Original Article

Vestibular Evaluation Using Rotatory Chair in Children with Cochlear Implants

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ABSTRACT

Introduction: Cochlear Implant surgery is a procedure to overcome the problem of severe to profound sensorineural hearing loss with no benefit from hearing aids. Although, it may cause postoperative changes of vestibular function. Vestibular evaluation is necessary to detect vestibular affection after surgery.

Aim: Vestibular evaluation in severe or severe to profound hearing loss children and cochlear implanted children by using Arabic Dizziness Handicap Inventory for children (DHI), vestibular bed-side tests for children and Rotatory chair testing..

Patients and Methods: This work included 60 children divided into three groups: group I (GI) consisted of 20 normal hearing children, group II (GII) consisted of 20 bilateral severe or severe to profound hearing loss children and group III (GIII) consisted of 20 unilateral cochlear implanted children. They were evaluated by full audiological evaluation, Arabic DHI for children, vestibular bed-side tests for children, Sinusoidal harmonic acceleration (SHA) and velocity step test (VST) of Rotatory Chair.

Results: This study showed significant affection in the Arabic DHI for children, Sharpened Romberg test and Fukuda Stepping test. Rotatory chair results in GII showed, ten children with unilateral peripheral vestibular affection and three children with bilateral vestibular affection. While GIII showed, eight children with unilateral peripheral vestibular affection ipsilateral to side of implantation and three children with bilateral vestibular affection.

Conclusion: Arabic DHI for children is a good valuable tool to detect parental observation of vestibular affection in children. Also, Rotatory chair test is a valid and non-invasive test for detection of vestibular affection in children.

Key Words: Dizziness Handicap Inventory (DHI), Sinusoidal harmonic acceleration (SHA), Velocity step test (VST).

Received: 19 July 2021, **Accepted:** 15 October 2021

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ISSN: 2090-0740, 2021

INTRODUCTION

Disturbances in cochlear function, which can result in sensorineural hearing loss (SNHL), could accompany vestibular impairment because the cochlea and the vestibular system share the continuous membranous labyrinth of the inner ear. Therefore, injury or trauma prenatally, or postnataly may cause damage to one or both systems[1]. Cochlear implantation surgery is the gold standard for treating severe to profound sensorineural hearing loss[2]. The vestibular system is at risk during cochlear implant surgery because it is housed in the labyrinth of the inner ear and it is connected to the cochlea. Since these two organs share the same fluid, changes in the cochlea could cause changes in the semicircular canals and the otolith organs of the vestibular system[3].

Different mechanisms that could lead to vestibular dysfunction during or after CI surgery such as 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[4]. An alternative mechanism by which CI may positively impact balance function is via direct stimulation of the vestibular nerve. Even in the face of end organ trauma, evidence suggested that peripheral vestibular afferents are preserved after CI. Just as current can spread from an intracochlear electrode array to the facial nerve, one must also consider the possibility of vestibular cross-stimulation 5. Cochlear implantation leads to postoperative modifications of the vestibular function in the form of fibrosis of the vestibule and distortion of the saccular membrane or direct injury and labrynthitis[5].

Subtle vestibular affection in children with severe to profound sensorineural hearing loss as well as cochlear implanted children may be detected by using Arabic dizziness handicapped questionnaire for children. Also objective evaluation of Vestibulo-Ocular reflex can detect those children who may need vestibular rehabilitation after cochlear implantation.

DOI: 10.21608/ejentas.2021.86951.1397

AIM OF WORK

Vestibular evaluation in severe or severe to profound hearing loss children and cochlear implanted children by using Arabic Dizziness Handicap Inventory for children (DHI), vestibular bed-side tests for children and Rotatory chair testing.

PATIENTS AND METHODS:

Sixty children were enrolled in this study. Their age range was 5-18 years. They were divided into three groups: group I (GI) consisted of 20 normal hearing children, group II (GII) which included 20 children with bilateral severe or severe to profound sensorineural hearing loss and group III (GIII) which included 20 children with unilateral cochlear implant.

The exclusion criteria included children with general health problems or history of ototoxic drugs intake. This study took place in Audio-Vestibular Medicine unit, Tanta University. It was approved by The Research Ethics Committee on September 2018 with code No. 32566/09/18.

