cVEMP, oVEMP and Caloric Test Results in Individuals with Meniere's Disease

Sujeet Kumar Sinha[1,*], Kruthika Shankar[1] and Rajeshwari Govindaswamy[2]

[1]*Department of Audiology, All India Institute of Speech and Hearing, Mysore, India*

[2]*Department of ENT, All India Institute of Speech and Hearing, Mysore, India*

Abstract: *Objective*: The present study aimed to characterize cVEMP, oVEMP and caloric test findings in individuals with Meniere's disease.

Methods: 29 participants with Meniere's disease and 29 participants with normal hearing were enrolled for the study. Out of 29 participants in the experimental group, 25 of them had unilateral Meniere's disease and 4 of them had bilateral Meniere's disease (Total 33 ears diagnosed with Meniere's and 25 ears with non-Meniere's disease). All the participants underwent routine audiological, cVEMP, oVEMP and Caloric testing.

Results: Out of 33 ears with Meniere's disease, 29 ears had absent responses on cVEMP, 23 ears showed absent oVEMP responses, 27 ears had hypo-activity, five ears showed hyper activity and one ear showed normal response to caloric stimulation. In the contralateral ear (25 ears with non-Meniere's disease) both cVEMP and oVEMP were absent in 5 of the ears, cVEMP was absent and oVEMP was present in 13 ears, cVEMP was present and oVEMP was absent in 1 ear, whereas both cVEMP and oVEMP were present in 6 ears in individuals with Meniere's disease. However, the caloric responses were present normally in the contralateral ear in individuals with Meniere's disease.

Conclusions: The combination of cVEMP, oVEMP and caloric test provides valuable information regarding localization of hydrops in individuals with Meniere's disease.

Keywords: cVEMP, oVEMP, Caloric test, Meniere's disease, Contralateral ear.

INTRODUCTION

Meniere's disease is a complex, multifactorial disorder of the inner ear which is the most common cause of the episodic vertigo along with fluctuating hearing loss [1]. In spite of several investigations, the etiology and pathophysiology of Meniere's disease remain controversial and incompletely understood [1]. In majority of the individuals, Meniere's disease is linked to idiopathic endolymphatic hydrops, which is an abnormal increase in the volume of endolymph in the inner ear [2, 3]. The excessive accumulation of endolymph may be due to altered absorption by the endolymphatic duct and sac [4] or due to increased secretion of the endolymph [5].

The different physiological/electrophysiological tests used to diagnose Meniere's disease includes Electrocohleography (EcochG), Glycerol test, CHAMP (cochlear hydrops analysis by masking paradigm), Caloric tests and Cervical Vestibular evoked myogenic potential (cVEMP). In EcochG test, the SP (summating potential)/AP (Action potential) amplitude as well as area ratio are found to be higher in individuals with Meniere's disease [6-9]. An improvement in hearing threshold was found to be associated with glycerol administration in individuals with Meniere's disease [6, 10-14]. The latency shift of wave V of auditory brainstem response (ABR) for click alone and click plus high pass masking noise is reported to be significantly reduced in individuals with Meniere's disease when compared to non-Meniere's normal hearing individuals [15].

However there are some inherent problems with the above mentioned tests. In EcochG, it has been reported that SP is present in 60% of the total normal hearing individuals [16]. Hence, making a diagnosis based on SP/AP (Action potential) ratio becomes difficult. In CHAMP test, the intensity used to record the responses is 60dB nHL [15] and hence an individual with hearing loss more than mild degree cannot be evaluated using this technique.

cVEMP is another electrophysiology test which has been utilized to assess the integrity of vestibulospinal reflex [17- 19]. Pathway of cVEMP includes the saccular macula, inferior vestibular nerve, the lateral vestibular nucleus, the medial vestibulospinal tract, and the motor neurons of ipsilateral SCM muscle [20]. cVEMP has been used as a part of the test battery for Meniere's disease [21- 23] and there is sufficient amount of evidence accumulated on its sensitivity in identifying individuals with Meniere's disease which ranges from 50% to 67% [24- 26].

