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INVESTIGATING THE VOR GAIN FUNCTION IN NORMAL HEARING SUBJECTS

Sam. A*	Clinical Audiologist, 23,Cholai Nagar,Kadavur Road,Morai,Chennai-600055 *Corresponding Author
Saranyaa Gunalan	Asst Professor, Dept of Audiology, MERF – Institute of Speech and Hearing, Chennai – 600028.
Ranjith. R	Principal, MERF – Institute of Speech and Hearing, Chennai – 600028

ABSTRACT The study aims to establish normative data for VOR gain and also to assess the test-retest reliability of the SYNAPSYS vHIT Ulmer II System (version 3.0.0.113) in young healthy adult participants. The VOR gain was measured for all canals across a range of head velocities for 200 participants divided into two groups in the age range of 17 to 25 years with a mean age of 20.38 years. Group I (GI) – 17 to 20. 11 years, Group II (GII) – 21 – 25.11 years with a male to female ratio of 1:3. Descriptive analysis, one way AVOVA was employed to find out the significance between the VOR gain value of right lateral, right posterior, right anterior and of left lateral, left posterior, left anterior , Independent T test was used to assess the difference in the mean VOR gain value and Paired t test was computed to calculate the test retest reliability. The mean and standard deviation of VOR gains were 0.99 ± 0.06, 0.98 ± 0.06, 0.97 ± 0.08, 0.97 ± 0.08, 0.97 ± 0.05, and 0.97 ± 0.06 for right lateral, left lateral, right anterior, left anterior, right posterior and left posterior canals respectively. Gain differences between groups and genders were not statistically significant. The Video Head Impulse Test (vHIT) has some advantages compared to the gold standard test of horizontal SCC function including lower cost, minimal space requirements, greater portability and increased patient comfort.

KEYWORDS : Vestibulo-Ocular Reflex Gain; Video Head-Impulse Test ; Synapse vHIT Ulmer II

INTRODUCTION

The human peripheral vestibular system helps to maintain the balance. There are three primary reflexes which originate from the vestibular system i.e. Vestibulo Ocular Reflex (VOR), Vestibulo Spinal Reflex (VSR), and Vestibulo Collic Reflex (VCR). The Vestibulo-Ocular Reflexes (VOR) helps in maintaining gaze on a stationary object while the head is in motion. When the head is in motion, VOR controls head stability by generating eye movements that are equal and opposite to head motion. Therefore, the gain of VOR is approximately unity for natural head movements and its measured by calculating eye velocity/head velocity. The main anatomic components of VOR are semicircular canals in the peripheral vestibular system, the vestibular nuclei, ocular motor nuclei in the brainstem and extraocular muscles.

The peripheral vestibular system consists of saccule, utricle and three semicircular canals (SCCs) on each side of the head. SCCs of both sides of head are paired with each other in orthogonal planes within the head that allows for the detection of head movement in three-dimension. The SCCs detect the angular acceleration and two coplanar canals work together on each side of head, i.e. left horizontal SCC and right horizontal SCC works in pair, the left anterior works with right posterior SCCs (LARP) and the right anterior and left posterior SCCs (RALP) function together while rotation of head in different directions.

The discharge rate from the left afferent nerve of horizontal SCC increases, when the head is rotated towards the left side. At the same time, the discharge rate from the right afferent nerve of horizontal SCC decreases relative to the resting discharge rate. This difference in output between the right and left horizontal SCCs cause the right side compensatory eye movement so that the eyes remain still in space during head rotation and helps in maintaining stable vision.VOR gain is the ratio between the rotation of eyes to the rotation of head and the gain of VOR is approximately unity (eye velocity/head velocity) in natural head motions.

Since the vestibular system consists of multiple structures, one single test cannot assess all the structures. Caloric test, which is considered as one of the gold standard test, assesses the horizontal SCC and the superior vestibular nerve (SVN). Ocular Vestibular Evoked Myogenic Potentials (oVEMP) and Cervical Vestibular Evoked Myogenic Potentials (cVEMP) assesses the utricle and the saccule respectively. Even if all the three tests are included in a single test battery, it does not give information about the anterior and the posterior canals. (Bansal & Sinha, 2016).

