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THE USE OF VIDEONYSTAGMOGRAPHY HEAD IMPULSE TEST (VHIT) IN THE DIAGNOSTICS OF SEMICIRCULAR CANAL INJURIES IN PATIENTS WITH VERTIGO

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Abstract

Objectives: The aim of the study was to assess the function of semicircular canal in videonystagmography head impulse test (VHIT) in the patients with vertigo and balance disorders. **Material and Methods:** The study was performed in 135 patients (86 women and 49 men) aged 22–79 years, who were divided into 2 groups: I (study group) – 73 patients with vertigo of peripheral, central or mixed origin, II (control group) – 62 patients without vertigo (healthy individuals). The function of canal was determined on the basis of GAIN and expressed as DG/RH×100% (where DG is deviation of gaze and RH is rotation of head). **Results:** In the study group the semicircular canal injuries were found in 37 (50.69%) patients, including 24 (32.87%) patients with 1 injury and 13 (17.8%) patients with 2 or more injuries in semicircular canal. The injured anterior semicircular canal was reported 13 times; the lateral – 9 times and the posterior – 31 times. **Conclusions:** In the study group, in the VHIT, injuries in semicircular canals were reported in peripheral vertigo, mixed vertigo with non-compensated and compensated function of the labyrinth in 50.68% cases, whereas in the caloric test dysfunction of the labyrinth was found in 58.49% cases.

Key words:
Videonystagmography head impulse test (VHIT), Diagnostics, Semicircular canal, Injuries, Vertigo

INTRODUCTION

The studies carried out by the National Institute of Health (NIH) [1] show that 90 million inhabitants of North America (42% of the population) experience vertigo at least once in their lifetime. Episodes of vertigo increase along with age and in people older than 65 they are observed in 25% of the people under the study. Therefore, researchers join efforts in developing more modern methods, which could assure much higher diagnostic and therapeutic effectiveness. The proper diagnosis of peripheral, central or mixed type vertigo is possible as soon as medical interview and oto-neurological examination have been conducted [2–5].

Despite application of highly specialized diagnostic techniques, such as videonystagmography (VNG) [6–9], vestibular evoked myogenic potential (VEMP) [10] or other recognized methods [11–14], determination of the injury localization in the area of vestibular organ is still impossible. This is of particular importance in fast

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diagnostics performed for the purpose of worker's compensation [15,16].

Introduction of new techniques enhances diagnostic opportunities and enables a clinician to precisely determine localization of a balance disorder. Semicircular canals, due to their specific orientation to one another, operate together in the following pairs: the left and right lateral canal (horizontal); the left anterior canal (vertical) and the right posterior canal; the right anterior canal (vertical) and the left posterior canal. Taking use of the above physiological assumptions, the function of semicircular canals was examined in VHIT.

Videonystagmography head impulse test (VHIT), which enables to examine vestibulo-ocular reflex (VOR) for individual semicircular canals, is the method that serves exactly this purpose.

In our earlier studies [17] application of VHIT in the diagnosis of semicircular canal function in healthy people was assessed. In the test, 98.3% specificity due to the clinical diagnosis was reached.

Caloric test evaluates the labyrinth excitability indirectly, via non-physiological stimulation (warm and cold, air/water) of lateral semicircular canal. In VHIT, individual semicircular canals are stimulated physiologically (movement), thus vestibulo-ocular reflexes are assessed by shifting eye direction to the head movements.

The aim of the present study was to assess the function of semicircular canal in the videonystagmography head impulse test in patients with vertigo and balance disorders diagnosed in the Department of Otolaryngology and Laryngological Oncology, Medical University of Lodz (Poland) in whom vertigo of central, peripheral and mixed origin was identified on the basis of complete videonystagmography.

MATERIAL AND METHODS

The study was performed in 135 patients (86 women, 49 men) aged 22–79 years, who were divided into 2 groups:

- I (study group) – 73 patients (54 women, 19 men) aged 22–59 years with vertigo of peripheral (among others, the cases of vestibular neuritis, kinetosis), central (mostly cases of carotid-vertebral ischemic syndrome, brain concussion), or mixed (comprising the cases of vertebral artery hypoplasia, vertebrobasilar insufficiency) origin.
- II (control group) – 62 patients (32 women, 30 men) aged 21–40 years without vertigo in medical interview and no features of balance disorders in VNG (healthy individuals).

