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Vestibular assessment in cochlear implanted children.

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Abstract

Objective: To assess and compare vestibular function in children with severe to profound hearing loss and post cochlear implant children by vHIT with normal hearing children.

Patients and methods: Case control study, normal children (n=46) underwent vestibular testing (Clinical office test battery, (VEMP) vestibular evoked myogenic potential and Video Head Impulse test) and the results was compared with severe to profound sensorineural hearing loss children (n=46) and cochlear implanted children (n=43) results. All were age matched.

Results: SNHL and CI children showed abnormality in office tests for Vestibulo-spinal reflex in the form of abnormal Modified CTSIB when eyes were closed. CI group showed (37%) and SNHL group showed (27%) VEMP abnormalities in one or more parameter either unilaterally or bilaterally, However vHIT results showed (47%) of abnormalities in CI group and (26%) of abnormalities in SNHL group. However, Anterior SCC VOR gain in CI group didn't affected, posterior (<0.001) and lateral semi-circular canals (<0.001) VOR gain is affected in implanted ear.

Cochlear implantation, Children, Vestibular tests, Video-head-impulse test. The CI children showed VEMP abnormalities in one or more parameter either unilaterally or bilaterally our results do not show any impairment of Anterior SCC VOR function in children with CI compared to normal-hearing children. CI does not affect saccular and VOR function. There was no any correlation between VEMP, vHIT weak side and the cochlear side. The risk posed by Cochlear Implantation (CI) to the vestibular system is still under debate.

Keywords: Cochlear implantation, Children, Vestibular tests, Video-head-impulse test.

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Introduction

Vestibular function in children has traditionally received little attention clinically or in research. While the overall prevalence of vestibular loss in typically-developing children is low; there is a significant association between children diagnosed with a peripheral vestibular disorder and sensory neural hearing loss [1].

The mechanism of vestibular damage after cochlear implantation may be due to, trauma during electrode insertion, labyrinthitis, postoperative fistula, secondery endolymphatic hydrops, intraoperative perilymph gusher, electrical stimulation of the vestibular implant, benign paroxysmal positional vertigo.

Beck noticed that vestibular impairement are highly associated with sensorineural hearing loss children. However, children may not have the vocabulary, history, or concepts to describe vestibular anomalies. Thierry reported that postoperative vestibular damage after cochlear implantation occurs in 6-80% of adult patients, and in 9%-50% of implanted children.

Vestibular testing techniques now provide a means for assessing whether vestibular dysfunction is isolated to the otoliths, semi-circular canals, or involves the entire peripheral vestibular system. The Video Head Impulse Test (vHIT) appears to be most useful as part of a rapid battery of bedside tests [2].

Few researches assess the vestibular function in children with severe to profound sensorineural hearing loss and after cochlear implantation. So this study will be conducted to assess and compare the vHIT in children with sensorineural hearing loss and cochlear implant recipients in contrast to normal children [3].

Materials and Methods

Patients

The current study was a case control study, conducted in Audiology department, Hearing Speech Institute and was classified into three groups (control and two study groups).

Group 1 (Normal group): This group included 46 normal children with age range between 5 and 18 years with mean of (8.7 years) and standard deviation of (± 2.7years).

They were selected according to the following criteria: Normal hearing sensitivity level and normal middle ear functions, normal speech and language development, normal motor skills development and no current or past history of vestibular dysfunction.

Group 2 (SNHL group): This group included 46 children with severe to profound sensorineural hearing loss, which were age matched with the control group.

Group 3 (CI group): This group included 43 cochlear implanted children, which were age matched with the control group.

Exclusion criteria: Children with history of otitis media with effusion, children with neurological and/or psychiatric diseases, children with orthopedic disorders which limit movements and children who are taking medication that is known to suppress the vestibular System.

Equipment

Two channel audiometer (Interacoustics, AC 40), immitancemeter (MADSEN Zadiac, 901), vestibular evoked myogenic potential (Audera, GSI) and video Head Impulse equipment (Interacoustics, Eye See Cam).

