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Cervical Vestibular Evoked Myogenic Potential (Cvemp) in Children With Sensorineural Hearing Loss

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ABSTRACT

Background: Sensorineural Hearing Loss (SNHL) has a detrimental effect on children's development, it makes a thorough examination of the inner ear crucial.

Aim of the work: To assess the saccular function in children with different degrees of SNHL by using cervical vestibular evoked myogenic potential (cVEMP) in comparison to normal children.

Patients and methods: Forty-five children were included in this study (fifteen normal children as a control group and thirty children with SNHL as a study group). Children in the study group were divided according to the degrees of hearing loss into mild, moderate, moderately severe, severe, and profound. cVEMP was done at a supra-threshold level of 95 decibels (normal Hearing Level dBnHL) using 500 Hertz (Hz) tone-burst to evaluate the vestibular system in both groups. cVEMP P13, N23 amplitude, and latency results were recorded.

Results: there was a statistically significant difference regarding latency of P13 & N23 among the two groups with increased mean in the study group, a statistically significant difference as regards absolute amplitude of P13 & N23 with decreased mean in the study group and a statistically significant difference regarding P13-N23 amplitude. But there is no statistically significant difference as regards asymmetry ratio, the interaural level difference (ILD), and P13-N23 interpeak latency (IPL).

Conclusion: A significant portion of kids with SNHL experience vestibular impairments. The largest percentage of aberrant cVEMP results were seen in children with severe or profound hearing loss. Cochlear implantation (CI) may affect the vestibular otolith organs, and the cVEMP waveform alterations can reveal how surgery affects the otolith organs.

Keywords: Cervical vestibular evoked myogenic potential, Sensorineural Hearing Loss.

INTRODUCTION

The vestibule and cochlea, which belong to the vestibular and auditory systems, respectively, are the peripheral sense organs. Because the vestibule and the cochlea are connected by a continuous membrane labyrinth in the inner ear, disturbances of functions of the cochlea, which can induce sensorineural hearing loss (SNHL), may occur with vestibular dysfunction [(1)].

Pediatric patients can benefit from early identification of peripheral vestibular dysfunction since it not only helps doctors and parents understand why children have balance problems but also makes it easier for kids to acquire compensatory balance control techniques. The lack of routine vestibular testing in the pediatric population is due to many factors. One of them is the dearth of workable and efficient healthcare methods. When performed on young children, the traditional techniques for vestibular assessment in adults, such as videonystagmography (VNG) and the caloric test, are difficult, if not impossible [(2)].

The development of kid-friendly vestibular assessment techniques has made significant strides. Cervical vestibular evoked myogenic potentials (cVEMP) are one such test for determining vestibular problems. It is a thorough, painless, quick, and well-tolerated exam to determine how effectively the saccule and inferior vestibular nerves operate [(3)].

A decrease in hearing sensitivity is typically the main complaint from parents and children with SNHL. Those kids' vestibular systems did not receive adequate consideration. The otolithic injury occurs often in children with severe SNHL. According to reports, children with SNHL have a maximum chance of detecting vestibular dysfunction of around 70%, but doctors haven't paid enough attention to this problem. Therefore, it is crucial to comprehend how children with SNHL's vestibular system is functioning [(4)].

This study aimed to assess the saccular function in children with different degrees of SNHL by using cVEMP and to compare cVEMP findings between them and normal children.

PATIENT AND METHOD

A total of 45 kids attending AL-Ahrar Teaching Hospital's Audiology Unit between December 2016 and August 2017 were randomly recruited in this study, they split up into two groups:

1- Control Group:

It consists of 15 normal healthy control children, aged between 6-17 years with the following inclusion criteria:

1. Absence of any background history of systemic disorders affecting the vestibular system.
2. No history of ear disease.
3. Neither acoustic nor physical trauma history.
4. No ototoxic drug history.

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5. There have been no reports of dizziness or vestibular problems.
6. No neurological or Musculoskeletal disorders.

2- Study Group:

It consists of 30 children with different degrees of sensorineural hearing loss 4 (13.4%) mild (26-40 dBHL), 4 (13.4%) moderate (41-55 dBHL), 4 (13.4%) moderately severe (56-70), 8 (26.5%) severe (71-90 dBHL) and 10 (33.3%) profound (>90 dBHL) and different configuration of audiogram 17 (56.6%) flat, 2 (6.7%) rising (low frequency sloping), 2 (6.7%) cookibite and 9 (30%) high frequency sloping. In terms of age and sex, they were comparable to the placebo group.