The criteria for inclusion into individual groups were: medical history, laryngological and otoneurological examinations including: cerebellar and static-dynamic tests.

Additionally, depending on the need, laboratory investigations were performed (blood cell count, glucose level, cholesterol level). Imaging investigations included: vertebrobasilar ultrasonography (USG-D) or angio-CT, X-ray or computed tomography of cervical spine and cerebral CT or MRI.

All the subjects were examined with VNG (including calibration, registration of possible spontaneous nystagmus, positional nystagmus, the alternate binaural bithermal caloric test with cool 30°C and warm 44°C air irrigations).

Computerized systems PC-ENG and VNG Ulmer – Synapsys were applied for automatic analysis of the recordings. The following parameters, i.e., presence of spontaneous nystagmus, values of frequency of induced nystagmus (FRQ), its slow phase angular velocity (SPV) and vestibular excitability (VE), as well as the scores of canal paresis (CP) and directional preponderance of nystagmus (DP) were considered in the analysis.

Values of CP, DP for ENG of ±14%, ±20%, respectively and CP, DP and VE for VNG of < 15%, < 11%, 6–80°/s, respectively were accepted as the normal values, as applied in the case of the data collected in our laboratory and approximate to those given by the producers of the equipment. The normal range of caloric responses is

diagnostically important to define an abnormally low or a hyperactive response as well as pathological CP or DP.

The patients with peripheral vertigo were qualified for the study due to the above inclusion criteria, while VNG was crucial and its results showed changes in caloric labyrinth stimulation. When they were compensated, neither spontaneous nystagmus nor directional preponderance was found, when they were non-compensated, these parameters were observed.

The patients with central vertigo showed features of central balance disorder, mainly in positional nystagmus, but they did not reveal any changes in labyrinth excitability in caloric testing.

In the mixed vertigo patients, injuries were found in VNG, both in the peripheral and central parts of the balance system.

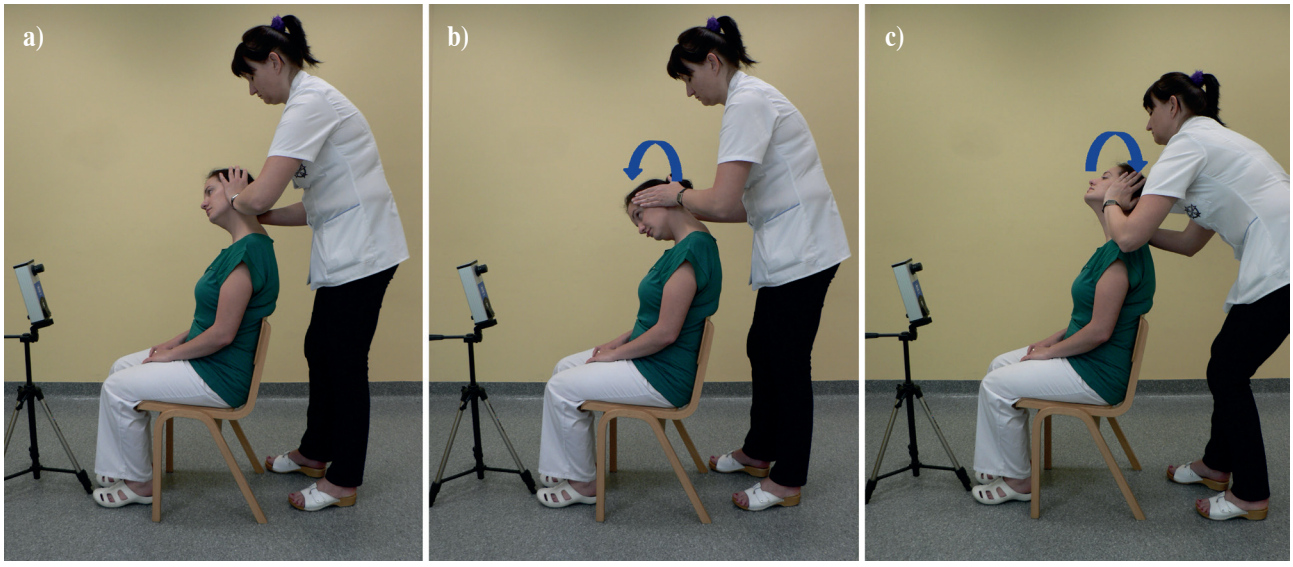
In the study material the following groups were identified: 24 (32.88%) patients with vertigo of central origin, including 20 (27.4%) women and 4 (5.48%) men; 37 (50.68%) patients with vertigo of mixed origin with compensated labyrinth function, including 27 (36.98%) women and 10 (13.7%) men; 9 (12.33%) patients with vertigo of mixed origin with non-compensated labyrinth function, including 5 (6.85%) women and 4 (5.48%) men; 2 (2.74%) women with vertigo of peripheral origin with compensated labyrinth function; and 1 (1.37%) man with vertigo of peripheral origin with non-compensated labyrinth function (Table 1).

