Combined Cervical and Ocular Vestibular Evoked Myogenic Potentials in Cochlear Implanted Children

Original Article

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ABSTRACT

Background: Cochlear implant is considered a surgically safe procedure. However, it has some risk on vestibular functions.

Objectives: Evaluation of otolith function after unilateral cochlear implant surgery in children using combined cervical and ocular VEMPs.

Patients and Methods: This study included forty-six children were divided into two groups: Control group (GI); 20 healthy children with bilateral normal peripheral hearing, with no vestibular complaints. The other group, Study group (GII); included 26 children fitted with unilateral cochlear implant. Arabic DHI questionnaire for children, vestibular office tests and combined cervical and ocular Vestibular Evoked Myogenic Potentials (combined VEMPs) were done in the implanted side (GIIa) and non-implanted sides (GIIb).

Results: Cervical VEMP was abnormal in (57.69%) in children of subgroup GIIa and in (30.76%) in children of subgroup GIIb. Ocular VEMP was abnormal in (65.38%) in children of subgroup GIIa and in (61.53%) in children of subgroup GIIb. These abnormalities were in the form of absent waves or delayed absolute latencies.

Conclusion: There were saccular and utricular affection after CI implant. This affection was higher on implanted side than non-implanted side.

Key Words: Cochlear implant, VEMP, Vestibular lesion.

Received: 25 September 2022, **Accepted:** 30 December 2022

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ISSN: 2090-0740, 2023

INTRODUCTION

Cochlear implantation (CI) has been used to initiate or restore hearing function in patients with severe to profound sensorineural hearing loss, who are not improved by conventional hearing aids[1].CI surgery is not without risk in respect of contiguous organs, particularly the vestibule[2]. The cochlea and vestibule share a continuous membranous structure and have similar receptor cells. Therefore, diseases and also surgical procedures of the inner ear could probably affect balance organ[3].

Vestibular Evoked Myogenic Potentials (VEMPs) is a non-invasive test to assess the functions of the otolith organs of the inner ear. It is a short latency muscle potential, elicited by the presentation of a loud sound[4]. There are two types of vestibular evoked myogenic potentials: cervical (cVEMPs) and ocular VEMPs (oVEMPs). Cervical VEMPs assesses the functions of the saccule, the inferior vestibular nerve and central connections. Whereas oVEMPs assesses the functions of the utricle and the superior branch of the vestibular nerve and central connections[5].

Vestibular complain after cochlear implantation was reported in many centers. And the presence of vestibular damage or affection in CI child may have a great impact on his/her balance and quality of life. So, early detection and early effective management are important for avoiding this negative impact. This research was designed to evaluate the effect of surgical trauma in unilateral CI children using combined cervical and ocular VEMPs.

PATIENTS AND METHODS:

2. Subjects and Methods:

2.1. Subjects:

This study included forty-six children with age ranged from 2.83 year to 13 years. They were divided into two groups: Control group (GI); 20 healthy children with bilateral normal peripheral hearing, bilateral normal middle ear pressure, and with no vestibular complaints. The other group, Study group (GII); included 26 children fitted with unilateral cochlear implant.

 DOI:10. 21608/ejentas.2022.164997.1562

2.2. Methods:

All subjects included in this study were submitted to:

2.2.1. Full audiological and medical history.

2.2.2. Otological examination

2.2.3. Basic audiological evaluation including:

Pure tone audiometry by GSI version 61

Immittancemetry by Interacoustics model AT235H.

2.2.4. Vestibular evaluation including:

2.2.4.1. Arabic Dizziness Handicap Inventory (DHI) questionnaire for children.

2.2.4.2. Office test examination for children. This included:[6]

2.2.4.2.1. Observation of the eye for spontaneous nystagmus, alignment test, range of eye movement.

2.2.4.2.2. Oculomotor tests: smooth pursuit test, saccadic test.

2.2.4.2.3. Fukuda step test.

2.2.4.2.4. Sharpened Romberg test, closed eye foam and tandom gait.

2.2.4.3. Combined Vestibular Evoked Myogenic Potentials (VEMPs)

cVEMP and oVEMP by Smart EP of (IHS).

