İSTANBUL UNIVERSITY PRESS

The Turkish Journal of Ear Nose and Throat,
Tr-ENT 2026, 36 (2): 43–48

https://doi.org/10.26650/Tr-ENT.2026.1917657

Submitted: 27.03.2026
Revision Requested: 09.04.2026
Last Revision Received: 10.04.2026
Accepted: 10.04.2026

The Turkish Journal of Ear Nose and Throat

Research Article

Open Access

Evaluation of the Relationship between Video Head Impulse Test Findings and Vestibular Nerve Anatomical Measurements in Patients with Benign Paroxysmal Positional Vertigo

Burak Olgun [1], Selçuk Güneş [2], Mustafa Çelik [1], Baver Maşallah Şimşek [3], Ercan Atasoy [4], Kamil Hakan Kaya [4], Can Berk Aşaroğlu [4]

[1] İstanbul Gelişim University, Faculty of Health Science, Department of Audiology, İstanbul, Türkiye
[2] İstanbul Aydın University, Faculty of Health Science, Department of Audiology, İstanbul, Türkiye
[3] Private Clinic, İstanbul, Türkiye
[4] Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Otorhinolaryngology, Head and Neck Surgery, İstanbul, Türkiye

Abstract

Objective: This study aimed to evaluate the relationship between video head impulse test results and vestibular nerve changes in patients with benign paroxysmal positional vertigo (BPPV).

Material and Methods: Thirty-four patients (6 males, 28 females; age range 18-65) presenting with vertigo were included. All patients underwent contrast-enhanced magnetic resonance imaging to exclude cerebellopontine angle tumours. MRI measurements of the cerebellopontine angle, internal acoustic canal, vestibular nerve long and short axes, and cross-sectional area were performed. All participants underwent vHIT testing, and the results were compared between the affected and unaffected sides.

Measurements were obtained in the axial plane aligned with the internal acoustic canal and performed by experienced radiologists.

These findings were interpreted as reduced VOR gain rather than true semicircular canal hypofunction.

Results: Ten patients had lateral semicircular canal involvement. Reduced VOR gain was observed in the affected canals. Twelve patients had anterior semicircular canal involvement, and 12 had posterior canal involvement. The vestibulo-ocular reflex (VOR) gains on the affected sides were lower compared to the unaffected sides (0.54-0.78 for affected canals and 0.84-0.98 for unaffected canals). However, there were no statistically significant differences in MRI measurements of the long axis of the vestibular nerve, short axis, or cross-sectional area between the affected and unaffected sides (p-values 0.836, 0.626, and 0.521, respectively).

Conclusions: vHIT proved to be an effective and reliable method for detecting the affected semicircular canal in BPPV. Despite changes in VOR gains, there were no significant differences in the MRI measurements of the vestibular nerve between the affected and unaffected sides.

Keywords Video head impulse test · Vestibulo-ocular reflex · Vestibular function · BPPV · Vertigo

Citation: Olgun B, Güneş S, Çelik M, Şimşek BM, Atasoy E, Kaya KH, et al. Evaluation of the relationship between video head impulse test findings and vestibular nerve anatomical measurements in patients with benign paroxysmal positional vertigo. The Turkish Journal of Ear Nose and Throat 2026;36(2):43-48. https://doi.org/10.26650/Tr-ENT.2026.1917657

Corresponding author: Ercan Atasoy ercanatasoy93@gmail.com

INTRODUCTION

Benign paroxysmal positional vertigo (BPPV) is the most common cause of peripheral vertigo and is characterised by brief episodes of vertigo triggered by changes in head position. The underlying mechanism is generally accepted as a mechanical disorder caused by the displacement of otolith particles into semicircular canals. Although BPPV is considered a mechanical pathology, recent evidence suggests that abnormal vHIT findings may also be observed. However, the relationship between these functional findings and vestibular nerve morphology remains unclear. Balance is maintained through the coordinated function of the peripheral and central nervous systems. Labyrinth, eyes, and proprioceptive spatial sensing are accepted as peripheral components of the balance system in providing equilibrium (1, 2). Physiological balance is provided by the motor responses as a result of keeping the visual field constant and the control of the posture in the gravitational field during the movement of the head. Vertigo occurs due to pathology in this physiological system (3).