*Address correspondence to this author at the Department of Audiology, All India Institute of Speech and Hearing, Mansagangothri, Mysore-06, Karanataka, India; Tel: 08212502579; Fax: 0821-2510515;
E-mail: sujitks5@aiishmysore.in

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Another variant of Vestibular evoked myogenic potentials (VEMP) is the ocular vestibular evoked myogenic potential (oVEMP). oVEMP are likely to be produced by synchronous activity in the extraocular muscles, i.e., myogenic potentials [27]. The neuronal pathway for oVEMP *via* the vestibulo-ocular reflex include, activation of the vestibular nerve, vestibular nucleus, medial longitudinal fasciculus, oculomotor nuclei, ocular nerves and to the contralateral extraocular muscles [28]. oVEMP responses (negative peak at 10 ms and a positive peak around 15 ms) are vestibular in origin and most likely originating from the otolith-ocular pathway [29].

oVEMP responses mainly assess the function of otolith organs and superior vestibular nerve. oVEMP have also been found to very useful in diagnosis of different vestibular disorders such as Meniere's disease, superior canal dehiscence syndrome, BPPV and auditory neuropathy [30- 33].

In the literature, there are few studies which have utilised all the three tests (cVEMP, oVEMP and Calorics) to characterize the findings in individuals with Meniere's disease [33, 30]. However, these studies have mainly discussed the results of the ipsilateral ear and not the contralateral ear. There are other studies which indicate an involvement of the contralateral ear in 31% to 37% of individuals with Meniere's disease based on several other tests [18, 34, 35]. Thus the present study aimed to characterize cVEMP, oVEMP and caloric test findings both in the ipsilateral and contralateral ears in individuals with Meniere's disease. The study also aimed at associating the findings of the three tests in individuals with Meniere's disease.

METHOD

Participants

Two groups of participants were enrolled in the present study, clinical group and the control group. Clinical group consisted of 29 participants (18 males & 11 females) with definite Meniere's disease in the age range of 18 to 55 years (Mean age = 39.25 years). Out of 29 participants, 25 participants had unilateral Meniere's disease and 4 had bilateral Meniere's disease. The diagnosis of definite Meniere's disease was based on symptoms exhibited by the participants and the guidelines proposed by the American Academy of Otolaryngology Head and Neck Surgery [36]. Further the diagnosis was also confirmed by an otolaryngologist.

Control group consisted of 29 aged matched individuals (17 males & 12 females). All the participants in the control group had normal hearing sensitivity with no middle ear pathology. Additionally these participants did not have any vestibular symptoms and any history or presence of any other otological disorders.

Instrumentation and Test Environment

A calibrated two channel GSI-61diagnostic audiometer with TDH – 39 headphones, and B-71 bone vibrator was used for pure tone audiometry. Calibrated GSI TYMPSTAR immitance meter was used for tympanometry and relexometry. Intelligent Hearing system (IHS version 4.3.02) was used for recording auditory brainstem responses (ABR) and air conducted cVEMP. Biologic navigator Pro EP instrument with biologic insert was used for ocular VEMP recording. RMS Medicare ENG instrument was utilised for recording caloric responses. All the audiological tests were conducted in the acoustically treated rooms and noise levels during the testing were within permissible limits [37].

Procedure

A detailed case history was taken for each participant prior to testing. Puretone Air conduction thresholds were obtained from 250Hz to 8000Hz and bone conduction thresholds were determined from 250Hz to 4000Hz at octave frequencies for all the participants. Immittance audiometry was carried out in both ears using a probe tone frequency of 226 Hz. Tympanomery was done initially and then ipsilateral and contralateral acoustic reflex threshold was measured for 500, 1000, 2000, and 4000 Hz stimuli. Uncomfortable loudness level (UCL) was obtained in both ears for air conducted speech stimuli using ascending method. Followed by this, ABR was re-corded for both the ears to rule out any retro cochlear pathology. Two channel ABR recording was done for 100µsec click stimuli at 90 dBnHL with the rarefaction polarity. The repetition rate used was 11.1/sec and 90.1/sec. The responses were filtered between 100 Hz to 3000Hz.

