Research Article

Assessment of Semicircular Canal Function using vHIT in Adults with Congenital Hearing Loss

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Abstract

Introduction: vHIT test to assess the functioning of three semicircular canals.

Objective: This study was designed to objectively assess the functioning of the three semicircular canals in individual with severe to profound sensorineural hearing loss using vHIT respectively.

Methods: Twenty adult participants (40 ears) having severe to profound hearing loss ranging in age from 15-40 years in group I. Group-II consisted of 20 adult participants (40 ears) in the age range from 15-40 years with normal hearing sensitivity. All the participants underwent a detailed case history, pure tone audiometry, immitance and reflexometry and vHIT tests.

Results: Mean VOR gain values for right and left horizontal canals, right anterior and left posterior canal for individual with hearing impaired is lesser than the individual with normal hearing. There were significant differences between group 1 and group 2 for VOR gain for right horizontal canal and left horizontal canal whereas significant difference was showed in right posterior canal, left anterior canal, right anterior canal and left posterior canal.

Conclusions: Vestibular abnormality was seen for semi circular canals in individual with severe to profound hearing loss. Therefore, vestibular tests should be included along with various audiological tests in the diagnostic protocol for the assessment of individual with severe to profound sensorineural hearing loss.

INTRODUCTION

In individuals with sensorineural hearing loss, disturbances of cochlear function could accompany vestibular impairment because the cochlea and the vestibule share the continuous membranous labyrinth of the inner ear. Several studies have reported dysfunction of the vestibular system in individuals with sensorineural hearing loss. Cushing et al. [1] reported Mild to moderate unilateral abnormalities in caloric response in 50 % of children with sensorineural hearing loss whereas 38% of children with sensorineural hearing loss had abnormal rotational response. Cushing et al.[1] also reported bilateral absent VEMP response in 19% and absent unilateral VEMP in 19% of the children with sensorineural hearing loss. Cushing et al. [2] reported mild abnormal response in 50 % of children with severe to profound hearing loss, severe hypofunctional responses in 37% of the children in caloric test. Rotational test showed abnormal response in 47% of children, whereas, VEMP was found absent bilaterally in 23% and unilaterally in 13% children with severe to profound hearing loss. Singh et al. [3] reported reduced amplitude of vestibular evoked myogenic potentials in children with sensorineural hearing loss compared to the normal hearing children.

Not only in the children but also in adults with acquired hearing loss there are several studies which have reported vestibular disturbances in individuals with sensorineural hearing loss. Sazgar et al. [4] found that individual with high frequency sensorineural hearing loss of greater that 40 dBHL have absence of VEMP response. Hong et al.,[5] assessed functioning of saccule in individual with sudden sensorineural hearing loss by recording VEMP and found the absence of VEMP in higher degree of hearing loss whereas, presence of VEMP in hearing loss less than 55dB. Chen & Young [6] recorded VEMP in idiopathic sudden deafness and found abnormal VEMP in 21% of individuals. Wang and Young [7] found normal caloric response in 45% of individual and absence of VEMP in 50% of individuals with chronic noise-induced hearing loss. Wang and Young [7] also reported normal VEMP and caloric response in 70% of the individuals with chronic noise-induced hearing loss. Bansal et al. [8] reported presence of cVEMP and oVEMP in 100% and 66% respectively in individual with severe to profound hearing loss.

Previous studies have utilized cVEMP, oVEMP, caloric and rotational chair test to study the vestibular system functioning in individuals with sensorineural hearing loss. These tests give information about the saccule, utricle and horizontal semicircular canal...
canal functions in individuals with vestibular disorders. There is a dearth of information regarding the function of all the six semicircular canal in individual with severe to profound hearing loss. In each vestibular labyrinth there are 5 sensory organs. Any one of these can become dysfunctional and can cause vestibular symptoms. Up to now the techniques for assessing the specific function of every sensory organs were not been available. Recently Video head impulse test (vHIT) has been developed as a tool to assess all the 6 semicircular canals. VOR gain value of vHIT and the presence of saccades during vHIT recording has been used to diagnose different pathology like Meniere’s disease [9,10], vestibular neuritis [10,13], benign paroxysmal positional vertigo [12], vestibular neuritis [10,13].

