

Original Research Article

A Study of Vestibular Dysfunction in Cochlear Implantees**Dr. Geetha Nair*, Dr. Abuzar Indorewala, Dr. P. Vijayakrishnan, Dr. S. Raghunandhan, Prof. Mohan Kameswaran**Department of Implant Otology, Madras ENT Research Foundation, No.1, first cross street, off 2nd main road, Raja Annamalaipuram, Chennai – 600028, Tamil Nadu, India.

*Presently at Department of ENT, Government Medical College, Ernakulam, Kerala, India

***Corresponding author**

Dr. Geetha Nair

Email: drgeethaent@yahoo.com

Abstract: The patho-physiology of inner ear is an intriguing entity, which is yet to be understood in its full entirety. It is an interesting phenomenon to explore the way in which the labyrinth responds to various insults with a myriad of presentations manifesting clinically. Otolologists have long wondered for a reasonable explanation as to why Stapedotomy patients may develop intense post-operative vertigo due to a small fenestra made in the foot plate, while cochlear implantees do not manifest similar vertiginous episodes even though a complete electrode array is inserted through a Cochleostomy or the Round Window. Such a mystery has triggered researchers to look into the vestibular changes that happen among cochlear implantees and recent literature has thrown light on such changes with reliable explanations based on clinical tests such as Vestibular Evoked Myogenic Potentials (VEMP) and Video Oculography (VOG). This review article explores the results of such studies and highlights the author's experience in assessing vestibular function among cochlear implantees.

Keywords: Cochlear Implants, Vertigo, Vestibular Evoked Myogenic Potentials (VEMP), Sacculo-Collic Reflex, Video Oculography (VOG)

INTRODUCTION

Cochlear implantation is an established procedure for restoration of hearing in bilateral severe to profound cochlear hearing loss unresponsive to conventional amplification with hearing aids. Postoperative dizziness and vertigo are accepted to be potential complications of cochlear implantation, but their incidence among cochlear implantees has presumably been low world over [1]. The probable reason being that most cochlear implantations are being performed in very young pre-lingual children lesser than 5 years of age, among whom clinical signs of vertigo like nystagmus are most often not noticeable post-implantation and these children are not able to

provide behavioural feedback regarding the presence of any vertiginous symptoms, if present in them [2]. Hence, post-operative vertigo in cochlear implantees has more often been recorded among adult post-lingual cochlear implantees, especially in those patients who have ended up with profound deafness due to long standing Meniere's syndrome, Cochlear Otosclerosis or in Presbycusis to a lesser extent (Table-1). The advent of recent clinical tools like the Video Oculography (VOG) and Vestibular Evoked Myogenic Potentials (VEMP), have paved the way forward for clinicians to objectively evaluate the peripheral vestibular system among cochlear implantees [3].

Table-1: Pre-operative variables associated with higher risk for Post Cochlear Implantation Dizziness

• Pre-operative dizziness (like in patients with Meniere's Syndrome)
• Advanced age at the time of implantation (> 70 years)
• Older age at onset of hearing loss (like in Presbycusis, Cochlear Otosclerosis)
• Pre-implantation abnormal Computerized Dynamic Posturography Test
• Usher's Syndrome Type 1 patients with Abnormal Pre-operative VNG / VOG

Literary Insights

Damage to the vestibular system after Cochlear Implantation was first described by Black as early as in 1977, when cochlear implants were still in the initial

phase of development. The reported prevalence of vestibular complaints then varied considerably over the years, ranging from 4% to 39%, or even up to 75% of patients in some subsequent studies. The estimated

prevalence of peripheral vestibular dysfunction as a result of cochlear implantation is around 20% for adults and 10% for children in the present day. Most often the vertigo is transient and self-limiting within few weeks. For patients implanted in the only functioning ear, the risk for vestibular loss is estimated to be around 30%, and bilateral cochlear implantation carries the risk of bilateral vestibular dysfunction for an estimated 5% of individuals implanted [3, 4].

