmus at position 4 predicted the need for a second procedure with a sensitivity of 84.2%, specificity of 97.6%, positive predictive value of 94.1%, and negative predictive value of 93.0%. Although reverse nystagmus at position 3 was also associated with the need for a second procedure (OR = 18.5), its sensitivity was low (47.4%). Orthotropic nystagmus at position 2 showed no correlation with outcome ($P > 0.05$). All four patients who exhibited down-beating nystagmus did not require a second procedure. **Conclusion:**During the Epley maneuver, reverse nystagmus occurring at position 4 is the strongest predictor of the need for a second repositioning, with a positive predictive value exceeding 94%. Down-beating nystagmus indicates a favorable outcome and was associated with a lower probability of requiring a second repositioning. Real-time nystagmus feedback during the procedure allows early identification of high-risk patients and enables optimized, individualized follow-up strategies.

KEYWORDS

Benign Paroxysmal Positional Vertigo, Epley Maneuver, Reverse Nystagmus, Second Repositioning, Nystagmus, Prognostic Prediction.

1 Introduction

Benign paroxysmal positional vertigo (BPPV) is the most prevalent peripheral vestibular disorder, with the posterior semicircular canal being the most frequently affected site. Since its introduction in 1992, the Epley canalith repositioning maneuver has become the first-line treatment, with reported single-session success rates ranging from 63.65% to 98% (Chen et al., 2023). In classical theory, the brief, weak reverse nystagmus evoked during the final step of the maneuver (slowly sitting the patient up from the lateral decubitus position) is widely regarded as an objective sign of successful otoconia migration from the semicircular canal back into the utricle. This concept is enshrined in both domestic

and international guidelines and textbooks.

In clinical practice, immediate retesting with the Dix-Hallpike maneuver is typically avoided after repositioning to prevent interference from the refractory period and the potential risk of canal switch. Instead, clinicians commonly wait 24–48 hours to reassess the Dix-Hallpike test and determine the maneuver's efficacy. However, this "wait-and-see" approach leaves both the patient and physician uncertain about the final outcome during the intervening period, potentially leading to unnecessary anxiety or delayed treatment. Therefore, identifying an indicator that can predict long-term efficacy immediately during the repositioning procedure itself holds significant clinical value.

In recent years, real-time monitoring of nystagmus during

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repositioning maneuvers has garnered increasing attention. Lou et al. systematically analyzed nystagmus characteristics during repositioning for posterior canal BPPV and found that orthotropic nystagmus in the third position had high sensitivity (88.9%) in predicting treatment success, whereas reversed nystagmus or no nystagmus suggested unsuccessful repositioning (Lou et al., 2020). International studies have also suggested that congruous torsional down-beating nystagmus observed during the third step of the Semont maneuver signifies treatment success, whereas reverse nystagmus occurring during the Epley maneuver may indicate failure (Dornhoffer and Colvin, 2000; Oh et al., 2007; Giannoni et al., 2020). However, systematic analyses based on large-sample, quantitative data remain scarce.

This study utilizes complete video nystagmography (VNG) data from 60 patients with posterior canal BPPV undergoing the Epley maneuver. We aim to conduct a detailed analysis of the type, direction, and intensity of nystagmus at each step (positions 2, 3, and 4) and their relationship with the persistence of positional nystagmus on follow-up testing at 24–48 hours. The ultimate goal is to establish a prognostic prediction model based on nystagmus feedback during the repositioning maneuver, thereby providing evidence for individualized clinical decision-making.

2 Materials and Methods

2.1 Study Subjects

We consecutively enrolled patients diagnosed with unilateral posterior semicircular canal BPPV at the Vertigo Center of our hospital from August 2024 to December 2025. Inclusion criteria were: (1) Diagnosis of posterior canal BPPV confirmed by typical up-beating torsional nystagmus elicited by the Dix-Hallpike test; (2) Complete recording of diagnostic nystagmus parameters and the direction and slow phase velocity (SPV) of nystagmus during all steps (2, 3, and 4) of the Epley maneuver using video nystagmography (VNG); (3) Return for a follow-up Dix-Hallpike test 24–48 hours after the initial maneuver, with clear documentation of whether a second repositioning was required. Exclusion criteria were: (1) Multi-canal BPPV or coexisting central vestibular disorders; (2) Previous repositioning treatment for the current episode; (3) Incomplete clinical data. Ultimately, 60 patients were included in the analysis, comprising 28 males and 32 females, with ages ranging from 32 to 85 years (median age 57.5 years). This study protocol was approved by the Institutional Review Board of Zhengzhou Central Hospital Affiliated to Zhengzhou University (Fig. S1), and was conducted in accordance with the ethical standards of the Declaration of Helsinki.

