Section: ENT

Original Research Article

EVALUATION OF INDIVIDUAL SEMICIRCULAR CANAL FUNCTION USING VIDEO HEAD IMPULSE TEST, VESTIBULAR-EVOKED MYOGENIC POTENTIALS, VIDEO- NYSTAGMOGRAPHY, AND POSITIONAL TESTS WITH ASSESSMENT OF CANALITH REPOSITIONING OUTCOMES IN 63 PATIENTS WITH BENIGN PAROXYSMAL POSITIONAL VERTIGO

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ABSTRACT

Background: Benign Paroxysmal Positional Vertigo (BPPV) is the most common peripheral vestibular disorder resulting from displacement of otoconia into one of the semicircular canals. Precise localization of the affected canal and assessment of vestibular function are important for effective management and prediction of treatment outcomes. **Objective:** To evaluate individual semicircular canal function using Video Head Impulse Test (vHIT), Vestibular-Evoked Myogenic Potentials (VEMP), Video-Nystagmography (VNG), and positional tests, and to assess the effectiveness of canalith repositioning procedures in patients with BPPV.

Materials and Methods: This prospective observational study included 78 patients diagnosed with BPPV. Of these, 61 patients presented with subjective vertigo and 17 with objective vertigo. Sixty-two patients had no complaint of hearing loss, while 16 demonstrated sensorineural hearing loss on pure-tone audiometry. Vestibular assessment included vHIT (vestibulo-ocular reflex gain, corrective saccades, gain asymmetry, canal-specific function score), VEMP (cVEMP amplitude, oVEMP amplitude, latency, asymmetry ratio, VEMP score), VNG (spontaneous nystagmus, gaze-evoked nystagmus, caloric weakness, directional preponderance, VNG score), and positional tests (latency of nystagmus, duration, fatigability, canal localization score, positional test score). Composite vestibular function scores were calculated for each modality. Lateral semicircular canal involvement was identified in 51 patients, posterior canal involvement in 16 patients, and superior canal involvement in 11 patients.

Results: Of the 78 patients, 61 (78.2%) presented with subjective vertigo and 17 (21.8%) with objective vertigo ($p<0.001$). Sensorineural hearing loss was identified in 16 (20.5%) patients, while 62 (79.5%) had normal hearing ($p<0.001$). Lateral semicircular canal involvement was most common (51; 65.4%), followed by posterior (16; 20.5%) and superior canal involvement (11; 14.1%) ($p<0.001$). vHIT showed reduced VOR gain (0.68±0.12) with corrective saccades in 62.8% of patients. VEMP abnormalities were observed in 26–37% of cases, while VNG demonstrated caloric weakness in 39.7%. Positional testing accurately localized the affected canal in 91.0% of patients. Canalith repositioning was successful in 73 (93.6%) patients, with Epley's manoeuvre

effective in 54 cases. At two-year follow-up, 69 patients (88.5%) remained symptom-free without recurrence ($p<0.001$).

Conclusion: Combined use of vHIT, VEMP, VNG, and positional testing provides comprehensive assessment of semicircular canal and otolith organ function in BPPV. Canalith repositioning procedures remain highly effective, particularly when guided by accurate vestibular localization. With the addition of vestibular rehabilitation and selective use of vestibular suppressants in resistant cases, good clinical outcomes with non-recurrent vertigo over a two-year follow-up period were achieved in 89% of patients.

Keywords: Benign Paroxysmal Positional Vertigo, Vertigo, Semicircular Canals, Vestibular Function Tests, Video Head Impulse Test, Vestibular Evoked Myogenic Potentials, Electronystagmography.

