Relationship Between Head-Only Rotation and Caloric Test Results in Vestibular Disorders

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Abstract: Our purpose was to determine the possible existence of a relationship between abnormal findings from head-only rotation and those from caloric tests applied in patients with peripheral vestibular disorders. We retrospectively studied the head-only rotation and caloric test results of 75 patients experiencing dizziness and peripheral vestibular dysfunction. We assessed the relationship between abnormal test results using the Cramér coefficient. Abnormal findings in the head-only rotation test occurred in 87.5% of patients with vestibular hypoexcitability and in 94.3% of those with hyperexcitability or directional preponderance of postcaloric nystagmus. Statistical analysis of the association between the values found for the parameters of head-only rotation and caloric test results revealed a Cramér coefficient that was less than 0.70. We found no relationship between abnormal findings from head-only rotation and caloric tests applied to individuals with peripheral vestibular disorders.

Key Words: dizziness; electronystagmography; reflex; vestibular function test; vestibuloocular

Dizziness, a frequently found symptom, is defined as a sensation of perturbed body equilibrium in relation to the environment. Body equilibrium depends on (among other mechanisms) adequate vestibuloocular reflexes (VOR) and vestibulospinal reflexes. These reflexes depend in turn on the integrity and coordination of the information that derives from the vestibular, visual, and proprioceptive systems and from the central nervous system.

The main function of the VOR is to control the position of the eyes during head movements so as to maintain a stable visual field. This is achieved if eye movements are as great as and opposite to those of the head. A change in this pattern suggests pathology of the vestibular system. This reflex responds to frequencies ranging from 0.01 to 30 Hz. Caloric and rotatory tests, including head-only rotation, objectively registered by electronystagmography (ENG) are procedures used in the evaluation of the VOR and contribute to the detection of vestibular lesions [1].

Caloric stimulus tests a small range of frequencies of the VOR but permits the separate evaluation of each labyrinth. This outcome allows the classification of vestibular disorders in those with hypoexcitability or hyperexcitability or those with directional preponderance of postcaloric nystagmus [2,3].

Head-only rotation tests permit the evaluation of horizontal and vertical VOR in physiological conditions that are similar to those of daily head movements. The stimulus frequencies used in these tests are as high as 8 Hz [4]. This procedure is highly sensitive to functional abnormalities of the labyrinth [5]. Gain (the relation between eye and head velocity), phase (if eye movement is delayed or early in relation to head movement), and symmetry (a comparison of opposite-direction head-movement gain) are studied for each frequency to

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which a patient is submitted. Like other rotatory tests, head-only rotation does not indicate whether the right or the left vestibular system is affected, nor does it provide information about whether the disorder is centrally or peripherally located. However, it often presents abnormal results, even in those patients with a normal caloric test result [6].

If proving the absence of association between head-only rotation and caloric test results were possible in those with vestibular disorders (hypoexcitability or hyperexcitability), it would suggest that the information these tests render is complementary. The intent of this study was to examine whether an association between these test results exists.

PATIENTS AND METHOD

This research was performed under the supervision of the otoneurology discipline of the Otolaryngology and Head and Neck Surgery Department of the Universidade Federal de São Paulo, Escola Paulista de Medicina. We retrospectively studied 75 head-only rotation test results from patients with a hypothesis of peripheral vestibular disorders, evaluated from 1999 to 2001 in the otolaryngology section of the Fleury Center for Diagnostic Medicine. Ages of the test subjects varied from 8 to 81 years. Thirty-four were male, and 41 were female.

All patients were instructed to refrain from drinking alcoholic beverages, coffee, tea, chocolate, and caffeine-containing soft drinks, smoking, and from ingesting antivertiginous drugs for 24 hours before the tests. They were instructed to have only light meals during those days.

Computed ENG was achieved with the Meta 4-Channel Ultra Computerized ENG, version 7.0 (Micromedical Technologies, Inc., Chatham, IL, USA). The head-only rotation test results were registered using the VORTEQ (Vestibular Ocular Reflex Test Equipment, Micromedical Technologies). Both of these instruments were connected to an IBM Pentium III computer. Masks containing a video camera and an angular velocity sensor were placed on patients' foreheads to permit the recording of eye and head movements.