3- Equipment:

1. Sound-treated room locally made.
2. Two-channel diagnostic audiometer (Interacoustics, model AC 40) calibrated according to the manufacturer's specifications.
3. Immittancemetry (MAICO model MI44) that calibrated according to the manufacturer's specifications.
4. Evoked Potential audiometer supported with cVEMP software (Bio-logic Model Navigator PRO).

METHODS

All subjects included in this study were subjected to:

1. Complete medical and audiological history taking.
2. Inspection of the ears.
3. Basic audiological testing, such as:
   (a)- Diagnostic pure tone audiometry: Bone conduction occurs between 500 and 4000 Hz and air conduction between 250 and 8000 Hz. (b)- Speech audiometry: By employing Arabic Bisyllabic Words, the Speech Recognition Threshold (SRT) test is conducted. the Arabic monosyllabic phonetically balanced words test for word discrimination (WD), (c) Immittancemetry: Tympanometry was done at varying pressure ranging from +200 to -400 mmH2O to evaluate the middle ear pressure and its compliance.

4- Vestibular evaluation including:

a-Vestibular office test: done only for the study group: It includes: posture and gait tests and ocular motor examination.

b- Cervical Vestibular Evoked Myogenic Potentials recorded using air-conducted acoustic stimulus: In response to 500 Hz tone burst stimuli, cVEMP amplitude, P13, and N23 delay were measured at maximal auditory stimulation (95 dBnHL). To measure amplitude, P13, and N23 delay, two replicated trials were averaged. When this threshold was not reached, a clearly characterized and repeatable cVEMP response was deemed lacking.

Analysis of the waves:

The amplitude of the wave was calculated by first calculating the lag time between the wave's lowest and highest points across all recorded traces. Two traces were taken in a row from each side to guarantee consistency.

The formula for determining the asymmetry ratio was as follows: by plugging the numbers into the equation 100 [(AR-AL)/(AR+AL)] (The right-side P13-N23 amplitude is denoted by AR, and the left-side amplitude by AL).

Stimulus parameters: Air-conducted acoustic stimuli with the following criteria:

1. Type: Tone burst 500 Hz, 1 ms rise-fall time, and 2 ms plateau.
2. Stimuli intensity: 95 dBnHL.
3. Sweeps number: 120.
4. Repetition rate: 5/sec.
5. Mode of stimulus delivery: Air conduction monaural stimulation through supra-aural earphones TDH. 39P

Recording parameters:

1. The filter settings: are 10- 1500 Hz.
2. Time window: 0-50 msec.
3. Gain: 5000.

Ethical consent:

This study was ethically approved by the Institutional Review Board of the Faculty of Medicine, Zagazig University, Written informed consent was taken from all participants. The study was conducted according to the Declaration of Helsinki.

Statistical analysis

The IBM SPSS software program version 20.0 was used. To determine the significance of the acquired results, a 5-percent threshold was used. It was a Chi-square test. For categorical variables, chi-square correction for more than 20% of cells with an anticipated count of less than 5 was required, Student t-test: to calculate the quantities of data of normal distribution and to compare between two studied groups. P value < 0.05 was considered significant.

RESULTS

No differences were found to be statistically significant regarding age and gender in both groups.

Table (1): Demographic data of both groups

Variable	Control (n=15)		Study (n=30)		t-Test	P-value
Age : (year) Mean ± SD	11.40± 3.54		11.73± 3.45		0.3	0.76
Range	6 - 17		6 - 17			
Variable	No	%	No	%	χ2	P
Gender:						
Female	7	46.7	14	46.7	0	1
Male	8	53.3	16	53.3		

A statistically significant difference was seen between the two groups in terms of P13 and N23 latency in the Rt and Lt ears, but not for ILD.

Table (2): Comparison of cVEMP latency P13, N23, and inter-latency difference (ILD) among both groups.