All children were subjected to: Full History taking, including prenatal, perinatal, natal and postnatal history in addition to developmental history, family history of hearing loss and family history of consanguinity. Otological examination, basic audiological evaluation including pure tone audiometry using both air and bone conduction, speech audiometry conducted in sound treated room using two channel audiometer (Madsen Astera (Type-1), Immittancemetry using Interacoustics (AT235) Impedance Audiometer. Vestibular evaluation using Arabic DHI for children, Vestibular office tests for children4 and Rotatory Chair test using Micromedical Technologies System 2000.

Dizziness Handicap Inventory (DHI) for children (Arabic form).

Arabic Dizziness Handicap Inventory was developed at Tanta University Audiovestibular Medicine unit. It reflected the paternal observation of the child balance performance and imbalance symptoms. It consisted of ten questions about the child activities that reflects his/her balance performance. Each question took a score 0 means no, 5 means sometimes, 10 means always. It has ten items so the total score ranged from 0 to 100. The whole score calculated as percent of 100. The score 0 meaning “no handicap” and 100 indicating “significant” self-perceived handicap.[6]

Vestibular office tests for children:

It included the following: Observation of the eye by observation of spontaneous nystagmus, alignment test which was done by instructing the child to follow a small toy in the frontal plane and the midsagittal plane and observation of range of eye movement. Oculomotor tests including Smooth pursuit test by observation of eye movements while moving toys in front of the child in horizontal and vertical directions and keeping the head stationary. Saccadic eye test was done by instructing the child to follow a little toy that appeared randomly behind a colored window. Moreover, Gaze test was done by asking the child to focus on a small fixed toy at 20 ° and 20 cm for 30 seconds at the right side then at the left. Head thrust test was performed by asking the child to fixate on the examiner’s nose where having a sticker on it and the head is rapidly turned 50–60 degrees to one side. Head shaking test was performed by rotating the head to the right and left sides rapidly with eyes closed for about 30 seconds then bringing it to an abrupt stop, and the eyes were observed for nystagmus.

Tests for posture and gait were performed. Theses included: Tandem gait test in which the child walked blind on a straight line to assess the general balance function. Foam test was performed by asking the child to stand on a foam mat covered with kids’ games pictures with both feet together with eyes open and then eyes closed. Fukuda stepping test was performed by asking the child to march 50 steps in place with outstretched arms and the eyes closed and without moving. Deviation for more than 30° or moving forward or backwards (more than 50 cm) were considered a positive test result. Romberg’s test was performed by asking the child to stand on one leg. While, Sharpened Romberg test was performed by asking the child to stand with feet in heel-to-toe position with arms folded against chest, first with eyes open and then with eyes closed.

As regard Rotatory Chair test: The child was seated in the chair independently using well fitted seat. If the child was short cushions were used to increase the height. Chair-mounted camera was used to subjectively observe nystagmus during rotation. Eye movements were recorded with video goggles. Some degree of mental tasking was used during rotation as rotatory chair gain can decrease with decreased alertness. Older children were generally engaged in a conversation or simple cognitive tasks such as counting or spelling. Children with hearing loss were encouraged to wear their hearing aids. Children were instructed to open their eyes and look forward. Two main Rotatory chair tests were used SHA and VST. SHA test was done at the frequencies of 0.01, 0.02, 0.04, 0.08, 0.16, 0.32, and 0.64 Hz (Figure 1).

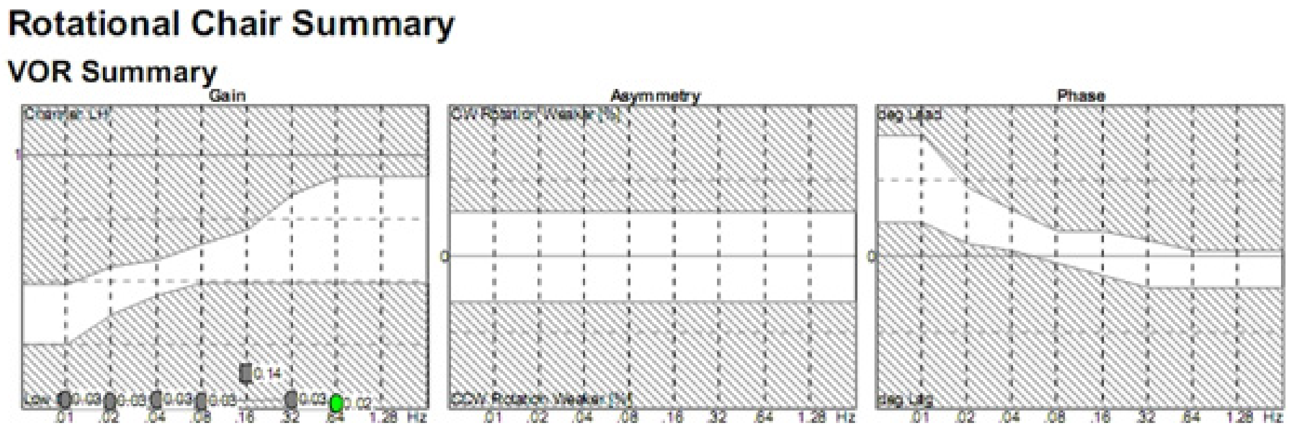

Fig. 1: abnormal SHA test (Low gain at all frequencies suggesting bilateral vestibular hypofunction)