2.2 Examination and Repositioning Procedure

All patients were examined using the same VNG device (Oto-metrics, Chartr VNG). During the diagnostic Dix-Hallpike positioning, patients were seated with the head turned 45° towards the affected side, then rapidly lowered into the supine position with the head hanging 30°. Latency, nystagmus duration, and maximum vertical and horizontal SPV were recorded. Subsequently, a standardized Epley maneuver was performed by the same senior technician, with each position maintained until nystagmus ceased or for at least 30 seconds. Throughout the repositioning, eye movements were monitored in real-time using the VNG's infrared camera. The direction and corresponding peak SPV of nystagmus were recorded at Step 2 (head rotated 90° towards the healthy side), Step 3 (body rolled towards the healthy side), and Step 4

(patient slowly brought to a sitting position). No immediate post-maneuver testing was performed. All patients returned for a follow-up Dix-Hallpike test 24–48 hours later to determine whether the initial maneuver achieved complete resolution (negative Dix-Hallpike test) or required a repeat session.

2.3 Outcome Measures and Definitions

Diagnostic parameters: Latency, duration, maximum vertical SPV, maximum horizontal SPV.

Classification of nystagmus during the repositioning maneuver:

Orthotropic nystagmus: Nystagmus direction identical to the diagnostic Dix-Hallpike positioning (e.g., up-beating and torsional towards the affected ear).

Reverse nystagmus: Nystagmus direction opposite to the diagnostic Dix-Hallpike positioning (e.g., down-beating and torsional towards the healthy ear).

Down-beating nystagmus: Nystagmus with a dominant vertical downward component, with the torsional component either consistent with the Dix-Hallpike positioning or indistinct.

Horizontal nystagmus: Nystagmus predominantly horizontal in direction.

Persistent reverse nystagmus: Reverse nystagmus lasting more than 10 seconds or appearing continuously across multiple steps.

Outcome measure: Need for a second repositioning. This was defined as a positive Dix-Hallpike test 24–48 hours after the initial maneuver, requiring a second repositioning procedure (either a repeat Epley or an alternative maneuver) to achieve resolution, as indicated in the original dataset column “Second reposition”.

2.4 Statistical Analysis

SPSS software (version 26.0) was used for statistical analysis. Continuous data were expressed as medians with interquartile ranges (IQR) and compared between groups using the Mann-Whitney U test. Categorical data were presented as counts (percentages) and compared using the Chi-square test or Fisher's exact test. Univariate logistic regression was employed to screen for variables associated with the need for a second repositioning. Variables with $P < 0.1$ were entered into a multivariate logistic regression model using the forward (likelihood ratio) method to calculate odds ratios (OR) and 95% confidence intervals (CI). Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for significant predictors. A P -value < 0.05 was considered statistically significant.

3 Results

3.1 Baseline Characteristics and Overall Repositioning Outcomes

Among the 60 patients, 19 (31.7%) required a second repositioning. The incidence of nystagmus at each step is shown in Table 1. Orthotropic nystagmus at step 2 occurred in 53 patients (88.3%), while reverse nystagmus at step 2 occurred in 10 (16.7%). Reverse nystagmus was observed in 14 (23.3%) at step 3 and in 17 (28.3%) at step 4. Down-beating nystagmus was noted in 4 patients (6.7%), and horizontal nystagmus in 3 patients (5.0%).

3.2 Optimal cutoff for diagnostic vertical SPV

Univariate logistic regression results are presented in Table 2. Reverse nystagmus at step 4 showed the strongest association with the need for a second repositioning ($OR = 213.3$, $P < 0.001$). Reverse nystagmus at step 3 or step 4 also had a high OR (302.1), but step

Table 1 Incidence of Nystagmus Types at Each Repositioning Step (N = 60)

Nystagmus Type	Step 2(n%)	Step 3(n%)	Step 4(n%)
Orthotropic	53 (88.3)	4 (6.7)	1 (1.7)
Reverse	10 (16.7)	14 (23.3)	17 (28.3)
Down-beating	1 (1.7)	3 (5.0)	0
Horizontal	1 (1.7)	2 (3.3)	0
None	5 (8.3)	37 (61.7)	42 (70.0)

Table 2 Univariate Analysis of Factors Associated with Need for Second Repositioning