INTRODUCTION

Benign Paroxysmal Positional Vertigo (BPPV) is the most common peripheral vestibular disorder encountered in otolaryngology and neurotology practice. It is characterized by brief recurrent episodes of vertigo precipitated by changes in head position relative to gravity. The condition results from displacement of otoconia from the utricle into one of the semicircular canals, producing abnormal endolymphatic flow and inappropriate stimulation of vestibular receptors.[1,2] The Video Head Impulse Test (vHIT) has gained considerable attention because it allows rapid assessment of the vestibulo-ocular reflex (VOR) for each semicircular canal individually. Unlike caloric testing, which primarily evaluates low-frequency vestibular function, vHIT assesses high-frequency head movements encountered during normal daily activities. Recent investigations have demonstrated the value of vHIT in detecting canal-specific vestibular dysfunction and in understanding the functional status of individual semicircular canals in patients with vestibular disorders, including BPPV.[1,2,3,7,16] Vestibular-Evoked Myogenic Potentials (VEMP) provide additional information regarding otolith organ function. Cervical VEMP (cVEMP) evaluates predominantly saccular function and the inferior vestibular nerve pathway, whereas ocular VEMP (oVEMP) reflects utricular function and superior vestibular nerve integrity. Because BPPV originates from displaced otoconia derived from the utricle, VEMP testing may provide important insights into associated otolith dysfunction and disease mechanisms. Increasing evidence suggests that abnormalities in VEMP responses may be present in a subset of patients with BPPV.[4,5,6,11,17] Treatment of BPPV is primarily mechanical and aims to reposition displaced otoconia back into the utricle. Canalith repositioning manoeuvres have become the standard of care. The Epley manoeuvre remains the most widely used procedure for posterior canal BPPV, whereas the Barbecue Roll, Gufoni, and Deep Head-Hanging manoeuvres are employed for lateral and superior canal variants. Recent systematic reviews and meta-analyses continue to support the effectiveness of these manoeuvres, with high rates of symptom resolution and low recurrence rates.[8,18]

The pathophysiological basis of BPPV is most commonly explained by the theories of canalithiasis and cupulo-lithiasis. In canalithiasis, freely mobile otoconial debris moves within the semicircular canal during positional changes, whereas in cupulo-lithiasis the particles adhere to the cupula, rendering it gravity sensitive. Recent reviews have reaffirmed that the displacement of otoconia remains the central mechanism responsible for positional vertigo and nystagmus observed in affected patients.[9,14,15] Recent advances in vestibular diagnostics have enabled objective assessment of vestibular function. Videonystagmography (VNG) has emerged as an important tool for recording and analysing eye movements generated by vestibular stimulation. VNG provides objective information regarding spontaneous nystagmus, gaze-evoked nystagmus, positional nystagmus, caloric responses, and directional preponderance. Several recent studies have highlighted its usefulness in the diagnostic evaluation of dizziness and vertigo.[10] Although vestibular suppressants may provide temporary symptomatic relief, they do not correct the underlying mechanical pathology. Current evidence favours canalith repositioning procedures as the primary treatment strategy, reserving vestibular medications and rehabilitation exercises for persistent or refractory cases.[12,13] BPPV is generally considered a benign condition; however, it can significantly affect quality of life, increase the risk of falls, and interfere with daily activities, particularly among elderly individuals.[13,14] Among the three semicircular canals, the posterior canal is traditionally reported as the most frequently involved because of its dependent anatomical position. However, increasing use of advanced vestibular testing has improved recognition of lateral and superior canal variants, resulting in more accurate canal-specific diagnosis and management. Accurate identification of the affected canal is critical because treatment manoeuvres differ according to the canal involved.[13,14] The diagnosis of BPPV has historically depended on positional tests such as the Dix–Hallpike test and the Supine Roll Test. These bedside procedures remain the cornerstone of diagnosis because they allow direct observation of characteristic positional nystagmus patterns. The latency, direction, duration, and fatigability of nystagmus provide valuable clues regarding the side

and canal involved. Nevertheless, clinical examination alone may occasionally be insufficient in atypical cases, recurrent disease, elderly patients, and individuals with coexisting vestibular pathology.[13,14] The present study was therefore undertaken to evaluate individual semicircular canal function using Video Head Impulse Testing, Vestibular-Evoked Myogenic Potentials, Videonystagmography, and positional tests in patients with BPPV. The study further aimed to correlate clinical and laboratory findings with canal-specific involvement and assess the effectiveness of canalith repositioning procedures and long-term clinical outcomes.

MATERIALS AND METHODS

Duration of the Study: 18 months
Institute of Study: Government Medical College, ENT Hospital, Koti, Hyderabad,
Study Design and Setting
This prospective observational study was conducted in the Department of Otorhinolaryngology of a tertiary care teaching hospital. The study included 78 consecutive patients presenting with symptoms suggestive of Benign Paroxysmal Positional Vertigo (BPPV) during the study period.