The following tests were analyzed by the ENG: eye movement calibration; positional nystagmus; spontaneous nystagmus with eyes open and eyes closed; gaze nystagmus; fixed and randomized saccades; pendular eye tracking; optokinetic nystagmus; head-only rotation; and caloric stimulation with air [7].

For the head-only rotation test, patients were instructed to keep the eyes fixed to a source emitting light at a distance of 1 meter while shaking the head to the right and to the left according to the speed of a sound signal of varying frequency produced by the VORTEQ software. The procedure was repeated with movements of the head in the vertical plane. During the test, the angular velocity sensor placed vertically on the forehead registered horizontal head movements at the same time that the ENG captured horizontal eye movements. In the horizontal position, the sensor captured vertical head movements at the same time that the ENG registered vertical eye movements. The software analyzed frequencies from 0.5 Hz to 8 Hz.

Three series of stimulus, called *cycles*, were analyzed in the horizontal plane: 1 Hz, 1–3 Hz, and 1–5 Hz. In the vertical plane, 1 Hz and 1–3 Hz were the frequencies analyzed. Before each test, we calibrated eye movement and carried out training of horizontal and vertical head movements for patients' better comprehension of the procedure.

The computer analyzed the data for all cycles. This permitted the grouping of results within different frequencies. Cycles around 1 Hz (0.5–1.5 Hz) constituted one group and so on. In each group, we calculated the average movement velocity curves of the eyes and head. For each group of frequencies, we made a comparison of parameter values of VOR: gain (absolute values), phase (degrees), and symmetry (percentage). Gain, phase, and symmetry were characterized as normal or altered, according to isolated or associated deviations from normal values [5]. For a complementary study of the results, we analyzed head movements from 2 to 5 Hz without the influence of the eye-tracking system.

We used a model 314 BERGER air cooler and heater (Berger Com. e Ind., São Paulo, Brazil) for the caloric stimulation of the ears. We kept patients in the supine position with the head elevated 30 degrees in relation to the floor, maintaining lateral semicircular canals in the vertical position. We stimulated the ears of all patients at 18°C and 42°C for 80 seconds. In cases with no reaction to the first two caloric stimuli, spontaneous nystagmus with eyes closed or precaloric nystagmus, we also used a stimulus at 10°C. The parameters analyzed in this test were the presence of vertigo and the direction and the slow component velocity of the postcaloric nystagmus with and without visual fixation. The lower limit of normalcy in absolute values for the caloric test was 3 degrees/sec. The upper limit was 28 degrees/sec [8].

We considered hypoexcitability, labyrinthine predominance, areflexia, directional preponderance of nystagmus, and hyperexcitability to be quantitative functional abnormalities. We considered hypoexcitability when vestibular response was lower than 3 degrees/sec in absolute values. An 18% asymmetry between the responses of both labyrinths indicated a labyrinthine predominance. Directional preponderance of the nystagmus was established in the presence of a nystagmus intensity that was greater than 15% in one direction. A slow component velocity greater than 28 degrees/sec indicated hyperexcitability.

The caloric test permitted the classification of patients into the following two groups: those having peripheral vestibular disorders with hypoexcitability and those having peripheral vestibular disorders with hyperexcitability. The first group included patients with hypoexcitability in absolute values, areflexia, and labyrinthine predominance equal to or less than 18%. The second group included those with hyperexcitability in absolute values or directional preponderance of the nystagmus equal to or greater than 15%. The Cramér coefficient was applied for the statistical analysis of a possible association between the results of both tests.

RESULTS

We established a diagnostic hypothesis of a peripheral vestibular disorder with hypoexcitability in 40 patients. A peripheral vestibular disorder with hyperexcitability or directional preponderance of the postcaloric nystagmus was the hypothesis for 35 patients. The abnormalities of the vertical and horizontal VOR, observed in the head-only rotation test, are summarized in Table 1. Figures 1–3 depict gain, phase, and symmetry of the peripheral vestibulopathy cases with hypoexcitability or hyperexcitability.

