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Original Research Article

Vestibular dysfunction after cochlear and auditory brainstem implantation: Madras ENT Research Foundation experience

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ABSTRACT

Background: Cochlear implantation is an established procedure for patients with bilateral severe to profound sensorineural hearing loss. CI may, in some implantees, have a detrimental impact on vestibular function. Auditory brainstem implantation is a safe and effective procedure in children with bilateral cochlear and cochlear nerve aplasia. The aim of the study was to assess the impact of cochlear implantation and auditory brainstem implantation on the vestibular function.
Methods: Three hundred and twenty patients who underwent CI surgery over a four years period from November 2016 to November 2020 were studied for symptoms of vestibular disturbance. Twenty three patients complained of giddiness and underwent vestibular function testing including videooculography, caloric test and vestibular evoked myogenic potentials. 48 patients with cochlear and cochlear nerve aplasia underwent ABI surgery from September 2009 to March 2019. The correlation between the size of the flocculus and the presence of vestibular symptoms was studied.
Results: After CI, vestibular disturbances were seen in 23 patients (7.2%) and were transient. In auditory brainstem implantees, vestibular disturbances were seen in eight patients (16.7%) and were found to correlate with the size of the cerebellar flocculus.
Conclusions: Vestibular disturbances are rare after cochlear and auditory brainstem implant surgery. During CI, the preservation of vestibular function should be attempted using minimally invasive techniques. ABI surgery requires meticulous dissection, especially of a large cerebellar flocculus to minimize the possibility of vestibular disturbances.

Keywords: Cochlear implantation, Auditory brainstem implantation, Vestibular disturbance

INTRODUCTION

Cochlear implantation (CI) is a safe and well-established procedure for severe to profound sensori-neural hearing loss (SNHL), with a very low rate of complications. CI has been reported to affect vestibular function in some implantees.[1] Labyrinthine function can be affected after CI by the pathology that caused the deafness, vestibular injury secondary to electrode insertion or may be secondary to spread of current from the electrode array. Auditory brainstem implantation (ABI) is indicated in a small sub-set of patients with bilateral profound SNHL due to cochlear aplasia or cochlear nerve aplasia in whom a CI is contraindicated. In experienced hands, ABI is a safe procedure. Rarely, vertigo can occur as a complication of ABI surgery.[2] The objective of this study was to assess the impact of cochlear implantation and auditory brainstem implantation on the vestibular function. The aim was to also study the correlation

between the size of the flocculus and the presence of vestibular symptoms after ABI.

METHODS

A retrospective study included all patients undergoing cochlear implantation in Madras ENT Research Foundation, a tertiary care centre in Chennai, Tamil Nadu between November 2016 and November 2020. The sample size included all 320 patients who underwent cochlear implantation in the specified period in our institution. Inclusion criteria in the study included 23 cochlear implantees with post-operative vestibular disturbance such as vertigo or unsteadiness after unilateral or bilateral CI. The study included adults as well as pediatric implantees. Patients with additional co-morbidities and anomalous cochlea were included. Exclusion criteria included patients who did not have any symptoms or signs of vestibular disturbance. A detailed history and clinical examination were done for all patients. Demographic data such as etiology of hearing loss, imaging findings, age at implantation, unilateral or bilateral implantation were studied. CI was done by posterior tympanotomy approach and the electrode insertion was by round window approach in all patients. Videooculography, caloric test of the lateral semicircular canal, cervical vestibular-evoked myogenic potentials (cVEMP) were done and the results were analyzed. The aim of the study was to evaluate the effects of CI surgery on vestibular function.

Auditory brainstem implantation was performed for 48 children who were diagnosed with bilateral cochlear and cochlear nerve aplasia and received ABI from september 2009 to march 2019. The sample size included all forty eight patients who had ABI during the specified period.

Inclusion criteria

All ABI patients with bilateral cochlear and cochlear nerve aplasia having post-operative vertigo were included in the study.

Exclusion criteria

Patients with neurofibromatosis type II were excluded from the study.

Procedure

Retrolabyrinthine approach was used in all patients. A working classification of the types of cerebellar flocculus into 4 types was done. Intra-operative electrically evoked auditory brainstem responses (EABR) confirmed device placement on the cochlear nucleus. Post-operatively intensive neuro-monitoring was done. The aim was to assess whether vertigo correlates with the size of the flocculus encountered during ABI surgery. The prevalence and duration of vestibular symptoms after implantation were studied. For the statistical analysis, Student's t test was used.