Recently, Lin and Young [14] recorded cVEMP, oVEMP and caloric test in individuals with congenital hearing loss and reported that congenitally deaf participants with pure tone average of greater than 65 dB may retain less vestibular function than those with lesser than 65dB of hearing loss as evidenced by higher percentage of absent oVEMP and hypofunctional caloric test. To our best of knowledge, there no published reports on vHIT test results in adult individuals with congenital severe to profound sensorineural hearing loss. The aim of the present study was to assess the function of all the six semicircular canals i.e., horizontal, anterior, posterior canal of both the sides in individual with severe to profound hearing loss.

**METHODS**

**Participants**

Two groups were taken in the present study. Group-I consisted of 20 adult participants having severe to profound hearing loss (>70dBHL) ranging in age from 15-40 years. These participants had non inherited, non-syndromic congenital hearing loss. These participants were clients of the Department and had bilateral sensorineural hearing loss since childhood. The presence of congenital hearing loss was confirmed with the audiological reports available at the medical records section of our Institute. All the participants had normal middle ear function as evidenced by the immittance evaluation. Group-II consisted of 20 adult participants in the age range from 15-40 years with normal hearing sensitivity (≤15dBHL). All the participants had normal middle ear function as evidenced by the immittance evaluation. None of the participants in both the groups had any history or presence of any other otological (like ear discharge, ear pain & itching sensation), neurological or neuromuscular problems. Participants had no complaints of balance problem and also no history of excessive loud noise exposure. All the participants were informed initially about the study in detail and a written consent form was obtained from all the participants.

**Instrumentation**

To calculate the air conduction and bone conduction thresholds, a calibrated Grason-Stadler-61 with TDH-39 supraaural headphones and B-71 bone vibrators respectively were used. Middle ear functions of all the participants were evaluated using the GSI-Tympstar middle ear analyser, which had a facility to deliver 226 Hz probe-tone frequency. For assessment of all the semicircular canal for all the participants in both the groups, Video Head impulse test device (ICS mpulse) by otometrics Inc. was utilized. All the measurements were carried out in an acoustically treated double room setup for pure tone audiometry and single room setup for immittance and video head impulse test for all the participants.

**Procedure**

Using the modified Hughson and Westlake procedure, air conduction threshold with the TDH 39 headphones and bone conduction threshold with B-71 bone vibrator was administered for octave frequencies from 250 to 8000 Hz and 250 to 4000 Hz respectively to investigate the hearing sensitivity of the each participant. Tympanometry and reflexometry was done to rule out any pathology at middle ear or auditory nerve level. Tympanometry was done at 226 Hz probe tone and acoustic reflex threshold for both ipsilateral and contralateral stimulation at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Vide head impulse test (vHIT) was carried out in a sound treated single room setup. Calibration of the video head impulse test instrument was done, before the actual video head impulse test was carried out for every participant. Participants were made to sit on a chair with adjustable height. Video head impulse test goggles were tightened to the head of the participant. The goggles were tightened in such a way that there was no slippage of the goggles during entire testing. To carry out the calibration of the instrument a target was kept 1 meter away from the participants at the eye level. The participants were asked to look at the target and the eye position was fixed. For calibration of the equipment two laser lights were generated from the instrument. These two laser lights were 10 degree away in the right and left direction at the level of the target fixed initially. During the calibration the two laser lights alternated between the 10 degree right and left and the participants were instructed to track the two laser dots.

Once the calibration was over, the clinician rotated the head of the participants in three planes; lateral, left anterior right posterior (LARP) and right anterior left posterior (RALP) planes.

The head were rotated abruptly in each plane at an angle of 15degrees approximately and a total of 20 impulses were given in each direction for all the participants. A high speed digital camera (which is a part of the instrument) was utilized to record the eye movement during and immediately after the head rotation.

**Analysis**

In the present study we calculated the VOR gain as well as presence of saccades (overt and covert) for both the groups. The calculations of the VOR gain and the saccades both are based upon several studies published in literature, where few studies have taken VOR gain as parameters other few have taken saccades as a parameter. However, in a recent study Korsager et al. [15] reported that for diagnosis of semicircular canal dysfunction, clinician shall first depend on the occurrence of saccades and second on the gain value. In the present study although, we have reported the VOR gain values we have given more importance to the presence of saccades during vHIT recording than the VOR gain values.

**RESULTS**

Mean vestibule ocular reflex (VOR) gain was analyzed in vHIT for both the groups. All individual with normal hearing had normal VOR gain for all six SCC’s. Before calculating the mean and the
standard deviation of the data and testing a significant difference between different parameters, Shapiro–Wilk test was done to check the normality of the data, and Shapiro–Wilk test showed a non-normal distribution of data. Therefore non-parametric statistics was done by using SPSS software.