According to the aetiology, vertigo is divided into peripheral and central. In the aetiology of peripheral vertigo, mainly benign paroxysmal positional vertigo (cupulolithiasis or canalolithiasis), vestibular neuritis, labyrinthitis, superior semicircular duct dehiscence, and broad vestibular aqueduct are considered, whereas in the aetiology of central vertigo, cerebrovascular bleeding, intracranial mass, intracranial pressure increase, and demyelinating diseases such as multiple sclerosis can be considered. Regarding the morbidity and mortality of the diseases involved in the differential diagnosis, each etiologic factor in the diagnostic algorithm creates the necessity to be considered (4-6).

Various methods are used in the investigation of the aetiology of vertigo. Initial studies on the diagnostic tests of vertigo were conducted at the beginning of the 20th century. Technological advances in modern medicine have enabled the development and spread of tests. For the first time, Hoegyes reported that each semicircular canal (SSC) was associated with appropriate eye muscles to adapt the eye movements to the head movements during head movements (7). Vestibulo-ocular reflex (VOR) is an important neuroanatomic reflex arc which keeps the visual field constant during head movements. Data from the stimulation of the SSC together with the head movement reach the vestibular core complex via the vestibular nerve. As a result, eye movements function to stabilise the visual field. Various tests have been developed to evaluate the function of the VOR arc. Although the Head Impulse Test (HIT), developed by Halmagyi and Cuthoys, has significant clinical value, especially in the differentiation of peripheral and central pathologies, its use is limited because it does not allow for quantitative objective assessment (8). Technological improvements have enabled high-speed video recordings to be taken and precise detection of eye positions, resulting in the development of a video head impulse test (vHIT), which enables the quantification of HIT measurements. vHIT is a bedside and easy-to-apply method. In addition, it is an important assessment tool that allows the evaluation of six SSCs and allows the visualisation of the hidden saccades as a result of VOR, which provides the acquisition of numerical data in the evaluation (3).

When the literature is evaluated, there is no study on the adaptation and modification of the vestibular nerves associated with the affected semicircular canal in patients with peripheral vertigo. Because neurons have physiological processes such as hypertrophy and atrophy, it is not known whether there is a physiological change in the nerve stimulated by the affected semicircular canal. In this study, vHIT was performed to determine the affected canal, and with magnetic resonance imaging (MRI), the long axis, short axis, and covered area data of the superior and inferior vestibular nerves were calculated, respectively, for the cases who presented due to peripheral vertigo. The intact ears of the patients were evaluated as the control group. The long axis, short axis and areas of vestibular nerves between the sides were compared.

MATERIAL AND METHODS

Diagnosis of BPPV was established based on positional tests. The Dix–Hallpike manoeuvre was used for posterior and anterior canal BPPV, whereas the supine roll test was used for lateral canal BPPV. Canal-specific diagnosis was determined according to characteristic nystagmus findings, including latency, direction, and fatigability.

This prospective clinical study was conducted between October 2017 and June 2018 at Bakırköy Dr. Sadi Konuk Training and Research Hospital Otorhinolaryngology Clinic. The study was conducted following the principles of the Helsinki Declaration and Good Clinical Practices Guide. The study was approved by Bakırköy Dr Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (Date: 19.06.2017, No: 2017/132). All patients were informed about the study, and informed consent was obtained.

The study included 34 cases (6 males, 28 females; mean age 50.2±14.8 years, age range 18-65 years) who presented to our clinic with complaints of vertigo. Patients with dizziness within the last six months who had not used any medication in the previous month, had no history of otologic surgery or head trauma, had no known systemic disease, and had no evidence of central pathology were included. Cases that did not meet these criteria were excluded from the study.