Variable		Group	N	Mean	± SD	Range		t-Test	P-value
P13	**Rt**	**Control**	15	14.12	0.72	12.93	16.05	3.10	**0.003****
		Study	29	15.46	1.58	13.09	19.17		
	Lt	**Control**	15	14.12	0.88	13.14	15.84	3.03	**0.004****
		Study	29	15.36	1.45	13.35	19.59		
N23	**Rt**	**Control**	15	21.37	1.63	18.97	24.59	3.64	**<0.001****
		Study	29	24.04	2.59	18.13	28.54		
	Lt	**Control**	15	21.78	2.47	18.76	26.88	2.1	**0.04***
		Study	29	23.51	2.62	17.72	29.59		
ILD	**P13**	**Control**	15	0.72	0.15	0.21	1.25	0.76	0.44
		Study	29	0.62	0.12	0	1.67		
	N23	**Control**	15	1.25	0.42	0.42	2.29	0.71	0.47
		Study	29	1.15	0.31	0	6.66		

One subject's cVEMP data was not included as the cVEMP responses were absent in both ears.

Regarding the absolute amplitude of P13 and N23 in the Rt and Lt ears, a highly statistically significant difference was discovered between the control and study groups. Between the control and study groups, there was no statistically significant difference in the asymmetry ratio.

Table (3): Comparison of the absolute amplitude of P13, N23, and asymmetry ratio among both groups.

Variable		Group	N	Mean	± SD	Range		t-Test	P-value
P13	**Rt**	**Control**	15	95.33	19.34	62.24	121.66	9.12	**<0.001****
		Study	29	45.71	11.41	30.55	80.41		
	Lt	**Control**	15	93	19.15	60.23	124.52	8.46	**<0.001****
		Study	29	47.52	11.39	31.25	70.84		
N23	**Rt**	**Control**	15	-75.9	12.72	-63.55	-98.61	7.16	**<0.001****
		Study	29	-47.89	11.45	-32	-75.45		
	Lt	**Control**	15	-72.8	10.73	-60.22	-98.34	7.04	**<0.001****
		Study	29	-47.59	12.22	-30.44	-66.88		
Asymmetry ratio		**Control**	15	9.26	2.32	1	25	1.60	0.11
		Study	29	13.17	3.43	1	25		

One subject's cVEMP data was not included as the cVEMP responses were absent in both ears.

Abnormal latency and amplitude were found in 50% of moderately-severe SNHL, 62.5% of severe SNHL, and 70% of profound SNHL. And absent cVEMP in 12.5% of severe SNHL. No abnormalities were found in mild and moderate SNHL.

Table (4): The quantitative effect of SNHL degree on VEMP response (frequency of cases)

Degree of hearing loss N %	Normal VEMP N %	Abnormal VEMP (Latency & amplitude) N %	Absent VEMP N %
Mild SNHL 4 (13.4%)	4 (100%)	0	0
Moderate SNHL 4 (13.4%)	4 (100%)	0	0
Moderately severe SNHL 4 (13.4%)	2(50%)	2(50%)	0
Severe SNHL 8 (26.5%)	2 (25%)	5 (62.5%)	1(12.5%)
Profound SNHL 10 (33.3%)	3 (30%)	7 (70%)	0
Total number	15 (50%)	14 (46.7%)	1 (3.3%)

There was a significant positive correlation between the Latency of P13 and N23 and pure tone average in children with moderately severe, severe, and profound SNHL and a negative correlation between P13-N23 amplitude and pure tone average in the same children.