RESULTS

Three hundred and twenty patients underwent cochlear implantation from November 2016 To November 2020 in Madras ENT Research Foundation, a tertiary ENT centre in Chennai, South India. Of 320 patients, 291 patients had unilateral CI, 29 patients had bilateral CI. Before implantation, none of the patients had vertigo. The mean age of the patients was 7 years (age range was 1 year to 77 years) (Figure 1) and male to female ratio was 1.2: 1. Twenty three patients aged 12 years and above had post-operative vertigo (7.2%) and were included in the study.

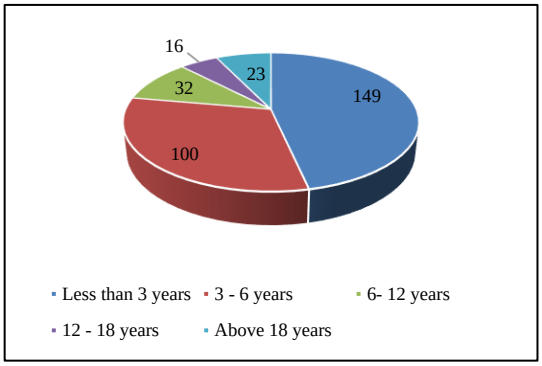

Figure 1: Age range of the patients who underwent cochlear implantation.

No vestibular symptoms could be elicited in any of the pediatric implantees post-operatively as differentiating between post-anesthesia induced vomiting from vomiting induced by vestibular disturbances may be difficult. The etiology in the cochlear implantees who had post-operative vertigo was normal cochlea/idiopathic (12 patients), progressive SNHL (4 patients), Meniere's disease (1 patient), cholesteatoma (1 patient), idiopathic sudden sensori-neural hearing loss (1 patient), post meningitic (1 patient), post trauma (1 patient) and enlarged vestibular aqueduct (2 patients). Vestibular function tests were done in 23 cochlear implantees and the results of the tests are as shown in (Figure 2).

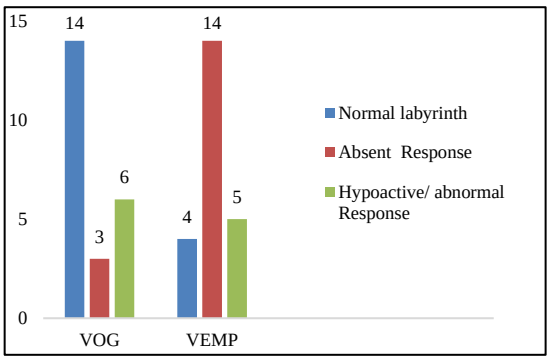

Figure 2: Results of vestibular function tests in cochlear implantees who had vertigo.

Normal vestibular function tests in a patient pre-operatively is shown in (Figure 3-5), in the same patient post-operatively, the VOG was normal; however, the caloric test and VEMP test showed an absent response (Figure 6-8).

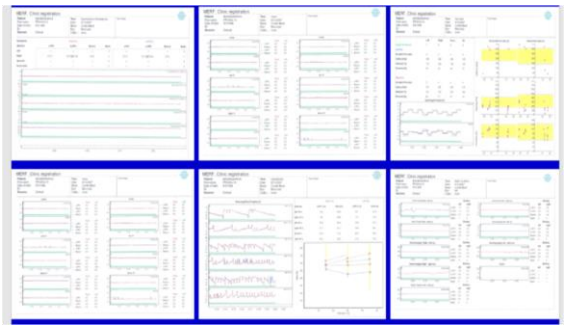

Figure 3: Pre-operative normal VOG.

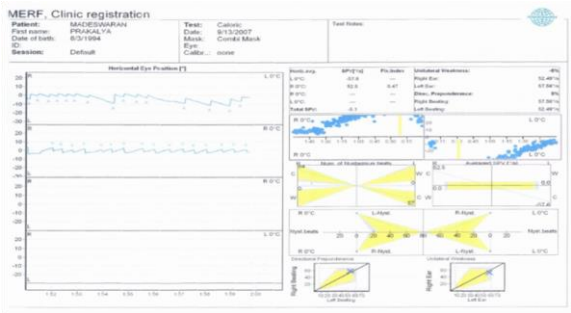

Figure 4: Pre-operative normal caloric test.