Video Head Impulse Test (vHIT) is relatively a new clinical test to measure the dynamic function of all three SCCs separately that uses a high-speed digital video camera to record head and eye movement during and immediately after passive head rotations and is based on the bedside head impulse test. The video head impulse test is mainly based on two principles, Stimulation of a particular canal leads to the eye movements in the plane of same canal and The excitatory responses are always larger than inhibitory responses.

The three SCCs are functionally orthogonal to each other, therefore head impulses delivered to one plane will stimulate only the pair of semicircular canal of that particular plane and not the other two pairs of SCCs. Hence, the video head impulse test (vHIT) helps to measure the VOR gain of all the three pairs of SCCs separately and can be utilized to find out the exact site of lesion in any of the three pairs of SCCs. In the case of unilateral vestibular hypofunction, the gain of the VOR during ipsilesional head impulses will be lower than the gain during contra lesional head impulses.

There are various equipment that are available to measure the VOR gain. Depending on the vHIT device, the camera is either embedded in head-worn goggles or mounted on a monopod facing the patient. Head movement is recorded either by an inertial measurement unit mounted on the head-worn goggles as in the ICS Impulse System from GN Otometrics Denmark, or by detecting the change in the angle of head position during and after the head impulse by an external camera as the vHIT Ulmer System from Synapsys Inc France. (Murnane, Mabrey, Pearson, Byrd, & Akin, 2014).

The SYNAPSYS Inc. vHIT Ulmer II device measures the deviation in gaze during passive head impulses in the horizontal and diagonal planes using an external camera (Ulmer& Chays, 2005).

The aim of this study was to establish normative data for VOR gain and also to assess the test-retest reliability of the SYNAPSYS vHIT Ulmer II System (version 3.0.0.113) in young healthy adult participants.

METHOD

PARTICIPANTS

The study was reviewed and approved by the institutional ethical committee. The study included 200 participants who were selected randomly in the age range of 17 to 25 years with a mean age of 20.38 years with the informed consent, with a male – female ratio of 1:3 respectively. The participants were grouped into two. GI – 17 to 20. 11 years, GII – 21 – 25.11 years.

Participants with normal hearing sensitivity and middle ear functioning were included for the study and those with the history of otological, neurological, balance, vestibular related issues, cervical spine injury and excessive loud noise exposure were excluded.

PROCEDURE

Pure tone audiometry was carried out using Cello Inventis diagnostic audiometer with TDH-39 headphones and Radio Ear B-71 bone vibrator utilizing the modified Hughson and Westlake procedure (Carhart, R., & Jerger, J. F, 1959). Immittance audiometry was done using Flute Inventis diagnostic middle ear analyser by sweeping the pressure from -200 daPa to +200 daPa and with the conventional probe tone of 226 Hz. The ipsilateral and contralateral acoustic reflex thresholds were obtained for 500, 1000, 2000, and 4000 Hz stimuli.

The Video Head Impulse Test (vHIT) was carried out in a well-lit room with the SYNAPSYS Inc. Video Head Impulse Test Ulmer II. The system consists of a high-speed (250 Hz) infrared digital video camera mounted on an adjustable monopod, computer, and the vHIT software (version 3.0.0.113). Target was kept at the eye-level at a distance of 2 meter in front of the subjects and the subjects were seated on a fixed immovable chair.

Participant's eyes were fixated on the target dot for calibration of eye position signal. On completion of the calibration procedure, they were instructed to maintain their eye gaze at the target object, located at the eye level beyond the camera at a distance of 1 meter on the wall straight ahead. Head impulse for assessing the horizontal canals were delivered by the clinician standing behind each subject by turning the head towards right and left side. Each participant was presented with a minimum of 5 head impulses in each plane and in each direction (lateral, Right Anterior and Left Posterior (RALP), Left Anterior and Right Posterior (LARP)). The head was rotated manually and abruptly in each plane at an angle of 10 – 20 degrees and the trails were randomized.

A high-speed digital infrared camera which is a part of the instrument was utilized to record the eye movement of the subject during and immediately after the head rotation. In order to assess the test retest reliability 20 participants were subjected to the test again after a period of 2 weeks. Mean VOR gain was calculated by taking the average VOR gain of minimum of 5 trials in each plane.

The SYNAPSYS software displays the results of the vHIT via a Canalogram Ulmer In the Canalogram Ulmer, the SCCs are represented by the six branches and the purpose of the Canalogram Ulmer is to present the gain values obtained for each semi-circular canal. Canalogram Ulmer is made of 6 branches, separated in 2 half-branches. White half-branches for VOR gains and grey half-branches for apparent gain after early saccade if any. At the end of branches, final result of VOR gain is shown as well as the number of valid collected impulses for each canal are represented.

