Vestibular Evoked Myogenic Potentials in Normals and in Individuals with Dizziness

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Abstract

The present study aimed at investigating VEMP in individuals with or without dizziness for click at 99 dBnHL and STB at 99 dBnHL and 105 dBnHL. Control group was divided into two subgroups, A and B. ABR test was carried out to check for the space occupying lesion. Results showed that p12 and n23 latency and peak to peak amplitude was approximately the same in group A and group B. As the intensity increased the peak to peak amplitude increased but the latency remained constant in both control and experimental group. Compared to normal group the experimental group subjects had prolonged mean latency and reduced peak-to-peak amplitude. It was observed that latencies with STB VEMP were longer than click evoked VEMP. Further, STB VEMP amplitude was longer than that of click evoked VEMP. The difference in response elecited by 105 dBnHL STB and 99 dBnHL STB or 99 dBnHL clicks was negligible in normals. The subjects who showed signs of vestibular symptoms such as "objects spinning or turning around you" showed either absent or abnormal VEMP responses. From the results it can be concluded that there will not be any change in VEMPs in age from 21 to 40 year. STB can be used at maximum intensity to check for VEMPs as the percentage of VEMP response increased from 94% to approximately 97% from 99 dBnHL to 105 dBnHl in normals. It can also be concluded that abnormal VEMPs can be associated with symptoms such as objects spinning or turning around, tendency to fall, loss of balance when walking and nausea or vomiting. Thus, it can be concluded that the subjects who complain these symptoms are likely to have saccular pathway lesion.

Introduction

Vestibular Evoked Myogenic Potentials (VEMPs) were first described by Bickford, Jacobson and Cody (1964) and recently have been proposed as a reliable clinical test of saccular /inferior vestibular nerve function (Cloebatch, 2001). VEMPs are short latency electromyogram (EMG) that are evoked by higher level acoustic stimuli and are recorded from surface electrodes over the tonically contracted sternocleidomastiod (SCM) muscle. The neurophysiological and clinical data indicate that the VEMPs are mediated by a pathway that includes the saccular macula, inferior vestibular nerve, the lateral vestibular nucleus, the lateral vestibulospinal tract and the motorneurons of the ipsilateral SCM muscle (Halmagyi & Curthoys, 2000).

Normal VEMP responses are characterized by biphasic (positive–negative) waves. In a majority of studies the peaks and troughs are usually labeled with the mean latency in milliseconds preceded by the lower case letters 'p' for positive or 'n' for negative, as proposed by Yoshie and Okodaira (1969) to distinguish them from neurally generated evoked potentials.

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The first positive-negative complex is often labeled as p13-n23. Robertson and Ireland (1995) found the second wave complex (n34-p44) to be present in 68% of their participants.

In recent past VEMP has been used as a diagnostic tool to identify the involvement of secular pathway in various diseases. Ribeiro, Almeida, Caovilla, and Gananca (2005) investigated that VEMPs were altered in 35% of the affected ears and in 25% of the asymptomatic ears in Meniere's disease. Study concluded that VEMPs could present abnormalities in the affected and asymptomatic ears in patients with diagnosis of unilaterally defined Meniere's disease. VEMPs in patients with Meniers disease and reported that 54% of the patients had no VEMPs when clicks were used as stimuli (De Waele, Huy, Diard, Freyss & Vidal 1999).

Need for the study

It has been reported in literature that VEMP can be false positive or false negative. Click sensitive vestibular hair cell might differ from short duration tone burst (STB) sensitive vestibular hair cell. Therefore, it is better to use two kinds of stimuli to confirm the result of sound evoked potential on SCM (Murofushi, Matsuzaki & Chih-Hsiu; 1999). Also VEMP is the recent tool in the field of audiology to find out the cause for vertigo. However, there are a few studies on this to know the effectiveness of VEMP to identify the lesion. Hence, many more such findings in different clinical population might highlight its effectiveness. It is also necessary to have norms to compare the results obtained in clinical population. So there is need to establish the norms for two stimuli click and short duration tone burst to know which should be the better stimuli to evoke VEMP response. Further, muscle artifact can contaminate the VEMP response. However, latency of muscle artifact is approximately 50 msec, which is different from VEMP latency. However, one must be clear as to how frequent one can set false positive response and ways to avoid or cross check the false positive responses. There is no study which finds one to one correlation between the type or symptoms related to dizziness and VEMP response. Thus, an attempt has to be made to find out the relationship between VEPM response and type of symptoms related to dizziness. VEMP provides important diagnostic information as the functioning of vestibular system can be simultaneously recorded without additional preparation while ABR is administered (Debatisse, Pralong, Guerit & Bisdorff, 2005). Hence, more extensive studies are required on clinical population.