All cases were evaluated using contrast-enhanced magnetic resonance imaging (MRI) to exclude the cerebellopontine angle tumour. The measurements of the cerebellopontine angle, internal acoustic canal, long axis, short axis, and area of the vestibular nerve measurements were obtained using contrast-enhanced MRI.

Magnetic resonance imaging of the internal auditory canal/cerebellopontine angle was performed using a dedicated high-resolution protocol. For morphometric assessment of the vestibulocochlear nerve, a 3D heavily T2-weighted sequence (such as CISS/FIESTA/DRIVE depending on vendor) was obtained with submillimetric isotropic voxels (slice thickness 0.4–0.8 mm, no interslice gap, small field of view), followed by multiplanar reconstruction. Measurements were performed on oblique sagittal images reconstructed perpendicular to the long axis of the IAC at the mid-IAC level, where the facial, cochlear, and vestibular nerve bundles could be individually identified.

All patients underwent vHIT test, and the results were recorded. vHIT measurements were performed using EyeSeeCam vHIT® (Interacoustics, A/S DK-5610, Assens, Denmark) and evaluated using the OtoAccessTM computer programme.

Vestibular canals (anterior and posterior semicircular canals) were evaluated by pushing the head in vertical canal planes while the patient was looking at the target in the midline. Since the right anterior (RA) and left posterior (LP) semicircular canals (RALP) and the left anterior (LA) and right posterior (RP) semicircular canals (LARP) occur in the same plane, they are tested together. In order to adjust the head thrust axis better according to the plane in which the test canal is located, the practitioner stood behind the volunteer on the right or left side. In the vertical canals, as in the lateral canals, the test was terminated by conducting at least 7-10 head thrust movements for each canal.

The VOR generated in response to the head pushing motion can be measured by the computer to which the vHIT glasses are connected, and the numerical values for the VOR are determined by the computer. After 6 semicircular canals on each side were tested, a report could be output in which the results could be monitored in bulk. In this report, there was a circular gain graph where canal gain can be compared and which showed the head eye movement curves for each canal, a regression curve showing the speed change in head push motion duration, gain values (average regression curve gain for vertical channels with 60 ms gain), and another graph showing the directions of vertical head movements. Video recordings of eye movements that occur during all tests can also be taken. In each vHIT test, the following variables were calculated and recorded:

- Gain asymmetry value for the lateral semicircular canals
- Average regression curve (gain) value for the right anterior semicircular canal
- Average regression curve (gain) value for the left posterior semicircular canal
- Gain asymmetry value for the right anterior and left posterior semicircular canals
- Average regression curve (gain) value for the left anterior semicircular canal
- Average regression curve (gain) value for the right posterior semicircular canal
- Gain asymmetry value for the left anterior and right posterior canals

The results obtained from each vHIT test were printed. In this study, the vestibular nerve long axis and the short axis of the ear affected by the vHIT test and the MR measurements of the area where the nerve covered were compared with the intact ear.

Statistical analysis

Although comparisons were made between the affected and unaffected sides of the same patients, the Mann–Whitney U test was used as a conservative approach due to the small sample size and variability. This limitation has been acknowledged in the Discussion section.

For statistical analysis, NCSS® (Number Cruncher Statistical System 2007 (Kaysville, Utah, USA) programme was used. Descriptive statistical methods (mean, standard deviation, median, frequency, ratio, minimum, maximum) were used to evaluate the study data. The distribution of variables was measured using the Kolmogorov–Smirnov test. Mann–Whitney U test was used to analyse the quantitative independent data. The chi-square test was used in the analysis of qualitative independent data. Significance was evaluated at $p<0.05$.

RESULTS

Ten patients (29.6%) had lateral semicircular canal involvement, 12 patients (35.2%) had anterior semicircular canal, and 12 of the cases (35.2%) had posterior semicircular canal involvement with reduced VOR gain.

