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Original contributions

Oscillopsia in labyrinthine defective patients: comparison of objective and subjective measures

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Abstract

Objective: To compare the oscillopsia sensation in vestibular defective patients, using a specific handicap questionnaire and a specific Visual Analog Scale, with objective measure of the vertical vestibulo-ocular reflex efficiency in the pitch plane, using the computerized Dynamic Visual Acuity (DVA) test and Gaze Stabilization Test (GST).
Design: Controlled retrospective study.
Setting: Day hospital in ENT Rehabilitation Unit.
Subjects: Sixty-five subjects: 35 controls (12 men and 23 women; mean age, 50.77 ± 13.39 years) and 30 patients with chronic dizziness: 18 with unilateral vestibular hypofunction (7 men and 11 women; mean age, 55.50 ± 12.72 years) and 12 with bilateral hypofunction (7 men and 5 women; mean age, 57.25 ± 9.18 years).
Main measures: Computerize vertical DVA and GST; subjective Visual Analog Scale, Oscillopsia Score questionnaire.
Results: Instrumental tests had different means between subject groups; vertical DVA results and subjective measures were significantly correlated.
Conclusions: Vertical DVA and GST test in up and down direction are able to separate healthy and vestibular patients. Moreover, the DVA test in down direction differentiates patients with unilateral vestibular hypofunction and with bilateral vestibular hypofunction. These results show that vertical DVA test can be used for the assessment of the visual field instability referred to as disabling.

1. Introduction

Oscillopsia is the illusion of movement of the visual surroundings, usually due to the eyes not remaining steady onto the visual target [1].

The vestibulo-ocular reflex (VOR) is the primary mechanism for gaze stability. During movements of the head, the VOR stabilizes gaze (eye position in space) by producing eye movements of equal velocity and in opposite direction to the head movement.

Patients suffering with oscillopsia often report the surroundings to bounce up and down as well as vertical shimmering of images during walking; this suggests a defective VOR, predominantly in the vertical plane, as the cause of the disease [2].

In most of the daily activities, head movements reach very high velocities and frequencies; for example, during running, velocities are up to 90° per second, with predominant frequencies up to 2.7 Hz for yaw and 8.2 Hz for pitch [3]. Therefore, it is important to asses vertical head movements as representative of everyday activities such as walking or running [4]. Until now, it has been complicated to relate oscillopsia to the vestibular function since it was difficult to objectively evaluate the fixation capacity during head movements which is the main vestibular function.

Several tests of Dynamic Visual Acuity (DVA), the acuity obtained during relative motion of either optotype or observer, have been reported as the means of assessing the impact of impaired vestibular function. The clinical version

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of this test is carried out by measuring the static visual acuity of the patient sitting at a predefined distance in front of an optotype table; the test is then repeated by moving the patient's head on the horizontal plane at a frequency of 2 Hz. A decrease greater than 2 lines in the letter identification indicates a reduction in the patients' ability in focusing a target with the head moving, meaning a deficit in VOR gain [5]. However, in this clinic DVA, test it is difficult to maintain correct head velocity and especially to avoid central pre-programming phenomena; thus, it is impossible to offer a really random presentation of the visual stimulus [6].

Recently, a computerized DVA test has become available as a new diagnostic instrument allowing a rapid dynamic visual acuity test for evaluating VOR efficiency. This test quantifies the impact of the impairment of VOR system on the patient's capacity to perceive objects accurately while moving the head at a given velocity on a given axis. Computerized DVA test provides a direct measure of VOR impairment in terms of visual loss measured in logarithm of the Minimum Angle of Resolution (logMAR) [7], which is a reference measure for the assessment of visual acuity.

The Gaze Stabilization Test (GST), which is performed with the same DVA device, measures visual acuity of the subjects at different head velocities, assessing the VOR efficiency in terms of maximum head velocity at which the subject still maintains fixation of a stable optotype at a specified level of visual acuity [5]. To the best of our knowledge, only a few publications have utilized both DVA and the Oscillopsia Score (OS) to asses oscillopsia but without significant relationship between subjective and objective measures of oscillopsia [8-10]. There are no studies analyzing the relationship between oscillopsia sensation and GST.

Computerized DVA and GST tests in the yaw plane have been demonstrated to be good vestibular rehabilitation outcome measures [5]. Therefore, we think that these tests in the pitch plane could also be used as rehabilitation outcome measures if proven to be related with oscillopsia sensation.