Vestibular Evoked Myogenic Potentials

cVEMP Recording

The participants were instructed to sit straight and turn their head to the opposite side of the ear in which stimulus was presented, so as to activate ipsilateral sternocleidomastoid muscle (SCM), as it gives reliable

and greater amplitude. cVEMP was recorded using 500 Hz tone burst presented at a rate of 5.1/sec using rarefaction polarity. 500 Hz tone burst stimuli was used as the 500 Hz tone burst stimulus gives better amplitude of the cVEMP [38]. The stimuli were presented to the test ear at an intensity of 95 dBnHL using ER – 3A insert ear phones. The responses were recorded for 70 msec post stimulus period along with the 10 msec pre-stimulus period. The recorded responses were then amplified (X 5000) and band pass filtered between 30 to 1500 Hz. The responses were averaged totally for 200 stimuli. Visual feedback system available in the instrument was utilized during the recording in order to ensure that the subjects monitored the tonic electromyogram (EMG) activity of the SCM and maintained it between 100% to 200 %(50µv to 100µv) to obtain optimum responses.

oVEMP Recording

oVEMP was recorded for all the participants with upper gaze. Participants were instructed to maintain the same upper gaze throughout the test run. 500 Hz tone burst was presented at a rate of 5.1/sec using rarefaction polarity. The stimuli were presented monaurally at an intensity of 95 dBnHL to the contralateral ear using ER-3A insert ear phones. 200 stimuli were used for response averaging. The response was analysed for 60 msec post stimulus period. A pre-stimulus period of 10 msec was utilised to record background electrical activity. The recorded electrical responses were amplified (X 5000) and band pass filtered between 1 Hz to 1000 Hz. oVEMP responses were recorded twice in each ear to ensure replicability of the responses.

Caloric Testing

Prior to the testing, ENG equipment was calibrated for each participant using a calibration light bar. All the participants were asked to stop taking anti-vertigo medications 48 hours before the testing. Participants were also asked not to consume alcohol 48 hours before the testing. In caloric test, open loop water irrigation was used to stimulate the horizontal semicircular canal. The temperature selected for warm stimulation was 44^{o} C and temperature for cold stimulation was 30^{o} C. 200ml of fluid was irrigated over a period of 30 secs. The order of irrigation used were, right 44^{o} C, left 44^{o} C, right 30^{o} C, and left 30^{o} C. Recording was done for 3 minutes including the period for which the fluid was irrigated. A rest period of 7 minutes was given between two successive irrigations. The alertness of participants was maintained throughout the test by giving simple arithmetic problems.

The cumulative frequency was chosen as the parameter to be represented on the butterfly chart. The response waves obtained in the 4 conditions were analysed and the cumulative frequency was calculated. In order to calculate it, the recordings were divided into 10sec intervals. The 3 adjacent intervals having the most number of nystagmus beats, as determined by manual calculations in each 10sec interval, were considered. Thus, the cumulative frequency represented the total number of beats present over a 30sec period. The cumulative frequency response was plotted on the Claussen butterfly chart as reported earlier [39- 41].

RESULTS

Test Findings in Control Group

cVEMP Results

cVEMP responses could be recorded in all the participants in the control group. In cVEMP, the latency of P1 and N1 peaks, amplitude of P1-N1 complex and amplitude asymmetry (between the two ears) was analyzed. Descriptive statistics was done to find out mean and standard deviation for P1 and N1 latencies, amplitude of P1-N1 complex, and inter ear amplitude asymmetry for P1-N1 complex. The descriptive results of latency, amplitude of P1-N1 complex and inter-ear amplitude asymmetry for P1-N1 complex for the control group is shown in Table **1**.

Table 1: Mean and Standard Deviation (SD) Values of Latency and Amplitude Measures of cVEMP in Control Group

Parameters	Mean	SD
P1 latency (msec)	15.10	1.24
N1 latency (msec)	22.45	2.05
Amplitude of P1-N1 complex (µv)	40.39	12.66

oVEMP Results

Latency of n1, p1 and n2, peak to peak amplitude of n1-p1 and p1-n2 complex, and inter-ear amplitude asymmetry were analyzed in oVEMP. The oVEMP could be recorded in all the participants of the control group. Descriptive statistics was done to find out the mean and standard deviation of latency and amplitude parameters of oVEMP. Mean and standard deviation of

latency of n1, p1 and n2 and amplitude measures are shown in Table **2**.