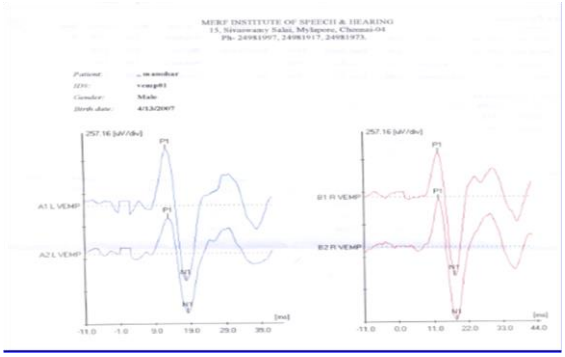

Figure 5: Pre-operative normal VEMP.

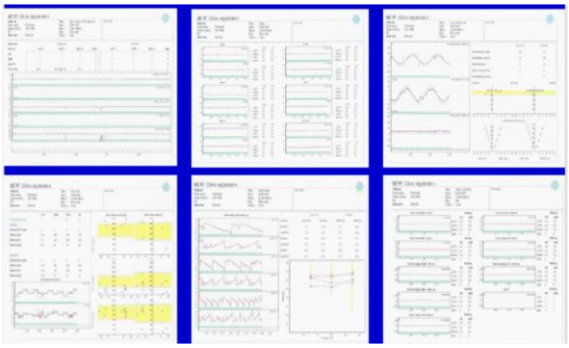

Figure 6: Post-operative normal VOG.

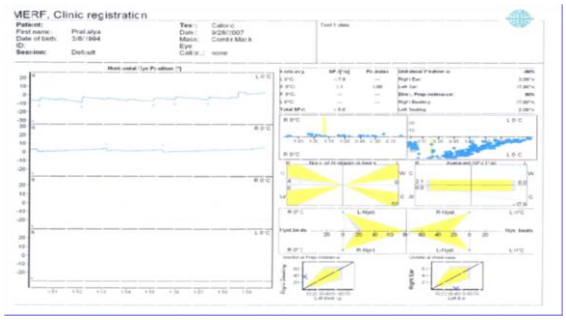

Figure 7: Post-operative absent caloric test in the implanted ear.

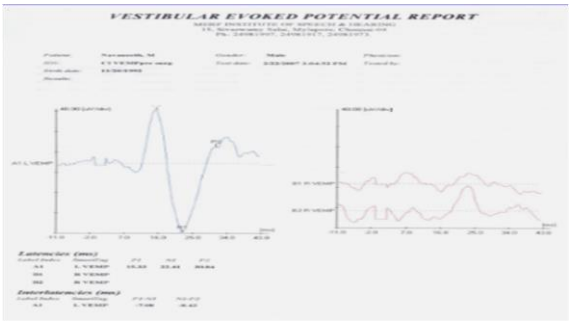

Figure 8: Post-operative absent VEMP in the implanted ear.

On post-operative assessment of the cochlear implantees who had vertigo, 19 implantees (82.6%) had absent/abnormal vestibular evoked myogenic potentials. Nine implantees (39%) had absent/hypoactive VOG responses. The follow-up of patients ranged from 1 month to 36 months. In all patients, the vertigo settled within ten days (2-10 days) with vestibular sedatives. None of the patients had disabling or long-term vertigo. 48 children diagnosed with bilateral cochlear and cochlear nerve aplasia received auditory brainstem implantation from september 2009 to march 2019. There were 23 males, 25 females with a mean age of 3.5 years (age range; 2-9 years) and the mean follow-up period was 3 years and 5 months. The grading of cerebellar flocculus was done intra-operatively as shown in (Figure 9).

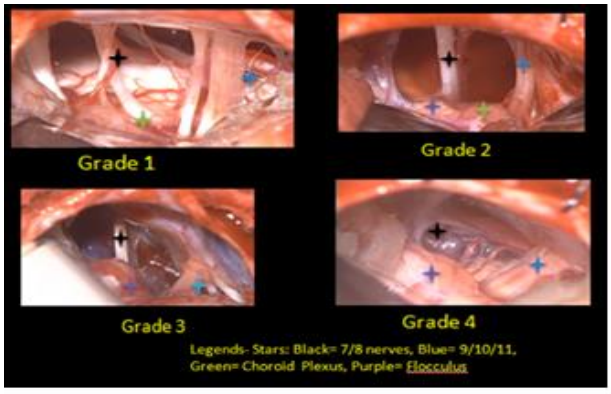

Figure 9: Intra-operative grading of cerebellar flocculus during ABI surgery.