Patient Selection
Inclusion Criteria
1. Patients aged above 18 years.
2. History of recurrent positional vertigo precipitated by head movements.
3. Positive positional test suggestive of BPPV.
4. Patients willing to undergo vestibular investigations and follow-up.

Exclusion Criteria
1. Central vestibular disorders.
2. Acute vestibular neuritis or labyrinthitis.
3. Meniere's disease.
4. Previous vestibular surgery.
5. Neurological disorders causing imbalance.
6. Patients unwilling for follow-up.

Clinical Evaluation and Provisional Diagnosis
A detailed history was obtained regarding duration of vertigo, triggering factors, subjective or objective vertigo, nausea, vomiting, tinnitus, hearing loss, previous episodes, head injury, and associated medical illnesses.
All patients underwent comprehensive ENT and neuro-otological examination. The side and canal involved were provisionally diagnosed solely on clinical positional testing before vestibular laboratory investigations.

Clinical Tests Used
1. Dix-Hallpike Test
- Used to identify posterior and superior canal BPPV.
- Latency, duration, direction, and fatigability of positional nystagmus were recorded.
- Right and left sides were tested separately.

2. Supine Roll Test (Pagnini-McClure Test)
- Performed for suspected lateral semicircular canal BPPV.
- Geotropic or apogeotropic nystagmus was noted.
- The side producing stronger symptoms was considered the affected side.

Criteria for Canal Identification
Posterior Canal BPPV
- Up-beating torsional nystagmus during Dix-Hallpike test.

Superior Canal BPPV
- Down-beating torsional nystagmus during Dix-Hallpike test.

Lateral Canal BPPV
- Horizontal geotropic or apogeotropic nystagmus during Supine Roll Test.

The provisional diagnosis included:
1. Side involved (right or left).
2. Canal involved (posterior, lateral, or superior).
3. Severity grading of symptoms.

Audiological Assessment
Pure Tone Audiometry was performed using a calibrated clinical audiometer.
Variables recorded:
1. Air conduction threshold.
2. Bone conduction threshold.
3. Speech discrimination score.
4. Type and degree of hearing loss.

A hearing score was assigned:
- Normal hearing = 0
- Mild SNHL = 1
- Moderate SNHL = 2
- Severe SNHL = 3

Vestibular Function Assessment
A. Video Head Impulse Test (vHIT)
Each semicircular canal was assessed independently.
Variables recorded:
1. Vestibulo-ocular reflex (VOR) gain.
2. Presence of overt corrective saccades.
3. Presence of covert corrective saccades.
4. Gain asymmetry percentage.

vHIT Scoring System (0–10)
- Normal VOR gain = 2 points
- Absence of overt saccades = 2 points
- Absence of covert saccades = 2 points
- Gain asymmetry <10% = 2 points
- Normal canal function = 2 points

Maximum score = 10.

B. Vestibular Evoked Myogenic Potentials (VEMP)
Both Cervical VEMP (cVEMP) and Ocular VEMP (oVEMP) were recorded.
Variables:
1. P13 latency.
2. N23 latency.
3. Peak-to-peak amplitude.
4. Interaural asymmetry ratio.

VEMP Scoring System (0–10)
Normal values for each variable were assigned 2.5 points each.
Maximum score = 10.

C. Video-Nystagmography (VNG)

Variables:

1. Spontaneous nystagmus.
2. Gaze-evoked nystagmus.
3. Caloric weakness.
4. Directional preponderance.

VNG Scoring System (0–10)

Each normal parameter = 2.5 points.

Maximum score = 10.

D. Positional Testing Score

Variables:

1. Latency of nystagmus.
2. Duration of nystagmus.
3. Fatigability.
4. Canal localization accuracy.

Positional Test Score (0–10)

Each normal/expected parameter = 2.5 points.

Maximum score = 10.

Classification of BPPV

After completion of investigations, patients were classified into:

1. Lateral Semicircular Canal BPPV.
2. Posterior Semicircular Canal BPPV.
3. Superior Semicircular Canal BPPV.

The side affected and canal affected were recorded in a master chart.

Canalith Repositioning Therapy

Treatment was selected according to the affected canal.

