

Original Article

Clinical Interpretation of Positional Nystagmus Provoked by both Dix-Hallpike and Supine Head-Roll Tests

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BACKGROUND: Both the Dix-Hallpike test and the supine head-roll test can provoke positional nystagmus in a group of benign paroxysmal positional vertigo patients, including but not limited to those with multiple canal involvement. This study aimed to determine the incidence and interpret the clinical significance of positional nystagmus provoked by both the Dix-Hallpike and the supine head-roll tests.

METHODS: The results of video-nystagmography sessions recorded in the computer database that included both the Dix-Hallpike and the supine head-roll tests were examined.

RESULTS: The records belonging to 2880 video-nystagmography sessions of 2387 patients were examined. Nystagmus was detected in both the Dix-Hallpike and the supine head-roll tests of 131 (5.5%) patients. The video images belonging to 142 session records of 122 patients were accessed and further analyzed. The diagnosis was posterior canal BPPV in 9.0%, and lateral canal BPPV in 62.3%. More than one canal was involved in 3.3%, one rehabilitation maneuver was performed in 75.0%, and recurrence was observed in 7.4% of those patients.

CONCLUSION: In both geotropic and apogeotropic variants of lateral canal BPPV, nystagmus can be observed during the Dix-Hallpike test in addition to the supine head-roll test. In patients with posterior canal benign paroxysmal positional vertigo, nystagmus can also be observed in the head-roll test. To reach a correct and comprehensive diagnosis and apply appropriate treatment in benign paroxysmal positional vertigo, the Dix-Hallpike test and the head-roll test should be completely performed on both sides, and the results of those tests must be interpreted concomitantly.

KEYWORDS: Vertigo, benign paroxysmal positional vertigo, Dix-Hallpike test, supine head-roll test, nystagmus

INTRODUCTION

Benign paroxysmal positional vertigo (BPPV) is the most frequent cause of recurrent vertigo.¹⁻³ Although BPPV is frequently self-limiting, it negatively impacts the quality of life and creates a significant personal and social burden.^{4,5} Most of the clinical features of BPPV, including the diagnostic and therapeutic maneuvers have been known for many years. As a historical landmark, Charles Skinner Hallpike and his co-worker Margaret Ruth Dix provided the first description of the provocative maneuver to elicit BPPV nystagmus and the classical nystagmus pattern observed during the provocative maneuver in 1952.⁶ Studies by Schuknecht, Hall, Epley, Pagnini, McClure, and others provided a better understanding of BPPV in the following decades, including an explanation of lateral semicircular canal BPPV in 1985.⁷⁻¹¹ Today, we have substantial knowledge of the clinical features of BPPV, and clinical practice guidelines have been established that improve the efficiency of management strategies, including diagnostic and therapeutic maneuvers.^{2,3} Nevertheless, the full understanding of the clinical presentation and pathophysiology of this common disorder in all its aspects has not yet been reached.

The Dix-Hallpike test and the supine head-roll test are commonly used to diagnose posterior and lateral semicircular canal BPPV, respectively.^{2,3} The affected canal and pathology are detected according to the characteristics of the nystagmus provoked by the position change. Interpretation of the positional nystagmus, however, can be difficult in some groups of patients. By definition,

the most prominent response for a given semicircular canal is provoked by an angular acceleration of the head in the plane of that semicircular canal. However, rotation of the head toward any semicircular canal plane evokes stimulation in all 6 semicircular canals to a degree. The semicircular canals in 1 labyrinth are oriented relatively orthogonal to each other, and the angle between the semicircular canals varies among healthy individuals.¹² Moreover, the plane of each semicircular canal deviates from that of its contralateral complementary pair.^{12,13} Thus, a provocative maneuver toward the semicircular canal to be tested can reflect nystagmus responses driven from another canal. Positional nystagmus due to lateral canal BPPV can be provoked on the Dix-Hallpike test, especially if the head is not extended appropriately in the supine head-hanging position. Similarly, positional nystagmus due to posterior canal BPPV can be provoked on the supine head-roll test, especially if the patient is rapidly brought supine from the upright position. In other words, vertigo and nystagmus can be provoked by both taking the patient to the head-hanging position in the Dix-Hallpike test and turning the head side to side in the supine head-roll test. This clinical finding is subject to misinterpretations, especially if the Dix-Hallpike and the supine head-roll tests are not completely performed on each side, and their results are not assessed as a whole.