Table 2: Mean and Standard Deviation (S.D) Values of Latency and Amplitude Measures of oVEMP in Control Group

Parameters	Mean	Standard deviation
n1 latency (msec)	11.37	0.96
p1 latency (msec)	16.49	0.90
Amplitude of n1-p1 complex (µv)	9.02	6.31
Amplitude of p1-n2 complex (µv)	8.16	5.62

Caloric Test

Bithermal caloric test was recorded from all the subjects in the control group. The culmination frequency was calculated for all the participants in the control group. In control group, the range of culmination frequency of nystagmus in response to different caloric stimulation is shown in Table **3**.

Table 3: Range of Culmination Frequency/30 Seconds for all Four Caloric Stimulation in Control Group.

Caloric stimulation	Range of culmination frequency per 30 seconds
Right warm	22 – 59
Left warm	20 – 70
Right cold	21 – 51
Left cold	22 – 64

Claussen's butterfly chart was made from the culmination frequency obtained from the participants in the control group. Figure **1** shows a butterfly chart obtained from one of the participants in the control group.

Vestibular Findings in Individuals with Meniere's Disease

A total of 29 subjects in the Meniere's disease group were evaluated using the vestibular evoked myogenic potentials (cVEMP and oVEMP) and caloric test. Out of 29 subjects 4 had bilateral pathology whereas 25 had unilateral pathology.

cVEMP Results

cVEMP recordings showed that, out of 33 ears (29 participants) with Meniere's disease, 29 ears had absence of cVEMP responses (87.87%), and remaining four participants the cVEMP recordings were present. Descriptive statistics was done to find out the mean and standard deviations for P1 latency, N1 latency and P1-N1 amplitude for the four subjects in whom the responses were present. The mean latency of P1 peak was 15.16 msec (SD=1.23 msec), the mean latency of N1 peak was 22.68 msec (SD=2.09 msec) and mean amplitude of P1-N1 peak complex was 40.30 µv (SD=12.90). We did not calculate the inter-ear amplitude asymmetry ratio, as in most of the individuals the cVEMP responses were absent. A Kruskal Wallis test was done to find out the significant difference between normal hearing participants and participants with Meniere's disease. Kruskal Wallis test revealed no significant difference for P1 latency between the two groups ($p>0.05$), P1-N1 amplitude complex between the two groups ($p>0.050$, however Kruskal Wallis test showed s significant difference for N1 peak latency between the two groups ($p<0.05$). cVEMP recording of one participant with Meniere's disease is shown in Figure **2**.

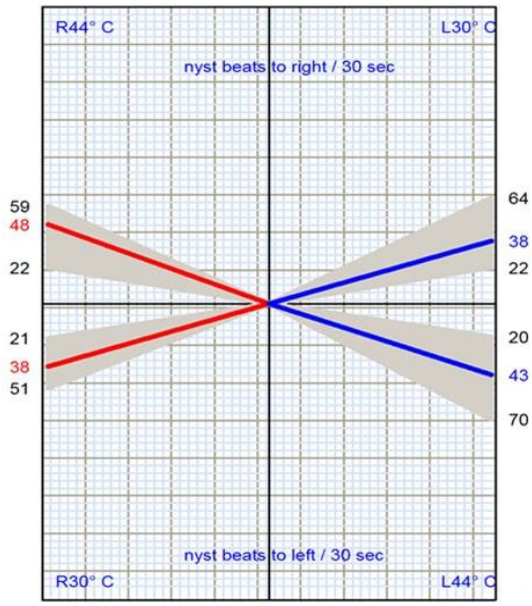

Figure 1: Results of caloric test for one participant in control group as shown in butterfly chart.

oVEMP Results

In oVEMP recordings, out of 33 ears, 23 ears showed absent responses (69.69%) and 10 ears showed present oVEMP response (30.30%). Descriptive statistics was done to find out the mean and standard deviations for the oVEMP parameters for the Meniere's disease participants for whom the responses were present.