Aims of the study are to find out:

1. age related changes of VEMP response in normal hearing subjects without dizziness
2. effect of intensity on VEMP responses in healthier subjects and subjects with dizziness for Short duration Tone Burst (STB)
3. comparison of VEMP responses obtained in control and experimental group
4. specificity of VEMP responses in subject with normal hearing without dizziness
5. association of VEMP responses with different symptoms of dizziness

Method

The subjects were divided into two groups, control group and experimental group. Control group was further divided into two subgroups on the basis of age, Group A (21-30year) and Group B (31-40year). 30 subjects consisting of 15 male & 15 female participated in each group. The experimental group included 25 subjects in the age range from 20-40 years.

Selection criteria

Group 1(control group): All the subjects had hearing sensitivity within 15 dBHL at frequencies from 250 to 8000 Hz with 'A' type tympanogram and normal reflexes in both ears. Uncomfortable levels (UCL) for speech for all the subjects were greater than 105 dBHL.

Group II (experimental group): The subjects were having either normal hearing or sensory neural hearing loss with air-bone gap not exceeding 10 dBHL. Immittance measurements showed 'A' type tympanogram with presence, elevated or absence of reflexes in both ears. None of them reported to have hypo or hypertension or spondylitis and did not have any evidence of space occupying lesion (decided based on auditory brainstem response results and neurologist report). All the subjects had to have complaint of dizziness. They had UCL (uncomfortable level) greater than 105 dBHL.

Instrumentation

Calibrated diagnostic audiometer was used to estimate the pure tone threshold and UCL for speech for all the subjects for both air and bone conduction. Calibrated middle ear analyzer GSI-Tympstar was used for tympanometry and reflexometry. IHS Smart EP version: 3140 (Intelligent hearing systems, Florida, USA) was used to record and analyze ABRs and VEMP.

Procedure

Pure tone threshold was obtained using modified version of Hughson and Westlake procedure (Carhart & Jerger, 1959, cited in Silman & Silverman, 1991). To determine the uncomfortable loudness level (UCL) of the subjects the speech material was presented through the headphone (TDH-39) at different intensities using ascending method. Tympanometry and reflexometry were carried out to know the status of the middle ear in all subjects. A part of dizziness questionnaire, a checklist described by Maryland Hearing and Balance Center was administered.

ABR was administered on experimental group to rule out space occupying lesion. VEMP recordings were done during seated upright position and instructed to turn their heads to opposite side of the test ear to activate unilaterally the sternocleidomastoid muscle (SCM). They were also asked to close their eyes to avoid extraneous movements of head, neck and jaw while recording the VEMP.

Two types of stimuli, short duration tone bursts and clicks were used. Tone burst VEMPs were recorded at 99 dBnHL and 105 dBnHL intensities and click stimulus at 99 dBnHL. VEMP was also recorded at 70 dBnHL to check for muscle artifact. For each subject VEMP latency and peak-to-peak amplitude of p13 and n23 were recorded.

Table 1: The parameters used to record VEMP

Analysis time	120msec
Filter setting	High pass: - 30Hz Low pass: - 1500Hz
Amplification	30,000
Type of stimulus	500Hz tone burst with 2-cycle rise/fall time and 0.1msec. Click.
Rate	5/sec
Polarity	Rarefaction
Total number of stimulus	250
Electrode montage	Non-inverting electrode (+): -mid point of the sternocleidomastoid muscle of the side being stimulated. Inverting electrode (-): - sternoclavicular junction. Ground electrode: - forehead.

Results and Discussion

1. Age related changes on VEMPs in subject with normal hearing without dizziness: It was observed that the p13 and n23 latency and peak-to-peak amplitude were approximately same. The variability in latency and amplitude for both the peaks were also very negligible. Independent sample t-test revealed no significant difference in VEMP responses for both latency and amplitude across the group except at the amplitude obtained at 105 dBnHL for STB stimuli. Similar findings were also reported by Su, Haung, young and Cheng (2004) and Welgampola and Colebatch (2001). They also did not find any significant difference in the age range from 21-40 years and as age increased over 60 years the response rate decreased dramatically showing that there is significant difference in amplitude as the age increase over 60 years. These changes are probably due to morphological changes occurring in the vestibular system and corresponding change in neural function. Hence, significant changes could not be observed in the present study.

There was significant difference in peak-to-peak amplitude at 105 dBnHL for STB in the two age groups in the present study. This might be due to chance factor or may be due to inability to keep the tonic muscle contraction constant. Thus, the present study suggests that there will not be any significant changes in VEMP test results in normal individuals who do not have symptoms of dizziness, within the age between 21 to 40 years. The latency, peak-to-peak amplitude value obtained in the two subgroups of control group did not differ significantly. Thus, data obtained in two subgroups were combined for the development of norms.