Individual data was analyzed for individual with hearing impaired and found that mean VOR gain for left anterior canal was reduced for 5 individuals and increased for 2 individuals. Mean VOR gain for right anterior canal was reduced for 6 individuals, left lateral canal was reduced for 6 individuals, left lateral canal was reduced for 6 individuals, right lateral canal was reduced for 7 individuals, left posterior canal was reduced for 3 individuals and right posterior canal was reduced for 5 individuals and increased for 3 individuals. Mean VOR gain of for individual with hearing impaired with normal VOR gain and with reduced VOR gain are shown in (Figures 1,2) respectively.

Descriptive analysis was done to obtain mean and standard deviation of VOR gain for right horizontal (RH), left horizontal (LH), right posterior (RP), left anterior (LA), right anterior (RA), left posterior (LP). Value of VOR gain for both the groups is listed in Table (1).

It can be seen from Table-1 that mean VOR gain values for right and left horizontal canals, right anterior and left posterior canal for individual with hearing impaired (Group-1) is lesser than the individual with normal hearing. Mean VOR gain for right posterior and left anterior canal are similar for both the groups.

Wilcoxon signed rank test was done to find the significant difference between different plane of semicircular canals of individual with normal hearing and individual with severe to profound hearing loss and values are shown in Table (2).

Mann-Whitney U Test revealed significant difference between group 1 and group 2 for VOR gain for right horizontal canal \([z = 3.07, p < 0.05]\) and left horizontal canal \([z= 3.01, p<0.05]\) whereas no significant difference was showed in right posterior canal \([z= 0.13, p>0.05]\), left anterior canal \([z=0.10, p>0.05]\), right anterior canal \([z=1.39, p>0.05]\) and left posterior canal \([z= 1.02, p>0.05]\).

Figure 1 Video head-impulse test results in 3 different planes of a participant with normal VOR gain in individual with severe to profound hearing loss. The head and eye velocities throughout different head impulses to the right or left side are shown. Also, the gain values are shown in the figure in the form of hexaplot.
Figure 2 Video head-impulse test results in 3 different planes of a participant with abnormal VOR gain in individual with severe to profound hearing loss. The head and eye velocities throughout different head impulses to the right or left side are shown. Also, the gain values are shown in the figure in the form of hexaplot.

Table 1: Mean and standard deviation of VOR gain for both the groups.

<table>
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<th>PLANES</th>
<th>Group 1 (Individual with severe to profound hearing loss)</th>
<th>Group 2 (Individual with normal hearing)</th>
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<tr>
<td></td>
<td>Mean</td>
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The re-fixation saccades were assessed for both the groups. Overall the re-fixation saccades were present in all the participants in one or the other plane in individuals with severe to profound hearing loss, whereas, in normal individuals it was absent in all the planes. Figures 1, 2 shows the types of re-fixation saccades present in hearing impaired individuals. Table (3) shows the details of presence of saccades in individuals with sensorineural hearing loss.

From, Table 3 it can be seen that percentage of occurrence of overt and covert saccades are different in different planes in hearing impaired individuals. Overall, the overt or the covert saccades were present in 100% of the hearing impaired individuals.

DISCUSSION

vHIT test has been added to the vestibular test battery to give additional information regarding the anterior and posterior canal involvement in various vestibular disorders. vHIT provides side and receptor specific information of the VOR in individuals with various vestibular disorders [16,17]. In the present study we observed significant reduced VOR gain values in lateral and
the right anterior-left posterior (RALP) plane in adults with congenital hearing loss. It can be interpreted from the present study that different semicircular canals of both ears are affected in adults with congenital severe to profound hearing loss. Present study supports some of the earlier findings present in the literature. Some of the earlier studies reported in literature have reported a reduced VOR gain function in individuals with sensorineural hearing loss of different origins. For example, Magliulo et al., [18] found abnormal vHIT in individual with Usher syndrome who had established hearing loss and found that 53.3% had significant superior semicircular canal (SSC) deficit, 33.3% individual with ushers syndrome confirmed with horizontal SCC deficits and posterior SCC deficits was presented with 40% of individual with usher syndrome. These results indicated SSC's damage in individual with Ushers syndrome that had being correlated with the result of present study. Lin et al., [19] reported to have abnormal vHIT that examined horizontal SCC VOR gain in 38.5% of idiopathic sudden hearing loss. Jutila, Aalto and Hirvonen [20] measured horizontal VOR gain in children with profound hearing loss was 0.77 ± 0.26. In different pathologies had also shown the lesser VOR gain for horizontal canal which shows dysfunction of horizontal SCC. 