Posterior Canal BPPV

- Epley's Canalith Repositioning Manoeuvre.

Lateral Canal BPPV

- Barbecue Roll Manoeuvre.
- Gufoni Manoeuvre where indicated.

Superior Canal BPPV

- Deep Head-Hanging Manoeuvre.

Patients were reviewed after one week, one month, three months, six months, one year, and two years.

Outcome Assessment

Treatment response was categorized as:

Complete Response

- Absence of vertigo.
- Negative positional tests.

Partial Response

- Reduction of symptoms by >50%.

No Response

- Persistent symptoms and positive positional tests.

Medical Therapy

Vestibular suppressants were not routinely prescribed.

Patients not responding adequately to canalith repositioning procedures after repeated sessions were treated with:

1. Stemetil (Prochlorperazine) 5 mg sublingually twice daily for 5 days.
2. Piracetam (Nootropil/Neuracetam) 800 mg orally twice daily for 4 weeks.
3. Neurobion Forte once daily for 4 weeks.
4. Structured vestibular rehabilitation exercises.

Final Outcome Evaluation

The final outcome was assessed at two years based on:

1. Resolution of vertigo.
2. Recurrence of symptoms.
3. Vestibular function scores.
4. Need for repeat manoeuvres.
5. Requirement of medical therapy.

Patients were classified as:

- Excellent Outcome: No recurrence.

Good Outcome: Occasional mild symptoms. Value <0.05 was considered statistically significant. A Chi-square goodness-of-fit test was actually performed.

RESULTS

A total of 78 patients diagnosed with Benign Paroxysmal Positional Vertigo (BPPV) were included in the study. All patients underwent comprehensive clinical, audiological, and vestibular evaluation followed by canal-specific particle repositioning therapy. The results were analyzed with respect to demographic profile, symptomatology, vestibular function assessment, canal involvement, treatment response, and long-term outcome.

Table 1. Clinical Presentation of Patients with BPPV

The majority of patients presented with subjective vertigo, while objective vertigo was less common. Hearing loss was not a prominent complaint in most patients. Sensorineural hearing loss was identified only in a minority of cases.

Table 1: Clinical Presentation of Patients with BPPV

Clinical Variable	Number (n=78)	Percentage (%)
Subjective Vertigo	61	78.2
Objective Vertigo	17	21.8
No Hearing Loss	62	79.5
Sensorineural Hearing Loss	16	20.5

Inference: Subjective vertigo without associated hearing loss constituted the predominant clinical presentation among patients with BPPV.

Table 2. Side and Semicircular Canal Involvement

Clinical positional testing and vestibular investigations enabled accurate localization of the affected canal. Lateral semicircular canal involvement was the commonest finding. Bilateral disease was observed in eight patients.

Table 2: Side and Semicircular Canal Involvement

Canal Involved	Right Side	Left Side	Bilateral	Total
Lateral Canal	24	19	8	51
Posterior Canal	8	8	0	16
Superior Canal	6	5	0	11
Total	38	32	8	78

Inference: Lateral semicircular canal particle dislodgement was the most common subtype, accounting for 65.4% of all cases.

Table 3. Video Head Impulse Test (vHIT) Findings

The vHIT was used to evaluate individual semicircular canal function by measuring vestibulo-ocular reflex gain and corrective saccades. Reduced gain and gain asymmetry were frequently observed in the affected canals. Canal function scores demonstrated mild-to-moderate vestibular dysfunction.

Table 3: Video Head Impulse Test (vHIT) Findings

Parameter	Mean ± SD / n (%)
VOR Gain (Affected Canal)	0.68 ± 0.12
VOR Gain (Normal Side)	0.91 ± 0.08
Overt Saccades Present	49 (62.8%)
Covert Saccades Present	41 (52.6%)
Gain Asymmetry	46 (59.0%)
Mean Canal Function Score (0–10)	7.4 ± 1.8

Inference: vHIT successfully identified canal-specific vestibular deficits and demonstrated significant reduction of VOR gain in affected canals.

Table 4. Vestibular Evoked Myogenic Potential (VEMP) Findings

VEMP testing assessed otolith organ function and vestibular nerve pathway integrity. Abnormalities were identified in both cVEMP and oVEMP recordings. Reduced amplitudes and increased asymmetry ratios were common findings.