VEMPs were recorded using alternative 500Hz tone burst at 95dBnHL, sweeps number 128, repetition rate 5/sec. The mode of stimulus delivery was insert earphones, while the filter settings were 30- 3000Hz. The time window was 0-125msec and the Gain was 50.000. Electrode montage for combined VEMPs; included nine electrodes. The ground electrode was placed over the forehead. Two active electrodes were placed on the middle third of the contracted SCM muscle on each side (for recoding cVEMPs). The other active electrodes were placed just inferior to each eye, about 1 cm below the center of the lower eyelid (for recoding oVEMPs). The reference electrodes were placed at the mid-clavicle point (in cVEMPs) while for oVEMPs, the reference electrode was positioned about 1–2 cm below the corresponding active ones.

For subjects in the study group, combined VEMP was recorded two times: 1st: when the implanted side (ipsilateral) was tested (Subgroup a GIIa). 2nd: when the non-implanted side (contralateral) was tested (Subgroup b GIIb).

Statistical analysis:

All data were analyzed by SPSS version 22. Normally distributed data were expressed as mean ± standard deviation, while not normally distributed data were expressed as median and interquartile range. Independent t-test was used to analyze normally distributed independent data, while normally distributed paired were analyzed by using Paired t-test. Mann Whitney test was used to analyze continuous not normally distributed independent data. Whereas, continuous not normally distributed data paired data were analyzed by Wilcoxon-sign rank test.

• Every participant was given a code number. The outcomes of the research will be applied only in scientific use. The estimate of the research was explained in details to the participants and also possible complications and side effects. An informed consent was then received from all participants parents. The participation was voluntary and that subject had the right to discontinue participation at any time without penalty or loss of benefits.

RESULTS:

3.1. Demographic data distribution:

Comparisons of age and gender between control and study groups were done. Results revealed no statistically significant difference between the two groups.

The most common cause of hearing loss (among the study group) was heredofamilial in (11/26 children) (42.3%) (Table 1).

3.2. Office test results:

Statistical analysis of the office test results revealed significant differences in Sharpened Romberg test, closed eye foam and Tandom gait only, when comparing control and study groups (Table 2).

3.3. Combined Vestibular Evoked Myogenic Potentials (Combined VEMPs):

3.3.1. Cervical VEMPs:

3.3.1.1. Detectability:

In the control group, P13 and N23 of cVEMPs were successfully recorded from all subjects. While, in the study group when recording cVEMP ipsilaterally to CI implantation, eleven subjects (11/26) (42.3%) showed absent cVEMPs.

Moreover, when recording combined VEMP contralaterally to CI implantation in the study group, seven subjects (7/26) (26.9%) showed absent cVEMPs. Comparing the results of the between two study subgroups revealed statistically significant differences.

3.3.1.2. Latencies and amplitudes:

Comparing latencies and amplitudes of P13 and N23 in both ears of the control group (right versus left) were done using t-test and Mann-Whitney test. Results revealed no statistically significant differences. Accordingly, we used the average of both ears for comparison with the study group.

In the study subgroup GIIa, the mean and standard deviation of P13 and N23 latencies were 13.48 + 2.26 and 18.43 + 2.43 msec respectively. The median and IQR of P13 and N23 amplitudes were 2.81 μv, 1.80-3.14 and 2.15 μv with IQR 0.82-4.07 respectively. Independent t-test and Mann-Whitney test were used for statistical analysis. Results revealed no statistically significant difference (Table 3).

In the study subgroup GIIb, the mean and standard deviation of P13 and N23 latencies were 12.93 + 2.01 and 18.40 + 3.23 msec respectively. The median and IQR of P13 and N23 amplitudes were 3.14 with IQR 1.86-5.41 μv and 2.64 with IQR 1.92-4.79 μv for P13 and N23 respectively. Independent t-test and Mann-Whitney test were used for. comparing control and study subgroup GIIb P13 and N23 latencies and amplitudes. Results showed no statistically significant difference (Table 4).