The function of semicircular canals was examined in VHIT in the following manner: the patient, in a sitting position with the head leaned forward at a 30° angle, was looking at motionless point while the examiner made rapid movements to the left and to the right (stimulation of the lateral semicircular canal, left or right, recorded by the VHIT-100 Ulmer Synapsys black-and-white videocamera with 1:2.1 35 mm lens; 25°/s frame rate – 25 Hz; x/y 72 dpi resolution; 8-bit greyscale). During examination of vertical semicircular canals the patient's head was leaned laterally towards the right side at a 45° angle, and the examiner made repeated forward and backward movements so that the left anterior canal or right posterior canal was stimulated (Figure 1). When the patient's head was leaned laterally towards the left side at a 45° angle and after repeated forward and backward movements, the right anterior canal or the left posterior canal was stimulated.

Each examination contains several image sequences. The word "images" means the photos of eyeballs that are fixed on a specific point. During the head movement, the patient is asked to keep his/her eyes fixed all the time on a specific point. Meanwhile, a series of photos is taken. The series includes Photo 1 of the initial position and other pictures

Table 1. The study group characteristics by gender, origin of vertigo and labyrinth function

Origin of vertigo	Women		Men		Total	
	n	%	n	%	n	%
Central	20	27.40	4	5.48	24	32.88
Peripheral with non-compensated function of labyrinth	–	–	1	1.37	1	1.37
Peripheral with compensated function of labyrinth	2	2.74	–	–	2	2.74
Mixed with non-compensated function of labyrinth	5	6.85	4	5.48	9	12.33
Mixed with compensated function of labyrinth	27	36.98	10	13.70	37	50.68
Total	54	73.97	19	26.03	73	100.00



a) Head leaned to one side (right) at a 45° angle.
b) Forward movements (the left anterior semicircular canal stimulation).
c) Backward movements (the right posterior semicircular canal stimulation).

Photo 1. Functions of the vertical semicircular canals in the videonystagmography head impulse test (VHIT)

taken in 120 ms intervals. The pupil position is assessed as well as the feature that appears on it, such as infrared lighting from the camera. Automatically, the computer program evaluates the size of the pupil and the position of the feature in 1 and 4 photos, i.e. within 0–120 ms. A computer program allows for a possible individual adjustment by a doctor when an incorrect recording occurs.

Each of these sequences enables a parameter, called represented GAIN, to be calculated in a form of a point on the canalogram. The GAIN represents the deviation of gaze in comparison to the deviation of head between the 1st (t = 0 ms) and the 4th image (t = 120 ms). The calculation formula is as follows:

$$\text{GAIN (in \%)} = 100 \times DG/RH \quad (1)$$

where:

DG – deviation of gaze ("gaze velocity in space"),

RH – rotation of head ("head velocity or impulse canal paresis").

The normal GAIN value ranges from 1% to 40%. The more deviated the gaze, the higher the percentage.

Statistical analysis

In the course of descriptive analysis of qualitative traits, data have been shown in a form of a fraction:

$$f = m/n \quad (2)$$

where:

f – fraction,

m – number of individuals with a particular (analysed) trait,

n – sample size.

Quantitative variables have been described by the measures of location – i.e., mean and median values, along with the measures of dispersion – standard error, standard deviation, 95% confidence interval, coefficient of variation, as well as minimum and maximum values.