Statistical analysis rendered Cramér coefficients that were less than 0.70, preventing a possible association between abnormal results in gain, phase, and symmetry of the VOR and abnormal caloric test results in peripheral vestibular disorders.

Table 1. Number and Percentage of Patients with Abnormal Findings

Abnormal Findings	**No. of Cases (%)**
Horizontal VOR	15 (20.0)
Vertical VOR	11 (14.7)
Horizontal and vertical VOR	42 (56.0)
Total	68 (90.7)

VOR = vestibuloocular reflex.
Note: n = 75.

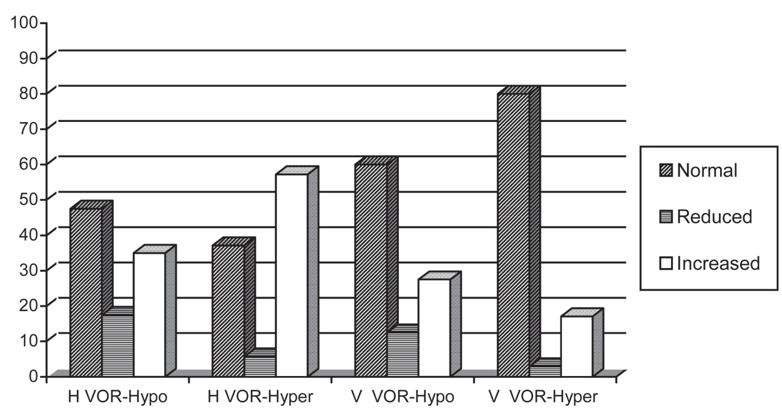

Figure 1. Percentage of gain findings in head-only rotation test vertical and horizontal vestibuloocular reflex (VOR) of 75 patients with peripheral vestibulopathy and hypoexcitability, hyperexcitability, or directional preponderance of the postcaloric nystagmus. (*H VOR-Hypo* = horizontal VOR of peripheral vestibulopathy with hypoexcitability; *H VOR-Hyper* = horizontal VOR of peripheral vestibulopathy with hyperexcitability or directional preponderance of nystagmus; *V VOR-Hypo* = vertical VOR of peripheral vestibulopathy with hypoexcitability; *V VOR-Hyper* = vertical VOR of peripheral vestibulopathy with hyperexcitability or directional preponderance of nystagmus.)

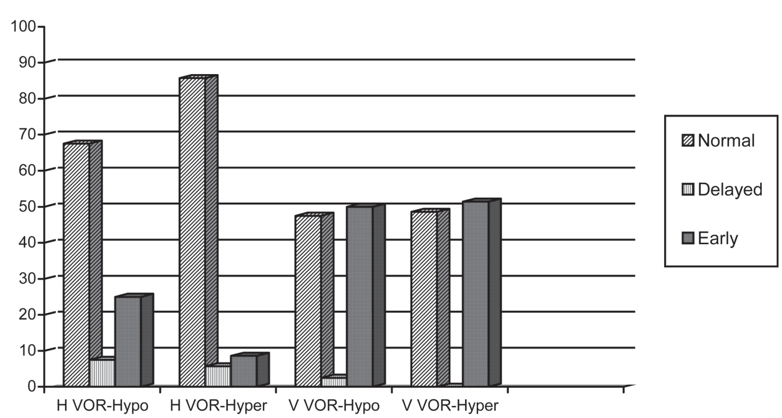

Figure 2. Percentage of phase findings in head-only rotation test vertical and horizontal vestibuloocular reflex (VOR) of 75 patients with peripheral vestibulopathy and hypoexcitability, hyperexcitability, or directional preponderance of the postcaloric nystagmus. (*H VOR-Hypo* = horizontal VOR of peripheral vestibulopathy with hypoexcitability; *H VOR-Hyper* = horizontal VOR of peripheral vestibulopathy with hyperexcitability or directional preponderance of nystagmus; *V VOR-Hypo* = vertical VOR of peripheral vestibulopathy with hypoexcitability; *V VOR-Hyper* = vertical VOR of peripheral vestibulopathy with hyperexcitability or directional preponderance of nystagmus.)