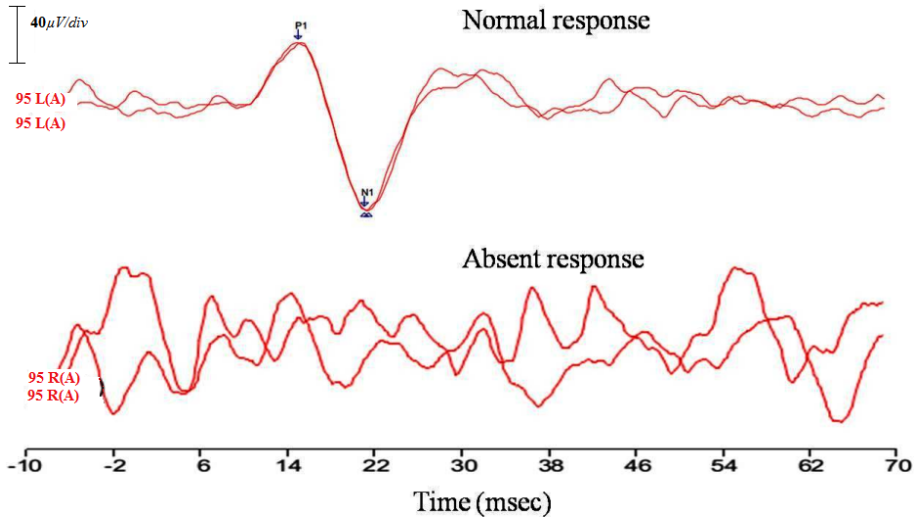

Figure 2: *c*VEMP responses of one participant with right Meniere's disease.

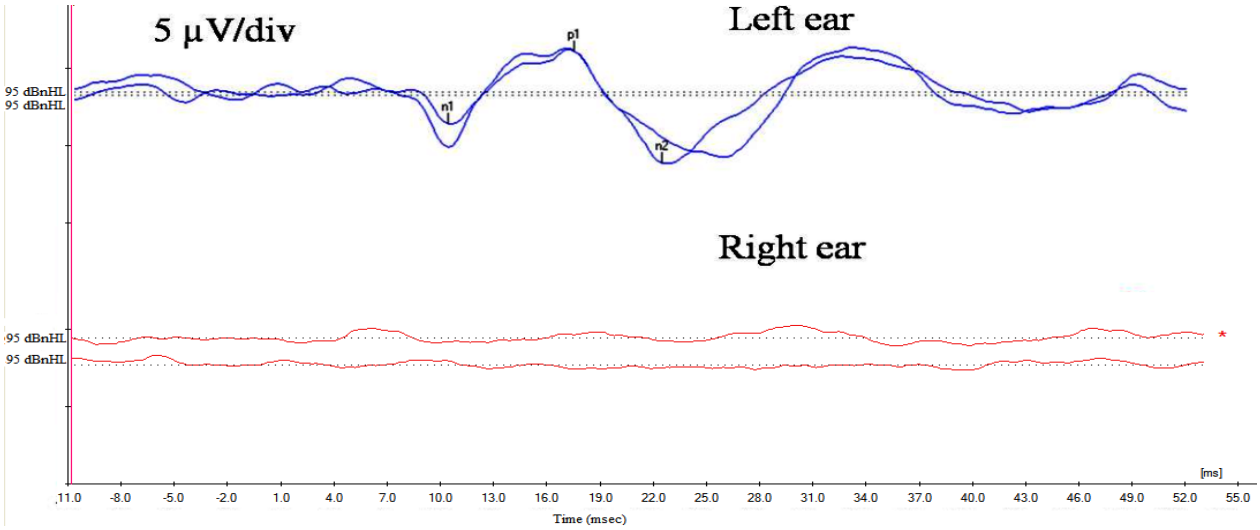

Figure 3: Ovemp response from one of the participants with Meniere's disease. Figure shows presence of oVEMP in left ear and absence of oVEMP in right ear.

The mean latency for n1 peak was 11.50 msec (SD= 0.93), mean latency for p1 peak was 16.57 msec (SD=0.90), mean latency of N2 peak was 21.71 msec (SD=1.67), the mean amplitude of n1-p1 peak complex was 7.86 μv (SD=5.90), whereas the mean amplitude of p1-n2 complex was 7.09 μv (SD= 5.26). Kruskal wallis test was done to determine the significant difference between normal hearing individuals and individuals with Meniere's disease. Kruskal wallis test did not reveal any significant difference for n1 latency, p1 latency and n2 latency between normal and Meniere's disease individuals ($p>0.05$), whereas Kruskal wallis test revealed a significant difference for n1-p1 amplitude complex ($p<0.05$) and also for p1-n2 amplitude complex ($p<0.05$). oVEMP recording of one participant with right Meniere's disease is shown in Figure **3**.