The affected canal VOR gains were 0.78 for the right lateral canal, 0.67 for the left lateral canal, 0.54 for the right anterior canal, 0.55 for the left anterior canal, 0.63 for the right posterior canal, and 0.58 for the left posterior canal. Non-affected canal VOR gains were 0.98, 0.88, 0.89, 0.89, 0.93, and 0.84, respectively (Table 1).

Table 1. Vestibulo-ocular reflex gains of each canal

Vestibulo-ocular reflex gains	Right lateral canal	Left lateral canal	Right anterior canal	Left anterior canal	Right posterior canal	Left posterior canal
Affected sides	0.78 (n:1)	0.67 (n:9)	0.54 (n:9)	0.55 (n:8)	0.63 (n:5)	0.58 (n:8)
Unaffected sides	0.98 (n:40)	0.88 (n:32)	0.89 (n:32)	0.89 (n:33)	0.93 (n:36)	0.84 (n:33)

n: Number

There was no statistically significant difference between the affected side and the superior vestibular nerve long axis, short axis, and area values of the intact side (p = 0.836, 0.626, and 0.521, respectively) (Table 2).

Table 2. Comparison of the superior vestibular nerve long axis, short axis and area values between the affected sides and the unaffected sides

	Unaffected sides		Affected sides		p
	Aver±SD	Median	Aver±SD	Median	
SVN long axis (cm)	0.12±0.02	0.12	0.12±0.02	0.12	0.836
SVN short axis (cm)	0.09±0.02	0.09	0.09±0.02	0.09	0.626
SVN area (mm²)	0.95±0.32	0.97	1.01±0.30	1.03	0.521

SVN : Superior vestibular nerve, cm: Centimeter, P<0.05

No statistically significant difference was found between the long axis, short axis, and area values of the affected side and the inferior vestibular nerve of the intact side (p values of 0.601, 0.328, and 0.786, respectively) (Table 3).

Table 3. Comparison of the inferior vestibular nerve long axis, short axis and area values between the affected sides and the unaffected sides

	Unaffected sides		Affected sides		p
	Aver±SD	Median	Aver±SD	Median	
IVN long axis (cm)	0.14±0.12	0.11	0.12±0.03	0.1	0.601
IVN short axis (cm)	0.10±0.16	0.08	0.08±0.02	0.09	0.328
IVN area (mm²)	0.93±0.37	0.95	0.90±0.31	0.90	0.786

IVN : Inferior vestibular nerve, cm: Centimeter, P<0.05

DISCUSSION

One of the most critical considerations in this study is the interpretation of vHIT findings in patients with BPPV. BPPV is classically defined as a mechanical disorder and is not expected to cause true semicircular canal hypofunction.However, functional changes in VOR values were observed in the affected canals. These findings should not be interpreted as permanent or structural canal hypofunction. Instead, they may reflect transient functional changes in the VOR, possible central adaptation mechanisms, or subtle vestibular dysfunction.

In this study, the affected canal was detected by using vHIT in patients with BPPV. The topographic measurements of the vestibular nerves of all patients were performed, and the affected and unaffected canals were compared. Whether compensatory vestibular nerve changes exist on the affected side was investigated. In the literature, there is no study on compensatory vestibular nerve changes in patients with BPPV. This is the first study examining the changes in vestibular nerve anatomic measurements that provide the innervation of the affected canal when the literature is evaluated.

The most commonly used tests in the evaluation of the vestibular system are videonistagmography test batteries (oculomotor, positional, and caloric tests) (9, 10). In addition to these tests, which are frequently used in clinical practice, HIT and vHIT tests have been started to be used in vertigo centres.