World literature proposes three mechanisms by which labyrinthine function can be compromised in Cochlear Implant recipients – a) Pre-existing pathology that caused the deafness, b) Cochleo-Vestibular injury secondary to electrode insertion and c) Secondary to spread of current from the electrode array during device

use. The second mechanism has been extensively investigated using animal models and post-mortem temporal bone dissections and researchers have concluded that, post-operative vestibular hypofunction in cochlear implantees may occur due to a secondary Endolymphatic Hydrops soon after CI surgery or due to BPPV which can be triggered due to the intra-cochlear trauma induced by electrode insertion [4, 5]. Cochlear Hydrops is caused by damage to the lateral cochlear wall during implantation or in rare cases due to obstruction of endolymphatic flow in the ductus reuniens or in the hook portion of the cochlea. Cochlear Hydrops when accompanied by Saccular collapse may cause recurrent attacks of vertigo of delayed onset, similar to Ménière's syndrome (Fig-1).

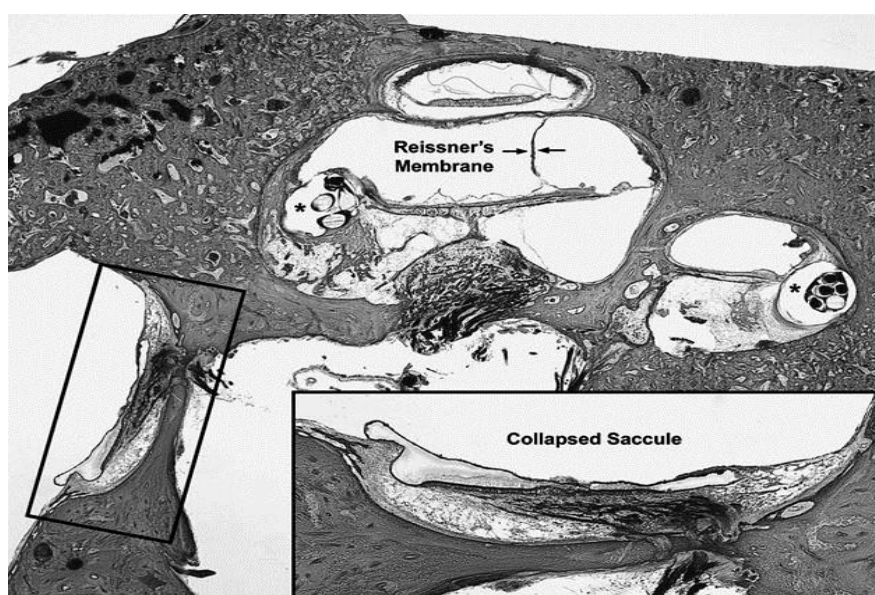


Fig-1: Reissner membranes of the ascending and descending limbs of the basal turn of cochlea – distended and abutting each other (black arrows), with collapsed Saccule. (Courtesy: Handzel - Otol Neurotol, Jan 2006, Vol. 27:1).

Chronic, persistent dizziness is largely based on a dysfunction of the saccular macula which is an integral component of the otolith system [6]. Histopathologic studies have revealed that saccule is the most frequently damaged organ due to cochlear implantation, followed by utricle, then rarely the semicircular canals. Vestibular nerve does not seem to be stimulated by the CI, since most vestibular dysfunctions seem to be transient and recover adequately in time due to isolated damage of the saccule whose dysfunction can be subtle or if clinically manifested, may be substituted, adapted or fully compensated by central influences over time [7].

VEMP test is a feasible and relatively easy method to perform vestibular evaluation in children, unlike VOG / ENG testing which requires ardent attention and cooperation from the patient, which is impractical among children. The VEMP test usually takes only 15–30 min and is well tolerated by children

at any age group. In an interesting recent study by Satbir Singh *et al.* [8], VEMP tests were performed in 15 children with severe to profound sensori-neural hearing loss. He reported that for his study group the mean P1 and N1 latencies values were 15.12 ms and 23.86 ms, respectively and for his control group the mean P1 and N1 latencies were 15.39 ms and 23.68 ms. The comparison of mean P1 and N1 latencies values between study and control groups revealed no significant difference ($p > 0.05$). Furthermore, the mean amplitude values of VEMP responses for study and control groups were 75.78 mV and 160.51 mV, respectively. The comparative mean amplitude values between study and control groups revealed statistically significant differences ($p < 0.05$). Out of 15 children in the study group 2 children had the absent VEMP response in both the ears. The authors thus concluded that vestibular function plays an important role in gross motor development in children and it is imperative that vestibular function tests should be routinely performed

