Compensated Vestibular Dysfunction Post Cochlear Implantation in Children with Sensorineural Hearing Loss: A Prospective Study

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Abstract Children with sensorineural hearing loss have risk of surgically induced vestibular dysfunction post cochlear implantation due to instrumentation. It is clinically important to estimate the risk of vestibular loss post cochlear implant so the patient can be made fully aware of these risks when considering cochlear implantation. The aim of the study was to identify compensated vestibular dysfunction post cochlear implantation. Vestibular function was evaluated both pre and post CI using monothermal warm air caloric testing. Recordings were made using head band camera on SYNAPSYS Ulmer VNG software. ‘Monothermal caloric asymmetry’ (MCA) was depicted as ‘unilateral weakness’ based on the slow phase velocity of nystagmus. MCA of >15% was taken as evidence of canal paresis. The incidence of compensated vestibular dysfunction post CI surgery was found to be 16.66%. The results were statistically significant (p value 0.02) and indicated worsening of canal paresis indicative of vestibular dysfunction. Children for cochlear implantation should undergo evaluation of their vestibular system pre and post surgery. Caution should be exercised before planning bilateral cochlear implantation in the same sitting.

Keywords Cochlear implants · Caloric · Vestibular · Sensorineural

Introduction

The auditory system is closely related to the vestibular system in terms of embryological development, innervation and blood supply and anatomical situation. Individuals with deafness are at risk of vestibular dysfunction because in inner ear deafness the damage extends to the vestibular receptor as well. Because the vestibular function plays an important role in gross motor development in children, audiologists and otologist should recognize and understand the vestibular dysfunction in hearing impaired children so as to provide necessary rehabilitation. A child with severe sensorineural hearing loss is considered as a cochlear implant candidate. The vestibular system is at risk during cochlear implantation because it is housed in the labyrinth of the inner ear and is connected to the cochlea. Since these two organs share the same fluid, changes in the cochlea could potentially cause changes in the semicircular canals and the otolith organs of the vestibular system. In the process of cochlear implantation, the electrode wire inserted into the inner ear can produce permanent damage to the sensory structures of the cochlea and the vestibule. Patients sometimes report imbalance or dizziness following cochlear implant surgery. The vestibular system could be disturbed during surgery or with the electrical stimulation of the electrode. It is clinically important to estimate the risk of vestibular loss post cochlear implant so the patient can be made fully aware of these risks when considering cochlear implantation [1, 2].

Although there are numerous reports of vestibular dysfunction in profoundly deaf adults receiving cochlear implants in literature, there is paucity of data describing vestibular function in children with profound SNHL receiving cochlear implant (CI). This may be due to the lower reporting of symptoms in children as they are not

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able to express themselves or may be due to the difficulties in the vestibular evaluation in a child. The aim of the study was to identify post CI vestibular dysfunction in children post cochlear implantation.

Methods

A prospective study was carried out in a tertiary care hospital over a period of one and a half year. 25 children less than 12 years of age with bilateral severe to profound SNHL who presented in the hospital for hearing rehabilitation and speech therapy were evaluated. Children with any pre existing middle ear pathology, visual or neurological condition and with symptoms of acute vestibular dysfunction were excluded from the study. History was taken in detail which included the onset, duration and progression of hearing loss. This was followed by a detailed ENT examination of the child. Audiological workup included pure tone audiometry/behavioural observational audiometry, tympanometry, diagnostic otoacoustic emissions and brainstem evoked response audiometry. High resolution computed tomography scan of temporal bone and magnetic resonance imaging of brain was also done to rule out any structural abnormality of cochlea, central audiovestibular connections and CNS. Written informed consent was taken from parents or guardians of all the children included in the study. Pre operatively, vestibular function assessment was done by monothermal warm air caloric test.