The study results were statistically analysed by the use of the following procedures:

- Generalized Linear Models (GLM) with robust standard errors,
- Manna-Whitney-Wilcoxon rank sum test,
- Wilcoxon signed-rank test,

– Pearson's Chi^2 test of independence,
– Fisher's exact test.

The test outcome was assumed statistically significant when p was smaller than 0.05 ($p < 0.05$).

RESULTS

In the study group of the patients, who had reported balance disorders and vertigo, semicircular canals injuries were found in 37 (50.69%) subjects (peripheral with non-compensated function of the labyrinth in 1 case – 1.37%; peripheral with compensated function of the labyrinth in 2 cases – 2.74%; mixed with compensated function of the labyrinth in 25 cases – 34.24%), while normal function of canals was found in 36 (49.31%) subjects (central of vertigo in 24 cases – 32.87%; mixed with compensation function of labyrinth in 12 cases – 16.44%).

Altogether, in 73 patients from the study group I, in VHIT, 53 semicircular canals were found injured (Table 2). The vestibular organ injury in 1 canal was found in 24 (32.87%) patients and in 2 or more canals in 13 (17.8%) patients. The injured anterior semicircular canal was reported in 13 cases; the lateral – in 9 cases and the posterior – in 31 cases.

The average GAIN values in the patients from the study group were as follows: for the anterior semicircular canal: 20.09(±22.21)% on the right side and 23.88(±17.0)% on the left side; for the posterior semicircular canal: 27.53(±26.93)% and 27.86(±20.67)%; for the lateral semicircular canal: 19.45(±18.46)% and 17.5(±16.81)%, respectively (Table 3).

The differences of GAIN mean values for semicircular canals in the patients from the study group obtained in VHIT between the right and left sides and between sex, and between the anterior, lateral and posterior canals were not statistically significant ($p > 0.05$).

The mean GAIN values for the injured semicircular canals in the patients from the study group were 2–4 times higher than the corresponding values in the control group, and ranged from 42% to 82.3%, which is depicted in Table 2.

The average GAIN values in the healthy controls were as follows: for the anterior semicircular canal: 17.56(±12.98)% on the right side and 17.87(±11.47)% on the left side; for the posterior semicircular canal: 19.19(±13.31)% and 15.90(±11.47)%, for the lateral semicircular canal; 12.85(±10.61)% and 10.47(±8.09)%, respectively (Table 3).

The differences of GAIN mean values for semicircular canals in the healthy control individuals obtained in VHIT

Table 2. The GAIN mean values* for the injured semicircular canals obtained in the patients from the study group in the videonystagmography head impulse test (VHIT)

Canal	GAIN (%)				Injured canals examined (N = 53) (n)	
	M		SD			
	women	men	women	men	women	men
Right anterior semicircular canal	82.3	80.6	4.9	11.1	3	3
Right posterior semicircular canal	69.8	76.8	8.7	8.4	13	5
Right lateral semicircular canal	75.0	48.0	6.0	0.0	4	1
Left anterior semicircular canal	65.4	–	6.5	–	7	–
Left posterior semicircular canal	64.8	77.8	5.6	7.6	8	5
Left lateral semicircular canal	58.3	42.0	7.8	0.0	3	1

* Mean value of all 53 injured canals.
M – mean; SD – standard deviation.

Table 3. The GAIN values (in %) for semicircular canals obtained in the patients from the study (N = 73) and control groups (N = 62) in the videonystagmography head impulse test (VHIT)

Canal	Group	Statistical parameter								Statistical significance
		M (%)	Me (%)	SD	SE	95% CI	CV (%)	min. (%)	max (%)	
Right anterior semicircular canal	study	20.09	12.00	22.21	2.58	14.95–24.24	110.51	0	110	ns.
	control	17.56	18.00	12.98	1.65	14.27–20.86	73.90	0	65	
Right posterior semicircular canal	study	27.53	19.50	26.93	3.13	21.29–33.77	97.85	0	110	$p = 0.012$
	control	19.19	18.00	13.31	1.69	15.81–22.57	69.33	0	71	
Right lateral semicircular canal	study	19.45	16.00	18.46	2.15	15.17–23.72	94.93	0	110	$p = 0.006$
	control	12.85	9.00	10.61	1.35	10.16–15.55	82.57	0	38	
Left anterior semicircular canal	study	23.88	17.00	26.35	3.06	17.77–29.98	110.33	0	110	ns.
	control	17.87	17.00	11.47	1.46	14.96–20.78	64.16	0	39	
Left posterior semicircular canal	study	27.86	25.00	20.67	2.40	23.08–32.65	74.17	0	92	$p < 0.001$
	control	15.90	15.50	11.47	1.46	12.99–18.82	72.10	0	39	
Left lateral semicircular canal	study	17.50	13.00	16.81	1.95	13.61–21.39	96.04	0	94	$p < 0.001$
	control	10.47	9.00	8.09	1.03	8.41–12.52	77.26	0	36	

