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Vestibular Evoked Myogenic Potential Response in Acquired Sensory Neural Hearing Loss

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Abstract:
Vestibular evoked myogenic potentials (VEMP) are widely used for assessment of vestibular function in individuals with balance disorders. However it is possible that hearing loss, if present, may affect the vestibular response. Hence, there is a need to understand the effect of various degrees of hearing loss on VEMP. Thus the present study was carried out to investigate the effects of degree of sensori-neural hearing loss on VEMP.A total of 31 individuals with hearing loss between 18 and 65 years participated in the study, and they were clustered in to four groups based on degree of hearing loss. VEMP was recorded from all the individuals using click at 95 dB nHL from both the ears. The result showed reduction in the amplitude of p1-n1 among individuals with hearing impairment however the reduction was not statistically significant across the groups. We conclude that degree of hearing loss may not be a significant factor in assessment of vestibular disorders using VEMP.

Key words: *Degree of hearing loss, Hearing impairment, cVEMP*

1. Introduction

The vestibular evoked myogenic potential (VEMP)can be measured as a small change in the muscle tone that occurs in response to an intense, transient acoustic stimulus(Akin & Murnane, 2001; Zhou & Cox, 2004).The sensitivity of the vestibular system to intense acoustic stimulation is well established and was first described by Bickford, Jacobson, & Cody(1964).VEMP can be recorded by measuring EMG responses of the sternocleidomastoid (SCM) muscle evoked by intense stimuli, such as clicks(Colebatch, Halmagyi& Skuse, 1994).Recently, ithas been proposed as are liable clinical tool to assess saccule, inferior vestibular nerve and descending vestibulospinal pathway(Colebatch, 2001).A normal VEMP is characterized by series of biphasic (positive – negative) waves, p1, n1, p2 and n2. In normal hearing individuals the first and second components (p1&n1)represent ipsilateral response to unilateral stimulation, whereas, the third and fourth components(n2&p2)reflect bilateral response for unilateral stimulation. In presence of sensorineural hearing loss usually p1&n1 are present or elicited whilen2&p2 are absent, but in presence of vestibular dysfunctionp1& n1peaks are not elicited or absent, indicate the origin of the peak from the vestibular system, however later response n2&p2peaks did not depend on the integrity of vestibular system as most likely to arises from the cochlea (Colebatch et al., 1994).

The development of the inner ear is a complex process that starts at the beginning of the fourth week and is completed by 25 weeks, and by that time even vestibular apparatus also achieves adult form and size (O'Rahilly, 1963).The cochlea and the vestibular apparatus are in close proximity to each other not only anatomically but also in terms of embryologic and physiologic interactions. In both systems, the sensory epithelium is contained of mechanoreceptors hair cells whose stereocilia are embedded in an overlying layer. The variation between the systems exists only in the nature of the overlying layer (i.e. basilar membrane vs. otoconia) and the organization of the hair cells within the sensory epithelium (organ of corti vs.macula vs. cupula).Since both auditory and vestibular structures of the inner ear are derived in a similar manner embryologically and they share the similar fluid environment. It is possible that a disorder of one may normally include a disorder of the other. This assumption is further strengthened based on the studies in

children with hearing impairment, which indicate a higher frequency of vestibular dysfunction (up to 80%) among children with severe hearing impairment(Arnvig, 1955; Brookhouser, Cyr, & Beauchaine, 1982; Potter & Silverman, 1984; Sandberg & Terkildsen, 1965; Selz, Girardi, Konrad, & Hughes, 1996).Kumar, Vivarthiniand Bhat(2010)investigated the effect of noise exposure on VEMPs among individuals with noise induced hearing loss. The results showed that with increase in degree of hearing loss, the VEMP latencies were prolonged and the peak to peak amplitude was reduced among individuals with noise induced hearing loss. Thus, it is also possible that various degrees of hearing loss might also have an impact on VEMPs. By keeping these facts in mind, the present study was carried out with an aim to investigate the effects of degree of sensorineural hearing loss (SNHL) on VEMP.