Caloric Test Findings

In caloric test, out of 33 ears with Meniere's disease, hypo activity was noted in 27 affected ear (81.81%), 5 ears showed hyper activity (15.15%) and one ear showed normal response (3.03%) to caloric stimulation. Figure **4** shows butterfly charts of a hypoactive, hyperactive and a normal response.

Association of Caloric Test, cVEMP and oVEMP Results in Affected Ears of Subjects with Meniere's Disease

Out of 33 ears, 22 ears showed (66.67%) abnormal results in both caloric test and oVEMP. None of the ear showed normal findings in both the tests. In 20 ears (60.60%) with Meniere's disease, both oVEMP and cVEMP were absent. One ear (3.03%) showed normal

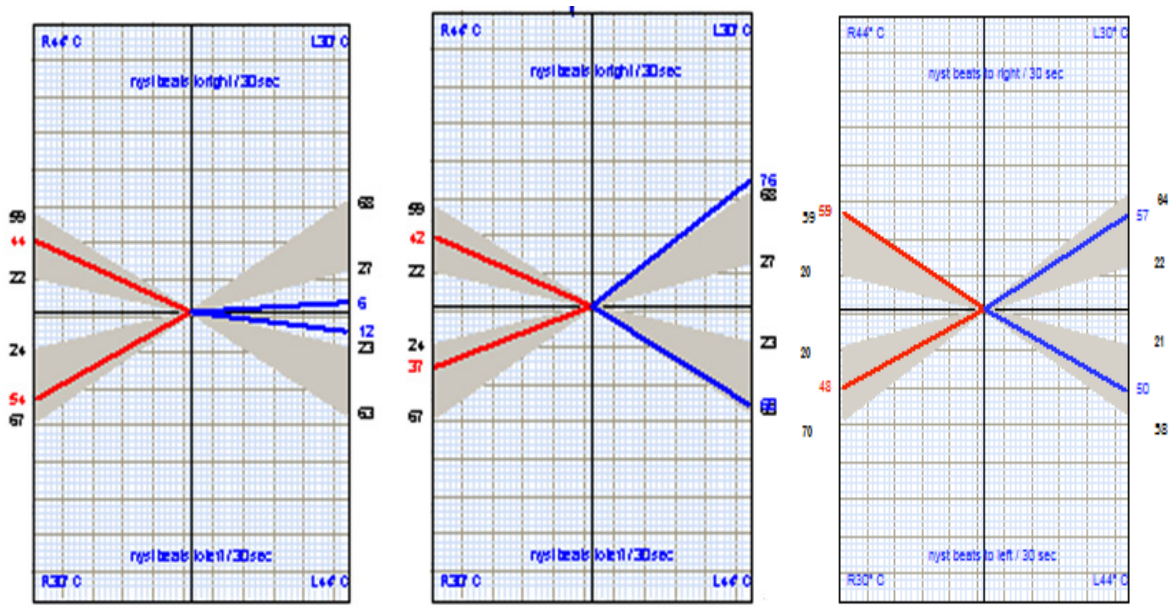

Figure 4: Butterfly chart showing a hypoactive, a hyperactive and a normal response in individuals with Meniere's disease.

response in both the tests. 28 ears showed (84.84%) abnormal results in both caloric test and cVEMP. None of the ear showed normal findings in both the tests.

To find out any significant association between the Calorics tests and cVEMP, Caloric tests and oVEMP, oVEMP and cVEMP responses, a Chi square test was done. Chi-square test revealed no significant association between any of the two tests. Results of chi-square test are shown in Table **4**.

It is evident from the Table **4** that none of the pair of vestibular tests show a significant association between them ($p>0.01$).