The aim of this study is to compare the oscillopsia sensation in vestibular defective patients, using a specific handicap questionnaire [11] and a specific Visual Analog Scale (VAS) [9], with objective measures of the vertical VOR efficiency in the pitch plane, using the computerized DVA-GST tests.

2. Materials and methods

2.1. Subjects

Sixty-five subjects were recruited for the study from the ENT Rehabilitation Unit, San Raffaele Pisana Scientific Institute, San Raffaele s.p.a., Rome, Italy, during 2007. Thirty-five control subjects (12 men and 23 women; mean age, 50.77 ± 13.39 years) and 30 patients with chronic dizziness: 18 unilateral vestibular hypofunction (UVH) subjects (7 men and 11 women; mean age, 55.50 ± 12.72 years) and 12 bilateral vestibular hypofunction (BVH) subjects (7 men and 5 women; mean age, 57.25 ± 9.18 years).

Table 1
Patients' classification by energy test

Classification	Diagnostic criteria	No.
N	Normal response at caloric test	35
UVH	Labyrinthine prevalence in the caloric test >50%	18
BVH	No significant bilateral labyrinthine responses obtained by bitermal energy stimulation	12

Table 1 outlines the classification of patients.

Patients exclusion criteria were cognitive deficits, not corrected severe visual acuity loss, joint replacement, degenerative neurological disease, whiplash injury, post-traumatic vertigo, and benign paroxysmal positional vertigo. The institutional internal review board approved the study. All subjects gave written informed consent for participation.

2.2. Instruments

The inVision (Neurocom, Clackamas, Oregon) system was used to perform computerized DVA and GST tests. Detailed descriptions of the DVA-GST test have been reported previously [5]. In brief, the test is performed at a distance of 1.5 meters with the subject seated; first of all the Static Visual Acuity (SVA) test on the horizontal plane is performed. The correct SVA test is then based on the least optotype rightly recognized by the subject: for this reason the optotype "E" is shown on the computer monitor with random spatial orientation (up, down, right, or left) and with random showing time. The starting size of the optotype, determined by the machine in relationship with the distance of the subject from the monitor, is equal to a visual acuity of 20/20 according to Snellen or to a 0.00 logMAR (logarithm of the minimum resolution angle).

2.3. DVA test

A given optotype size appears in a random spatial orientation a maximum of 5 times. If the patient responds incorrectly to 3 of 5 possible presentations of a given optotype size, the optotype size is increased 1 level until the patient accurately identifies 3 of the 5 possible presentations [7]. Subsequently the DVA is assessed on the pitch plane; the patient wears a rate sensor mounted on the headband, which is used to monitor the velocity and direction of the head movements.

Even if the instrument instructions advises to let the patient move the head actively, it was decided to move the subjects' head passively to avoid learning and central preprogramming phenomena [5]. Patient's head is moved in the pitch plane (up and down) at a minimum speed of 120° per second; under this limit, the optotype is not shown. Once the required velocity is achieved during a trial, the system randomly selects the direction of the head movement during which the optotype is to be presented. This avoids subject identifying the optotype during a fixation period and that the

pursuit system is used in order to minimize the retinal slip [8]. This test is carried out at a constant speed; in the beginning, the optotype is shown 3 sizes bigger than the patient's SVA and is gradually reduced whenever the patient identifies the right orientation of at least 3 out of 5 sequential showings. When the patient cannot clearly distinguish the optotype anymore, the assessment is finished.

The analysis system compares the DVA with SVA and reports the change as DVA loss in logMAR units. This difference (large or small) is the fixation ability of the subject and then the VOR efficiency.

2.4. GST

The GST protocol quantifies the maximum velocity in degrees per second of the head movement at which the patient is able to maintain a specified level of visual acuity. During the GST, patient is asked to look at the optotype "E" which remains at a constant size (the patient's SVA) while moving passively his/her head in the pitch plane. Patient's head velocity is increased according to the accuracy of their response to the orientation of the E, As in the DVA test, once the required velocity is achieved during a trial, the system randomly selects the direction of the head movement during which the optotype is to be presented. When the subject can no longer accurately recognize the orientation of the optotype, the test is complete.