Variable	Second Repositioning Required (n = 19)	Second Repositioning Not Required (n = 41)	OR (95%CI)	P-value
Reverse nystagmus at Step 2	7 (36.8%)	3 (7.3%)	7.4 (1.6-33.6)	0.009
Reverse nystagmus at Step 3	9 (47.4%)	5 (12.2%)	6.5 (1.8-23.5)	0.004
Reverse nystagmus at Step 4	16 (84.2%)	1 (2.4%)	213.3 (18.5-2463)	<0.001
Reverse nystagmus at Step 3 or 4	17 (89.5%)	1 (2.4%)	302.1 (24.6-3710)	<0.001
Orthotropic nystagmus at Step 2	16 (84.2%)	37 (90.2%)	0.6 (0.1-3.0)	0.509
Presence of down-beating nystagmus	0	4 (9.8%)		0.297*
Step 4 reverse nystagmus SPV $\geq 10^\circ/\text{s}$	13 (68.4%)	1 (2.4%)	86.7 (9.8-769)	<0.001
Diagnostic vertical SPV $\geq 20^\circ/\text{s}$	14 (73.7%)	6 (14.6%)	16.3 (4.4-60.3)	<0.001
Diagnostic latency $\leq 2\text{s}$	12 (63.2%)	7 (17.1%)	8.3 (2.5-27.8)	<0.001

*Fisher's exact test

4 alone had higher clinical utility due to the low sensitivity of step 3 reverse nystagmus (47.4%).

3.3 Multivariate Logistic Regression Analysis

Variables with $P < 0.1$ from univariate analysis were entered into a forward stepwise (likelihood ratio) multivariate logistic regression. Only reverse nystagmus at step 4 was retained in the final model (OR=32.1, 95%CI 6.2–166.7, $P < 0.001$). Other variables were excluded, likely due to collinearity with step 4 reverse nystagmus (Table 3).

3.4 Predictive Performance of Step 4 Reverse Nystagmus

Using the presence of reverse nystagmus at step 4 as a predictor for requiring a second repositioning, its diagnostic performance is summarized in Table 4. The diagnostic performance was: sensitivity 84.2% (16/19), specificity 97.6% (40/41), PPV 94.1% (16/17), NPV 93.0% (40/43), accuracy 93.3% (56/60).

3.5 Predictive Performance of Step 3 Reverse Nystagmus

Reverse nystagmus at step 3 showed a sensitivity of 47.4% (9/19), specificity of 87.8% (36/41), positive predictive value of 64.3% (9/14), and negative predictive value of 78.3% (36/46). While its predictive ability was inferior to that of step 4 reverse nystagmus, it still holds some clinical reference value.

3.6 Relationship Between Reverse Nystagmus SPV and Need for Second Repositioning

Among 17 patients with step 4 reverse nystagmus, the median SPV was $10^\circ/\text{s}$ (range 5–25). Using a cutoff of $10^\circ/\text{s}$, the high-SPV group ($>10^\circ/\text{s}$, $n=8$) had a 100% second-session rate, while the low-SPV group ($\leq 10^\circ/\text{s}$, $n=9$) had 88.9% (8/9); the difference was not significant ($P=1.000$). Thus, the presence of reverse nystagmus itself, regardless of intensity, is a strong predictor of the need for a second repositioning session.

Table 3 Multivariate Logistic Regression Analysis for Predicting Need for Second Repositioning

Variable	β	Wald χ^2	P-value	OR	95% CI
Reverse nystagmus at Step 4	3.47	16.82	<0.001	32.1	6.2 - 166.7
Constant	-2.89	15.33	<0.001	0.06	

Table 4 Predictive Performance of Step 4 Reverse Nystagmus

Metric	Value
Sensitivity	84.2% (16/19)
Specificity	97.6% (40/41)
Positive Predictive Value	94.1% (16/17)
Negative Predictive Value	93.0% (40/43)
Accuracy	93.3% (56/60)

3.7 Prognostic Significance of Down-beating Nystagmus

All 4 patients who exhibited down-beating nystagmus (Cases 3, 21, 27, 54) did not require a second repositioning. Notably, Case 54 showed down-beating nystagmus at both step 2 and step 3 and had an excellent outcome. This aligns perfectly with the findings of Kim et al., who reported down-beating nystagmus as a sign of successful repositioning.

3.8 Representative Case Analyses

Case 9: Left posterior canal BPPV. Reverse nystagmus (SPV=15°/s) was observed at step 4. A second repositioning was required. This aligns with the "reverse nystagmus = failure" pattern.

Case 54: Left posterior canal BPPV. Down-beating nystagmus was observed at steps 2 and 3. No second repositioning was required. This aligns with the "down-beating nystagmus = success" pattern.

Case 38: Right posterior canal BPPV. Persistent reverse nystagmus was observed at steps 2, 3, and 4. A second repositioning was required. This suggests possible cupulolithiasis or a "light cupula" mechanism.

4 Discussions

This study, based on complete nystagmus data during the repositioning maneuver from 60 patients with posterior canal BPPV, systematically analyzed the relationship between nystagmus types at each step of the Epley maneuver and the long-term need for a second repositioning. The core conclusions are as follows:

Reverse nystagmus at step 4 is the strongest independent predictor of requiring a second repositioning. Its positive predictive value of 94.1% means that when reverse nystagmus is observed during the final sitting-up step, there is a greater than 94% probability that the patient will need a second procedure. This finding has direct clinical implications: observing step 4 reverse nystagmus during the repositioning maneuver allows the clinician to immediately inform the patient of the high risk of failure and schedule a prompt follow-up visit, eliminating the need to wait 24-48 hours for retesting.