Table 2: Mean, SD and range of VEMP latency and peak-to-peak amplitude in control group (Group A & Group B together)

VEMP parameters	**Intensity (dBnHL)**	**Range**	**Mean**	**SD**
P13	105 (STB)	11.90-17.00	13.6020	1.0301
P13	99 (STB)	11.20-17.40	13.5712	1.0913
P13	99 (click)	9.80-15.20	11.5450	1.0758
N23	105 (STB)	16.20-26.80	21.8014	1.9184
N23	99 (STB)	16.20-26.00	21.3528	2.1244
N23	99 (click)	14.00-27.00	19.2032	2.2640
PP	105 (STB)	7.17-105.20	32.6154	17.3838
PP	99 (STB)	7.20-90.00	25.6209	15.4465
PP	99 (click)	7.80-65.00	21.6777	11.0327

STB- short duration tone burst; C - click; P13 and n23 - latency; PP - peak to peak amplitude

2. Effect of intensity on VEMPs in control and experimental group for STB: It can be seen in table 3; the mean p13 latency is same at 105 dBnHL and 99 dBnHL. For n23 latency there is slight difference in mean values and peak-to-peak amplitude at 105 dBnHL when compared to 99 dBnHL. Standard deviation is less for latency p13 and n23; however the variance of peak-to-peak amplitude is more for both 99 dBnHL and 105 dBnHL. In control group from the "t" values of independent sample t-test it can be inferred that there is no significant difference in VEMPs for p13 latency. Statistically significant difference in VEMPs for n23 latency and peak-to-peak amplitude between 99 dBnHL and 105 dBnHL were obtained. As can be seen in table 3, in experimental group there is no significant difference in VEMPs response at p13 and n23 latency. However, there is significant difference in VEMP results for peak-to-peak amplitude.

Table 3: Mean, SD and "t" value of VEMPs at 105 dBnHL and 99 dBnHL in control and experimental group for STB

Pair		Intensity (dBnHL)	Control			Experimental		
			Mean	Standard deviation	t-value	Mean	Standard deviation	t-value
1	P13	105	13.5792	1.0258	.117	14.5521	1.6165	1.660
		99	13.5712	1.0913		14.2864	1.7690	
2	N23	105	21.7873	1.9404	4.015*	22.5543	1.5381	1.354
		99	21.3528	2.1244		22.1929	2.0544	
3	pp	105	33.1250	17.3052	6.923*	32.3025	14.0870	6.608*
		99	25.6209	15.4465		22.4821	10.1787	

In the present study there was a significant difference for n23 latency at 99 dBnHL and 105 dBnHL in subject with normal hearing without dizziness. Significant difference in n23 latency could be due to chance factor. This study also supports the results obtained by Akin, Murnane and Profitt (2003); Colebatch, Halmagyi and Skuse (1994); Lim, Closton, Sheean, and Yiannikas (1995) and Ochi, Ohashi and Nishino (2001). They had reported that as the level of the click increased there is a corresponding increase in the level of the VEMP amplitude; however the VEMP latency p13 and n23 did not vary as a function of intensity level after the change in intensity level. The present study result could suggest that at the higher level from 99 dBnHL to 105 dBnHL the saccule pathway reaches the plateau, which could have resulted in no change in p13 and n23 latency.

3. Comparison of VEMP responses in control and experimental group and for STB and click evoked VEMPs: It was observed that there is a mean difference for p13 and n23 latency and peak-to-peak amplitude of control group than that of experimental group. Compared to normal groups the experimental groups had prolonged mean latency for p13 and n23 latency. Peak to peak amplitudes were slightly reduced in experimental group compared to control group at both 105 dBnHL and 99 dBnHL for STB and 99 dBnHL for click. The standard deviation values reveal less variability. From the "t" values of independent sample t- test of statistical significance, it can be inferred that there is significant difference in VEMP responses in normal hearing subjects without dizziness and subjects with dizziness for latencies P13 and n23 for STB at two different levels (99 dBnHL & 105 dBnHL), as well as for clicks at 99 dBnHL. There was no significant difference for peak-to-peak amplitudes at both the intensity levels (105 dBnHL & 99 dBnHL) for STB as well as clicks at 99 dBnHL in both control and experimental group.