The diagnosis and treatment of BPPV might be challenging in some cases, not only including those with rare variants but also in those with more frequently encountered forms, including lateral and even posterior canal BPPV. Both the Dix-Hallpike test and the supine head-roll test can provoke positional nystagmus in a group of patients, including but not limited to those with canalolithiasis of more than one canal.^{2,3,14} The incidence, and significance of this clinical finding, however, are not clear. The aim of this study was to determine the diagnoses and clinical characteristics of patients who underwent testing in a tertiary care referral center and were found to have positional nystagmus on both the Dix-Hallpike and the supine head-roll tests.

METHODS

This study was approved by Başkent University Institutional Review Board (Project No: KA19/38, Approval No: 94603339-604.01.02/4448)

MAIN POINTS

- Both the Dix-Hallpike test and the supine head-roll test provoked nystagmus in 5.5% of 2387 patients reviewed.
- Of those patients that had nystagmus in both the Dix-Hallpike test and the supine head-roll test, the diagnosis was posterior canal benign paroxysmal positional vertigo in 9.0%, and lateral canal BPPV in 62.3%.
- In both geotropic and apogeotropic variants of lateral canal benign paroxysmal positional vertigo, nystagmus can be observed during the Dix-Hallpike test.
- In patients with posterior canal BPPV, nystagmus can also be observed in the supine head-roll test.
- To reach a correct and comprehensive diagnosis and apply appropriate treatment in benign paroxysmal positional vertigo, the Dix-Hallpike test and the head-roll test should be completely performed on both sides, and the results of those tests must be interpreted concomitantly.

and supported by Başkent University Research Fund. Informed consent is not necessary due to retrospective nature of the study.

Patient Data

A retrospective review was made of the clinical and diagnostic information of patients who underwent video-nystagmography in a tertiary care otolaryngology clinic between October 2016 and November 2019.

The video-nystagmography records of patients that included the complete set of the Dix-Hallpike test and the supine head-roll test were retrieved from the computer database. Those records were then printed and examined by a single researcher (EH). In each printout, the nystagmography tracings showed (1) 2 different conditions for the spontaneous nystagmus, that is, with and without visual fixation, (2) 4 different positions of the Dix-Hallpike test, that is, head-hanging and upright positions for the left and right sides, and (3) 3 different positions of the supine head-roll test, that is, head on the right, in the middle and on the left, were evaluated for the presence of nystagmus. Eye movements in the horizontal and vertical planes were evaluated separately, and the direction of the rapid phase of the nystagmus, if present, was noted. The records that revealed nystagmus in both the head-hanging position for the right or left side of the Dix-Hallpike test and the head-right or head-left positions of the supine head-roll test were noted for further evaluation.

The patient files and video images of those records showing nystagmus in both the Dix-Hallpike test and the supine head-roll test were then analyzed by 2 different researchers independently. Data including age, gender, the diagnosis as agreed by both researchers, recurrence(s), and the number of canalith repositioning maneuvers (CRM) required for the treatment on first and subsequent admission(s), if any, were noted. The diagnosis was made according to the diagnostic criteria of the Committee for the Classification of Vestibular Disorders of the Bárány Society for BPPV.² Patients with incomplete or inadequate quality video records due to a short recording duration, artifacts, or blinking were excluded from the study group.

VisualEyes 4 Channel test battery (Micromedical Technologies, Ill, USA) was used to obtain the video-nystagmography recordings, and Spectrum 9 balance software (Micromedical Technologies, Ill, USA) was used to analyze the data. The software was calibrated before the testing of each patient.

All patients with BPPV were treated with CRM(s). Epley's maneuver was used for the posterior canal, and the barbecue maneuver was used for the lateral canal BPPV. In patients with cupulolithiasis, the CRM was applied following mastoid vibration. Patients were reassessed, and follow-up Dix-Hallpike and supine head-roll tests were performed 2-4 days after the initial CRM. For patients with a positive positional test at follow-up visits, the appropriate CRM was repeated at 2-4-day intervals until recovery was observed.

Statistical Analysis

Data obtained in the study were analyzed statistically using SPSS Statistics v.22.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean \pm standard deviation and median (maximum-minimum), values, and categorical variables as number (n) and percentage (%). The Student's *t*-test, and the chi-square

test were used to compare the mean age, and gender between the groups, respectively. A value of $P < .05$ was considered statistically significant.