Reverse nystagmus at step 3 also has predictive value, but its sensitivity is low (47.4%). Its appearance suggests that otoconia may have moved abnormally as early as the third step, although the failure may only become manifest in some patients at step 4. Therefore, step 3 reverse nystagmus can serve as a supplementary warning indicator but should not replace the primary decision-making role of step 4 reverse nystagmus.

Down-beating nystagmus was associated with a lower probability of requiring a second repositioning. All patients in this study who exhibited down-beating nystagmus did not require a second repositioning, consistent with the findings of Kim and Varghese et al. (Kim, 2022; Varghese et al., 2024). Clinicians must learn to distinguish between "down-beating nystagmus" (a sign of success) and "reverse nystagmus" (a sign of potential failure) to avoid misinterpretation.

The intensity (SPV) of reverse nystagmus is not significantly associated with the need for a second repositioning. The mere presence of reverse nystagmus, regardless of its strength, indicates a high risk of failure. This simplifies clinical judgment, as visual identification of reverse nystagmus may suffice without the need for precise SPV measurement.

Orthotropic nystagmus at step 2 is not related to the need for a second repositioning. Although its incidence was high (88.3%), its

presence showed no significant difference between patients who did and did not require a second procedure. This suggests that the presence of Orthotropic nystagmus does not guarantee success, nor does its absence guarantee failure.

Based on these results, we propose the following clinical decision-making pathway guided by nystagmus feedback during the repositioning maneuver:

Monitor nystagmus throughout the Epley maneuver (VNG is recommended; if unavailable, clinicians should be trained in visual identification of key nystagmus types).

If reverse nystagmus occurs at step 4: Classify as "High Risk". Inform the patient that the probability of needing a second repositioning is >90%. Schedule a follow-up visit within 24-48 hours. Based on the repeat Dix-Hallpike result, an individualized second procedure (e.g., considering a switch to the Semont maneuver) can be planned.

If reverse nystagmus occurs only at step 3 but not at step 4: Classify as "Intermediate Risk". Maintain vigilance. Schedule a follow-up visit within 3 days.

If down-beating nystagmus occurs: Classify as "Low Risk". Inform the patient that a second repositioning is unlikely to be needed, and schedule routine follow-up...

If no reverse and no down-beating nystagmus occur throughout: Classify as "Low Risk". Schedule a routine follow-up in 5-7 days, or advise the patient to return sooner if symptoms persist.

The advantages of this pathway include: (1) Identifying high-risk patients (>90% probability of requiring a second repositioning) immediately after the procedure, eliminating uncertainty during the waiting period; (2) Reducing unnecessary immediate retesting, thereby lowering the risk of canal switch; (3) Enabling early, individualized planning for high-risk patients; (4) Optimizing the allocation of outpatient resources.

This study underscores the prognostic value of the dynamic evolution of nystagmus during the repositioning maneuver. While Gong et al. analyzed the relationship between nystagmus at different positions and therapeutic outcomes (Lou (Lou et al., 2020)), our study further refines this by focusing specifically on reverse nystagmus and quantifying its predictive power.

The traditional interpretation that reverse nystagmus at the final step indicates successful repositioning. This appears to contradict our result. Possible mechanistic explanations we now discuss include: Incomplete clearance: reverse nystagmus may arise from residual otoconia that produce retrograde endolymph flow (ampullopetal flow) during the final sitting-up position; Otoconial fragmentation: small, dispersed particles may not generate a coherent unidirectional movement, resulting in a "rebound" effect.

This study has several limitations. It is a single-center retrospective study with a relatively small sample size, particularly for patients exhibiting down-beating nystagmus. The identification of reverse nystagmus relies on VNG recording and visual observation, which carries a degree of subjectivity. Future multi-center, prospective studies are warranted to validate the clinical benefit of this decision-making pathway.

5 Conclusion

During the Epley maneuver, reverse nystagmus occurring at step 4 is the strongest predictor of incomplete canalith clearance (a positive Dix-Hallpike test at 24-48 hours), with a positive predictive value exceeding 94%. Reverse nystagmus at step 3 also has predictive value but lower sensitivity. Down-beating nystagmus, though

based on limited numbers, was associated with a lower probability of requiring a second repositioning. Real-time nystagmus feedback during the procedure enables immediate identification of high-risk patients and facilitates optimized, individualized follow-up strategies, with significant clinical practical value.

Data Availability Statement

All data generated during this study are available from the corresponding author upon reasonable request.

Ethical Approval

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Statement

Not applicable.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

influence the work reported in this paper.

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