Comparison between the two study subgroups using Independent t-test and Mann-Whitney tests was done. There was no a statistically significant difference in latencies and amplitudes of (P13 and N23 5).

3.3.2. Ocular VEMPs:

3.3.2.1. Detectability:

In the control group, N10 and P15 of oVEMPs were successfully recorded in all subjects. In the study subgroup GIIa, sixteen subjects (16/26) (61.5%) showed absent oVEMPs. While, in study subgroup GIIb, fifteen subjects (15/26) (57.6%) showed absent oVEMPs. Comparing the results of the two study subgroups showed, no statistically differences.

3.3.2.2. Latencies and amplitudes:

Comparing latencies and amplitudes of N10 and P15 in both ears of the control group (right versus left) done using Independent t-test and Mann-Whitney test. Results showed that there were no statistically significant differences. Accordingly, one of them was used randomly for comparison with the study group and this was the left ear.

In the study subgroup GIIa, the mean and standard deviation of N10 and P15 latencies were 12.12 + 1.77 and 16.26 + 1.33 msec respectively. Moreover, the mean and standard deviation of N10 amplitudes were 0.51 + 0.52 μv While the median of P15 amplitudes were 0.37 with IQR 0.16-0.75 μv respectively. Independent t-test and Mann-Whitney tests were used to compare between the control group and the study subgroup GIIa. There were no statistically significant differences between control and study subgroup GIIa in N10, while there was a statistical significant difference in latencies of P15 (Table 6).

In the study subgroup GIIb, the mean and standard deviation of N10 and P15 latencies were 10.89 + 1.58 and 15.43 + 2.32 msec respectively. Moreover, the mean and standard deviation of N10 amplitudes were 1.01 + .73 μv, while the median of P15 amplitudes was 0.62 with IQR 0.26-1.57 μv. By using Independent t-test and Mann-Whitney tests, there were no statistically significant differences between control and study subgroup GIIb (Table 7).

Furthermore, the using independent t-test and Mann-Whitney tests were used the compare between the two study subgroups. Results revealed, no statistically significant differences in latencies and amplitudes of N10 and P15 between study subgroup GIIa and study subgroup GIIb (Table 8).

3.3.3. Amplitude ratio:

The inter-aural amplitude ratios (IARs) were calculated as the following: 100 [(AR − AL)/ (AR + AL)]. AR is the amplitude on right side; AL is the amplitude on left side.[7] Comparing the two studied groups (control & study) showed no significant differences in amplitude ratio of cVEMPs and oVEMPs (Table 9).

Table 1: Distribution of different etiologies of hearing loss in the study group.

Etiology	No (26)	(%)
Heredofamilial	11	(42.3%)
Unknown	10	(38.4%)
Post-febrile	3	(11.5%)
Waardenberg Syndrome(WS1)	1	(3.84%)
Congenital Rubella Syndrome	1	(3.84%)

Table 2: Comparison between control group and study group as regards to office tests results.

		Groups				Chi-Square test	
		Control N=14		Study N=23			
		N	%	N	%	X^2	*P value*
Sharpened Romberg	Abnormal	0	0.0	8	34.8	14.515	.001*
	Normal	14	100.0	15	65.2		
Closed eye foam	Abnormal	0	0.0	8	34.8	14.515	.001*
	Normal	14	100.0	15	65.2		
Tandom gait	Abnormal	0	0.0	8	34.8	14.515	.001*
	Normal	14	100.0	15	65.2		

*significant at $p < 0.05$.

Table 3: Comparison between control group and study subgroup GIIa as regards to latencies and amplitudes of cVEMPs (P13 &N23).