RESULTS

A total of 7523 patient records in the video-nystagmography computer database were reviewed. The records of 2880 video-nystagmography sessions of 2387 patients were found to include the set of bilaterally performed Dix-Hallpike test and supine head-roll test completely. Of those, 148 (5.1%) session records of 131 (5.5%) patients showed nystagmus on both the Dix-Hallpike test and the supine head-roll test. The video images of 142 sessions of 122 patients were accessed and further analyzed.

The total of 122 patients comprised 80 (65.6%) females and 42 (34.4%) males with a mean age of 58 ± 15 years (median, 61 years; range 13–92 years). The mean age of patients with nystagmus on both the Dix-Hallpike test and the supine head-roll test was higher than those without nystagmus on both tests ($P < .01$). There was no statistically significant difference in respect of gender between the 2 groups of patients ($P > .05$).

The distribution of patients' diagnoses as determined by the review of the video recordings is given in Table 1.

Canalith repositioning maneuvers were applied to 92 patients, as 1 CRM to 75.0% ($n=69$), 2 to 16.3% ($n=15$), 3 to 5.4% ($n=5$), 4 to 2.2% ($n=4$), and 1 patient (1.1%) received 7 CRMs.

The video records of the follow-up tests were also reviewed to assess the effectiveness of the applied CRM(s). A nystagmus-free video record was considered "recovery." Accordingly, the video records confirmed that 38, 5, 2, 2, and 1 patients recovered with 1, 2, 3, 4, and 7 CRM(s), respectively. There were no video recordings of the follow-up tests for 44 patients. Examination of the nystagmography tracings of those patients revealed that 31, 10, and 3 patients received 1, 2, and 3 CRM(s), respectively.

Recurrence was observed in 9 patients (7.4%) during the study period (Table 2).

Table 1. Distribution of the Diagnoses of 122 Patients That Had Nystagmus on Both the Dix-Hallpike and the Supine Head-Roll Tests

Diagnosis	Frequency (%)
Right posterior canal BPPV	8 (6.6)
Left posterior canal BPPV	3 (2.5)
Right lateral canal BPPV (canalolithiasis)	10 (8.2)
Right lateral canal BPPV (cupulolithiasis)	23 (18.9)
Left lateral canal BPPV (canalolithiasis)	29 (23.8)
Left lateral canal BPPV (cupulolithiasis)	14 (11.5)
Anterior canal BPPV	2 (1.6)
Vestibular neuritis	3 (2.5)
Multi-canal involvement BPPV	2 (1.6)
Nonspecific positional nystagmus/undiagnosed	28 (23.0)
Total	122 (100.0)

The data of 4 patients (3.3%) with nystagmus patterns consistent with multiple canal involvement can be seen in Table 3. In 1 (0.8%) of those patients, the initial diagnosis was cupulolithiasis of the left lateral canal. That patient received CRM following mastoid vibration. On the third-day follow-up test, multiple canal involvement (left posterior canal canalolithiasis with left lateral canal cupulolithiasis) was observed.

DISCUSSION

The Dix-Hallpike and the supine head-roll tests are recommended for the evaluation of posterior and lateral semicircular canal BPPV, respectively.^{2,3} In clinical practice, a group of patients exhibits vertigo and nystagmus response on both the head-hanging position of the Dix-Hallpike test and the supine head-roll test. In other words, lateral canal BPPV can be observed on the Dix-Hallpike test, and posterior canal BPPV can be observed on the supine head-roll test. The incidence and clinical implications of this finding, however, have not been documented.

Positional nystagmus results from a canal-specific response to the rotation of the head in a semicircular canal plane.² As a general rule, positional nystagmus in BPPV occurs in the plane of the affected

Table 2. Patients that Showed Recurrence During the Follow-Up Period

Age	Gender	First Diagnosis	Recurrence Time [†]	Recurrence Diagnosis
44	Female	Right lateral canalolithiasis	8 months	Right posterior canalolithiasis
55	Female	Right posterior canalolithiasis	8 months	Right posterior canalolithiasis
49	Male	Right lateral cupulolithiasis	6 months	Right lateral cupulolithiasis
53	Female	Left lateral canalolithiasis	5 months	Right posterior canalolithiasis
71	Female	Nonspecific	3 months	Right posterior canalolithiasis
67	Female	Multi-canal involvement (left posterior canalolithiasis + left lateral canalolithiasis)	22 months	Left posterior canalolithiasis
73	Female	Right lateral cupulolithiasis	12 months 6 months 6 months	Nonspecific Left lateral cupulolithiasis Left posterior canalolithiasis
57	Female	Left lateral canalolithiasis	15 months	Left lateral canalolithiasis
49	Female	Right lateral canalolithiasis	11 months	Right lateral canalolithiasis

[†]Time since the last admission.