In monothermal air caloric testing, warm air was preferred over cold air because studies revealed that warm air is more sensitive than cool air for caloric responses [3, 4]. British Society of Audiology guidelines also do not recommend the use of cool monothermal caloric test [5]. During this test, child was placed on a reclining chair with head elevated at an angle of 30° to the horizontal. Uncooperative children were mildly sedated with Syp Triclofos at the dose of 0.5 mg/kg since this drug does not affect the vestibular function. Head band camera was placed over the eyes of the patient (Fig. 1) and results recorded on SYNAPSYS Ulmer VNG software. DIFRA coolstar air insufflator (Fig. 2) was used to insufflate air @ 8L/min at temperature 50° celsius into the child's external auditory canal. The warm air insufflation was done for 60 s in one ear and caloric responses were recorded simultaneously on the software (Fig. 3). A break of 05 min was given and similar responses were recorded in the opposite ear. 'Monothermal caloric asymmetry' (MCA) was depicted in the recording software as 'unilateral weakness'. This was based on the slow phase velocity of the nystagmus generated by the warm air. MCA of >15% was taken as canal

Fig. 1 Head band camera on a child seated on reclining chair

Fig. 2 DIFRA coolstar air insufflator

paresis indicative of vestibular dysfunction according to the British Society of Audiology guidelines [5].

The child then underwent CI surgery using MED-EL Pulsar standard CI (with 12 twin electrodes). Surgery was done by the same Neurotologist to eliminate surgeon related variables. Post aural posterior tympanotomy approach was used for cochlear implantation.

Fig. 3 Monothermal warm air caloric test: SYNAPSYS Ulmer VNG software

Cochleostomy was done antero inferior to the round window in each case. Post 6 weeks of CI surgery, vestibular function assessment was again done by monothermal warm air caloric test.

Results

The study included 25 children with SNHL, out of which 17 were male and 08 were female. The youngest child was 3 years old and the oldest was 7. The mean age of the children was 5.48 years (Male: 5.53 years, Female: 5.38 years). All 25 children had Congenital Non Syndromic SNHL. 23 children had Profound and 02 had severe SNHL.

2 out of the 25 children were uncooperative during warm air monothermal caloric testing pre operatively and were excluded. Of the 23 children, 5 children had pre op vestibular dysfunction indicative of canal paresis (defined as greater than 15% Monothermal Caloric Asymmetry (MCA)). These 5 children continued to have vestibular dysfunction post CI surgery also. 3 children developed vestibular dysfunction post cochlear implant surgery. The incidence of compensated vestibular dysfunction post CI surgery was found to be 16.66%. The details of vestibular dysfunction pre and post CI surgery is shown in Fig. 4.

It was also noted in our study that in children who did not have any vestibular dysfunction pre op ($n = 18$), the median value of MCA increased from pre op value of 9.05% to post op value of 12.9%. The results were statistically significant (p value 0.02) and indicated worsening of canal paresis indicative of vestibular dysfunction.

Fig. 4 Dot diagram showing incidence of compensated vestibular dysfunction pre and post CI surgery

Discussion

Cochlear implantation is the standard, safe and effective treatment in patients with severe to profound SNHL. However, post mortem histopathologic studies on the temporal bones of patients with cochlear implant have demonstrated significant damages to the inner ear structures, e.g. fibrosis in the vestibule, collapse of the saccule, decrease in ganglion cells, and formation of hydrops in the inner ear [6]. This potential vestibular damage in cochlear implantation usually occurs during the following two processes: 1. Cochleostomy, in which an opening is drilled in the basal turn of the cochlea and, 2. Insertion of the CI electrode array. This results in changes in the intracochlear

fluid pressure which may result in significant mechanical alterations of the cupulae and cristae [7].