2. Methods

2.1. Participants

The present research was conducted at the Department of Audiology and Speech Language Pathology of Kasturba Medical College, Mangalore between March 2012 and February 2013. All the tests were conducted in acoustically treated room with permissible noise levels as per ANSI S3.1. A total of 31 individuals between 18 and 65 years participated in the present study. They were divided into control and experimental groups. The control group(Group I) comprised of nine individual sin the age range of 18 to 26 years (mean =21.6) with normal hearing in both ears (pure tone thresholds less than 15 dB HL for the octave frequencies of 250 to 8000 Hz). In addition, all the individuals had 'A' type tympanogram with acoustic reflexes present at normal levels in both ears indicating normal middle ear function, and uncomfortable levels (UCL) for speech was greater than 100 dB HL. The experimental group included22individuals with acquired SNHL and were further sub-divided into three groups (Group II, Group III and Group IV) based on the degree of hearing loss. Group II included nine individuals with mild SNHL between 45 and 61 years (mean = 54.4 years) and the pure-tone thresholds ranged between 25 dB HL and 40 dB HL. Group III involved seven individuals between 42 and 55 years (mean =48.5 years) with moderate SNHL, and had pure-tone thresholds between 40 and 55dB HL. Similarly, group IV comprised of six individuals with moderately severe SNHL, having pure-tone threshold between 55 and 70 dB HL. The mean age was 48.5 years which ranged between 31 and 63 years. All the participants in the experimental groups also had 'A' type tympanogram with acoustic reflex present at normal or elevated levels, or absent. None of the participants had complaint or history of giddiness, vertigo or balance related problems. All the individuals willingly participated in this study and an informed consent was obtained prior to the VEMP assessment.

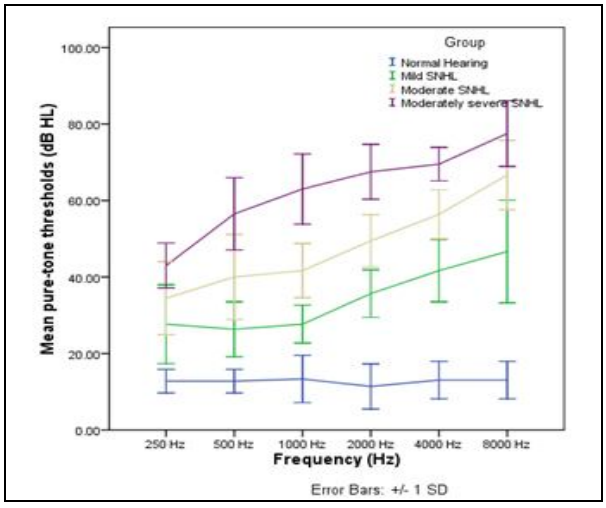

Figure 1: Shows mean thresholds across the frequencies for all the participants.

3. Procedure

3.1. Vestibular evoked myogenic potential

VEMP was recorded from all the participants in the present study in a position ofhead flex approximately 30° forward and rotated 30° to the opposite side of the test ear. Participants were instructed not to move their head and neck while recording VEMP and also not close their eyes at the time of recording to avoid interference by occulomotor reflexes. Before placing the electrodes, the electrode placement sites were cleaned using skin preparation paste and then the silver chloride electrodes were placed with the conduction paste to increase the conductivity.

Recording of VEMP was done using three electrode placements. A single-channel recording was obtained with a non-inverting electrode (+) placed on the midpoint of the sternocleidomastoid muscle, inverting electrode (-) placed on the sternoclavicular junction, and ground electrode was placed on the forehead. The electrode impedance was checked and it was ensured that the absolute

impendence at each electrode site within 5 kΩ and inter electrode impendence was within 3 kΩ. The following parameter was used to record VEMP.

Type of stimulus	**Clicks**
Transducer	Insert ear phone
Analysis time	100msec
Filter Settings	High pass : 30Hz Low pass :1500Hz
Intensity	95dBnHL
Polarity	Rarefaction
Repetition Rate	5.1/sec
Notch filter	Off
Amplification	5000
Sweeps	250
Electrode	Disc type

Table 1: Shows different parameters used for VEMP recording.

While recording VEMP, the tonic EMG level was monitored and maintained for each of the participants between 50-150 microvolts. A visual feedback available in the instrument was provided to each of the participants to monitor the tonic EMG level of strenocleidomastoid muscle activation.

4. Analysis

The recorded VEMP waveforms were analysed by two experienced audiologists and parameters absolute latency of p1 and n1 and p1-n1 peak to peak amplitude of VEMP was measured.

5. Results

The statistical analysis was performed using statistical package for social sciences (SPSS) software, version 15.The waveforms obtained from all the participants were grand averaged separately for each ear and the averaged waveforms are shown in figure 2.