Methods

All subjects in the study groups were subjected to the following:

- **Collection of detailed anamnestic history.**
- **Otological examination.**
- **Audiological evaluation**: Pure tone audiometry for threshold testing from (250 Hz-8000Hz), Speech audiometry (Speech Reception Threshold (SRT) using bisyllabic words and word Discrimination (WD%) scores using monosyllabic words, Acoustic immitancemetry, threshold testing and aided sound field response: using warble tones of 250 Hz, 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.
- **Vestibular evaluation**

Clinical office tests for vestibular functions: (Occulomotor tests, Evaluation of vestibuleocular reflex and Evaluation of Vestibulo-Spinal Reflex)

Vestibular Evoked Myogenic Potential (cVEMP): Surface silver electrodes were placed on symmetrical sites over the midpoint of each sternomastoid muscle with reference electrode over the upper sternum and the ground electrode was put on the forehead. The electrode impedence was kept below 5 KΩ. The subjects were instructed to rotate their head to the opposite side of the stimulated ear as much as possible (unilateral muscle activation). The stimulus was rarefaction tune burst 500 Hz at 100 dBnHL intensity. The repetition rate was 5/sec. The EMG response from each side was amplified, band pass filtered (10-1000 Hz). 200 sweep were average [4].

Video Head Impulse Test (vHIT): Subjects were seated and instructed to maintain their gaze on a fixed visual target located at a distance of 1 meter straight ahead at eye level at zero azimuth. Goggles were mounted on the eyes, resting on the nasal bridge with no gap between the goggle and nasal bridge to avoid slippage during testing. The strap should be above subject's ear and behind his head; the strap should be tightened to ensure that it will not slip during testing. The lateral canals were first tested followed by the vertical canals. Prior to any gain calculations, each subject head and eye velocity record was checked to ensure that an adequate head impulse was obtained [5].

Statistical analysis

The collected data was revised, coded, tabulated and introduced to a PC using Statistical package for Social Science (SPSS 15.0 for windows; SPSS Inc, Chicago, IL, 2001). Data was presented and suitable analysis was done according to the type of data obtained for each parameter. Descriptive statistics: mean, median, standard deviation (± SD), minimum and maximum values (range) for numerical data and frequency and percentage of non-numerical data. If analytical statistics with normality of distribution parameters, it will be evaluated by One-Sample Kolmogrovo-smirnov first; then for normal distribution will be used One-Way ANOVA test and One-Way ANOVA Post Hoc Tests While; for nonparametric distribution will be used Kruskal-Wallis Test and Mann-whitney Test. A statistically significant difference was set at $p<0.05$.

Results

A total number of 135 subjects were included in this study. They were classified into three groups. The normal group (1) consisted of 46 healthy normal children's with no history of hearing loss or sense of imbalance, (25 females (54.3%) and 21 males (45.7%)) with an age range between 5 and 15 years old. The 2nd group consisted of 46 severe to profound sensorineural hearing loss; 31 females (67.4%) and 15 males (32.6%) with an age range between 5 and 16 years with mean of (9.3 years) and standard Deviation of (± 3.5 years). The 3rd group included 43 cochlear implant children 23 females (53.5%) and 20 males (46.5%). All groups were age and gender (Tables 1 and 2).

Table 1. *Comparison between studied groups as regards age.*

Age	N	Mean	SD	Median	Range	Kruskal-Wallis	P Value	Sig.
Normal children	46	8.7	2.7	8	15-May	2.26	0.323	NS
SNHL children	46	9.3	3.5	9	16-May			
Cochlear children	43	8	2.5	8	16-May			

Table 2. *Comparison between studied groups as regards gender.*

Gender	Male(n=56)	Female (n=79)	Total(n=135)	X^2	P Value	Sig.
Normal children	21 (45.6%)	25 (54.3%)	46 (100%)	2.27	0.321	NS
SNHL children	15 (32,6%)	31 (67.4%)	46 (100%)			
Cochlear children	20 (46.5%)	23 (53.5%)	43 (100%)			

The Tables 1 and 2 shows that (The three groups are gender matched).

Audiological findings

The control group has bilateral within normal hearing sensitivity, SNHL group has severe to profound hearing loss using hearing aids and the CI group has satisfactory aided hearing threshold using CI device (within the Long Term Average Speech Spectrum) (LTASS) (Table 3).