prior to planning cochlear implantation in children with severe to profound hearing loss and appropriate counseling needs to be provided regarding the possibility of vestibular dysfunction after surgery. He also opines that a simple vestibular rehabilitation program involving simple gaze stabilization exercises stimulating the vestibular-ocular reflex, should be offered for children experiencing a significant vestibular disturbance, since these simple exercises have previously been shown to promote faster compensation and speed recovery after unilateral vestibular loss due to cochlear implantation among adults.

Buchman *et al.* [9] studied the effects of unilateral CI on the vestibular system, using the dizziness handicap inventory (DHI), vestibulo-ocular reflex (VOR) testing using both alternate bithermal caloric irrigations (ENG) & rotational chair-generated sinusoidal harmonic accelerations (SHA), and computerized dynamic platform posturography (CDP) at pre-operative, 1-month, 4-month, 1-year and 2-year post-implantation intervals. Their comparisons revealed no significant differences between pre-operative and post-operative values for VOR testing (ENG and SHA) at any of the follow-up intervals. Likewise, DHI testing was also unchanged except for significant reductions (improvements) in the emotional subcategory scores at both the 4-month and 1-year intervals. CDP results demonstrated substantial improvements in postural sway in the vestibular conditions (5 and 6) as well as composite scores with the device “off” and “on” at the 1-month, 4-month, 1-year, and 2-year intervals.

These authors felt that Device activation appeared to improve postural stability in some conditions. Excluding those patients with pre-operative areflexic or hyporeflexic responses in the implanted ear (total [warm _ cool] caloric response <15 deg/s), substantial reductions (>21 deg/s maximum slow phase velocity) in total caloric response were observed for 8 (29%) patients at the 4-month interval. These persisted throughout their study period. These changes were accompanied by significant low frequency phase changes on SHA testing confirming a VOR insult. There were no effects of age, sex, device manufacturer, or etiology of hearing loss (HL) for these patients. Hence, they concluded that unilateral CI rarely results in significant adverse effects on the vestibular system as measured by the DHI, ENG, SHA, and CDP. On the contrary, patients that underwent CI experienced significant improvements in the objective measures of postural stability as measured by CDP. Device activation in music appeared to have an additional positive effect on postural stability during CDP testing. Although VOR testing demonstrated some decreases in response, patients did not suffer from disabling vestibular effects following Cochlear Implantation, the underlying reason for which still remained unclear.

In a recent study, Shereen M *et al.* [10] compared 20 cochlear implantees with well-matched controls, with an aim to assess (CDP) and vestibular evoked myogenic potential (VEMP) and to correlate findings of these two tests with the patients’ imbalance symptoms. They found that vertigo was present in 5/20 cases. Eleven had postoperative dizziness. 13 out of 20 cases had SOT balance function in CI recipients using sensory organization test (SOT) of computerized dynamic posturography abnormalities, 10 of which had vestibular ratio abnormality. The cases had statistically significant lower scores than their controls in SOT conditions 4, 5, 6, composite score, vestibular, visual & visual preference ratios. VEMP response was preserved bilaterally in 11/20, out of which 5 had abnormal inter-aural amplitude difference, which was statistically significantly lower than the controls. The remaining 9 had lost VEMP irrespective of the tested side. Statistically significant differences in p13 latency were found comparing implanted and non-implanted ears, as well as comparing implanted ears with the controls. There was no statistically significant correlation between patients’ age, duration of sensory deprivation or implant duration with any of the posturographic or VEMP parameters. This comprehensive analysis has shown that balance dysfunction is not uncommon in CI recipients post-operatively, and such patients may require vestibular rehabilitation. These authors hence recommend adding CDP and VEMP to the routine pre- and post-surgical testing.