The results of the present study are in contrary to the study by Cheng et al, 2003 where they reported that the peak-to-peak amplitude for click evoked VEMP were larger than the tone burst VEMP. The difference between the two studies may be due to the difference in contraction of the sternocleidomastoid muscle of the subjects. In the present study there was a significant difference between control group and experimental group for mean latency and the amplitude. The mean latency was prolonged in the experimental group compared to control group for both STB and click evoked VEMP. This might be due to the lesion in the saccula or in the saccular pathway, resulting in abnormal VEMP for both STB and click evoked-VEMP.

In the present study there was a significant difference between the latency of tone burst and click evoked VEMP. The latencies with tone burst VEMP are longer than the click evoked VEMP. The findings of the present study are consistent with that of Cheng, Huang, and Young (2003). The delay in latencies may be attributed to the different firing patterns of the vestibular neurons to the tone burst. It has been reported that the primary vestibular neurons might have double or triple firing to one tone burst hence, the delayed latency of tone burst evoked-VEMP might be due to the second or third spikes (Cheng & Murofushi, 2001b). Further, tone burst VEMP amplitudes were larger than that of click evoked-VEMP, when comparisons were made at equal SPL. The observed differences between the STB VEMP and Click evoked-VEMP may be due to the differences in stimulus spectrum level. When comparisons are made at equal peak SPL, the click has a lower spectrum level than the tone bursts due to its wider bandwidth (Akin, Murnane & Proffittm, 2003).

4. Descriptive analysis of VEMP responses obtained in control and experimental group: It is evident from the table 4 that percentage of VEMP responses elicited in control group is higher for tone burst at 105 dBnHL compared to 99 dBnHL for STB and click stimuli. The elicited response rate was higher for clicks compared to STB at 99 dBnHL. However, the difference in response elicited by 105 dBnHL STB and 99 dBnHL STB or 99 dBnHL clicks were negligible.

Table 4: Number of ears and % VEMP responses in normal hearing subjects without dizziness

Stimuli	Intensity level (dBnHL)	Total no. Of ear	Present VEMP response	Response rate (%)
Short duration tone burst	105	120	116	96.66
	99	120	114	94.16
Click	99	120	115	95

In the experimental group 30 ears were having either absent or abnormal VEMPs at 99 dBnHL out of 50 ears. The same results were consistent for both clicks and STB i.e. when VEMP was absent or abnormal it was absent or abnormal for both STB and clicks.

Table 5: Number of ears and percentage of VEMP responses elicited in subject with dizziness

Stimulus	Intensity level (dBnHL)	Total No. of ear	Present VEMP response (No. of ear)	Percentage (%) of VEMPs
Short tone burst	105	50	23	46
	99	50	18	36
Click	99	50	30	40

It is evident from table 5 that VEMP response was higher at the 105 dBnHL compared to 99 dBnHL for STB stimuli in subject with dizziness. Click is having slightly higher response rate

compared to STB at 99 dBnHL. However, when comparison was made at 105 dBnHL for STB and 99 dBnHL for click, it was observed that STB had higher response rate in subject with dizziness.

Cheng, Huang and young (2003) had reported that click stimulation produced 98% VEMP responses whereas STB-VEMP produced 88% positive responses at 95 dBnHL. From this study it can be concluded that the sensitivity of VEMP is higher for click than the STB. Previous reports demonstrated that 34 affected ears of vestibulocochlear disorders revealing same 88% VEMP response rates with STBs and clicks (Murofushi, Matsuzaki & Wu, 1999). As the VEMP responses eliciting rate at the higher intensity level is approximately same for both STB and click stimuli, either STB or click stimuli can be used to elicit the VEMP response at higher intensity. However, the maximum level at which click can be presented is less compared to STB. Thus, STB can be used to elicit VEMP due to its dynamic range.

It was observed that some of the subjects had noisy VEMP response or very less amplitude which could not be taken as response. Hence, to check the VEMP response it is necessary to check with lower intensity where the VEMP response usually is absent to ensure that the responses obtained were not due to muscle artifact.

5. Symptoms related VEMPs in subjects with dizziness: A part of dizziness questionnaire developed at Maryland hearing and balance center was administered to subjects with dizziness to find the symptoms related VEMPs. There were two major symptoms observed in subject with dizziness like "objects spinning or turning around you and sensation that you are turning or spinning inside". Either one of the symptoms always present in subjects with dizziness among all the symptoms were taken into consideration. It is observed that subjects who reported symptoms of "objects spinning or turning around you" showed either absent or abnormal VEMP response in 76.47% of subjects. However, subject who had symptoms of "sensation that you are turning or spinning inside" showed either absent or abnormal VEMP response in 23.52% of subjects. It was observed that 62.50% subjects reported as having symptoms of "sensation that you are turning or spinning inside" had normal VEMP response while 37.50% of the subjects who complained of symptom of "objects spinning or turning around you" had normal VEMP.