***Table 3**. Comparison of audiological evaluation parameters between control and study groups.*

	Group	N	Mean	SD	Median	Min.	Max.	Kruskal-Wallis	Pvalue	Sig.
SRT	Normal[a]	92	7.4	3.6	10	0	15	98.31	<0.001	HS
	Cochlear [b]	43	24.4	9.5	20	15	60			
	SNHL[c]	92	39.3	9.5	40	30	70			
500	Normal[a]	92	9.3	2.9	10	0	15	100.87	<0.001	HS
	Cochlear[b,c]	43	27.3	8.4	25	20	60			
	SNHL[c,b]	92	42.1	8.4	40	30	75			
1000	Normal[a]	92	7.8	3.7	10	0	15	98.58	0.001	HS
	Cochlear[b,c]	43	29.7	10.1	30	20	40			
	SNHL[c,b]	92	47.7	4.3	50	40	75			
2000	Normal[a]	92	7.8	3.9	10	0	15	100.32	0.001	HS
	Cochlear[b,c]	43	34.5	10.6	30	25	80			
	SNHL[c,b]	92	54.4	9.2	50	25	90			
4000	Normal[a]	92	7.5	3.6	10	0	15	100.24	0.001	HS
	Cochlear[b,c]	43	37.1	10.9	35	30	80			
	SNHL[c,b]	92	61.6	9.8	60	50	90			

Office tests

In the control group: Office tests in the form of Range of movement, Smooth Pursuit Test, Saccadic Test, Spontaneous Nystagmus, Head Shake Test, Head Thrust Test (HTT), Modified CTSIB, Fukuda Test, Gait Test, Tandem walk and Dix-Halpike test were normal in all the group.

In the study groups: All Office tests were normal except Fukuda andModified CTSIB tests.

***Table 4.** Distribution of office test findings in SNHL and CI group.*

	Group	Normal	abnormal	Total	X^2	P value	Sig.
Fukuda and M-CTSIB	Cochlear	36 (45%)	7 (77.8%)	43 (48.3%)	3.48	0.083	NS
	SNHL	44 (55%)	2 (22.2%)	46 (51.7%)			
	Total	80 (100%)	9 (100%)	89 (100%)			

The Table 4 shows the percentage of abnormality was higher in the SNHL group than CI group. However, there is no statistically significant difference between study groups (SNHL and CI) as regards Fukuda and M-CTSIB results.

Vemp results

Vemp results in the control group: Clear VEMP response is obtained on both sides from all control children. The peak latencies of P13 and N23 are measured (Tables 9 and 10). The mean +2 SD is calculated and is used as cutoff limit for the normal values throughout this study.

Table 5. *Comparison of cVEMP Parameters between right and left ears in control group.*

Normal		N	Mean	SD	Median	Range	t	P-value	Sig.
P13 latency ms	Right	46	15.4	1.4	15	13.3-19.2	0.04	0.972	NS
	Left	46	15.1	1.7	14.7	12.4-19.6			
N23 latency ms	Right	46	20.7	1	20.8	18-22.5	0.21	0.836	NS
	Left	46	20.7	1.2	20.8	18.2-22.7			
Interamp µv	Right	46	63.3	20.6	65.5	28.5-100	0.66	0.513	NS
	Left	46	62.4	17.5	67.3	29.9-93.3			
Assymetrey	Right	46	11.7	4.4	11.5	25-Feb	0.46	0.591	NS
	Left	46	11.8	4.5	11.8	25-Jan			

The Table 5 shows that there is no statistical significant difference between right and left ears in the control group, so both ears were added together.

Table 6. *Comparison between cVEMP parameters in control and study groups.*

	Group	N	Mean	SD	Median	Min.	Max.	Kruskal-Wallis	Pvalue	Sig.
P1latency ms	Normala	92	15.4	1.6	15	12.4	19.6	34.99	<0.001	HS
	Cochlearb	40	16.5	2.1	16.2	12.7	21.1			
	SNHLc	88	17.8	3	17.7	11.4	25.2			
N1latency ms	Normala	92	20.8	1.1	21	18	22.7	27.59	<0.001	HS
	Cochlear b,c	40	22	2	21.4	17.3	27.1			
	SNHLc,b	88	23.1	3.4	22.6	15.4	32.1			
Inter Amp µv	Normal a	92	64.1	19.7	67.3	28.5	100	14.03	0.001	HS
	Cochlearb,c	40	52.8	19.4	53.6	21.4	89.6			
	SNHLc,b	88	54.1	18.8	56.8	26.2	89.6			
Asymmetry	Normala	92	11.5	4.4	11.7			9.22	<0.001	HS
	Cochlear b,c	40	19.6	11.4	16	5	48			
	SNHLc,b	88	20.9	14.7	18	4	45			