In the absence of sophisticated equipment and vestibular laboratory facilities, caloric testing is said to be the “gold standard” test for detecting unilateral vestibular dysfunction. This is also true as this test is cheap and easy to perform with acceptable reliability. It also tests the function of the lateral semicircular canal of both the ears separately. British Society of Audiology guidelines [5] have recommended that monothermal caloric test can be used effectively for screening children for evidence of vestibular dysfunction. As per these guidelines, the monothermal caloric asymmetry (MCA) should be >15% to establish evidence of vestibular dysfunction. The use of warm monothermal caloric testing is preferred over cold monothermal caloric testing as a superior modality [8]. In a study by Longridge et al., warm caloric screening was superior to bithermal caloric test results as excess false positive results were absent [9]. According to a study by Melagrana et al., use of monothermal warm air caloric test gave good sensitivity and specificity with respect to bithermal caloric test (83 and 90% for 90% probability; 78 and 92.5% for 95% probability) [10]. Lightfoot et al. in their study concluded that monothermal warm air caloric test could be used as an alternative to bithermal caloric test in children to detect vestibular dysfunction [3].

British Society of Audiology guidelines, last reviewed in 2010, recommended that monothermal caloric test can be used effectively for screening children for evidence of vestibular dysfunction. They recommended that the monothermal caloric asymmetry (MCA) should be >15% to establish evidence of vestibular dysfunction. The use of warm monothermal caloric testing was advocated over cold monothermal caloric testing as a superior modality [5]. In a study by Longridge et al., it was seen that the hot caloric screen detected almost all patients who gave abnormal bithermal caloric test results without producing an excess of false positive results [8]. According to a study by Melagrana et al. [9], use of monothermal warm air caloric test gave good sensitivity and specificity with respect to bithermal caloric test (83% and 90% probability; 78 and 92.5% for 95% probability). Jacobson et al. [10] in his study suggested that a warm monothermal screening test can predict normal bithermal caloric responses with greater than 97% accuracy. Lightfoot et al. [11] in his study concluded that monothermal warm air caloric test can be used as an alternative to bithermal caloric test in children to detect vestibular dysfunction. Hence, the method we adopted in our study to screen for vestibular dysfunction was warm air monothermal caloric testing.

Approximately two out of three CI patients suffer from acute, short term and in most cases transient vertigo after CI surgery [12]. The time interval from surgery to the post

operative examination in our study was 06 weeks. As the acute symptoms are limited to the first month after surgery, the chronic vestibular effects rather than the acute effects were the focus of the study. The incidence of post cochlear implant newly developed compensated vestibular dysfunction was 16.66%. Dizziness after CI occurs frequently, with a reported incidence between 2 and 60% [13]. This may be attenuated/modified by vestibular compensation mechanisms and with visual and proprioceptive cues. It reported 38% risk of diminished vestibular function after CI [14]. Many other reports have also appeared on the results of vestibular tests in children with intracochlear implantation and majority of them estimate the risk of vestibular function loss post cochlear implantation to be between 10 and 70% [15, 16] Chiong et al. [17] in his study reported findings in 25 patients whose vestibular function was evaluated before and after cochlear implantation using caloric testing and found that 19% of the patients had a substantial reduction in vestibular function in the implanted ear. The results of our study closely match the results obtained by other authors.

In the 18 patients who went for CI surgery and who did not have vestibular dysfunction pre op, the median percentage MCA value was 9.05%. Their post op value was 12.9%. When analyzed statistically on rank signed test, the results were statistically significant. These results show that post cochlear implantation, there is a trend towards lowering of vestibular function. A study by Wagner et al. [18] also suggests that there is a higher risk of subjective vertigo after bilateral cochlear implantation.

Conclusion

We recommend that children who are taken up for cochlear implantation should undergo evaluation of their vestibular function pre and post surgery. This will help to identify subtle/compensated vestibular dysfunction. Caution also needs to be exercised before planning for bilateral cochlear implantation in the same sitting since vestibular dysfunction may occur in both ears simultaneously post CI surgery and present with non compensated vertigo.

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Compliance with Ethical Standards

Conflicts of interest None.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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