Grade 1 flocculus was seen in seventeen patients, grade 2 in fifteen patients, grade 3 in eight patients and grade 4 flocculus in eight patients. During ABI surgery, the easiest entry was in grade 1 and grade 2 flocculus and difficult entry was noted in grade 3 and 4 where more retraction of cerebellum was required for visualization of root entry zone of lower cranial nerves. The lifting of the cerebellar flocculus for implant placement was difficult in grade 3 and 4 due to adhesions. Vestibular symptoms were monitored post-operatively. Eight patients (16.7%) had vertigo on the first post-operative day which lasted from 2 to 5 days. In eight patients with post-operative vertigo, the cerebellar flocculus was found to be grade 3 or 4 due to which difficult entry of ABI was noted. Six patients had unsteadiness and 2 patients had rotatory vertigo associated with nystagmus. Grade 3 and 4 flocculus significantly increased the risk for vertigo ($p<0.05$) (Figure 10). The p value as shown here is significant. In all 8 patients, the vestibular dysfunction settled down within 5 days. None of the patients had persistent or recurrent vertigo. The size of the flocculus did not have any influence on the audiological outcomes of ABI.

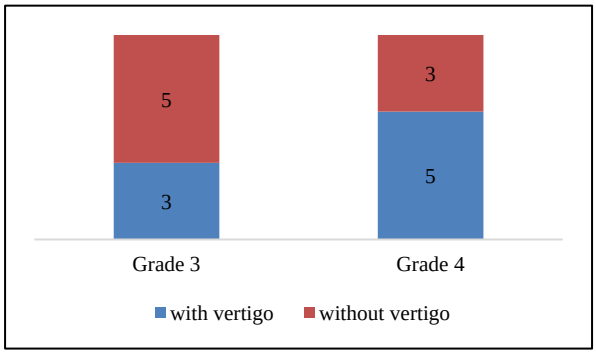

Figure 10: Correlation of vertigo with higher grade of flocculus in ABI surgery.

DISCUSSION

Cochlear implantation has proven to be a safe procedure with few complications. Vestibular disturbances may occur rarely after CI. Damage to the vestibular system after CI surgery was first described by Black in 1977.[3] Cochlear implantation may affect vestibular function through direct current spread from the cochlea to the vestibular system.[4] Ito reported dizziness in 2.5% of patients when the CI was activated.[5] After CI surgery, otolithic organs and canal function can be compromised, leading to potential clinical manifestations such as post-operative imbalance, vertigo, and falls. In children undergoing bilateral implantation, bilateral vestibular dysfunction after CI may be a concern.[4] CI can potentially result in disruption of saccular function in pediatric patients. The estimated prevalence of peripheral vestibular dysfunction after CI is around 20% for adults and 10% for children.[3] Age and etiology of hearing loss may affect the vestibular function after CI surgery. Regardless of objective results, no evidence for subjective symptoms of dizziness occurring in the pediatric population after cochlear implantation was reported.[4] The true incidence of injury after unilateral CI surgery may be masked by central compensation of vestibular hypofunction. The worse balancing ear should be implanted.[6] Bilateral cochlear implantation predisposes to bilateral vestibular dysfunction for an estimated 5% of individuals implanted.[3] Greater occurrence of vestibular alteration in patients with bilateral CI may be because those with unilateral implantation are more able to compensate for the vestibular alteration at the injured side.[7] Vestibular dysfunction has more often been recorded among adult post-lingual cochlear implantees, especially in profound deafness due to long standing Meniere's syndrome and cochlear otosclerosis. After cochlear implantation in very young pre-lingual children lesser than 5 years of age, clinical signs of vertigo like nystagmus are most often not seen and these children are not able to provide a history of vertiginous symptoms.[3] Transient acute dizziness is common after CI, but long-term disability due to vestibular dysfunction after unilateral CI appears to be low.[6] Most often the vertigo is self-limiting within a few weeks.[3] Vertigo is especially disabling for elderly subjects.[8] In a study by Zawawi et al of 122 patients, dizziness was evident in 45.9% post-CI and in 27% pre-CI.[9] The dizziness was mild in most patients. Unsteadiness was most common (53%) post implantation. Vertigo was reported in less than 10% of implanted patients. Preoperative labyrinthine status and inner ear diseases such as Meniere's were reported to play a role.[9]