2.5. Subjective measures

The Italian version of a specific "questionnaire" on oscillopsia was used [11]. This questionnaire is aimed at detecting the presence of oscillopsia and at assessing if patients experienced symptom as disabling. The questionnaire consists of 12 items relating to difficulties experienced in everyday tasks. Each item is scored from 1 (no difficulty) to 4 (cannot do). The OS ranges from 12 (no handicap) to 48 (higher level of handicap) [11]. The last part of the questionnaire consists of 3 items about the possible limitations in daily life and a free question about the presence of disabling symptoms. The list of symptoms was not shown to patients to avoid influencing them and to obtain unconditional answers.

To measure oscillopsia we used an OS and a 10-cm vertically oriented VAS. Word cues representing the extreme of the oscillopsia sensation: "as bad as it could be" or "I can see clearly" were at the top and bottom of the line.

Subjects were instructed to walk straight ahead at a freely chosen speed for a distance of 10 meters while looking in front of them. During this exercise the patients were asked to rate the amount of visual blurring or motion they experienced in the environment by marking along the 10-cm line [9].

Table 2
Mean (SD) vertical DVA results divided by group

	Down (logMAR)	Up (logMAR)	Symmetry (%)
N	0.19 (0.11)	0.15 (0.10)	2.23 (6.09)
UVH	0.40 (0.17)	0.51 (0.22)	−11.33 (18.00)
BVH	0.65 (0.17)	0.68 (0.17)	−5.50 (32.26)

Table 3
Mean (SD) vertical GST results divided by group

	Down (°/s)	Up (°/s)	Symmetry (%)
N	124.14 (27.48)	119.14 (22.80)	−0.94 (11.33)
UVH	86.11 (43.13)	78.33 (38.99)	−3.83 (14.10)
BVH	70.00 (31.33)	65.00 (28.76)	−3.00 (14.55)

2.6. Statistical analysis

Means of the 3 groups to determine if at least 1 group mean was different from the other data were analyzed by 1-way analysis of variance after all the variables were checked for normality (with Skewness Normality of Residuals test) and for equal variance (with Modified-Levene Equal-Variance Test). Post hoc Bonferroni test was performed as multiple comparison procedure. Pearson correlation coefficients (ρ), with 2-tailed test of significance, were computed to analyze the correlations between all possible pairs of variables. Variables were considered well correlated if $|\rho| \geq .60$.

3. Results

3.1. Analysis of variance

Mean results of vertical DVA and GST divided by groups are shown in Tables 2 and 3.

Results show that DVA, in both down and up direction, was significantly different between the 3 groups ($P < .001$). Post hoc test showed that the 3 groups had all significantly different DVA down ($P < .050$), although in the up direction, there was a significant difference between normal (N) and UVH and BVH groups but not between UVH and BVH groups. The symmetry of vertical DVA was significantly different between groups ($P = .019$), but this difference was significant only between N and UVH groups ($P < .050$).

GST means in both down and up directions were significantly different between the 3 groups ($P < .001$). Post hoc test showed that, both in up and down directions, there was a significant difference ($P < .050$) between N and UVH and BVH groups but not between UVH and BVH groups.

There was no significant difference between groups in vertical GST symmetry ($P = .730$).

Table 4 shows mean results of OS and Questionnaire divided by groups. Significant differences in both indices

Table 4
Mean (SD) OS and questionnaire results divided by group

	OS	Questionnaire
N	10.00 (0.00)	12.00 (0.00)
UVH	6.89 (1.99)	27.00 (7.39)
BVH	6.60 (1.83)	28.67 (6.39)

Table 5
Pearson correlation coefficients matrix

	DVA Down	DVA Up	DVA Symmetry	GST Down	GST Up	GST Symmetry	OS	Questionnaire
DVA down	1.00	0.80†	0.37†	−0.77†	−0.66†	0.08	−0.72†	0.69†
DVA up	0.80†	1.00	0.39†	−0.68†	−0.72†	−0.01	−0.73†	0.75†
DVA symmetry	0.37†	0.39†	1.00	−0.36†	−0.31*	0.15	−0.36†	0.39†
GST down	−0.77†	−0.68†	−0.36†	1.00	0.73†	0.05	0.54†	−0.47†
GST up	−0.66†	−0.72†	−0.31*	0.73†	1.00	−0.10	0.59†	−0.57†
GST symmetry	0.08	−0.01	0.15	0.05	−0.10	1.00	−0.07	0.01
OS	−0.72†	−0.73†	−0.36†	0.54†	0.59†	−0.07	1.00	−0.93†
Questionnaire	0.69†	0.75†	0.39†	−0.47†	−0.57†	0.01	−0.93†	1.00

* $P < .05$.
† $P < .001$.

were observed between the 3 groups ($P < .001$). Post hoc test showed a significant difference ($P < .050$) between N and the vestibular groups but not between UVH and BVH groups in both OS and Questionnaire.