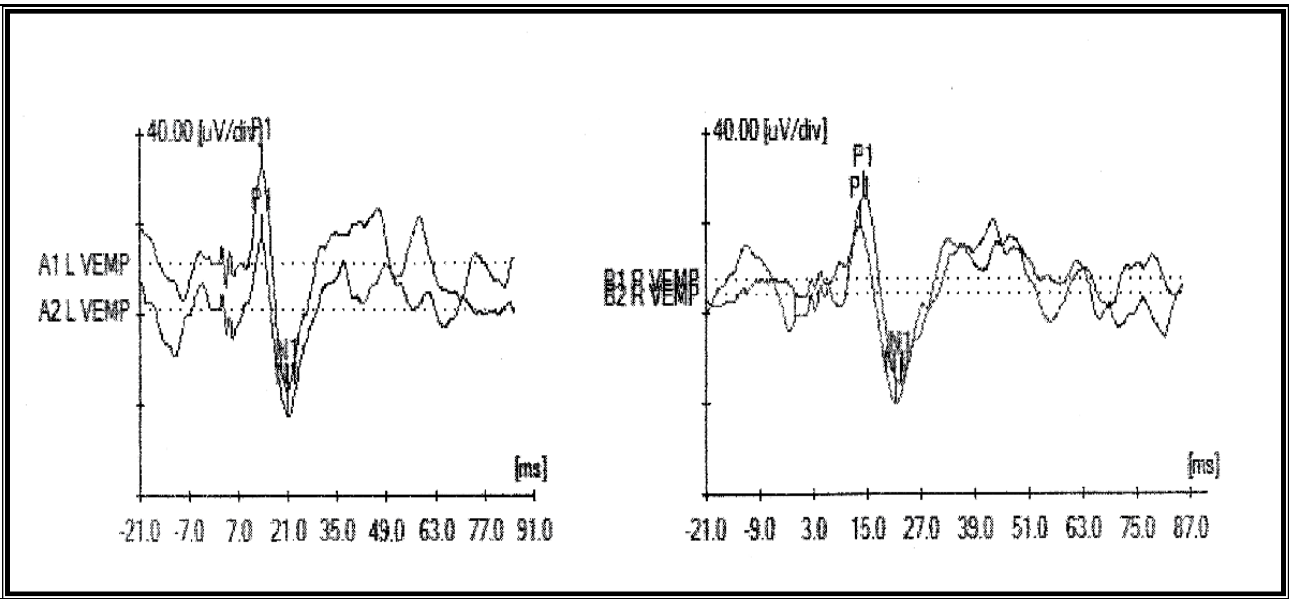
Table (5): Correlation between degree of hearing loss and cVEMP parameters in the study group.

Degree of H.L		Latency				P13-N23 Amplitude	
		P13 Rt	P13 Lt	N23 Rt	N23 Lt	P13-N23 Rt	P13-N23 Lt
MILD SNHL	**R**	0.78	0.72	-0.34	0.72	-0.9	-0.8
	P	0.21	0.29	0.66	0.27	0.09	0.1
MODERATE SNHL	**R**	0.6	0.47	-0.19	0.49	-0.6	0.4
	P	0.39	0.52	0.8	0.5	0.3	0.5
MODERATELY SEVERE SNHL	**R**	0.47	0.57	0.49	0.68	-0.9	-0.9
	P	**0.01***	**0.03***	**0.04***	**0.03***	**0.03***	**0.004***
SEVERE SNHL	**R**	0.62	0.66	0.57	0.73	-0.8	-0.8
	P	**0.04***	**0.03***	**0.05***	**0.05***	**0.01***	**0.02***
PROFOUND SNHL	**R**	0.77	0.72	0.75	0.77	-0.8	-0.6
	P	**0.03***	**0.02***	**0.01***	**0.02***	**0.004***	**0.04***