Statistical analysis

Descriptive analysis was done to calculate the mean and standard deviation of VOR gain in all three planes in both the directions for the first and the second session. One way AVOVA was employed to find out the significance between the VOR gain value of right lateral, right posterior, right anterior SCCs and of left lateral, left posterior, left anterior SCCs. Independent T test was used to assess the difference in the mean VOR gain value between right-left lateral canals, right-left anterior canals, right-left posterior canals, left anterior-right posterior canals and between right anterior-left posterior canals. Paired t test was computed to calculate the test retest reliability. Statistical Package for the Social Sciences (SPSS) software version 16 was utilized for all the analysis.

RESULTS

The study included 200 normal hearing participants to assess the various objectives of the study. Descriptive analysis was done to calculate the mean and standard deviation of VOR gain in all three planes in both the directions for session one and two.

One way AVOVA analysis showed a significant difference in the VOR gain values of right lateral, right anterior, and right posterior canals ($F = 8.339$, $p = 0.00$) and of left lateral, left anterior, and left posterior canals ($F = 5.760$, $p = 0.03$). Independent T test showed no significant difference for the mean VOR gain value between right and left ear.

Test Retest Reliability

Paired T test was administered to find out if there is any significant difference between the VOR gain values between session 1 and 2. The test showed no significant difference for the mean VOR gain value between sessions of right anterior canals, left anterior canals, right lateral canals, left lateral canals, right posterior canals, and left posterior canals.

DISCUSSION

In the current study, it was observed that the lateral canals had more gain compared to anterior and posterior canals. This finding is in line with similar results that have been reported by Murnane et al., (2014), McGarvie et al., (2015) & Bansal and Sinha (2016).The large mean gain obtained for horizontal canals may be related to the smaller amplitude of eye movement in the vertical plane than in horizontal plane, the camera's smaller field of vision in the vertical plane than in the horizontal plane and the smaller number of pixels in the vertical plane than in the horizontal plane (Murnane et al.,(2014)). In the current study, it was observed that it is easier to generate head impulse in the horizontal plane than vertical plane.

It was also observed that there was no significant difference between the mean VOR gain values during the test and retest sessions for each semicircular canal. The results of the present study suggest that the gain parameters of the vHIT are reliable which is in line with the findings reported by Ulmer et al., 2011 & Murnane et al., 2014.

The vHIT has many advantages over the bedside head impulse test (HIT) first described by Halmagyi and Curthoys (1988, 2003). The bedside HIT is a subjective test, and there is no objective measure of the eye movement response; the outcome of the bedside HIT is based on the clinician's subjective visual observation of the presence or absence of overt saccades (large fast changes in eye position also referred to as corrective or catch-up saccades) that occur at the cessation of head rotation. If the corrective saccades occur during the head rotation, then it is likely that they will not be observed by the clinician (covert saccades) and thereby increase the likelihood of a false-negative result. (Weber, K. P., Aw, S. T., Todd, M. J., McGarvie, L. A., Curthoys, I. S., & Halmagyi, G. M (2008) &Weber, K. P., MacDougall, H. G., Halmagyi, G. M., & Curthoys, I. S. (2009)). In contrast to the bedside HIT, the vHIT records eye movement and, depending on the device, provides objective measures of either gaze deviation (Ulmer et al., 2005; Ulmer et al., 2011) or VOR gain Weber et al., 2009).

CONCLUSION

The human vestibular system is a complex organ in the ear which principally governs the balance in conjunction with the visual and proprioceptive systems. There are various tests that are present which can successfully evaluate the components of the vestibular system. One such test is the vHIT which is the only test that is able to assess the functioning of the all the semicircular canals. VOR gain is calculated as the ratio between eye velocity and head velocity when head impulses are presented. Based on the findings of the present study, it is clearly evident that the test is a simple procedure which takes approximately 10 minutes to finish and also shows good reliability in terms of VOR gain functions. Additionally, this test is reliable in detecting the slightest changes in the VOR gain parameters thereby suggesting an underlying pathology. The Video Head Impulse Test (vHIT) has some advantages compared to the gold standard test of horizontal SCC function including lower cost, minimal space requirements, greater portability and increased patient comfort.

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