The saccule and the lateral semi-circular canal have been considered the vestibular organs that are more likely to be affected by Handzel et al.[1] Mechanisms for vestibular dysfunction include direct trauma related to insertion of the electrode, intra-operative perilymphatic fluid leakage, electrical stimulation of the otolithic organs, and foreign body labyrinthitis.[4]

Approximately 10-20% of patients were reported to have developed BPPV post cochlear implantation.[10] Meniere's after CI may occur due to cochlear hydrops accompanied by saccular collapse which may cause attacks of vertigo of delayed onset, similar to Meniere's syndrome. Cochlear hydrops is caused by damage to the lateral cochlear wall during CI or rarely due to obstruction of endolymphatic flow in the ductus reuniens or in the hook portion of the cochlea.[11] Histopathologic studies have shown that saccule is the most frequently damaged organ due to CI, followed by utricle, then rarely the semicircular canals.[3] Lesinski reported a case of Tullio's, after CI and attributed it to scar tissue surrounding the ossicles suggesting that sound may have been stimulating a displaced saccule.[10] When the electrode migrates, it may start to stimulate the saccule. Tange et al reported a patient who developed vertigo because the implant was misdirected into the vestibular part of the inner ear.[10] Trauma can result in a perilymphatic fistula, which can result in dizziness.[10] Enlarged vestibular aqueduct and

other anomalous cochleovestibular anatomy e.g. common cavity malformation, incomplete partition have been shown to be responsible for higher rates of intraoperative CSF leaks, which could potentially put the patient at a higher risk for post-operative vestibular dysfunction. Atraumatic cochlear implantation may play a role in reducing the potential for vestibular injury.[4]

Reduced vestibular function may be seen in deafness following meningitis due to ossification of the labyrinth. Pneumolabyrinth is defined as the presence of air within the inner ear including cochlea, vestibule or semicircular canals and may rarely occur after CI in patients with malformed cochlea, enlarged vestibular aqueduct, and vestibular schwannoma after cochlear implantation surgery. Acute pneumolabyrinth causing severe vertigo after cochlear implantation in the early post-operative period has been reported after excessively drilling the promontory cochleostomy with possible basilar membrane damage.[12] Histological changes such as soft tissue changes might result in impaired vestibular function.[5] Kubo et al reported that in most CI patients vertigo resolved within one month.[10] Clinical tools like the video oculography (VOG) and vestibular evoked myogenic potentials (VEMP), have helped objectively evaluate the peripheral vestibular system among cochlear implantees.[3] After cochlear implantation, subjective vestibular symptoms seem uncorrelated with the results of objective tests.[13]