The chair was rotated with a maximum velocity of 80°/s at each test frequency. The program calculates the gain (the ratio of the amplitude of eye movement to the amplitude of head movement), phase (the timing relationship between head movement and reflexive eye response), and symmetry (comparison of the slow component of the nystagmus when rotated to the right versus left for each frequency).

Velocity Step test is a rapid measurement of gain and time constant of the VOR rotating in both a clockwise (CW) and counterclockwise (CCW) direction The program calculate time constant (the length of time takes to go from peak nystagmus slow-phase velocity to 37% of that velocity in an exponential decay pattern), and gain (the peak slow-phase eye velocity divided by the peak chair (head) velocity) (Figure 2).

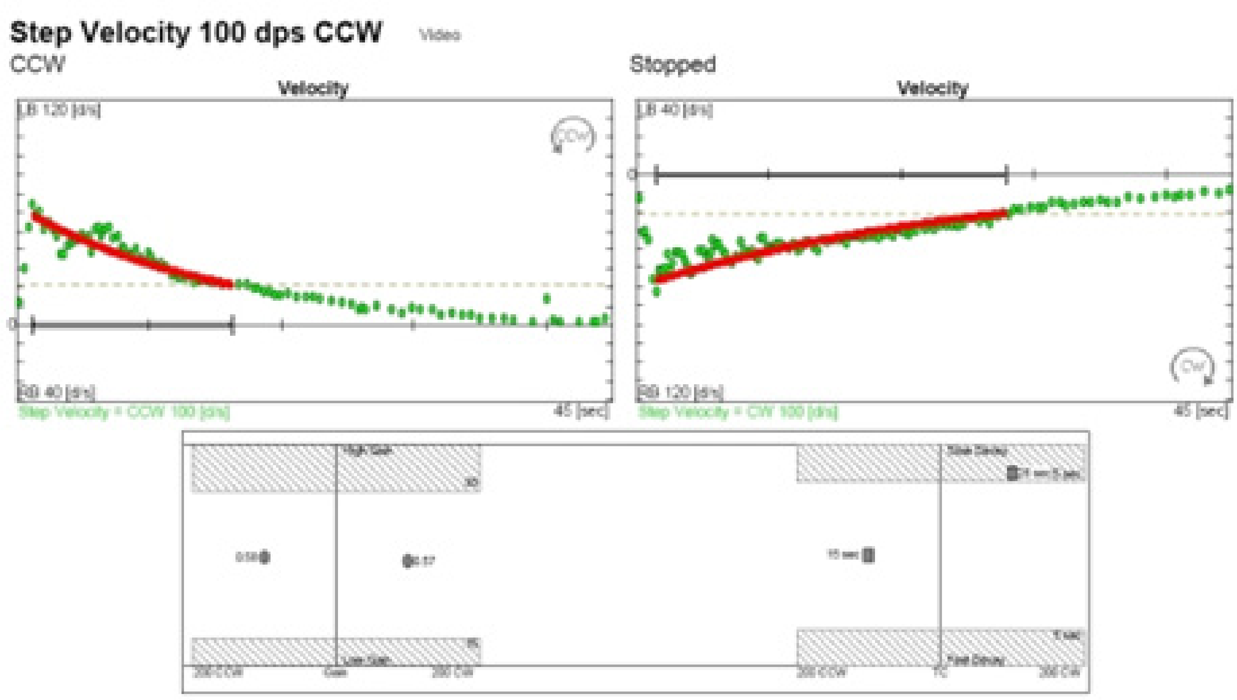

Fig. 2: Velocity Step test

RESULTS

The age range of the group I (GI) was 6-15 years with the mean of 9.55 ±3.05 years. They were 10 males (50%) and 10 females (50%). While, the age of the group II (GII) ranged from 6-14 years with the mean of 10.03 ±2.67years. They were 9 males (45%) and 11females (55%). The age of group III (GIII) ranged from 6-15 years with the mean of 8.28 ±2.09 years. They were 6 males (30%) and 14 females (70%). No statistical significant difference was found among the three groups regarding the age range. History of motor development showed that all children in GI had normal history. While in GII and GIII there were five children in each group who had delayed motor development in the form of delayed head support (mean: 7.2 ±2.09 months), delayed sitting (mean: 9.3 ±1.08 months), delayed crawling (mean:12.5 ±2.1 months), and delayed walking (mean: 24.6 ±2.7 months). Results of PTA revealed that all children in GI had normal peripheral hearing with PTA thresholds less than or equal to 15 dB HL. While for GII and GIII had severe and severe to profound hearing loss with pure tone average 91.5 ± 5.9 dB. Furthermore, all children in the third group showed satisfactory CI aided response.

Results of Arabic DHI for children revealed significant difference between GIII & GI groups and between GIII & GII with higher score in GIII than other groups (Table1). While, results of bed-side test for children showed significant differences in Sharpened Romberg test and Fukuda stepping test among the three groups and no abnormalities were found on other tests (Table 2 & 3).