Vestibular Findings in Contralateral Ears of Individuals with Meniere's Disease

The intact ears (n=25) of individuals with Meniere's disease, all ears showed normal caloric results. Out of 25 ears, 16 ears had absent responses for cVEMP and 6 ears had absence of responses in oVEMP. Caloric test indicated normal responses in all the contralateral ears considered for the current study. Descriptive statistics was done to find out the mean and standard deviations for the latency and amplitude parameters of the cVEMP and oVEMP and are given in Table **5**.

Kruskal Wallis test was done to find out the significant difference between the cVEMP and oVEMP of Meniere's disease and normal hearing individuals. Kruskal Wallis test results revealed a significant difference for n1 latency of oVEMP ($p<0.05$) and p1n2 amplitude of the oVEMP between normal and Meniere's disease individuals. For rest of the cVEMP and oVEMP parameters, Kruskal Wallis test did not reveal any significant difference between the two groups.

Table 4: Association of Caloric Test, oVEMP and cVEMP in Individuals with Meniere's Disease

Test		oVEMP			cVEMP		
		Normal	Absent	Total	Normal	Absent	Total
Caloric test	Normal	0	1	1	0	4	4
	Absent	10	22	32	1	28	29
	Total	10	23	33	1	32	33
	p value*	0.697			0.879		
cVEMP	Normal	1	3	4			
	Absent	9	20	29			
	Total	10	23	33			
	p value*	0.649					

*Chi-square test.

Table 5: Mean and Standard Deviation (SD) for the Latency and Amplitude Parameters of the cVEMP and oVEMP in the Contralateral Ear

Potentials	Parameters	Mean	SD
cVEMP	P1 Latency (msec)	14.89	1.09
	N1 Latency (msec)	22.14	2.29
	P1-N1 amplitude complex (μv)	39.66	13.01
oVEMP	n1 latency (msec)	12.04	0.75
	p1 latency (msec)	16.39	0.86
	n1-p1 amplitude complex (μv)	5.21	2.39
	p1-n2 amplitude complex (μv)	4.95	2.94

Association of Caloric Test, cVEMP and oVEMP Results in Contralateral Ears of Subjects with Meniere's Disease

To find out any association between the cVEMP, oVEMP and Caloric test in contralateral ears of Meniere's disease a Chi-square test was administered. Chi square test could be administered only between cVEMP and oVEMP and could not be done between caloric test and cVEMP or oVEMP as the responses for caloric test was present normally in all the subject. Results of the Chi-square test are given in Table **6**.

Table 6: Association of cVEMP and oVEMP Results in Contralateral Ears of Individuals with Meniere's Disease

Test		cVEMP		
		Absent	Present	Total
oVEMP	Absent	5	1	6
	Present	13	6	19
	Total	18	7	25
	p value*	0.50		

*Chi-square test.

It can be seen in Table **6** that both cVEMP and oVEMP were absent in 5 of the ears, cVEMP was absent and oVEMP was present in 13 of the ears, cVEMP was present and oVEMP was absent in 1 ear, whereas both cVEMP and oVEMP was present in 6 individuals with Meniere's disease. Chi-square test failed to reveal any significant association between cVEMP and oVEMP results in unaffected ears of individuals with Meniere's disease.

DISCUSSION

In the present study, cVEMP responses were absent in 87.87 % of the participants with Meniere's disease whereas, in 69.69% individuals with Meniere's disease the oVEMP responses were absent. In the literature there have been equivocal findings regarding the presence or absence of cVEMP in participants with Meniere's disease. De Waele *et al*. [25] have reported a 54% positive rates on cVEMP Murofushi *et al*. [17] reported 65% positive rate whereas, Young and groups [42] reported 88% detection rates in cVEMP for individuals with Meniere's disease. Huang *et al*. [43] reported absence of oVEMP in 44% of the Meniere's disease, whereas, Murofushi *et al*. [33] reported absence of oVEMP in 50% of the cases with Meniere's disease. Also, Chivarovano *et al*. [30] reported absence of oVEMP in 70% of the cases with Meniere's disease. The differences in different study might be due to the different stage of Meniere's disease. In the early Meniere's disease the VEMP might be present but might disappear at a later stage [42]. All the participants in the present study were diagnosed as having definite Meniere's disease. We assume that all the participants of this study were in the later stage of Meniere's disease.