Unlike adults, the most common presentation of peripheral vestibular loss in young children is delayed motor development and loss of postural control. This phenomenon illustrates the remarkable plasticity of the central sensori-motor input–output mechanisms that serve human balance, especially during early development. Vestibular loss can impair the process of integration of sensory stimuli critical to the normal development of motor coordination and locomotion. The vestibular system is also responsible for maintenance of visual acuity during active head movements. Vestibulo-spinal influences contribute both to the posture adopted by an individual and maintenance of that posture despite postural perturbations. Vestibular function loss puts children at risk of significant vestibulo-ocular interaction impairment during normal activity and maintaining equilibrium in dark environments. But it remains unclear why many hearing-impaired children with abnormal VEMP outcomes do not have complaints of vestibular symptoms.

The MERF Experience

In this author’s clinical study for objective assessment of vestibular functions in cochlear implantees, results were found to be consistent and in comparison with world literature. We performed a prospective study of vestibular functions among 20 individuals with progressive cochlear hearing loss

(Post-lingual older children and adults aged 10 to 24 years), who had normal inner ear anatomy and no syndromic associations or co-morbidities. Vestibular tests - Video-oculography (VOG) and Vestibular Evoked Myogenic Potentials (VEMP) were performed 1 week before surgery (as base line investigations), to compare with post implant changes after cochlear implantation at 1, 6 and 12 months intervals. All candidates underwent cochlear implantation by the same surgeon with the same type of implant using the

same standard cochleostomy and soft-insertion technique. We observed that pre-operatively 17 patients (85%) had a normal VOG with caloric response, while 3 patients (15%) had hypoactive caloric response in the ear to be implanted. All these patients had a normal VEMP (100%) irrespective of their caloric response. After Cochlear Implantation, VOG with caloric responses and post-operative VEMP results have been shown in Table-2.

Table-2: Vestibular Responses In Cochlear Implantees (n=20)

	1 month	6 months	12 months
VOG - Normal Labyrinth	11 (55%)	11 (55%)	11 (55%)
VOG - Absent Caloric Response	3 (15%)	3 (15%)	3 (15%)
VOG - Hypoactive Caloric Response	6 (30%)	6 (30%)	6 (30%)
VEMP - Absent Response	14 (70%)	14 (70%)	14 (70%)
VEMP - Abnormal Response	5 (25%)	5 (25%)	5 (25%)
VEMP - Normal Response	1 (5%)	1 (5%)	1 (5%)

Based on the above results, we inferred that all implantees in this study had normal saccular function before cochlear implantation. 3 implantees had pre-operative abnormal vestibular functions, possibly implicated to viral meningitis with labyrinthitis, which was their aetiology for profound hearing loss and labyrinthine dysfunction. On post-operative assessment, all except 1 implantee, had abnormal vestibular evoked myogenic potentials at first post-operative assessment, 5 implantees showed poor morphology of VEMP waveforms. 9 implantees had abnormal VOG with caloric functions 1 month after surgery, out of which 6 had normal pre-operative VOG with caloric tests. Thus In our study, cochlear implantation had induced persistent hypo-activity in the labyrinth, even though patients didn't have any symptoms or signs of vestibular dysfunction either because of adequate central compensation or vestibular adaptation over time.

CONCLUSION

Cochlear implantation may lead to saccular and vestibular dysfunction in the implanted ear post-operatively. Saccular dysfunction is more predominant than its vestibular counterpart, due to the proximity of saccule to cochlea. Recovery of the saccule and vestibule may take significant periods of time, in spite of absence of any vestibular symptoms probably due to adequate central compensation. The advent of advanced objective vestibular tests like VOG and VEMP, have added a valuable tool to analyze the effect of implantation on the vestibular system.

Cochlear Implant surgeons must anticipate the chances of vestibular dysfunction among their patients post-operatively and be prepared to manage this entity appropriately. While choosing the side for cochlear implantation, in patients with pre-operative vertigo, it is preferable to choose the ear with a reduced caloric response, rather than the normal labyrinthine side. Patient's age, etiology of deafness, type of implant or

the pre-operative caloric functions do not seem to be significant predictors of post-operative dizziness. The severity of vestibular abnormalities correlates well with the severity of intra-cochlear damage caused by the implanted electrode. Hence soft insertion minimizing the intra-cochlear damage is now preferred. Vestibular disturbances after CI are transient and self-limiting in most cases. If persistent, post-operative vestibular rehabilitation therapy is helpful in the management of vestibular symptoms in cochlear implantees.

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