Table 3. Patients That Had Positional Nystagmus Consistent with Multiple Canal Involvement

No	Age	Gender	Diagnosis
1 [†]	53	Female	Left posterior canalolithiasis + left lateral cupulolithiasis
2	67	Female	Left posterior canalolithiasis + left lateral canalolithiasis
3	52	Male	Right posterior canalolithiasis + right lateral cupulolithiasis
4	70	Female	Right posterior canalolithiasis + right lateral cupulolithiasis

[†]That patient had multiple canal involvement following the first canalolith repositioning maneuver with a diagnosis of left lateral cupulolithiasis.

canal and the direction expected according to the canal excitation or inhibition.¹⁵ However, interpretation of positional nystagmus can be complex in some cases. Provoking maneuvers are subject to limitations pertinent to the anatomic nature of the semicircular canals. The planes of ipsilateral semicircular canals deviate significantly from being exactly orthogonal.¹² In addition, contralateral synergistic semicircular canals, particularly the horizontal canals, are not precisely co-planar with their contralateral counterparts.¹² Therefore, angular acceleration in any semicircular canal plane will cause some level of stimulation in all canals. Any rotatory movement of the head evokes a response in all 6 semicircular canals in the head, and all semicircular canals are affected during a particular diagnostic positional maneuver. The total response originates mainly from the semicircular canal in the plane where the greatest position change occurs.

The posterior semicircular canal of a given side is evoked during the supine head-roll test when the head is turned to that side. In the neutral position of the supine head-roll test (when the head is in the midline), the plane of the posterior semicircular canal of either side is positioned to be at an angle of approximately 45° to the plane of gravity. When the head is rolled to either side, the planes of the posterior semicircular canals are changed 90° relative to their neutral position. Thus, stimulation of the posterior canal during the supine head-roll test might cause nystagmus. In lateral canal BPPV, the “lying-down nystagmus” can be induced when the patient is brought from the sitting position to the supine position.^{16,17} The lateral canal of a given side is also stimulated in the Dix-Hallpike test when bringing the patient to the head-hanging position on that side. In the head-hanging position of the Dix-Hallpike test on either side, the planes of the lateral semicircular canals are positioned to be at an angle of 45–75° to the plane of gravity, depending on the degree of head-hanging. In other words, a posterior canal-driven response can be provoked in the supine head-roll test, and a lateral canal-driven response can be provoked in the Dix-Hallpike test. Thus, BPPV nystagmus of the lateral or posterior canal on either side can be provoked with both the Dix-Hallpike and the supine head-roll tests.

The presence and direction of the torsional component of positional nystagmus are essential to be able to interpret the results and identify the affected canal correctly. In posterior canal BPPV, the nystagmus is expected to be torsional upward and toward the undermost ear in the head-hanging position of the Dix-Hallpike test. In lateral canal BPPV, whether the pathology is canalolithiasis or cupulolithiasis, the nystagmus is expected to be horizontal, that is, geotropic

or apogeotropic, when the head is turned to one side in the supine head-roll test. However, due to the complexity of the canal-driven responses inherent to the variations in anatomic positions of the canals and depending on the angle of the posterior canal in the test position, the torsional component might be small or covert. In a study of spatial characteristics of benign positional nystagmus determined using scleral search coils in a group of clinically refractory positional nystagmus patients, including those with incorrectly defined canal involvement, there was determined to be a small torsional component in patients with both canalolithiasis and cupulolithiasis of the lateral canal.¹⁸ If the tests are not performed on the other side, it can be hard to differentiate between canalolithiasis of the lateral canal and the posterior canal. Examination of the video records in this study revealed that 9.0% of the patients had posterior, and 62.3% had lateral semicircular canal (51.3% geotropic and 48.7% apogeotropic variants) BPPV. In other words, most cases that were found to have nystagmus in both the Dix-Hallpike and the supine head-roll tests had lateral canal BPPV. One of the possible explanations for that finding might be based again on the anatomy of the semicircular canals. The change in the vectorial magnitude of gravitational force that acts on the lateral semicircular canals during the Dix-Hallpike test might be more significant than that of the posterior semicircular canals during the supine head-roll test. In patients with confirmed posterior canal BPPV, the clinical prevalence and characteristics of nystagmus observed in the supine head-roll test should be assessed to further speculate on this suggestion. Recurrence was observed in 9 (7.4%) of the patients during the follow-up period. The initial diagnosis of most of those patients was lateral canal BPPV, while most of the recurrences were posterior canal BPPV.