In this study, the percentage of absence of cervical VEMP was more compared to the ocular VEMP in individuals with Meniere's disease. In individuals with Meniere's disease, during the latent period, ocular VEMP and cervical VEMP could be affected. Katayama *et al*. [44] showed with previous MRI data that endolymphatic hydrops distension in the vestibule has a large effect on the cervical VEMP. Here, the present data also showed that cervical VEMP were more frequently absent than occular VEMP, suggesting that sacular function could be more affected than the utricular function in individuals with Meniere's diseases.

None of the subject with Meniere's disease showed prolonged latency of either cVEMP or oVEMP. Only latency of N1 peak of the cervical VEMP was prolonged for normal hearing individuals compared to the individuals with Meniere's disease. It has been reported that the latency is not affected by saccular or utricular pathology as a result of Meniere's disease as changes in latency are thought to arise from changes in the neural conduction pathways of the sacculo-collic reflex pathway for the cervical VEMP [23] or utricular ocular pathway for oVEMP [30]. However, a neural delay at the level of the receptor organ may contribute to changes in response latency. Studies by Young *et al*. [42], Murofushi *et al*. [17] and Ochi *et al*. [45] have confirmed this and determined that VEMP latency measures are stable in Meniere's disease. Evidence from the cVEMP & oVEMP data in this study supports

this theory. The prolongation of N1 peak alone could just be a chance factor.

Hypo activity to caloric stimulation in the affected ear was the most common finding in the present study, which is similar to the studies reported in the literature [46]. In the present study, 27 out of 33 affected ears (81.81%) showed hypo activity in caloric test. Hypo activity in caloric response could be due to the damage to the hair cells in the horizontal semicircular canal [33]. Five out of 33 ears diagnosed with Meniere's disease had hyperactive responses. The hyperactive caloric responses in patients who suffer from Meniere's disease may be a transient phenomenon, caused by fluctuations of the vestibular condition, central compensation, age and/or mental state of the patients [47].

Other significant results were obtained in the contralateral ears of the individuals with Meniere's disease. In the contralateral ears (n=25) of the individuals with Meniere's disease cVEMP and oVEMP were absent in 5 of the ears, cVEMP was absent and oVEMP was present in 13 of the ears, cVEMP was present and oVEMP was absent in 1 ear, whereas both cVEMP and oVEMP was present in 6 individuals with Meniere's disease. However, the caloric test showed a normal test results in the contralateral ears of individuals with Meniere's disease. Studies in the literature showed that second ear involvement in individuals with unilateral Meniere's disease was seen in 31% to 37% of cases [34, 35]. Study by Lin *et al*. [18] found that 27% of participants with unilateral Meniere's disease showed abnormal cVEMP responses in the contralateral ear, which is similar to the present study [18].

Histopathological studies of temporal bones of individuals with Meniere's disease showed that hydrops were more common in saccule and utricle compared to the semicircular canal [48] so it can be concluded that, abnormal cVEMP or oVEMP responses may precede the symptoms in the contralateral ear, so VEMP (cVEMP and oVEMP) responses can be used to predict the chances of involvement of contralateral ear in individuals with Meniere's disease.

In the present study, no statistically significant association between caloric test, cVEMP and oVEMP could be obtained. Significant association only between caloric and oVEMP results, not between caloric and cVEMP or between oVEMP and cVEMP have been reported in peripheral vestibular disorder [33]. It can be hypothesised that the three tests assesses different pathways and extent to which these pathways are affected might vary and hence there might not be any association between the three test results. However, combining caloric test, oVEMP and cVEMP may provide localization of site of lesion in the vestibular labyrinth in affected as well as unaffected ears.

CONCLUSIONS

Caloric test, cVEMP and oVEMP mainly assess the functioning of semi circular canal ocular reflex pathway, sacculo-collic pathway and utriculo-ocular reflex pathway respectively. In vestibular dysfunction, one or more reflex pathways are affected. The combination of cVEMP, oVEMP and caloric test, provides valuable information regarding the involvement of saccular, utricular and semicircular canal involvement in individuals with Meniere's disease. Also, the cVEMP and oVEMP can provide useful information about the involvement of unaffected ears in individuals with Meniere's disease.

CONFLICT OF INTEREST

The authors report no conflict of interests.

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