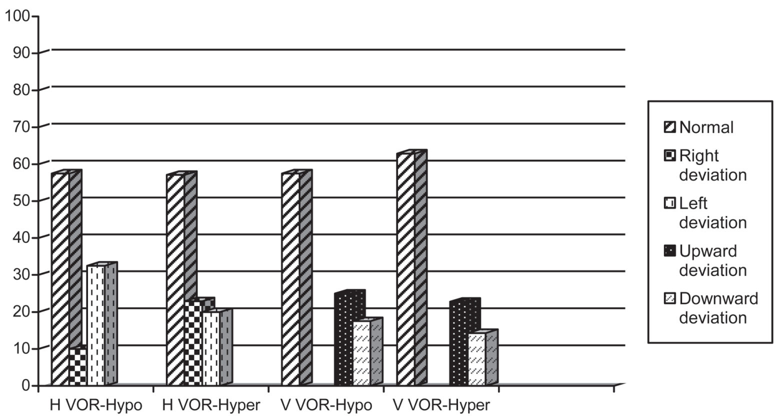

Figure 3. Percentage of symmetry findings in head-only rotation test vertical and horizontal vestibuloocular reflex (VOR) of 75 patients with peripheral vestibulopathy and hypoexcitability, hyperexcitability, or directional preponderance of the postcaloric nystagmus. (*H VOR-Hypo* = horizontal VOR of peripheral vestibulopathy with hypoexcitability; *H VOR-Hyper* = horizontal VOR of peripheral vestibulopathy with hyperexcitability or directional preponderance of nystagmus; *V VOR-Hypo* = vertical VOR of peripheral vestibulopathy with hypoexcitability; *V VOR-Hyper* = vertical VOR of peripheral vestibulopathy with hyperexcitability or directional preponderance of nystagmus.)

DISCUSSION

The caloric test permits the separate evaluation of each labyrinth. It is considered of great importance in the interpretation of vestibular reactions, characterizing vestibular disorders in those patients with hypoexcitability, hyperexcitability, or directional preponderance of the postcaloric nystagmus [2]. Although it helps physicians to elaborate a diagnosis, the caloric test is limited owing to the fact that it does not access high-frequency reactions corresponding to the head movements of daily activities [4,6,7,9].

The head-only rotation test is a physiological evaluation of a greater range of habitual head movement frequencies [5,6,10]. The application of the head-only rotation and caloric tests has been described as being of great importance in the detection of vestibular disorders [1].

In this study, we compared these two tests for the evaluation of the VOR in patients with vestibular disease. Head-only rotation was altered in 90.7% of the patients with dizziness. This high percentage of abnormal results denotes the sensitivity of this test in reading vestibular disorders. It agrees with other studies as well [3,11–15]. Only 9.3% of the studied patients presented normal results. According to the literature, 8% of head-only rotation test results are normal in patients with altered caloric tests [11]. Compensation might explain why these vertiginous patients have normal head-only rotation test parameters [1,7,16].

We observed abnormality of both horizontal and vertical VOR in 56.0% of the patients. Exclusive horizontal VOR deviation was seen in 20% of the patients. Only 14.7% of the cases presented abnormal vertical VOR as the only sign of disorder. Other authors [15,17] noted horizontal and vertical deviations of the VOR in 30–50% of patients. Exclusive horizontal VOR deviation was found in 28% of the patients, and vertical VOR abnormalities were seen in 18% of patients [15].

In the group evincing hypoexcitability, 87.5% had abnormal head-only rotation test results. One author found that all patients with hypoexcitability had abnormal head-only rotation test results [11].

In the group demonstrating hypoexcitability, 12.5% had abnormal horizontal VOR results, 12.5% had abnormal vertical VOR results, and 62.5% had both vertical and horizontal abnormal VOR results. This prevalence was similar to that found in vestibular neuritis with hypoexcitability in the caloric test [17].