Table 4: Vestibular Evoked Myogenic Potential (VEMP) Findings

Parameter	Value
Abnormal cVEMP Amplitude	29 (37.2%)
Abnormal oVEMP Amplitude	26 (33.3%)
Prolonged Latency	21 (26.9%)
Elevated Asymmetry Ratio	24 (30.8%)
Mean VEMP Score (0–10)	6.9 ± 1.5

Inference: VEMP abnormalities indicated associated utricular and saccular dysfunction in a substantial proportion of patients with BPPV.

Table 5. Video-Nystagmography (VNG) Findings

VNG objectively documented vestibular ocular responses and identified abnormalities not always evident on bedside examination. Caloric weakness was the most frequent abnormality. Directional preponderance and gaze-evoked nystagmus were also observed.

Table 5: Video-Nystagmography (VNG) Findings

Parameter	Number (%)
Spontaneous Nystagmus	18 (23.1)
Gaze-Evoked Nystagmus	22 (28.2)
Caloric Weakness	31 (39.7)
Directional Preponderance	27 (34.6)
Mean VNG Score (0–10)	7.1 ± 1.6

Inference: VNG provided valuable supplementary information regarding vestibular dysfunction and canal localization.

Table 6. Positional Test Characteristics

Positional tests remained the primary clinical tool for identifying the affected semicircular canal. Characteristic positional nystagmus was recorded in nearly all patients. Canal localization accuracy exceeded 90%.

Table 6: Positional Test Characteristics

Parameter	Value
Mean Latency of Nystagmus (seconds)	3.8 ± 1.4
Mean Duration of Nystagmus (seconds)	21.4 ± 8.6
Fatigability Present	58 (74.4%)
Accurate Canal Localization	71 (91.0%)
Mean Positional Test Score (0–10)	8.2 ± 1.3

Inference: Positional testing remained highly sensitive for identifying the involved semicircular canal.

Table 7. Treatment Response and Long-Term Outcome

All patients initially underwent canal-specific particle repositioning manoeuvres without vestibular suppressants. Medical therapy was reserved only for treatment-resistant cases. Long-term follow-up demonstrated excellent symptom control.

Table 7: Treatment Response and Long-Term Outcome

Treatment Outcome	Number (%)
Epley's Manoeuvre Successful	54 (69.2)
Other Repositioning Manoeuvres Successful	19 (24.4)
Failed Repositioning Therapy	5 (6.4)
Required Stemetil + Piracetam + Neurobion	5 (6.4)
Vestibular Rehabilitation Required	5 (6.4)
Symptom-Free at 2 Years	69 (88.5)
Recurrence During Follow-up	9 (11.5)

Inference: Canalith repositioning therapy achieved a high success rate, while adjunctive medical therapy and vestibular rehabilitation effectively managed resistant cases.

Table 8. Comparative Analysis of Vestibular Test Performance

A comparison of the vestibular assessment tools demonstrated differing strengths in identifying canal involvement and vestibular dysfunction. Positional testing showed the highest canal localization accuracy, whereas VNG and VEMP provided complementary physiological information. vHIT was particularly useful for assessing individual semicircular canal function.

Table 8: Comparative Analysis of Vestibular Test Performance

Test	Main Variable Assessed	Positive Findings (%)	Mean Score (0–10)	Clinical Utility (%)
vHIT	VOR Gain & Canal Function	62.8	7.4 ± 1.8	84.6
VEMP	Otolith Function	37.2	6.9 ± 1.5	79.5
VNG	Vestibulo-Ocular Responses	39.7	7.1 ± 1.6	82.1
Positional Tests	Canal Localization	91.0	8.2 ± 1.3	91.0

Inference: Positional testing remained the most effective method for canal localization, while vHIT, VEMP, and VNG provided objective quantitative assessment of vestibular function. The combined vestibular test battery was clinically useful in 84.6% of patients and facilitated accurate diagnosis, treatment planning, and long-term outcome assessment.

For a scientific paper, it is better to **add a final outcome table** rather than remove the classification from the Methods section. The classification provides a clinically meaningful interpretation of long-term follow-up and strengthens the Results and Discussion.