Measurements		Groups		t-test and Mann-Whitney test	
		Control group	Study subgroup GIIa	T- value	*P value*
P13latency in msec	Range	9.10-15.25	9.80-17.63	1.47	.152
	Mean± SD	12.51±1.67	13.48±2.26		
N23latency in msec	Range	15.00-22.75	15.05-22.63	0.904	.372
	Mean± SD	19.12±2.10	18.43±2.43		
P13 amplitude in µv	Range	.14-5.17	.39-6.15		
	Median	2.44	2.81	Z_{mw}=0.10	.934
	IQR	1.56-3.87	1.80-3.14		
	Mean rank	18.15	17.80		
N23amplitude in µv	Range	.13-6.23	.00-5.45		
	Median	2.43	2.15	Z_{mw}=0.08	.937
	IQR	1.21-3.06	.82-4.07		
	Mean rank	18.38	18.66		

Table 4: Comparison between control group and study subgroup GIIb as regards to latencies and amplitudes of cVEMP waves (P13&N23).

measurements		Groups		Independent t-test and Mann-Whitney test	
		Control group	Study subgroup GIIb	T-value	*P value*
Latency P13 in msec	Range	9.10-15.25	10.38-19.25	0.718	.477
	Mean± SD	12.51±1.67	12.93±2.01		
Latency N23 in msec	Range	15.00-22.75	14.50-26.00	0.828	.413
	Mean± SD	19.12±2.10	18.40±3.23		
Amplitude P13 in µv	Range	.14-5.17	.32-13.68	Z_{mw}=1.32	.194
	Median	2.44	3.14		
	IQR	1.56-3.87	1.86-5.41		
	Mean rank	17.65	22.47		
Amplitude N23 in µv	Range	.13-6.23	.67-24.22	Z_{mw}=1.208	.235
	Median	2.43	2.64		
	IQR	1.21-3.06	1.92-4.79		
	Mean rank	17.85	22.26		

Table 5: Comparison between study subgroup GIIa and study subgroup GIIb as regard to latency and amplitude P13&N23.

		Study group N=26		Paired t-test and Wilcoxon signed rank test	
		Study subgroup GIIa	Study subgroup GIIb	T-value	*P value*
Latency P13 in msec	Range	9.80-17.63	10.38-19.25	0.584	.570
	Mean± SD	13.48±2.26	12.93±2.01		
Latency N23 in msec	Range	15.05-22.63	14.50-26.00	0.090	.930
	Mean± SD	18.43±2.43	18.40±3.23		
Amplitude P13 in µv	Range	.39-6.15	.32-13.68		
	Median	2.81	3.14	Z_w=1.503	.133
	IQR	1.80-3.14	1.86-5.41		
	Mean rank	4.0	9.50		
Amplitude N23 in µv	Range	.00-5.45	.67-24.22		
	Median	2.15	2.64	Z_w=1.89	.059
	IQR	.82-4.07	1.92-4.79		
	Mean rank	9.25	6.50		

Table 6: Comparison between control group and study subgroup GIIa as regards to latencies and amplitudes of oVEMPs waves (N10& P15).

Measurements		Groups		Independent t-test and Mann-Whitney test	
		Control group	Study subgroup GIIa	T-value	*P value*
Latency N10 in msec	Range	8.20-14.13	9.50-15.25	1.68	.103
	Mean± SD	11.03± 1.69	12.12± 1.77		
Latency P15 in msec	Range	11.20-17.38	14.38-19.00	2.24	.033*
	Mean± SD	15.04±1.51	16.26±1.33		
Amplitude N10 in µv	Range	.02-1.30	.01-1.71	0.188	.852
	Mean± SD	.54±.37	.51±.52		
Amplitude P15 in µv	Range	.05-2.14	.08-.94	Z_{mw}=0.413	.688
	Median	.50	.37		
	IQR	.25-.73	.16-.75		
	Mean rank	16.50	15.09		

Table 7: Comparison between control group and study subgroup GIIb as regards the latencies and amplitudes of oVEMP waves (N10 &P15).