Me – median; SE – standard error; CI – confidence interval; CV – coefficient of variation; min. – minimal value; max – maximal value; ns. – not significant.
Other abbreviations as in Table 2.

between the right and left sides and between sex, and between the anterior, lateral and posterior canals were not statistically significant ($p > 0.05$). A 100% specificity due to the clinical diagnosis was obtained.

The statistical differences of GAIN mean values for semicircular canals in the patients from the study and control groups, which were obtained in VHIT, are illustrated in Table 3.

DISCUSSION

Introduction of VNG with its thorough computerized analysis into the diagnostics of vertigo enabled us to identify absolute directional preponderance (DP) expressed as angular velocity units (°/s) and excitability (reflexivity) assessing the effect of the central nervous system on the labyrinth [7,8].

Moreover, the VNG examination provides a unique opportunity for the simultaneous quantitative and qualitative assessment of both, horizontal and vertical components of nystagmus. The possibility of analyzing vertical component of nystagmus, identified as an exponent for peripheral disorders, is of great significance [8].

In our earlier studies [17], concerning the VHIT application in the assessment of semicircular canal function in healthy people, 58 healthy subjects that were examined showed the GAIN values of individual canals within the normal range and were similar to the values in the control group from this study. High standard deviations provide evidence that strengthening of individual semicircular canals (GAIN) in the examined subjects is significantly diversified.

The obtained mean GAIN values in the control group, both in men and women, were also within normal limits.

The examination performed in 73 patients with vertigo of central, peripheral and mixed origin revealed semicircular canal injuries in 37 (50.69%) patients, of which 24 (32.87%) patients showed the injury in 1 semicircular canal and 13 (17.8%) patients in 2 or more canals. The concurrent injury of the lateral and anterior canals in 5 cases on the right and in 4 cases on the left can be a consequence of a superior vestibular neuritis in the past, which was discussed in the studies by Halmagyi et al. [11] and Aw et al. [15]. In 36 patients (49.31%), in whom caloric testing revealed central (24 patients – 32.87%) or mixed (12 patients – 16.44%) vertigo, in VHIT no injury of the canal was found.

Semicircular canal injuries were found in all the cases of vertigo of peripheral origin with both, non-compensated and compensated labyrinth function, as well as in the cases of vertigo of mixed origin with non-compensated labyrinth function. In addition, in 25 (67.56%) patients the injury applied to vertigo of mixed origin with compensated labyrinth function. The VHIT detected injuries in peripheral cases on the same sides as the diagnosed disorder.

Data from VHIT confirm that lower excitability of one of the labyrinths indicates changes within a semicircular canal, usually posterior canal.

The study results indicate that VHIT allows for defining the localization of canal injury within the area of the vestibular organ and that it can be used in early diagnosis of semicircular canal injuries for the purpose of medical certification, as well as for selective motor rehabilitation of these injuries and monitoring of its effectiveness.

This test can be useful in the diagnostics of out-patients when assessing balance dysfunctions connected with occupation as well as in vertigo treatment by movement (selective habituation exercises on the injured semicircular canal).

CONCLUSIONS

1. In the study group, the VHIT revealed injuries in semicircular canals in peripheral vertigo, mixed vertigo with non-compensated and compensated function of the labyrinth in 50.68% cases, whereas the caloric test indicated the dysfunction of the labyrinth in 58.49% cases.

2. Videonystagmography head impulse test allows for defining a precise localization of the vestibular organ injuries and can be used in the diagnostics of ambulatory patients with vertigo.

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