It was observed that the subjects who had symptoms of "objects spinning or turning around you" most often had other symptoms associated as nausea or vomiting, tendency to fall and loss of balance while walking. Hence, all these symptoms also showed higher percentage of either absent or abnormal VEMP response. One of the other symptoms "loss of balance when walking" had 32% absent or abnormal VEMP responses. When VEMP response was absent most often, the symptoms of "sensation that you are turning or spinning inside" was associated with headache and pressure in the head. When VEMP response was present most often, the symptoms "sensation that you are turning or spinning inside" was associated with blacking out or loss of consciousness and lightheadedness or swimming sensation in the head. Hence, it can be concluded that one can expect absent or abnormal VEMP responses when the individual has symptoms of "objects spinning or turning around you", which might indicate abnormality in Saccular pathway.

However, this can be concluding that this symptom produces realistic VEMP. Interesting point is that most of the subjects who reported tendency to fall, nausea or vomiting and loss of

balance when walking have also reported of "objects spinning or turning around you", which are more commonly associated with Meniere's disease.

Table 6: Descriptive analysis of VEMPs based on symptoms

Symptoms	No. of subject having absent or prolonged VEMPs	Total No. of subject having absent or abnormal VEMP	% of subjects having abnormal VEMPs
Lightheadedness or swimming sensation in the head	3	17	17.64
Blacking out or loss of consciousness	4	17	23.35
Tendency to fall	6	17	35.29
Objects spinning or turning around you	13	17	76.64
Sensation that you are turning or spinning inside	4	17	23.52
Loss of balance when walking	8	17	47.05
Headache	5	17	29.41
Pressure in the head	4	17	23.35
Nausea or vomiting	6	17	35.29

In Meinere's disease, nausea or vomiting is a major complaint. Ribeiro, Almeida, Caovilla and Ganan, (2005) reported altered VEMP in 35% of the affected ears and in 25% of the asymptomatic ears in Meinere's diseases. Absence of biphasic VEMP wave in 40 to 50% of Meniere's disease clients has been reported by Waele, Huy, Diard, Fressy and Vidal (1999); Murofushi, Matsuzaki and Takeghoshi (2001b); Seo, Node, Yukimasa and Sakagami (2003); Shojaku, Takemori, Kobayashi and Wantanable (2001) and Young, Haung, and Cheng (2003).

From the present study it can be suspected that if the dizziness patients show the symptoms of "objects spinning or turning around you, tendency to fall, loss of balance when walking and nausea or vomiting", they may have the lesion in the Saccular pathway.

One of the other symptoms "sensations that you are turning or spinning inside" has less percentage of abnormal VEMP response. Those who had complained of "sensation that you are turning or spinning inside" most often had associated symptoms of lightheadedness or swimming sensation in the head and pressure in the head. Thus, it can be concluded that individual having such symptoms may not have any Saccular impairment

Summary and Conclusions

There was no significant difference in VEMP responses at two age groups i.e. between 21 to 30 and 31 to 40 years for both stimuli across all the intensity levels. As the intensity level of STB was increased from 99 dBnHL to 105 dBnHL there was increase in peak-to-peak amplitude. However, there was no change in p13 and n23 latency. It was observed in both control and experimental group. Experimental group showed prolonged latency of p13 and n23 and reduced peak-to-peak amplitude compared to control group. It was also observed that click is having

shorter latency and shorter amplitude as compared to STB. At the higher intensity levels the VEMP response rates were higher compared to threshold level of VEMP. The incidence of abnormal VEMPs were more in subjects who complained "objects spinning or turning around you" tendency to fall, loss of balance when walking and nausea or vomiting.

Thus, it can be concluded that there will not be any change in VEMPs in age from 21 to 40 years. Click evoked VEMPs were likely to have shorter latency and reduced amplitude than STB evoked VEMPs at same dBnHL. However, the maximum limit can be present for STB is higher than the click. Thus, STB can be used at maximum intensity to check for VEMPs as the percentage of VEMP response increased from 94% to approximately 97% from 99 dBnHL to 105 dBnHl in normals. It can also be concluded that abnormal VEMPs can be associated with symptoms of "objects spinning or turning around you, tendency to fall, loss of balance when walking and nausea or vomiting". Thus, it can be concluded that the subjects who complained of these symptoms are likely to have Saccular pathway lesion.

Implication

1. Norms established could be used to compare the data obtained in clinical population.
2. It also highlights the symptoms are more likely to be associated with abnormal VEMP which in turn can suggest the possible site of lesion.

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