Sinusoidal harmonic acceleration (SHA) and velocity step test (VST) of Rotatory Chair test were done to all children. SHA gain, phase and symmetry were measured along the frequency range of 0.01–0.64 Hz. VST time constant (TC) and gain were calculated by the program. Results of this study revealed that 13 children (65%) in GII had abnormal Rotatory chair test results. Ten children (50%) had unilateral peripheral vestibular affection and three children (15%) had bilateral vestibular affection.

While, in GIII there were 11 children (55%) with abnormal Rotatory chair test results. Eight children (40%) had unilateral peripheral vestibular hypofunction ipsilateraly to the side of implantation and three children (15%) had bilateral vestibular hypofunction.

As regard relation between Arabic DHI for children and rotatory chair test in GIII, there were three children (15%) in GIII had affection in Arabic DHI for children and abnormal rotatory chair test results. Two children had unilateral peripheral vestibular hypofunction with Arabic DHI for children score 45 and 15. The third one had a score of 25 in Arabic DHI for children and bilateral vestibular hypofunction. As regard office test, there were four children (20%) of GIII who had affection in Fukuda stepping test, Sharpened Romberg test and abnormal rotatory chair test results. One child had bilateral vestibular hypofunction with sway to the same side of cochlear implant and abnormal Fukuda stepping test. Another one had unilateral peripheral vestibular hypofunction with sway to the same side of cochlear implant. The last two children had bilateral vestibular hypofunction with sway to both sides of cochlear implant.

Table 1: Comparison of the Arabic DHI questionnaire among the three tested groups

	Group	Range	Mean ± S D	F test	*P value*	Post-Hoc Test	
DHI	GI	0 – 0	0.00 ± 0.00	2.730	0.049*	P2	0.048*
	GII	0 – 0	0.00 ± 0.00			P3	0.048*
	GIII	0 – 45	4.25 ± 11.50				

P ≥ 0.05 *significant, *P ≥ 0.001* ** highly significant
P2: between GII and GIII.
P3: between GIII and GI.

Table 2: Comparison of Sharpened Romberg test among the three groups

Sharpened Rom.			GI	GII	GIII	Total
+ve		N	0	0	5	5
		%	.0%	.0%	25.0%	25.0%
-ve		N	20	20	15	55
		%	100.0%	100.0%	75.0%	91.7%
Total		N	20	20	20	60
		%	100.0%	100.0%	100.0%	100.0%
Chi-square	X^2			10.909		
	P-value			0.004*		

P ≥ 0.05 *significant, *P ≥ 0.001* ** highly significant.

Table 3: Comparison of Fukuda stepping test among the three groups.

Fukuda stepping.			GI	GII	GIII	Total
+ve		N	0	0	5	5
		%	.0%	.0%	25.0%	25.0%
-ve		N	20	20	15	55
		%	100.0%	100.0%	75.0%	91.7%
Total		N	20	20	20	60
		%	100.0%	100.0%	100.0%	100.0%
Chi-square	X^2			10.909		
	P-value			0.004*		

P ≥ 0.05 *significant, *P ≥ 0.001* ** highly significant.