3.2. Correlations

Vertical DVA (up and down directions) and vertical GST results were significantly correlated (Table 5). Only DVA correlated well with OS and with the questionnaire, particularly DVA in the up direction showed better correlation with the subjective tests than in down direction.

OS and questionnaire were highly correlated ($\rho = -0.93$).

4. Discussion

The aim of this study was to asses the relationship between oscillopsia sensation in the vestibular defective patients and DVA-GST tests in the pitch plane. Our data suggest that subjects with impaired vestibular function perform significantly poorer than those with normal vestibular function on the vertical head movement condition, especially for BVH patients both in up and in down direction. In the up direction, results of the DVA test were similar for UVH and BVH patients but were significantly greater in terms of logMAR loss compared to the healthy subjects. In addition, the difference between the UVH and BVH patients was statistically significant in the down direction.

In BVH subjects, there was no significant difference in the symmetry of the response with respect to N group; instead symmetry variation was significant between N and UVH groups. We are unable to find a convincing neurophysiological explanation for this difference due to the direction in the UVH patients.

GST data in the up and down direction showed significant differences between groups by 1-way analysis of variance, but the more conservative Bonferroni test showed that GST cannot discriminate significantly between unilateral and bilateral vestibular groups. Moreover, there was no significant difference between groups in the vertical GST symmetry.

To assess oscillopsia sensation, we used a VAS OS and an oscillopsia questionnaire. In the 3 subject groups results showed a significant difference in mean between healthy and vestibular defective patients but not between UVH and BVH groups in both OS and Questionnaire.

The main finding of our study is that vertical DVA (up and down directions) and vertical GST results are significantly correlated, but only DVA is well correlated with the OS and the questionnaire. OS and questionnaire are highly correlated.

A group of UVH patients treated with vestibular rehabilitation showed no significant correlation after therapy between DVA improvement (done in the horizontal plane) and oscillopsia sensation while walking [8]. In another study, a group of BVH patients treated with vestibular rehabilitation showed no clear relation between DVA improvement and complaints of oscillopsia after therapy [10]. Herdman hypothesized first that oscillopsia is more evident in the pitch plane than in the horizontal plane; and secondly, that complaint of oscillopsia may be related to the patient's tolerance for retinal slip [8,10].

Vertical DVA scores of UVH patients were found to be similar to those of healthy individuals, in BVH subjects vertical DVA was significantly reduced with respect to healthy and UVH patients [9]. Shubert [9] found not significant positive relationship between report of oscillopsia and vertical DVA scores for any patients group. Moreover, in BVH patients, there was a negative correlation with the OS, suggesting that some patients may become tolerant to retinal slip. Possible explanations of these differences with our study are that, in our study, UVH patients have a labyrintyne asymmetry greater than 50% while the above study [9] selected subjects with an asymmetry greater than 25%. Furthermore, another difference with our study is the etiology of vestibular hypofunction. In fact, the majority of our patients were not affected by vestibular neuritis that is a partial vestibular lesion that could spare the function of the posterior semicircular canal.

Hillman studied by horizontal DVA 10 healthy subjects and 5 BVH patients while standing or walking on a treadmill. Patients had significant decreased DVA scores especially

while walking, revealing their inability to compensate for motion and maintain visual acuity during movement [12]. They concluded that this test may be useful to assess the severity of oscillopsia.

Another study reported that, in patients with impaired vestibular function, there was no difference in performance between treadmill task and volitional vertical head movement task, and BVH subjects had a larger decrement in DVA with respect to UVH in a different test condition [13].

5. Conclusions

Vertical DVA and GST tests in both up and down direction are able to separate healthy and vestibular patients. Moreover, DVA test in down direction differentiates patients with UVH and patients with BVH. In our study, there was a significant correlation between vertical DVA and impaired VOR function in the same plane and complaints of oscillopsia and experience of disabling symptoms were related to a lack of equilibrium. These results show that vertical DVA test can be used for the assessment of the visual field instability referred to as disabling. Therefore, we suggest that this test could be used as an additional parameter for vestibular rehabilitation outcomes [5].

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