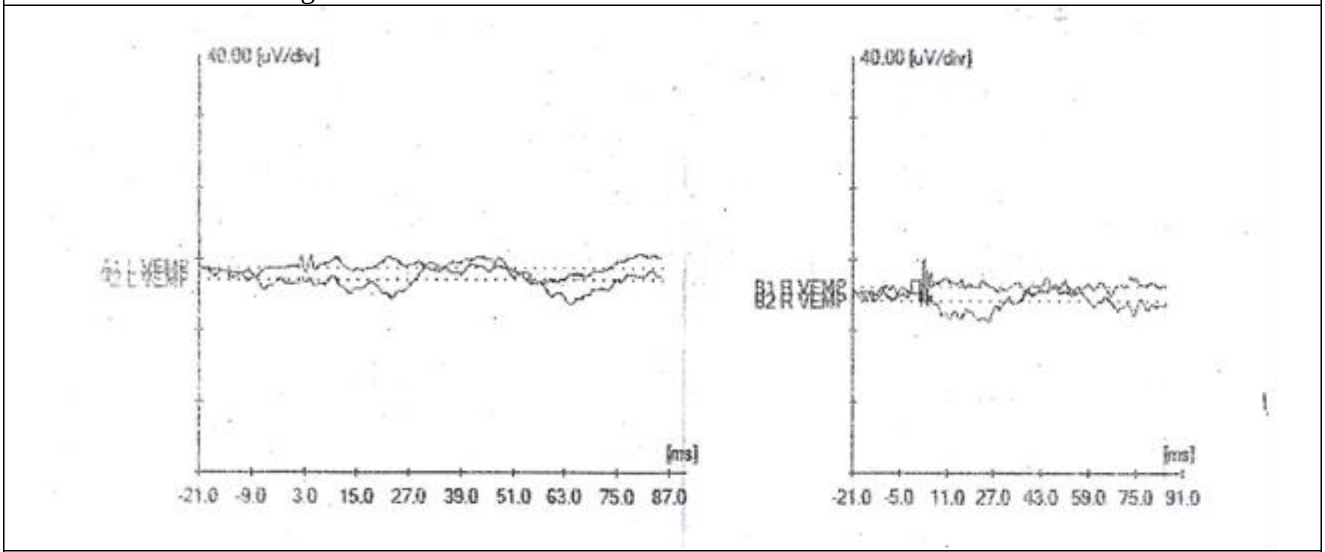
Abnormal latency and amplitude were found in 75% of heredofamilial, 44% of unknown etiology, and absent cVEMP in 100% after gentamycin.

Table (6): The quantitative effects of the source of hearing loss on VEMP response (frequency of cases).

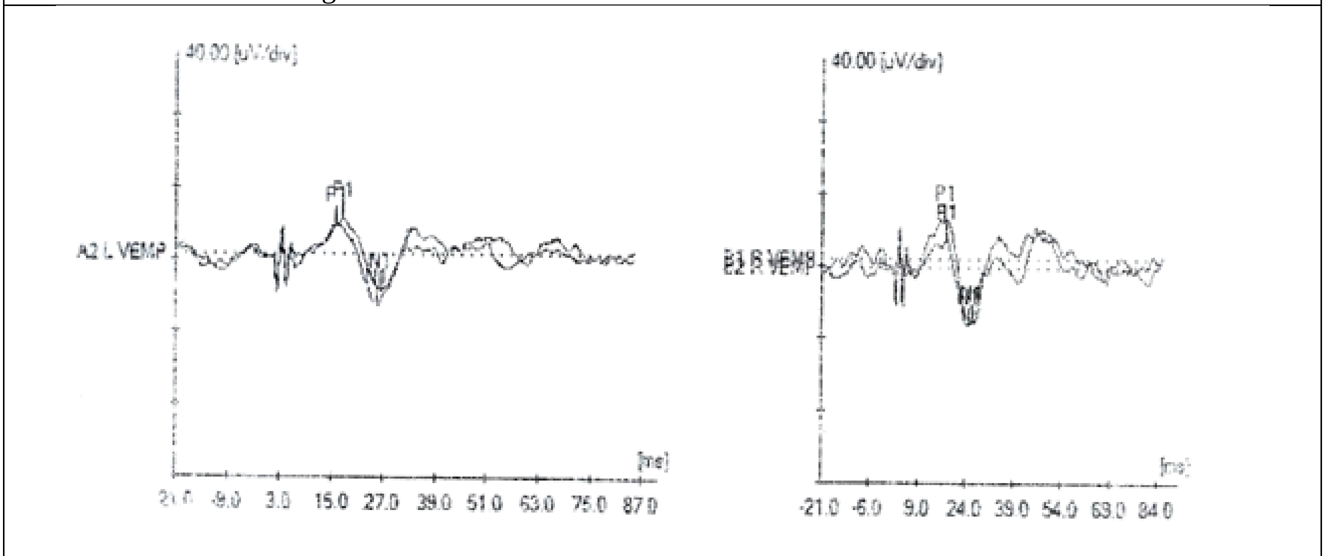
Cause of hearing loss N %	Normal VEMP N %	Abnormal VEMP (latency & amplitude) N %	Absent VEMP N%
Heredofamilial 4 (%13.4)	1(25%)	3 (75%)	0
Gentamycin 1 (%3.3)	0	0	1 (100%)
Unknown 25 (%83.3)	14 (56%)	11 (44%)	0
Total number	15(50%)	14 (46.7%)	1 (3.3%)