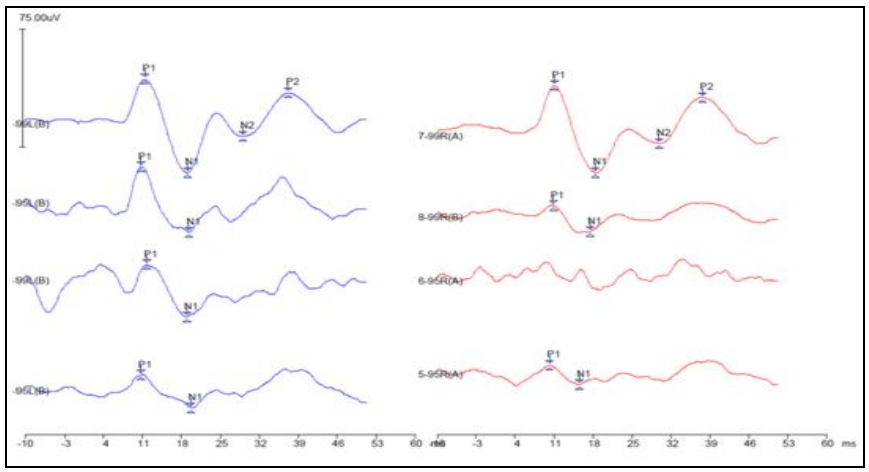

Figure 2

Figure 2: Grand averaged waveforms obtained in normal hearing listeners (top row), mild sensorineural hearing loss (second row), moderate sensorineural hearing loss (third row) and moderately severe sensorineural hearing loss (fourth row). Blue waveforms represents response obtained from left side and red waveforms represents response obtained from right side. X-axis represents the latency in m sec and y-axis represents amplitude in μV.

In group I (individual with normal hearing), it was observed that click elicited both short latency waves (p1 and n1) and long latency waves (p2 and n2) of VEMP from both the ears in all individuals. The mean latency of p1 and n1 was 10.99 (SD=1.035) and 18.4 ms (SD=1.168) for right ear and 11.3 (SD=0.660) and 18.36 ms (SD=1.029) for left ear respectively, further the mean p1-n1 peak-to-peak amplitude was found to be 59.16 µV (SD=18.696) in right ear and 69.94 µV (SD=11.817) left ear.

Among individuals with mild sensorineural hearing loss (Group II) as depicted in the figure 2 it can be observed that, similar to normal hearing listeners, both short and long latency waves of VEMP are present in individuals with mild sensorineural hearing loss. Further, the latencies of p1 and n1 are also similar to normal hearing listeners, but, the p1-n1 amplitude is smaller than that observed for normal hearing listeners. It can be noted that p1-n1 amplitude was greatly reduced in the right ear when compared to left ear. The mean latency of p1 was 12.35 and 11.72 ms in right and left ears, and the mean latency of n1 was 20.25 and 18.99 ms in right and left ears respectively. Further, the mean p1-n1 amplitude was found to be 28.02 and 21.26 µV in right and left ear respectively. However VEMP was found to be absent in two (22.2%) individuals in both the ears. Out of remaining seven participants, VEMP was present bilaterally in three (33.3%) individuals and in remaining four (44.4%) participants it was present only in one ear. Further, among individuals having VEMP present in only one ear, in three individuals it was present in left ear and in remaining one participant it was present in right ear. Overall, VEMP was found to be present in four out of nine (44.4%) individuals in right ear and six out of nine (66.6%) individuals in left ear.

In individuals with moderate hearing loss (Group III) VEMP was found to be absent in right ear of all the individuals, while it was present in left ear among five out of seven (71%) participants. Figure 2 shows the mean latency of p1 and n1 respectively 12.26 and 19.36 ms for left ears and p1-n1 amplitude of 22.46 µV in left ear. From the figure it is evident that only short latency waves of VEMP are present among individuals with moderate sensorineural hearing loss. Further, the latencies of these waves are similar to individuals with normal hearing and mild hearing loss. In addition, the amplitude of p1-n1 is reduced among moderate Sensorineural hearing loss when compared to normal hearing individuals, but there is no difference between mild and moderate hearing loss.