Since the tests used in the evaluation of vertigo were mostly subjective and connected to the tester, there has been a need to develop objective tests. Although the caloric test is a widely used clinical trial for peripheral vestibular pathologies, it examines a limited portion of the vestibular system. In the caloric test, only lateral SSCs can be tested at low frequency (0.002-0.004 Hz) (11, 12). In daily life, SSCs are stimulated at higher frequencies in three planes. Therefore, there is a need to develop reliable objective methods that can test the larger part of the peripheral system.

The clinical head impulse test (HIT) evaluates the findings obtained from the eye while the head short-term and rapid push movements are applied. It is based on the observation of open saccades (overt saccades), which occur as a result of a peripheral disorder in the canal stimulated during head thrust (13-15). HIT evaluates VOR with higher sensitivity than caloric (16). There are many studies in the literature comparing clinical caloric test performances with HIT. In a study by Perez and Rama-Lopez referring to the caloric test, the specificity of clinical HIT was 91% and its sensitivity was 45% (12). In a study of 79 unilateral vestibular patients with reduced VOR gain with 32 bilateral vestibular reduced VOR gain, Schubert and his colleagues reported that clinical vHIT detected vestibular reduced VOR gain with 82% specificity, unilateral reduced VOR gain of 71% sensitivity, and bilateral reduced VOR gain with 84% sensitivity (17). In a study by Rohrmeier et al. on patients with 151 vestibular disorders, they used spontaneous nystagmus, head-shaking nystagmus, and clinical HIT testing and reported a specificity of the HIT test as 85% sensitivity (18).

Under normal circumstances, if the head of a person facing a distant target is pushed in one direction, the eyes continue to look at the target. The realisation of this situation is achieved by the movement of the eye at the same speed and in the opposite direction as the head movement. These eye movements are accomplished by activating the VOR formed by the stimulation of the crystals of the semicircular canals. In normal people, the VOR gain should be one because the head speed will be equal to the eye speed. However, if the VOR gain is less than 1; it is observed that the movement of the eye with the head movement is shifted from the target point and in the opposite direction corrective saccades are formed to correct this abnormality. If these corrective actions occur when the head movement is ended, it is called (overt) saccades. Overt saccades are an important clinical finding in patients with unilateral canal paralysis. If these movements occur during the head movement, they are called covert saccades. It is very difficult to observe these corrective actions with the naked eye, and this difficulty is a disadvantage of clinical HIT. This disadvantage is overcome with vHIT, and the VOR gain due to head speed can be shown graphically. VOR can be measured in a short time with high head acceleration (19, 20). In addition, 6 SSCs can be evaluated together with the vHIT method. Weber and colleagues reported that the high level of error of HIT is because the hidden saccades are not visible to the naked eye and can be overlooked (21). Perez and Rama-Lopez compared the results of HIT and vHIT in 179 patients with various vestibular disease diagnoses and reported different results in 32.1% of the tests (12).

The diagnostic value of vHIT has been shown in many studies. Bell and his friends reported that the sensitivity of vHIT was 29% and its specificity was 96% (22). Blödow et al. reported that caloric and vHIT results showed a 55% correlation in the Meniere group and 40% correlated with vestibular migraine in their study in two groups of patients with Meniere and vestibular migraine. (23). Walther and Blödow, in their study of acute vestibular neuritis patients, evaluated the patients' oVEMP, cVEMP, and vHIT tests together and reported that vHIT provides additional information about the region where the vestibular neuritis originates.

In this study, the vHIT test was used to evaluate the vestibular system. Unilateral reduced VOR gain was detected in all patients with vertigo. For the evaluation of vestibular nerves, measurements of the superior and inferior vestibular nerves were performed in the ear MRI. The affected and unaffected sides were compared. No difference was found in the measurements of the nerves between the sides. There is no information in the literature about the differences in vestibular nerve anatomical dimension measurements and BPPV patients. The factors affecting the anatomical measurements of the vestibular nerve are unknown. The factors affecting the anatomical measurements of the vestibular nerve need to be investigated.