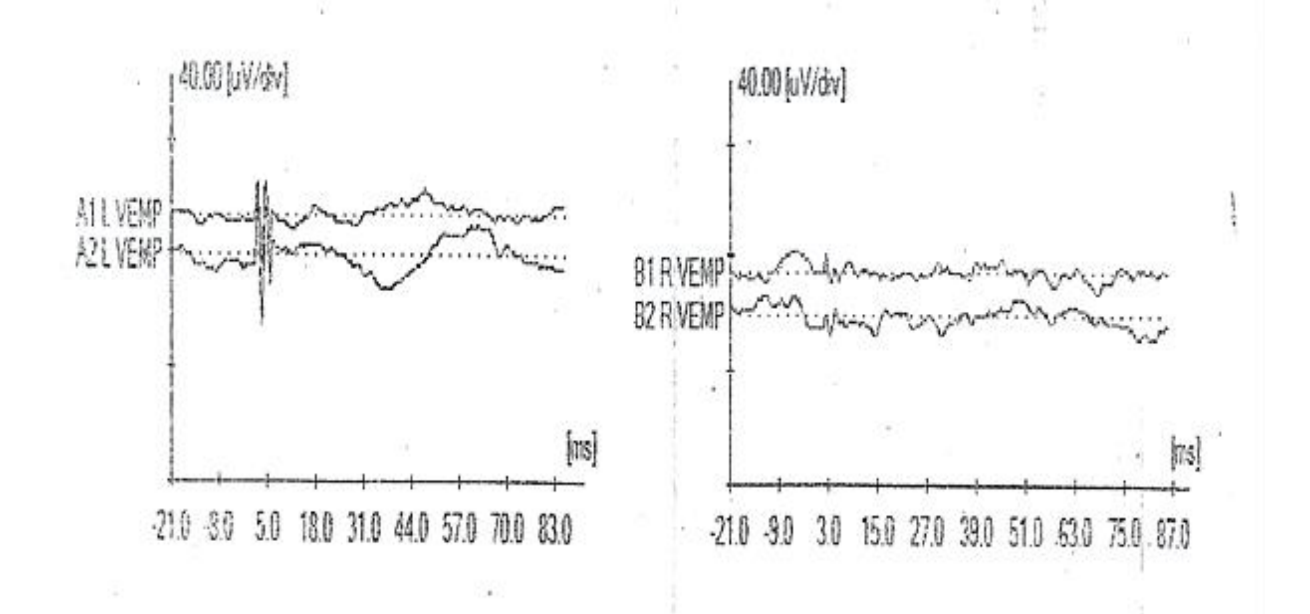
(A) cVEMP trace from the current study for a child with mild SNHL, using 500Hz tone burst at 95dBnHL the figure showed normal cVEMP trace in both ears



(B) cVEMP trace from the current study for a child with severe SNHL, using 500Hz tone burst at95dBnHL the figure showed absent cVEMP trace in both ears



(C) cVEMP trace from the current study for a child with profound SNHL, using 500Hz tone burst at 95dBnHL the figure showed delayed latency of p13 & N23 at (17.6 & 28.6 ms) respectively and decreased amplitude P13 and N23 (20 & 30 microvolts) respectively in both ears.



(D) cVEMP trace from the current study for a child using a cochlear implant, using 500Hz tone burst at 95dBnHL the figure showed absent cVEMP trace in both ears

Figure (1)

DISCUSSION

Children with hearing loss experience issues that are typically mentioned in terms of communication difficulties. Children with hearing loss may experience verbal communication deficits as their main physical repercussion, however other physical issues are also possible. According to studies, children with congenital or early acquired severe-to-profound hearing loss may experience balance issues. The development of other motor skills, visual-perceptual-motor abilities, and sensory integration may all be significantly impacted by these balance issues [(5)].

To evaluate otolith function (saccule) in children with varying degrees of sensorineural hearing loss, the current study aimed to compare air-conducted cVEMP in these children with control subjects. The research and control groups were comparable in terms of age and gender composition.