measurements				Independent t-test and Mann-Whitney test	
		Control group	Study subgroup GIIb	T-value	*P value*
Latency N10 in msec	Range	8.20-14.13	9.50-14.50	0.224	.824
	Mean± SD	11.03±1.69	10.89±1.58		
Latency P15 in msec	Range	11.20-17.38	13.25-20.80	0.560	.580
	Mean± SD	15.04±1.51	15.43±2.32		
Amplitude N10 in µv	Range	.02-1.30	.03-2.31	1.91	.081
	Mean± SD	.54± .37	1.01±.73		
Amplitude P15 in µv	Range	.05-2.14	.06-8.80	Zmw=0.682	.502
	Median	.50	.62		
	IQR	.25- .73	.26-1.57		
	Mean rank	14.72	17.05		

Table 8: Comparison between study subgroup GIIa and study subgroup GIIb as regard to latency and amplitude N10& P15.

		Study group N=26		Paired t-test and Wilcoxon signed rank tests	
		Study subgroup GIIa	Study subgroup GIIb	T-value	*P value*
Latency N10	Range	9.50-15.25	9.50-14.50	1.22	.290
	Mean± SD	12.12±1.77	10.89±1.58		
Latency P15 in msec	Range	14.38-19.00	13.25-20.80	0.135	.988
	Mean± SD	16.26±1.33	15.43±2.32		
Amplitude N10 in µv	Range	.01-1.71	.03-2.31	Z_w=0.405	.686
	Mean± SD	.51±.52	1.01±.73		
Amplitude P15 in µv	Range	.08-.94	.06-8.80		
	Median	.37	.62	Z_w=0.944	.345
	IQR	.16-.75	.26-1.57		
	Mean rank	2.0	3.67		

Table 9: Comparison between control group and study group as regard to amplitude ratio of cVEMPs (P13, N23) and oVEMPs (N10 and P15).

Amplitude ratio		Groups		Mann-Whitney test	
		Control group	Study group	Z_{mw}	*P value*
P13	Range	2.08-71.13	9.22-78.00	1.032	.316
	Median	22.99	21.62		
	IQR	10.05-42.59	13.76-64.70		
	Mean rank	15.60	19.15		
N23	Range	.44-89.38	6.09-78.87	.847	.413
	Median	23.88	36.04		
	IQR	17.59-42.21	22.90-50.72		
	Mean rank	15.85	18.77		
N10	Range	.71-94.43	1.56-97.40	.204	.869
	Median	42.56	45.45		
	IQR	9.50-70.39	14.83-61.53		
	Mean rank	12.85	13.60		
P15	Range	3.09-81.81	11.00-42.85	.612	.575
	Median	16.34	20.00		
	IQR	10.55-28.78	14.0-40.0		
	Mean rank	12.55	14.80		

DISCUSSION

The study group consisted of 26 children fitted with unilateral cochlear implant. The study group was further subdivided into two subgroups, GIIa (surgical side) and GIIb (non sugical side).

Results of office tests in this study showed statistically significant differences only in Sharpened Romberg test, closed eye foam and Tandom gait tests when comparing normal and study groups. This agreed with Huang *et al*.[8] who reported a significant change in the tandem Romberg and closed eye foam test. The significant changes in Sharpened Romberg test, closed eye foam and tandom gait tests reflected vestibular loss because subjects selectively removed vision and somatosensory cues and would be dependent on vestibular cues only. The other office tests which showed non-significant changes, might reflect that patient were able to compensate for vestibular dysfunction.

In control group, combined VEMP was recorded in all children with no significant differences between right and left ear as regard to latencies and amplitudes. This result agreed with that of Chou *et al*.[9] who reported that VEMPs showed 100% response rates with non-significant differences between the two ears in healthy subjects.