From group IV (Moderately severe hearing loss) in the figure 2 it is evident that, the latencies of p1 and n1 are similar to other groups, while p1-n1 amplitude is smallest when compared to any group in the present study. The mean latency of p1 and n1 in the left ear was 11.24 and 17.88 ms respectively and p1-n1 amplitude was 19.53 µV. However out of six participants who were included in this group, VEMP was found to be present bilaterally in only one participant (16.6%), while in other five participants it was present only in left ear.

- **Comparison of VEMP between the ears**

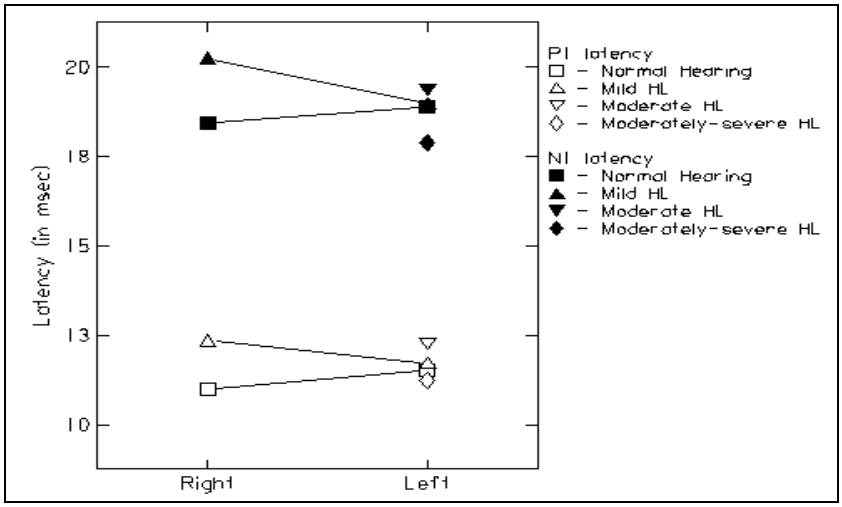

Figure 3: Mean p1 and n1 latency for right and left ears across the groups.

From the figure 3it can be observed that among normal hearing listeners the mean latency of p1 and n1 is shorter in right ear, while in individuals with mild hearing loss shorter latency was found in the left ear. Similar finding was also observed in an individual with moderately severe hearing loss having VEMP present in both the ears. To investigate if the mean latency of p1 and n1 and amplitude of p1-n1 are significantly different between the ears, the data was subjected to further statistical analysis. Wilcoxon Signed Rank test showed that the latency of both p1 and n1 was not significant different between the ears among group I ($Z=0.475$, $p>0.05$ and $Z=-0.416$, $p>0.05$) and group II ($Z=1.604$, $p>0.05$ and $Z=1.082$, $p>0.05$). It was not performed for group III and group IV as sufficient data was not available for pairwise comparison. In addition to latencies, Wilcoxon Signed Rank test also showed no significant difference between the ears for p1-n1 amplitude among group I ($Z=-1.481$, $p=0.05$) and group II ($Z=-1.604$, $p>0.05$). Since the mean latency and amplitude of VEMP were not significantly different for two ears, the data from both ears were combined and further statistical analysis was carried out to compare across the groups.

- **Comparison of VEMP across the groups**
  To investigate the effect of hearing loss across the groups, the combined latency and amplitude data was subjected to Kruskal–Wallis test. It was found that the latency of p1 and n1 was not significantly difference across the groups but, the mean p1-n1 amplitude across the groups was significantly different. Further, results of a pair wise comparison carried out using Mann-whitney u-testare shown in table 2, which indicates that the mean n1-p1 amplitude of group I is significantly different from other groups. This shows that the amplitude of p1-n1 was significantly greater among normal hearing individuals when compared to individuals with hearing impairment of any degree of hearing loss. Further it can also be observed that the mean amplitude of p1-n1 across groups II, III and IV (i.e., hearing impaired individuals) was not significantly different from each other.