DISCUSSION

Severely delayed posturomotor milestones, such as stabilizing the head, sitting and walking independently result from absence of vestibular information, whether congenital or acquired at very young age. In this study, there were five children (25%) with severe or severe to profound hearing loss and five children (25%) with cochlear implantation who had delayed motor development which agreed with Coudert *et al*.,[7] who reported that CI children and SNHL children may have delayed motor development in the form of poor head control beyond six weeks, delayed independent sitting beyond nine months, and/or delayed walking beyond 18 months as history often revealed signs of vestibular disease in these children.

As regard Arabic DHI for children score, children with cochlear implant had variable scores of DHI (ranged from 0-45). This means higher score (more vestibular affection) in cochlear implant group than other groups. Dagkiran *et al*.,[9] reported that there was a significant DHI increase in (30.9%) of patients when comparing preoperative with postoperative results. However, Barbara *et al*.,[9] showed no significant difference in DHI scores when preoperative and postoperative results were compared. As another version of DHI was used and the study was conducted on older cases.

Vestibular bed side tests for children in cochlear implanted children in this study showed significant abnormalities in Sharpened Romberg test and Fukuda stepping test when compared to other groups. This result indicated the presence of a peripheral vestibular system impairment. This was manifested as an asymmetry in lower extremity vestibulospinal reflex. This result is consistent with vestibular loss because they selectively remove vision and somatosensory leaving the subject more reliant on vestibular cues. Patel *et al*.,[10] reported that children with hearing impairment performed poorly on vestibule-ocular reflex test and static balance tests as compared with their normal-hearing peers.

As regard rotatory chair test reduced VOR gain over a range of test frequencies may indicate that there is a bilaterally peripheral vestibular weakness. The presence of phase lead is suggestive of central pathology. An asymmetric SHA response means that there is a di□erence between maximum left-beating and maximum right-beating eye velocity during sinusoidal rotation. High asymmetry and increased phase in lower frequencies reflect unilateral vestibular weakness, while low degree of asymmetry is most probably of central pathology. Time constant normal range is 10 to 30 s as the two standard deviations away from the mean value for normal. If the TC is below 10 s, the implication is possible peripheral system involvement as long as brainstem involvement can be ruled out. If the TC is at or greater than 30 s, it means central Vestibulo-cerebellar involvement. Gain from the step test is used to determine (with TC) indications for bilateral hypofunction. This would be reflected by right and left gain values less than 0.4 and as indicated above TC for the right and left of 5 to 7 s or less. Gain values at 1.0 or above would be considered hyperactive and could suggest possible cerebellar involvement[11]. This study showed abnormality in 13 children (65%) with severe or severe to profound hearing loss. There were ten children (50%) who had unilateral peripheral vestibular affection and three children (15%) had bilateral vestibular affection. Moreover, in cochlear implant children group, 11 children (55%) had abnormal Rotatory chair test results. There were eight children (40%) who had unilateral peripheral vestibular hypofunction and three children (15%) had bilateral vestibular hypofunction. These results reflect more vestibular affection in children with severe or severe to profound SNHL and cochlear implanted children than normal hearing children. This results may be due to close anatomic and developmental relationship between cochlear and vestibular system.

These results also agreed with, Kotait *et al*.,[12] whom SHA test results showed 16 children (50%) had abnormal results: seven (21.88%) children had unilateral peripheral vestibular hypofunction and three children (9.37%) had bilateral vestibular hypofunction and six children (18.75%) had bilateral severe vestibular hypofunction with severe gain affection and out of range results of both the phase and symmetry.

As Rotatory chair assesses only lateral semicircular canal and assesses mid to high frequencies. So, vestibular affection cannot be excluded by using it only. Accordingly, other tests should be used to assess other parts of vestibular system and assess low frequencies as VNG. This should be done in order to assess laterality and low frequencies.

Evident of vestibular affection in children with hearing loss and children with cochlear implantation was reported by Melvin *et al*.,[13]. These authors reported saccular injury in 31% of implanted ears by using VEMP. It could be explained by the close proximity of the saccule to the cochlea.

Hänsel *et al*.,[14] showed a significant increase in postoperative vertigo and significant impairment of nystagmography and cVEMP detection in cochlear implanted children. On the other hand, other studies showed no effect of CI or hearing loss on vestibular system as Ajalloueyan *et al*.,[15] studied 27 children with bilateral profound hearing loss (all were candidates for cochlear implantation). Patients were evaluated for vestibular function before and after cochlear implantation. The results showed that cochlear implant surgery did not have any significant effect on vestibular function at least in children younger than five years old.