VEMP Finding in the study group

The Table 6 shows highly statistically significant difference between control, SNHL and CI group regarding cVEMP parameters (P1, N1, inter amplitude difference and asymmetry). There is highly statistically significant difference between SNHL group and CI group regards only P1 in cVEMP parameters. There is no statistically significant difference between SNHL group and CI group as regards cVEMP parameters (N1, inter amplitude difference and asymmetry).

Table 7. *Distribution of VEMP results in SNHL group and CI group.*

	Group	Normal	abnormal	Total	X^2	P value	Sig.
Fukuda and M-CTSIB	Cochlear	36 (45%)	7 (77.8%)	43 (48.3%)	3.48	0.083	NS
	SNHL	44 (55%)	2 (22.2%)	46 (51.7%)			
	Total	80 (100%)	9 (100%)	89 (100%)			

The Table 7 shows no statistically difference between SNHL group and CI group regarding VEMP results. There is no statistically significant difference between the two ears as regards VEMP results.

Table 8. *Distribution of VEMP results in in implanted side (ear) and non-implanted side (ear) in CI group.*

	Group	Normal	Abnormal		Total	X^2	Pvalue	Sig.
VEMP	Non-implanted	30 (49.2%)	8 (32%)	5 (20%)	43 (50.0%)	0.06	0.812	NS
	implanted	31(50.8%)	9 (36%)	3 (12%)	43 (50.0%)			
	Total	61 (100%)	25(100%)		86 (100%)			

The Table 8 shows no statistically significant difference between the two ears as regards VEMP results.

vHIT results

The Tables 9 vHIT results in control subjects. Standardization was done as regards VOR gain

Table 9. Comparison between right and left vHIT gain in control group.

Normal		N	Mean	SD	Median	Range	Z	pvalue	Sig.
Lat canal	Right	46	1	0.2	1	0.6-1.4	1.25	0.211	NS
	Left	46	1	0.3	1	0.6-1.9			
Ant. canal	Right	46	1.3	0.4	1.2	0.7-2.6	1.09	0.274	NS
	Left	46	1.3	0.5	1	0.7-2.6			
Post. canal	Right	46	1	0.3	0.9	0.7-1.6	1.86	0.062	NS
	Left	46	1.1	0.3	1.1	0.7-1.9			

The Table 9 shows that there are no statistically differences between right and left gain in control group. So, both ears are added together. The results of vHIT in the control group serve as a reference for comparison with the study groups.

Table 10. Comparison between vHIT gain in control and study groups.

	Group	N	Mean	SD	Median	Min.	Max.	Kruskal-Wallis	Pvalue	Sig.
Lateral canal	Normal[a]	92	0.98	0.23	0.98	0.58	1.9	28.26	<0.001	HS
	Cochlear[b]	43	0.65	0.36	0.65	0.03	1.7			
	SNHL[c]	92	0.84	0.32	0.9	0.03	1.42			
Anterior canal	Normal[a,b]	92	1.17	0.41	1	0.7	2.6	8.03	0.018	S
	Cochlear[b,a,c]	43	1.32	1.4	0.69	0.01	6.8			
	SNHL[c,b]	92	1.01	0.48	0.9	0.23	2.9			
Posterior canal	Normal[a]	92	1.11	0.34	0.96	0.65	2	58.22	<0.001	HS
	Cochlear[b]	43	0.53	0.46	0.42	0.01	2			
	SNHL[c]	92	0.86	0.36	0.84	0.16	1.9			

The Table 10 shows statistically significant difference between control and study groups as regards lateral and posterior canals. There is statistically significant difference between control group and SNHL group as regards anterior canal. There is no statistically significant difference between control group and CI group as regards anterior canal.