In a study by Yong et al of vestibular dysfunction after pediatric cochlear implantation, CI was associated with a statistically significant decrease in VEMP responses post-operatively.[4] In a study of the vestibular function through electronystagmography in 38 cochlear implantees, it was reported that the main complaint was dizziness, followed by postural vertigo and non-postural vertigo.13% of the patients showed an improvement in vestibular function post CI and this could be related to the vestibular compensation phenomenon and to electric stimulation.[14] In a review by Kuang et al 37% of patients had reduced reflex, and 34% had caloric asymmetry after CI surgery.[15] A meta-analysis of vestibular function after cochlear implantation reported a significant negative effect on caloric and VEMP testing in adults, although the symptomatic manifestations were found to be insignificant. A change in VEMP threshold, amplitude, or latency or absent VEMP measured post-operatively when that ear had baseline normal VEMP results is considered significant. Reduction in caloric responses following implantation occurs. A study on perceptual visual tilt using the static subjective visual vertical test has shown that the implant may have a role in actually improving vestibular function by helping to correct abnormal perception of vertical.[4] After cochlear implantation, otolithic function is most frequently impaired. cVEMPs are lost in 86-100% of cases according to the meta-analysis by Krause et al.[8] In a study by Buchman et al the effects of unilateral CI on the vestibular system were assessed using the dizziness handicap inventory (DHI), vestibuloocular reflex (VOR) testing using both bithermal caloric irrigations (ENG) and rotational chair-generated sinusoidal harmonic accelerations (SHA), and computerized dynamic posturography (CDP). They concluded that unilateral CI rarely results in significant adverse effects on the vestibular system as measured by the DHI, ENG, SHA, and CDP. Patients who underwent CI experienced significant improvements in the objective measures of postural stability as measured by CDP.[3] Following CI, there was no statistically significant difference in the gain values obtained using vHIT or subjective VAS and DHI between the cochleostomy approach and the round window approach.[16] Compromised vestibular function after a CI is potentially reversible with vestibular rehabilitation.[5] Preservation of the residual hearing and vestibular function should be attempted using minimally invasive surgical techniques.[7] Karimi et al reported that in 6 of 9 patients, resealing of the cochleostomy improved vertigo.[10] Nguyen et al described techniques of atraumatic implant insertion thereby conserving residual inner ear function.[17] Slow insertion of electrodes and topical intra-operative corticosteroids have shown efficacy for residual hearing and also for vestibular function. Insertion in the scala tympani rather than in the scala vestibuli protects vestibular receptors better. Implant insertion depth does not affect vertigo or objective test results.[8] Implanting the ear with poorer vestibular function may enable the better ear for a central compensatory mechanism.[1] Cochlear implant surgeons must anticipate the possibility of vestibular dysfunction and manage it appropriately.

In current study, 23 patients aged 12 years and above had post-operative vertigo (7.2%). No vestibular symptoms could be elicited in any of the pediatric implantees post-operatively. On post-operative assessment, 19 cochlear implantees (82.6%) had absent/abnormal vestibular evoked myogenic potentials. Nine implantees (39%) had absent/hypoactive VOG responses. The vertigo was a minor problem in all patients and settled within ten days (2-10 days) with vestibular sedatives. None of the patients had disabling or long-term vertigo. Auditory Brain-stem Implants are increasingly being performed as a means of hearing restoration in children with bilateral congenital profound hearing loss due to absent development of cochlea (Michel deformity) or cochlear nerve. Implant placement is in the lateral recess of the fourth ventricle close to the foramen of Luschka to stimulate the dorsal and ventral cochlear nuclei. Vestibular disturbance is a rare complication after ABI surgery. The mechanism of vertigo may be due to the presence of a large flocculus and more cerebellar retraction or may be secondary to electrical stimulation of the vestibular system. Classification of the cerebellar flocculus reported by Vasudevan et al was done as below: grade 1; non-visualization of cerebellar flocculus with a prominent choroid plexus, grade 2; cerebellar flocculus is hypoplastic, lies rostrally with a prominent choroid plexus, grade 3; cerebellar flocculus is small and more

central with a small choroid plexus, grade 4; cerebellar flocculus is large, central with a small choroid plexus.[18]

In the series by Colletti et al, one 6 year old non tumoral child had postoperative dizziness that resolved after 5 days.[2] In current study, although vertigo was a complication of ABI, it was a minor and temporary post-operative complication. In current study, no vestibular symptoms could be elicited in any of the younger pediatric cochlear and auditory brainstem implantees post-operatively and hence this was a limitation of this study. Only eight patients had vertigo after ABI surgery and this small size was found to be a limitation. Hence, data from multi-centric studies from other centres may be more significant in assessing the prevalence of vertigo after implantation.

CONCLUSION

Cochlear implantation entails risks to vestibular function. CI surgery may affect the vestibular apparatus, which is in close anatomical proximity to the auditory system. However, significant loss of vestibular function due to CI is uncommon. Vestibular disturbances after CI are transient in most cases. There is a poor correlation between vestibular testing and subjective vestibular complaints. In unilateral reduced caloric response, CI in the ear with reduced response is preferable. Soft insertion minimizing intra-cochlear damage is advisable to minimize damage to the labyrinth. Post-operative vestibular rehabilitation therapy may prove helpful in patients with vestibular disturbance post CI. In ABI surgery, the size of the flocculus influences the access to the cochlear nucleus. A large flocculus involves more cerebellar retraction and may be associated with a higher incidence of vertigo. The conclusion of this study was that vestibular disturbances are infrequent and a minor post-operative complication after cochlear implantation and auditory brainstem implantation.