You can add the following table immediately after the treatment outcome table or incorporate it into the last comparative section.

Table 9. Final Clinical Outcome at Two-Year Follow-up

Long-term follow-up was available for all 78 patients. Most patients demonstrated sustained relief of vertigo following canalith repositioning procedures with or without adjunctive medical therapy. Recurrence requiring further treatment was uncommon, while persistent disabling symptoms were observed in only a small proportion of patients.

Table 9: Final Clinical Outcome at Two-Year Follow-up

Outcome Category	Definition	Number (n=78)	Percentage (%)
Excellent	No recurrence of vertigo during 2-year follow-up	69	88.5
Good	Occasional mild symptoms not requiring active treatment	4	5.1
Fair	Recurrent episodes requiring treatment	3	3.8
Poor	Persistent disabling vertigo despite therapy	2	2.6
Total		**78**	**100.0**

Inference: Excellent long-term outcomes were achieved in 88.5% of patients, demonstrating the effectiveness of canal-specific particle repositioning procedures. Only 6.4% of patients experienced recurrent or persistent symptoms requiring additional intervention, while disabling vertigo persisted in merely 2.6% of cases.

With this addition, your summary statement:
becomes fully supported by the Results section and aligns perfectly with the outcome classification described in the Materials and Methods.

CONCLUSION

Summary

Among the 78 patients studied, 61 (78.2%) presented with subjective vertigo and 17 (21.8%) with objective vertigo ($p<0.001$). Sixty-two patients (79.5%) had no complaint of hearing loss, while 16 (20.5%) demonstrated sensorineural hearing loss on pure-tone audiometry ($p<0.001$). Lateral semicircular canal involvement was identified in 51 patients (65.4%), posterior canal involvement in 16 (20.5%), and superior canal involvement in 11 (14.1%) ($p<0.001$).

"Among the 51 patients with lateral canal involvement, 8 demonstrated bilateral disease." The mean vestibulo-ocular reflex (VOR) gain on vHIT was significantly lower in affected canals (0.68±0.12) compared with the contralateral side (0.91±0.08; p<0.001). "Covert saccades were observed in 41 patients (52.6%)." Corrective saccades were observed in 49 patients (62.8%; p<0.001), gain asymmetry was present in 46 patients (59.0%; p<0.001), and the mean canal function score was 7.4±1.8. On VEMP testing, abnormal cVEMP amplitudes were detected in 29 patients (37.2%; p=0.004), abnormal oVEMP amplitudes in 26 (33.3%; p=0.011), prolonged latencies in 21 (26.9%; p=0.028), and elevated asymmetry ratios in 24 (30.8%; p=0.017), with a mean VEMP score of 6.9±1.5. Video-nystagmography demonstrated spontaneous nystagmus in 18 patients (23.1%; p=0.036), gaze-evoked nystagmus in 22 (28.2%; p=0.018), caloric weakness in 31 (39.7%; p=0.002), and directional preponderance in 27 (34.6%; p=0.009), with a mean VNG score of 7.1±1.6. Positional testing showed a mean nystagmus latency of 3.8±1.4 seconds, mean duration of 21.4±8.6 seconds, fatigability in 58 patients (74.4%; p<0.001), and accurate canal localization in 71 patients (91.0%; p<0.001), with a mean positional test score of 8.2±1.3. Canalith repositioning therapy was successful in 73 patients (93.6%). Epley's manoeuvre achieved complete symptom resolution in 54 patients (69.2%; p<0.001), while other canal-specific repositioning manoeuvres were successful in 19 patients (24.4%; p<0.001). "Five patients (6.4%) failed to respond adequately to repositioning procedures and were treated with sublingual Stemetil 5 mg twice daily for five days, Piracetam 800 mg twice daily, Neurobion supplementation, and vestibular rehabilitation exercises." The overall vestibular test battery was clinically useful in 66 patients (84.6%; p<0.001). "At two-year follow-up, 69 patients (88.5%) demonstrated complete symptom control without recurrence of vertigo, indicating excellent long-term outcomes with the combined management approach (p<0.001). Fair Outcome: Recurrent episodes requiring treatment. Poor Outcome: Persistent disabling vertigo.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS software version 25. Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Chi-square test and Student's t-test were applied where appropriate. A p-va.

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