Although this study contains important information, it has some limitations. The small number of patients may be accepted as the main limitation. Another limitation is the inclusion of patients with BPPV as a case group. There is a need to investigate the relationship between different etiologic factors and anatomical measurements of the vestibular nerve.

CONCLUSION

The absence of significant differences in vestibular nerve morphology between the affected and unaffected sides supports the concept that BPPV does not lead to structural neural changes. This finding strengthens the hypothesis that BPPV primarily remains a mechanical disorder despite the presence of functional test abnormalities.

Additionally, the relatively small sample size limits the generalizability of the results. Therefore, this study should be considered preliminary and hypothesis-generating.

In this study, vHIT is an effective, reliable, and easy-to-use test for the detection of the affected canal during the investigation of the aetiologygy of the BPPV. The long axis of the vestibular nerve in the BPPV, the short axis, and the area covered by MR measurements; no statistically significant difference between the intact and affected sides. was found. Further studies are needed to investigate the different etiologic factors to be performed using morbidity.e patients.

Ethics Committee Approval	The study was approved by Bakırköy Dr. Sadi Konuk Training and Research Hospital Clinical Research Ethics Committee (Date: 19.06.2017, No: 2017/132).
Informed Consent	All patients were informed about the study, and informed consent was obtained.
Peer Review	Externally peer-reviewed.
Author Contributions	Conception/Design of Study- B.O., S.G., M.Ç., B.M.Ç, K.H.K.; Data Acquisition- B.O., S.G., M.Ç., E.A., K.H.K., C.B.A.; Data Analysis/Interpretation- B.O., S.G., B.M.Ş.; Drafting Manuscript- B.O., S.G., M.Ç., E.A., K.H.K.; Critical Revision of Manuscript- B.O., S.G., M.Ç., E.A., K.H.K., C.B.A.; Final Approval and Accountability- B.O., S.G., M.Ç., B.M.Ş., E.A., K.H.K., C.B.A..
Conflict of Interest	The authors have no conflict of interest to declare.
Financial Disclosure	The authors declared that this study has received no financial support.

Author Details

Burak Olgun
[1] İstanbul Gelişim University, Faculty of Health Science, Department of Audiology, İstanbul, Türkiye
0009-0003-1019-1883

Selçuk Güneş
[2] İstanbul Aydın University, Faculty of Health Science, Department of Audiology, İstanbul, Türkiye
0000-0001-9458-5799

Mustafa Çelik
[1] İstanbul Gelişim University, Faculty of Health Science, Department of Audiology, İstanbul, Türkiye
0000-0003-2610-2622

Baver Maşallah Şimşek
[3] Private Clinic, İstanbul, Türkiye
0000-0002-7782-1603

Ercan Atasoy
[4] Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Otorhinolaryngology, Head and Neck Surgery, İstanbul, Türkiye
0000-0003-2472-9691 ercanatasoy93@gmail.com

Kamil Hakan Kaya
[4] Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Otorhinolaryngology, Head and Neck Surgery, İstanbul, Türkiye
0000-0002-3819-8177

Can Berk Aşaroğlu
[4] Bakırköy Dr. Sadi Konuk Training and Research Hospital, Clinic of Otorhinolaryngology, Head and Neck Surgery, İstanbul, Türkiye
0009-0001-2686-9359

REFERENCES

1 Baloh RW, Honrubia V. Vestibular physiology. In: Cummings CWea, editor. Otolaryngology Head and Neck Surgery. 3rd edition ed. St Louis, A.B.D.: Mosby Years Book; 1998. p. 2584-622.

2 Hızal E. Vestibüler sistemin anatomi ve fizyolojisi. In: Belgin E, editor. Temel Odyoloji. Ankara: Güneş Tıp Kitabevleri; 2015. p. 57-69.

3 Gacek RR. Anatomy of the central vestibular system. In: Jackler RK, Brackmann DE, editors. Neurotology. Philadelphia, USA: Elsevier Mosby; 2005. p. 75-90.