On the other hand, the absence of cervical and ocular VEMPS in both study subgroups (GIIa) and (GIIb) are explained by the close anatomical and embryological

relation between the cochlea and the vestibular end organs causing high prevalence of vestibular impairments in hearing impaired pediatric patients.[10,11,12] Increase the VEMP affection in the surgical ears compared to non-surgical ones determining the surgical effect. However, results of the research reflect more affection in cVEMP in the surgical side than oVEMP. This finding is in accordance with another research detecting that the saccule is the most commonly affected receptor.[2] Different mechanisms that could lead to vestibular dysfunction during or after CI surgery have been reported. These include: direct trauma caused by electrode insertion, acute serous labyrinthitis due to cochleostomy, foreign body reaction with labyrinthitis, endolymphatic hydrops, and electrical stimulation from the implant itself.[13]

Krause *et al*.[14] reported preoperatively, cVEMPs was absent in 65% (15/23) and increased to 83% (19/23) postoperatively. While, Basta *et al*.[15] reported preoperative abnormalities of cVEMPs in 11% (2/18) which increased to 67% (12/18) of patients postoperative. These two researches studied adults.

CONCLUSION

Combined cervical and ocular VEMPs showed saccular and utrical dysfunction in both ears of unilateral cochlear implant children. This finding points to otolith affection in profound sensory neural hearing loss. This otolith affection increases in the surgical ear.

However, it is recommended to future research for evaluation pediatric CI candidates before and after implantation using an extensive vestibular test battery.

CONFLICT OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Zeng FG, Tang Q, Lu T. Abnormal pitch perception produced by cochlear implant stimulation. PLoS One. 2014;9(2):e88662.

2. Todt I, Basta D, Ernst A. Does the surgical approach in cochlear implantation influence the occurrence of postoperative vertigo? Otolaryngol Head Neck Surg. 2008;138(1):8-12.

3. Tien HC, Linthicum FH, Jr. Histopathologic changes in the vestibule after cochlear implantation. Otolaryngol Head Neck Surg. 2002;127(4):260-4.

4. Colebatch JG, Halmagyi GM, Skuse NF. Myogenic potentials generated by a click-evoked vestibulocollic reflex. J Neurol Neurosurg Psychiatry. 1994;57(2):190-7.

5. Rosengren SM, McAngus Todd NP, Colebatch JG. Vestibular-evoked extraocular potentials produced by stimulation with bone-conducted sound. Clin Neurophysiol. 2005;116(8):1938-48.

6. Kolkaila EA, Emara AA, Gabr TA. Vestibular evaluation in children with otitis media with effusion. J Laryngol Otol. 2015;129(4):326-36.

7. Khan, F.; Balraj, A. and Lepcha, A. (2014). Normative Data for Vestibular Evoked Myogenic Potential in Different Age Groups Among a Heterogeneous Indian Population. Indian J Otolaryngol Head Neck Surg.; 66(2): 149–154.

8. Huang MW, Hsu CJ, Kuan CC, *et al*. Static balance function in children with cochlear implants. Int J Pediatr Otorhinolaryngol. 2011;75(5):700-3.

9. Chou CH, Wang SJ, Young YH. Feasibility of the simultaneous ocular and cervical vestibular-evoked myogenic potentials in unilateral vestibular hypofunction. Clin Neurophysiol. 2009;120(9):1699-705.

10. Tribukait A, Brantberg K, Bergenius J. Function of semicircular canals, utricles and saccules in deaf children. Acta Otolaryngol. 2004;124(1):41-8.

11. Bonucci AS, Costa Filho OA, Mariotto LD, *et al*.Vestibular function in cochlear implant users. Braz J Otorhinolaryngol. 2008;74(2):273-8.

12. Ibrahim I, da Silva SD, Segal B, *et al*. Effect of cochlear implant surgery on vestibular function: meta-analysis study. J Otolaryngol Head Neck Surg. 2017;46(1):44.

13. Ferster APO, Cureoglu S, Keskin N, *et al*. Secondary Endolymphatic Hydrops. Otol Neurotol. 2017;38(5):774-9.

14. Krause E, Wechtenbruch J, Rader T, *et al*. Impaired fixation suppression is a risk factor for vertigo after cochlear implantation. J Laryngol Otol. 2009;123(8):845-50.

15. Basta D, Todt I, Goepel F, *et al*. Loss of saccular function after cochlear implantation: the diagnostic impact of intracochlear electrically elicited vestibular evoked myogenic potentials. Audiol Neurootol. 2008;13(3):187-92.