Comparison Group	P value	Z –value
Group 1Vs Group 2	.000	-4.067
Group 1Vs Group 3	.001	-3.206
Group 1Vs Group 4	.000	-3.601
Group 2Vs Group 3	.713	-0.367
Group 2Vs Group4	.914	-0.108
Group 3 Vs Group 4	.584	-0.548

Table 2: Z- values and significant level between p1-n1 amplitude and comparison group

6. Discussion

The main objective of this study was to investigate the effect of degree of hearing loss on VEMP. The results showed that both short and long latency waves of VEMP were elicited among all the individuals with normal hearing. This finding in the present study is in consonance with various investigators who also reported the presence of both short and long latency waves among normally hearing listeners (Colebatch et al., 1994; Sheykholeslami, Kaga, Murofushi, & Hughes, 2000).Further, the result of the study shows that among individuals with hearing impairment VEMP was present only in 50% of the ears. The possible reason for absence of VEMP among these large numbers of individuals with hearing impairment may be attributed to three possible reasons. Firstly, the absence of VEMP may be directly attributed to changes in the vestibular organs that would have occurred simultaneously along with the pathological changes that might have taken place in the cochlea resulting in hearing loss. Secondly, studies in normally hearing listeners have shown a reduction in occurrence of VEMP as the stimulus level is decreased below 100 dB nHL (Akin, Murnane, & Proffitt, 2003). Thus it is possible that the stimulus level used in the present study may not be adequate to elicit VEMP among individuals with hearing impairment. Lastly, the mean age of normally hearing listeners who participated in the present study was 21.6 years of age but in contrast, the mean age of individuals with hearing impairment was 54.4, 48.5 and 48.5 years for the three groups. Based on this difference in the mean age between the groups it may be speculated that the absence of VEMP among experimental group is may be because of age of the participants. Mandal and Barman have reported a gradual decrease in the percentage of occurrence of VEMP among normally hearing listeners beyond 40 years of age, thus suggesting that the VEMP may be absent in older individuals (Mandal & Barman, 2011).However, in contrast to Mandal and Barman, other investigators(Janky & Shepard, 2009; Su, Huang, Young, & Cheng, 2004)have reported a decrease in the occurrence of response only after the age of 60 years. Based on these studies investigating the effect of age on VEMP, the lack of response in the present study may also be attributed to age of the participants in the group.

6.1. Comparison of VEMP between the ears

This study indicated that the mean latency of p1 and n1 was shorter and amplitude of p1-n1 was larger in right ear, however, there was no significant difference between latency and amplitude between the ears. This finding in the present study is in agreement withColebatch et al.(1994) who also reported lack of significant difference for latency of p1 and n1 between the ears. Various other investigators have also reported no significant difference for the latency of p1 and n1 and p1-n1 peak to peak amplitude between the ears (Aidar & Suzuki, 2005; Ochi, Ohashi, & Nishino, 2001; Versino, Colnaghi, Callieco, & Cosi, 2001).

6.2. Comparison of VEMP across the groups

The present study showed that there was a significant reduction in peak to peak amplitude of p1-n1 among individuals with hearing impairment, when compared to normally hearing listeners. But, the p1-n1 amplitude was not significantly different across the groups of individuals with hearing impairment. This reduction in amplitude of p1-n1 of VEMP may be attributed to two reasons. The reduction in amplitude of VEMP among hearing impaired listeners may be related to changes in the vestibular organs due to pathological changes in inner ear. But, studies among individuals with sudden deafness (Wu & Young, 2002), unilateral profound

sensorineural hearing loss and noise induced hearing loss(Wang & Young, 2007)have showedno significant difference for amplitude of VEMP when compared to normally hearing individuals. While on the other hand, studies have also shown absent or abnormal response in individuals with noise induced hearing loss(Kumar et al., 2010).Thus the reduction in amplitude of VEMP in the present study may not be completely attributed to the effect of hearing loss. Secondly the reduction in amplitude of VEMP in the present study among individuals with hearing loss may also be a consequence of difference in age between the groups. Various studies have investigated the effect of age on the amplitude of VEMP, these studies have consistently shown a reduction in amplitude of VEMP with increasing age(Basta, Todt, & Ernst, 2007; Brantberg, Granath, & Schart, 2007; Lee, Cha, Jung, Park, & Yeo, 2008; Ochi, Ohashi, & Watanabe, 2003; Su et al., 2004; Welgampola & Colebatch, 2001; Zapala & Brey, 2004),thus it may be speculated that the difference is amplitude may also be due to difference in age of the participants across the groups.Further, in contrast to amplitude, latency of p1 and n1 was not significantly different across the groups. This finding in the present study is comparable to findings of other investigators (Basta et al., 2007; Welgampola & Colebatch, 2001).

7. Conclusion

The present study investigated the effect of degree of hearing loss on VEMP. The result of the study shows that when VEMP was present, its latency or amplitude was not significantly different across various degrees of hearing loss.

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