4 Schwarz DWF, Tomlinson RD. Physiology of the vestibular system. In: Jackler RK, Brackmann DE, editors. Neurotology. Philadelphia, USA: Elsevier Mosby; 2005. p. 91-121.

5 Barin K. Clinical neurophysiology of the vestibular system. In: Katz J, editor. Handbook of Clinical Audiology. Philadelphia, USA: Lippincott Williams&Wilkins; 2009. p. 431-67.

6 Fife TD. Overview of anatomy and physiology of the vestibular system. In: Eggers SDZ, Zee DS, editors. Vertigo and imbalance: Clinical neurophysiology of the vestibular system. Handbook of clinical neurophysiology. 9. Amsterdam: Elsevier; 2010. p. 5-17.

7 Guyton AC, Hall JE. Cortical and brain stem control of motor function In: Guyton AC, Hall JE, editors. Textbook of Medical Physiology. Eleventh ed. Philadelphia, USA: Elsevier Saunders; 2006. p. 685-97.

8 Akyıldız AN. Kulak Hastalıkları ve Mikrocerrahisi. 1. Baskı ed. İstanbul: Nobel Tıp Kitabevi; 1998. p. 103-16.

9 Kim JS, Zee DS. Clinical practice. Benign paroxysmal positional vertigo. N Engl J Med 2014;370(12):1138-47.

10 Velenovsky DS. Electronystagmography and Videonystagmography (ENG/ VNG). Ear Hear 2015;36(2):e61.

11 Silva C, Amorim AM, Paiva A. Benign paroxysmal positional vertigo–a review of 101 cases. Acta Otorrinolaringol Esp 2015;66(4):205-9.

12 Perez N, Rama-Lopez J. Head-impulse and caloric tests in patients with dizziness. Otol Neurotol 2003; 24(6): 913-7.

13 Nuti D, Masini M, Mandalà M. Benign paroxysmal positional vertigo and its variants. Handb Clin Neurol 2016;137:241-56.

14 Wiest G. The origins of vestibular science. Ann N Y Acad Sci 2015;1343:1-9.

15 Halmagyi GM, Curthoys IS. A clinical sign of canal paresis. Archives of Neurology 1988;45(7):737-9.

16 Jorns-Häderli M, Straumann D, Palla A. Accuracy of the bedside head impulse test in detecting vestibular reduced VOR gain. J Neurol Neurosurg Psychiatry 2007;78(10):1113-8.

17 Schubert MC, Tusa RJ, Grine LE, Herdman SJ. Optimizing the sensitivity of the head thrust test for identifying vestibular reduced VOR gain. Physical Therapy 2004;84(2): 151-8.

18 Rohrmeier C, Richter O, Schneider M, Wirsching K, Fiedler I, Haubner F, Kühnel TS. Triple test as predictive screen for unilateral weakness on caloric testing in routine practice. Otol Neurotol 2013;34(2):297-303.

19 MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP. Application of the video head impulse test to detect vertical semicircular canal dysfunction. Otol Neurotol 2013;34(6):974-9

20 MacDougall HG, McGarvie LA, Halmagyi GM, Curthoys IS, Weber KP. The video Head Impulse Test (vHIT) detects vertical semicircular canal dysfunction. PLoS One 2013;8(4):e61488.

21 Weber KP, MacDougall HG, Halmagyi GM, Curthoys IS. Impulsive Testing of Semicircular - Canal Function Using Video - oculography. Ann N Y Acad Sci 2009;1164(1):486-91.

22 Bell SL, Barker F, Heselton H, MacKenzie E, Dewhurst D, Sanderson A. A study of the relationship between the video head impulse test and air calorics. Eur Arch Otorhinolaryngol 2014;272(5):1287-94.

23 Blödow A, Heinze M, Bloching MB, von Brevern M, Radtke A, Lempert T. Caloric stimulation and video-head impulse testing in Ménière's disease and vestibular migraine. Acta Otolaryngol 2014;134(12):1239-44.