Table 11. Distribution of vHIT results in group.

	Group	Normal	Abnormal	Total	X^2	P value	Sig.
VHIT	Normal	46 (44.7%)	0 (0%)	46 (34%)	3.74	0.043	S
	Cochlear	23 (22.3%)	20 (62.5%)	43 (32%)			
	SNHL	34 (58.9%)	12 (37.5%)	46 (34%)			
	Total	103 (100%)	32 (100%)	135 (100%)			

Table 12. Comparison between vHIT gain in implanted side (ear) and non-implanted side (ear) in CI group.

The Table 11 shows that there is statistically significant difference between SNHL and CI groups as regards vHIT abnormality present.

Cochlear		N	Mean	SD	Median	Min.	Max.	t	P-value	Sig.
Lat. canal	Non-implanted	43	0.65	0.41	0.7	0.04	1.6	0.02	0.987	NS
	implanted	43	0.65	0.36	0.65	0.03	1.7			
Ant. canal	Non-implanted	43	1.32	1.4	0.69	0.01	6.8	2.91	0.005	HS
	implanted	43	0.65	0.56	0.47	0.02	2.5			
Post. canal	Non-implanted	43	1.18	1.11	0.81	0.01	5.4	3.45	0.001	HS
	implanted	43	0.53	0.46	0.42	0.01	2			

The Table 12 there is highly statistically significant difference between two sides as regards anterior and posterior canals. There is no statistically significant difference between two sides as regards lateral canal.

Discussion

Cochlear Implantation (CI) is the best standard for management of severe to profound Hearing Loss (HL) with unsatisfactory hearing aids. Injury to the vestibular organs may occur during surgery and result in vestibular dysfunction. In the present study we assess and compare vestibular function in cochlear implant children with severe to profound hearing loss and normal children [6].

Office Tests

In the control group: Office tests in the form of Occulomotor-tests, evaluation of VOR test and evaluation of VSR test were normal in normal children.

In the study groups: Despite office tests did not show occulmotor or VOR abnormality in the current study, 2 children (4%) of 2nd group and 7 children (16%) of 3rd group showed abnormality in office tests for Vestibulo- spinal reflex in the form of abnormal Modified CTSIB when eyes were closed and the patient was standing on a compliant surface (Table 4).

These results agrees with Baudhuin (2010) who noticed abnormality in the tandem Romberg test and Modified CTSIB when eyes were closed on foam test, while other tests show normal results. The abnormality was implied with vestibular origin because subjects removed vision and somatosensory origin. So, they were dependent on vestibular cues only.

Laurence studied postural function in children using CI. They compare the postural function in CI children with normal children of the same age using static and dynamic platform, open and closed eye condition, under conditions of CI activated and deactivated. They demonstrated that the postural function of children with CI was abnormal on eye closed condition. They concluded that children with CI became visually dependent, especially in changing postural conditions.

According to Suarez the dysfunction of the balance after CI didn't last forever, in spite of this vestibular function loss, the children could have an adequate balance control.

VEMP results: cVEMP was recorded in all children in the normal group in right and left ear when stimulated. The two components of cVEMP response were identified: a biphasic positive-negative wave P13-N23 and their latencies were comparable to those demonstrated by Piker (Table 5).

VEMP results in study group: In the present study cVEMP abnormalities was found in one or more parameter. Latency prolongation either unilaterally or bilaterally was the most frequent abnormality in SNHL group (60%) and (40%) in CI group. Complete absence of the response was also encountered in (4%) of SNHL group and (7%) of CI group (Tables 6 and 7).

This agreed with Hazzaa who reported that hearing impaired children with variable etiologies had VEMPs abnormalities, (55%) for cVEMPs and (37.9%) for oVEMPs. Abnormal bilateral responses were more frequent than unilateral abnormalities. However; the predominant abnormality was absent response. Moreover, this is similar to that reported by Said (2014) who found abnormal VEMP in 75% of profound hearing impaired children and reported that bilateral affections were more common than unilateral.