Multiple canal involvement is another factor that makes the interpretation of positional nystagmus more complicated. More than one semicircular canal might be affected in BPPV cases.^{14,19–23} Lopez-Escamez et al²⁴ observed multiple positional nystagmus in 20% of 70 patients with BPPV symptoms and positional nystagmus. Multiple canal involvement is frequently seen in the canals on the same side, but bilateral involvement may also occur.^{21,25} In the current study, 4 (3.3%) of the patients with positional nystagmus on the video records of both the Dix-Hallpike test and supine head-roll test were considered to have more than one canal involvement. No bilateral canal involvement was found. Multiple positional nystagmus, however, does not necessarily show multiple canal involvement. Complex nystagmus patterns consistent with multiple canal involvement should be differentiated from those that reflect single canal involvement. Both the Dix-Hallpike and the supine head-roll tests should be performed in each patient to evaluate both vertical and horizontal semicircular canals comprehensively. Characteristics of nystagmus can then be assessed according to the diagnostic criteria defined in the clinical practice guidelines,^{2,3} as was the case in this study.

The factors related to the testing and recording technique also affect the results and should be considered in interpreting the positional nystagmus. Examination of the printed nystagmography tracings in this study revealed nystagmus in 27.9% and 25.5% of the records for the left and the right head-hanging positions of the Dix-Hallpike test, and for 18.9% and 19.9% of the records for the right and left sides of the supine head-roll test, respectively. Examination of the video records of those tracings exposed significant differences in terms of the direction of nystagmus between the nystagmography tracings

and the video records. The direction of the nystagmus was incorrectly reflected in the majority of the nystagmography tracings compared with the video records. In addition, the nystagmography tracings did not reflect torsional eye movements, as expected. In other words, the results of the positional tests should not be interpreted by evaluating the nystagmography tracings or printouts alone. The real-time eye movements or video records should also be assessed.

Management protocols and diagnostic workflow in patients with vestibular complaints show great diversity among clinics and clinicians. The clinician that performs the positional tests and the one that interprets the results might be different. The examiner that performs the tests is responsible for reporting the characteristics of nystagmus response accurately. This is critical, especially if another clinician will interpret the results. A CRM (Epley's maneuver) should not be performed immediately following a positive Dix-Hallpike test on one side if the other side has not been tested. The sequence of the provoking positional tests and timing of the changes in head positions during testing might also affect the results. In most preset protocols used in commercially available video-nystagmography software, the supine head-roll test is performed following the Dix-Hallpike test. If there is not an adequate waiting time of at least the time constant after each positional change, that is, the Dix-Hallpike test upright position and the first and the second steps of the supine head-roll test, the effect of the previous positional stimulation on canals might persist and further complicate the interpretation of the response in the new position.

A precise definition of the affected canal and pathology is also crucial for appropriate treatment of BPPV. Similar head-turning directions are used in both the barbecue maneuver and Epley's maneuver to guide the otoliths to the ventricle. Thus, some patients that are incorrectly identified with posterior canal BPPV of a given side but actually have canalolithiasis of the lateral canal on that side might be treated inadvertently with the Epley's maneuver. Likewise, some patients with posterior canal BPPV might accidentally benefit from the barbecue maneuver. The diagnosis should be reconsidered, especially in those who cannot be treated with a single CRM.

CONCLUSION

In conclusion, geotropic and apogeotropic variants of lateral canal BPPV can be observed on the Dix-Hallpike test, and posterior canal BPPV can be observed on the supine head-roll test. Benign positional nystagmus in more than one provoking test condition does not necessarily indicate multiple canal involvement. The results of this study suggest that both the Dix-Hallpike and the supine head-roll tests should be performed on each side to test the horizontal and vertical semicircular canals completely, and characteristics of positional nystagmus in different test positions should be assessed as a whole to reach a comprehensive and accurate diagnosis in BPPV.

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