Concomitant vertical and horizontal abnormalities (48.6%) were also more common in the patients with hyperexcitability. These were followed by exclusive horizontal VOR abnormalities (28.6%) and exclusive vertical VOR abnormalities (17.1%). Such findings are typically encountered in Ménière's disease [15]. We were able to observe an increased gain of the horizontal VOR of 35% in the patients in the hypoexcitability group. In the same group, 17.5% had a reduced gain of horizontal VOR. Gain was reduced in only 5.7% of patients with hyperexcitability and increased in 57.2%. A reduction in gain indicates that eye movements are subcompensated. Gain increase is a result of supercompensated eye movements [18]. Horizontal VOR gain increase was found in healthy elderly patients [19], in those with benign paroxysmal positional vertigo (BPPV), and in vertiginous patients in general [13,20]. Reduced VOR gain in patients with hypoexcitability is a frequent finding [9,21,22]. In Ménière's disease and vestibular neuritis, a reduction of gain was observed in 60.0% of patients, and an increase was seen in 30.0% of patients [23].

This work demonstrated a reduction of the vertical VOR gain in those with hypoexcitability in 12.5% of patients and an increase in 27.5% of patients. In the hyperexcitability patients, a reduction of vertical VOR gain was seen in 2.9% and an increase in 17.1%. In Ménière's disease and in BPPV, vertical VOR gain was increased [13,24].

We saw a horizontal VOR phase lag in 7.5% of the hypoexcitability patients and a horizontal VOR phase lead in 25.0% of the hypoexcitability patients in this study. In those in the hyperexcitability group, horizontal phase lag occurred in 5.7% and horizontal phase lead in 8.6%. Horizontal phase lag has been observed in Ménière's disease and other peripheral disorders [1,21]. VOR phase lead is a common finding in the elderly [19]. Early horizontal phase is also found in gentamicin-exposed patients [25]. Some authors agree that abnormal phase corresponds to a permanent labyrinthine disorder [12]. Some of the hypoexcitability patients in this study might have had a permanent disorder of the labyrinth. This could justify phase abnormalities in these patients.

Vertical VOR phase lead was seen in 50.0% of the hypoexcitability patients. Vertical VOR phase lag was found in 2.5% of the hypoexcitability patients. In those with hyperexcitability, vertical VOR phase lead was observed in 51.4%. Vertical VOR phase lag was not found in this group of patients. Vertical VOR phase lead was described in patients with BPPV and motion sickness [14,25]. No standard phase result was found in research that analyzed head-only rotation results for Ménière's disease [10,23].

Horizontal VOR symmetry deviation was to the right in 10.0% of the hypoexcitability patients and to the left in 32.5% of the patients. In the hyperexcitability patients, the deviation was to the right in 22.9% and to the left in 20.0%. O'Leary et al. [26] stated that symmetry is related to the size and side of the labyrinthine disorder. Symmetry can be related or not to the size and side of the vestibular disorder [3].

The hypoexcitability patients presented upward asymmetry of the vertical VOR in 25.0% and a downward deviation in 17.5%. Upward symmetry deviation of the vertical VOR was observed in 22.8% of patients and a downward deviation in 14.3% of patients in the hyperexcitability group. Increased gain and abnormal symmetry of the vertical VOR were noted in 20.0% of the patients with Ménière's disease and in 50.0% of the patients with vestibular neuritis [23].

In this study, no standard was found between head-only rotation gain, phase, and symmetry in relation to hypoexcitability or hyperexcitability results in peripheral vestibular disorders. Although the head-only rotation test and caloric test can help in the identification of vestibular disorders in patients with dizziness, a characteristic that justifies their inclusion in the set of tests for equilibrium assessment, we found no association between their results. This could be owing to a fundamental difference between the two tests: The head-only rotation test evaluates VOR response to high-frequency stimulus, and the caloric tests permit the analysis of VOR under low-frequency stimulus.

CONCLUSION

According to what we observed in this investigation, we find no association between the abnormal findings of the head-only rotation test and the caloric test in patients with peripheral vestibular disorder and hyperexcitability, hypoexcitability, or directional preponderance of the postcaloric nystagmus.

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