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REFERENCES

1. Barbara M, Talamonti R, Benincasa AT, Tarentini S, Filippi C, Covelli E, et al. Early Assessment of Vestibular Function after Unilateral Cochlear Implant Surgery. Audiol Neurootol. 2020;25(1-2):50-9.
2. Colletti V, Shannon RV, Carner M, Veronese S, Colletti L. Complications in auditory brainstem implant surgery in adults and children. Otol Neurotol. 2010;31(4):558-64.
3. Nair G, Indorewala A, Krishnan PV, Raghunandhan S, Kameswaran M. A Study of Vestibular Dysfunction in Cochlear Implantees. SASJ Surg. 2016;2(5):228-32.
4. Ong M, Young E, Lea J, Foggin H, Zaia E, Kozak FK, Westerberg BD. Subjective and objective vestibular changes that occur following paediatric cochlear implantation: systematic review and meta-analysis. J Otolaryngol Head Neck Surg. 2019;48 (1):22.
5. Zur O, Ben-Rubi Shimron H, Leisman G, et al. Balance versus hearing after cochlear implant in an adult. BMJ Case Rep. 2017;45(6):55-9.
6. Melvin TA, Della Santina CC, Carey JP, Migliaccio AA. The effects of cochlear implantation on vestibular function. Otol Neurotol. 2009;30(1):87-94.
7. Melo, Juliana Jandre, Gibrin, Paula Carolina Dias, Marchiori, Luciana Lozza de Moraes. Vestibular dysfunction and postural balance in cochlear implant users: a narrative literature review. Revista CEFAC. 2018;20(1):101-9.
8. Colin V, Bertholon P, Roy S, Karkas A. Impact of cochlear implantation on peripheral vestibular function in adults. Eur Ann Otorhinolaryngol Head Neck Dis. 2018;135(6):417-20.
9. Zawawi F, Alobaid F, Leroux T, Zeitouni AG. Patients reported outcome post-cochlear implantation: how severe is their dizziness? J Otolaryngol Head Neck Surg. 2014;43(1):49.
10. Timothy C. Hain. Vertigo from Cochlear Implants (CI). Available at: https://www.dizziness-and-balance.com/disorders/hearing/hearing-aids/vertigo_cochlear_implant.html. Accessed on 6 January 2021.
11. Handzel O, Burgess BJ, Nadol JB. Histopathology of the Peripheral Vestibular System after Cochlear Implantation in the Human. Otol Neurotol. 2006; 27(1):57-64.
12. Karataş E, Toplu Y, Gündüz E, Demir İ. Severe vertigo after cochlear implantation: acute pneumolabyrinth. Balkan Med J. 2018;35(5):408-9.
13. Abouzayd M, Smith PF, Moreau S, Hitier M. What vestibular tests to choose in symptomatic patients after a cochlear implant? A systematic review and meta-analysis. Eur Arch Otorhinolaryngol. 2017; 274(1):53-63.
14. Bonucci AS, Costa Filho OA, Mariotto LD, Amantini RC, Alvarenga Kde F. Vestibular function in cochlear implant users. Braz J Otorhinolaryngol. 2008;74(2):273-8.
15. Ibrahim I, da Silva SD, Segal B, Zeitouni A. Effect of cochlear implant surgery on vestibular function: meta-analysis study. J Otolaryngol Head Neck Surg. 2017;46(1):44.
16. Korsager LEH, Schmidt JH, Faber C, Wanscher JH. Vestibular Outcome After Cochlear Implantation Is Not Related to Surgical Technique: A Double Blinded, Randomized Clinical Trial of Round Window Approach Versus Cochleostomy. Otol Neurotol. 2018;39(3):306-12.
17. Nguyen S, Cloutier F, Philippon D, Côté M, Bussières R, Backous DD. Outcomes review of modern hearing preservation technique in cochlear implant. Auris Nasus Larynx. 2016;43:485-8.

18. Sunil G, Shyam SK, Kameswaran M, Vasudevan MC, Ranjith R, Kiran N. Does cerebellar flocculus size affect subjective outcomes in pediatric auditory brainstem implantation. Int J Pediatr Otorhinolaryngol. 2017;97:30-4.

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