Pure tone audiometry was used to identify the kind, pattern, and degree of hearing loss. The air conduction threshold is between 250 and 8000 hertz, while the bone conduction threshold is 500 hertz. All of the kids in the research exhibited symmetrical SNHL on both sides. This study confirms the findings of **Kumar *et al.*** [(6)], who found that the mean delay of P13 and N23 was extended in persons with NIHL compared to the control group. **Said** [(7)] relative to children with normal hearing, most children with SNHL exhibited delayed P13 and N23 latencies; however, this difference did not achieve statistical significance. A study done by **Trivelli *et al.*** [(8)] and reported that When comparing children with SNHL to children with normal hearing, there was an increase in P13 latency but no increase in N23 delay, while this disagrees with the study done by **Xu *et al.*** [(9)] who stated that when compared to those with normal hearing, patients with SNHL had shorter P13 and N23 latencies.

Inter-latency difference between the study and control groups in the current investigation did not differ significantly from each other inter-latency difference (ILD). This agrees with **Zhou and Cox** [(10)] who revealed that the response's latency is often less variable and does not considerably change from the right to left sides.

In this study, the mean absolute amplitude of P13 and N23 was significantly lower in the study group compared to the control group. This may be because the surviving otolith organ receptor cells are unable to respond to sound stimulation due to damage caused by inner ear diseases. This agrees with the study done by **Xu *et al.*** [(11)] who observed that children with SNHL had lower amplitudes than children with normal hearing. On contrary, this disagrees with the study done by **Trivelli *et al.*** [(8)] who found no statistically significant difference in the absolute amplitude of P13 and N23 between children with SNHL and those with normal hearing. The discrepancy between this study's findings and those of others can be explained by the fact that cVEMP amplitudes can range from a few microvolts to several hundred microvolts depending on muscle tension and the severity of the stimulus [(10)].

In the current investigation, the asymmetry ratio between the study and control groups did not differ in a statistically significant way. This agrees with the study done by **Wu *et al.*** [(12)] who found that the asymmetry ratio between patients with normal hearing and those who had acute low-tone sensorineural hearing loss was not significantly different.

Two patients with moderate-severe SNHL, five patients with severe SNHL, and seven patients with profound SNHL were all observed to have aberrant latency and amplitude in the current study. One patient with severe SNHL had no cVEMP response at all, suggesting that cVEMP abnormalities tend to worsen in tandem with SNHL severity. This can be explained by the chance that the entire inner ear will be impacted rising with the severity of hearing loss. This is consistent with the findings of research by **Jin *et al.*** [13] who found that 50% of children with severe SNHL exhibited abnormalities in saccular function and cVEMP responses.

In the present study, there was a positive correlation between pure tone average and latency of P13 and N23, an increase in the degree of hearing loss is accompanied by an increase in latency of P13 and N23. This agrees with the study done by **Kumar *et al.*** [6] who found a substantial positive association between the pure tone average and the P13 and N23 delay. In the current study, there was a negative correlation between pure tone average and P13-N23 amplitude, an increase in the degree of SNHL is accompanied by a decrease in P13-N23 amplitude. This agrees with a study done by **Kumar *et al.*** [6] who claimed that the P13-N23 amplitude and pure tone average did not correlate well with one another.

In the current study, abnormal latency and amplitude were found in 3 (75%) of heredofamilial causes, 11 (44%) of unknown causes, and absent cVEMP in 1 (100%) after gentamicin injection. **Said** [7] Relative to children with other etiologies, 16 (84.2 percent) of children with SNHL of acquired etiology had the highest aberrant cVEMP response score: Six (75%) of the infants with an unclear etiology and 14 (56.5%) of the children with heredofamilial SNHL.

During this study, two female children using CI attended to audiology unit. The cVEMP results of those children were bilateral absent cVEMP. This agrees with the study done by **Xu *et al.***[11] who reported that 18 from a total of 22 patients lost cVEMP after CI.

CONCLUSION

A significant portion of kids with SNHL experience vestibular impairments. The largest percentage of aberrant cVEMP results were seen in children with severe or profound hearing loss. CI may affect the vestibular otolith organs, and the cVEMP waveform alterations can reveal how surgery affects the otolith, in the current study those with heredofamilial etiology and/or severe or profound degree of HL had the highest abnormality. Changes in the waveform of the vestibular evoked myogenic potential (cVEMP) provide insight into the effect of vestibular otolith surgery on these structures.

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