The high prevalence of vestibular impairments in hearing impaired children was also reported by many researches [7]. Moreover, the results of this study showed no significant difference between sensory-neural hearing loss group and cochlear implant group (Tables 6 and 7). Because of difficulties in examination of children before and after cochlear implantation and a lot of children miss the follow up visits; in this study the comparison between implanted and non-implanted ears in office test, VEMP, vHIT response was done. Preliminary results showed that patients may exhibit vestibular loss associated with hearing loss even with the absence of vestibular complaints. In the cochlear group, it was found that abnormal VEMP results was present in 13 (30%) in non-implanted ear compared to 12 (28%) of implanted ear (Table 7). Moreover, there was no significant difference regards cVEMP results between implanted and non-implanted ears (Table 8). This agreed with Basta who found no loss of saccular function after CI by VEMP testing. This was explained by the close anatomical and phylogenetic relation between the cochlea and saccule, as they are closely related in innervation and vascular supply. They share the continuous membranous labyrinth of the inner ear and function by means of similar receptor cells. So, whatever the cause that damage the cochlea, the same agent could actually damage the saccule [8-12].

This indicates that there was vestibular impairement before the cochlear implant device was implanted probably in both ears.

In contrast, Singh revealed no significant difference between normal children group and hearing impaired group as regard P1 and N1 latencies values (p>0.05).

On the other hand, El-Rasheedy found that there was significant difference between cVEMP results pre and pos cochlear implantation [13-17].

vHIT results: vHIT In the control group: The main vHIT parameter is the VOR gain. In the control group, the mean VOR gain ranged between 0.6-1.6 across different canals (Table 9). This also reported by MacDougall who reported that the criterion for a normal VOR gain should be 0.68 or greater. Moreover, Matino-Soler set a cut-off point of VOR gains below 0.8 for horizontal canals and 0.7 for vertical canals to be considered pathological. There was no significant difference between right andleft gain in the control group. This agreed with MacDougall (Table 9).

The results of this study revealed decrease in the VOR gain in both study groups compared to control (Table 10). Also, there was significant difference between both cochlear group and hearing impaired group regarding lateral andposterior VOR gain results (Table 10).

Wolter reported the same results; namely, in children with CI showed significantly more abnormalities in lateral canal function. The same conclusions were also reported by other authors, using low-frequency caloric stimulation test in adults after CI [18].

Our results showed VOR gain decreased in 12 (26%) of SNHL group compared to 20 (46.5%) in CI group (Table 11). Wolter reported the same results, children with CI showed significantly more lateral canal function abnormalities than children without CI.

We compared the VHIT results between implanted and non-implanted ear in (cochlear) group and the results revealed that there was decreased anterior andposterior VOR gain in implanted ear (Table 12). On the other hand there was no significant difference between implanted and non-implanted ear in CI group regarding LSC VOR gain (Table 12). This may be explained by impairment is localized to the low frequencies, thus vHIT and rotatory chair results remain normal [19-24].

The results of this study also agreed with Nassif who examined LSC high frequency VOR using vHIT in children after bilateral CI. They found that LSC high frequency VOR gain in 16 children with unilateral and bilateral CI did not differ between the non-implanted ears in children with CI and profound sensorineural hearing loss children. Also, these results agreed with Lemajic-Komazec who examined 28 children with sensorineural hearing loss who underwent cochlear implantation and showed no statistically significant difference of VOR gain of lateral semicircular canal measured in implanted ears and non-implanted ears [25].

However, in this study significant difference between implanted and non-implanted ear in 3rd group regarding posterior and anterior semicircular canal was found (Table 13).

According to Thierry after implantation, 50% of children had bilateral within normal vestibular responses, whereas the other 50% showed abnormal vestibular response: unilateral or bilateral vestibular impairement, 19% of children had asymmetry of vestibular response in implanted ear, while one third of them had abnormal response in the contralateral ear.

However, if cochlear implantation causes vestibular impairment, after implantation children reported rapid compensation of the sensory deficit, and thus the vestibular dysfunction cannot be detected at all. This is the reason for discrepancy between subjective symptoms and objective vestibular tests [26].

Conclusion

The risk of Cochlear Implantation (CI) to the vestibular system is still not well understood. A large percentage of patients showed VEMP abnormalities in one or more parameter either unilaterally or bilaterally. LSC VOR gain is not affected by implantation. Posterior and anterior semicircular canals VOR gain shwed affection in implanted ear.

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