In the present study the refixation saccades (overt or covert saccades) was present in all the participants with hearing loss. Presence of refixation saccades in the presence of a normal or reduced VOR gain values is an indication of vestibular pathology [17,18,11]. This is the first study which has measured the presence or absence of refixation saccades in adults with congenital hearing loss. Earlier studies have measured only VOR gain values in individuals with severe to profound hearing loss with various origins. However, few of the earlier studies have reported presence of refixation saccades in 16%-43% of the individuals with various vestibular deficits [17,18,11] The difference in amount of refixation saccades in different studies could be because of the different population studied.

In the present study the VOR gain values for the adults with congenital severe to profound hearing loss ranged 0.7 to 0.9 in different planes and in normal young adult it ranged from 0.9 to 1.02. Published data on normative VOR gain values for the vHIT values is still sparse. The manufacturers of the ICS impulse vHIT system consider 0.8 as normative value for the VOR gain values. Mac Dougall et al. [22] suggested that a VOR gain values of 0.68 is normal. Curthoys et al. [23] state that typical VOR gain values in normal adults vary from 0.7 to 1.1. If we look in to the data carefully, it can be seen that although a significant reduced VOR gain values was noticed in adults with congenital hearing loss, the VOR gain values are typically normal as per the published studies in adults with congenital hearing loss.

The observation of a normal VOR gain with the occurrence of refixation saccades is a rare condition. Based on the results of the current study the explanation cannot be defined at this moment. However, the duration of the vestibular deficit as well as central compensation can influence the vHIT results. Palla et al. [24] has shown that the VOR gain improved over the time in various vestibular pathologies, which is due to the central compensation rather that the improvement in the peripheral system. As, we all understand that the damage to the peripheral vestibular system is a sensory damage and any kind of sensory damage cannot be improve. Thus, it is possible that the normal VOR gain in the presence of refixation saccades is an

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<th>Table 2: Wilcoxon signed ranks test in individual with severe to profound hearing loss and individual with normal hearing.</th>
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<td>vHIT</td>
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**Abbreviations:** LL: Left Lateral; RL: Right Lateral; LP: Left Posterior; RA: Right Anterior; LA: Left Anterior; RP: Right Posterior

| Table 3: Presence of refixation saccades in hearing impaired individuals. |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                             | Overt Saccades | Covert Saccades | Reduced Gain | Percentage |
|                             | Percentage (%) | Percentage (%)  |                |              |
| RL                           | 12             | 60              | 15             | 75            | 5               | 25              |
| LL                           | 10             | 50              | 8              | 40            | 7               | 35              |
| RA                           | 10             | 50              | 13             | 65            | 4               | 20              |
| LP                           | 11             | 55              | 10             | 50            | 4               | 20              |
| LA                           | 6              | 30              | 13             | 65            | 7               | 35              |
| RP                           | 12             | 60              | 13             | 65            | 6               | 30              |

Abbreviations:
- LL: Left Lateral
- RL: Right Lateral
- LP: Left Posterior
- RA: Right Anterior
- LA: Left Anterior
- RP: Right Posterior

| Abbreviations: z value: Wilcoxon z value; P value: Wilcoxon p value. |
indicator of the compensation from the central vestibular system in individuals with peripheral vestibular damage. Thus, from the results of the present study it can be interpreted that, although the adults with congenital hearing loss may have a vestibular deficit, compensation from central system would have occurred in these individuals. Hence, these individuals may not report of any significant balance problems. Utilizing calorics test and cVEMP test, recently, Lin and Young [25] also reported vestibular deficit in 100% of the adults with severe to profound congenital hearing loss. The present study also supports the findings of the previous study suggesting that adults with congenital hearing loss have vestibular deficit.

CONCLUSIONS

vHIT is a recent tool that evaluates the function of the semicircular canal function in the three planes of both the sides in individuals with various vestibular pathologies. In the present study we found reduced VOR gain function and presence of reflexion saccades in adults with congenital hearing loss indicative of the vestibular pathology. However, these individuals do not report of significant dysbalance problems probably due to compensation occurring from visual, propeoceptive and the central vestibular system. The results of the present study also indicate that vHIT can be utilized to study the central vestibular compensation in individuals with vestibular pathologies. Comprehensive assessment of the residual vestibular function can help us in predicting the occurrence of any kind of episodic vertigo in the future.

REFERENCES


Cite this article