CONCLUSION

Cochlear implant surgery and severe or severe to profound hearing loss may affect vestibular system. Arabic DHI questionnaire for children is a good valuable tool to detect parental observation of vestibular affection in children. Vestibular bed-side tests for children are easy, cheap, noninvasive and attractive technique. These tests can be used to evaluate vestibular function in children. Rotatory chair test in children is a valid and non-invasive test for detection of vestibular affection in children.

ACKNOWLEDGEMENT

We are thankful to all members of the Audio-vestibular Unit, (Professors, doctors, nurses and workers) Tanta University. Also, thanks for the cooperative participants of this study who helped us a lot for the service of humanity.

CONFLICT OF INTEREST

There are no conflicts of interest.

REFERENCES

1. Said, E. A. (2013). Clinical balance tests for evaluation of balance dysfunction in children with sensorineural hearing loss. The Egyptian Journal of Otolaryngology, 29(3), 189-201.

2. Cushing, S. L., Chia, R., James, A. L., Papsin, B. C. and Gordon, K. A. (2008). A test of static and dynamic balance function in children with cochlear implants: the vestibular olympics. Archives of Otolaryngology–Head & Neck Surgery, 134(1), 34-38.

3. Jacot, E., Van Den Abbeele, T., Debre, H. R. and Wiener-Vacher, S. R., (2009). Vestibular impairments pre-and post-cochlear implant in children. International journal of pediatric otorhinolaryngology, 73(2), 209-217.

4. Ibrahim, I., da Silva, S. D., Segal, B. and Zeitouni, A. (2017). Effect of cochlear implant surgery on vestibular function: meta-analysis study. Journal of Otolaryngology-Head & Neck Surgery, 46(1), 1-10.

5. Parkes, W.; Gnanasegaram, J.; Cushing, S.; McKnight, C.; Papsin, B. and Gordon, K. (2017): Vestibular evoked myogenic potential testing as an objective measure of vestibular stimulation with cochlear implants. The Laryngoscope, 127(2), E75-E81.

6. Kolkaila, E. A., Emara, A. A., Gabr, T. A., (2015). Vestibular evaluation in children with otitis media with effusion. The Journal of laryngology and otology, 129(4), 326.

7. Coudert, A., Van, H. T., Ayari-Khalfallah, S., Hermann, R., Lina-Granade, G., Truy, E., Ionescu, E., (2017). Vestibular assessment in Cochlear implanted children: how to do? When to do? A review of literature. Current Otorhinolaryngology Reports, 5(4), 259-267.

8. Dagkiran, M.; Tuncer, U.; Surmelioglu, O.; Tarkan, O.; Ozdemir, S.; Cetik, F. and Kiroglu, M. (2019): How does cochlear implantation affect five vestibular end-organ functions and dizziness? Auris Nasus Larynx, 46(2), 178-185.

9. Barbara, M., Talamonti, R., Benincasa, A. T., Tarentini, S., Filippi, C., Covelli, E., Monini, S. (2020). Early assessment of vestibular function after unilateral cochlear implant surgery. Audiology and Neurotology, 25(1-2), 50-59.

10. Patel, H., Malawade, M., Butte-Patil, S., Khairnar, P., & Gawade, S. (2017). Comparison of balance in children with and without hearing impairment. Int J Healthcare Biomed Res, 5(5), 19-27.

11. Schwam, Z. G., Babu, S., & Schutt, C. A., (2019). Bilateral Vestibular Hypofunction. In Diagnosis and Treatment of Vestibular Disorders (pp. 291-300). Springer, Cham.

12. Kotait, M. A., Moaty, A. S., & Gabr, T. A. (2019). Vestibular testing in children with severe-to-profound hearing loss. International journal of pediatric otorhinolaryngology, 125, 201-205.

13. Melvin, T. A. N., Migliaccio, A., Carey, J. P., Santina, C. C. D. (2008). The Effects of Cochlear Implantation on Vestibular Function. Otolaryngology-Head and Neck Surgery, 139(2_suppl), P60-P60.

14. Hänsel, T., Gauger, U., Bernhard, N., Behzadi, N., Romo Ventura, M. E., Hofmann, V., Coordes, A. (2018). Meta□analysis of subjective complaints of vertigo and vestibular tests after cochlear implantation. The Laryngoscope, 128(9), 2110-2123.

15. Ajalloueyan, M., Saeedi, M., Sadeghi, M., Abdollahi, F. Z. (2017). The effects of cochlear implantation on vestibular function in 1-4 years old children. International journal of pediatric otorhinolaryngology, 94, 100-103.