

Review Article

Vertigo following cochlear implantation: a review

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ABSTRACT

Cochlear implantation may cause a detrimental effect on vestibular function and residual hearing. A significant number of patients with a cochlear implant present with vertigo. There are several mechanisms for dizziness following cochlear implantations. The causes may be surgical trauma, disruption of normal cochlear physiology, or ensuing endolymphatic hydrops. Vibratory trauma affecting the cochlea during cochleostomy plays a vital role in causing paroxysmal vertigo in patients with a cochlear implant. In addition, the vibrations affecting the cochlea are enough to dislodge otoconia particles. During cochlear implantation, it is necessary to insert an electrode array into the cochlea and thus the chance of damage to cochlear and function may happen. Dizziness or vertigo may develop after cochlear implantation. It usually occurs due to vestibular hypofunction. Vertigo following cochlear implantation has not frequently been documented in the literature previously. However, the increasing number of cochlear implantations in the current scenario is showing different postoperative complications like vestibular symptoms among patients with an implant. The vestibular symptoms following cochlear implantation range from a gradual sense of mild unsteadiness or lightheadedness to brief attacks of whirling vertigo. Vertigo following cochlear implantations affects the quality of life although vestibular therapy is often helpful to manage this condition. The article aims to provide a comprehensive review of vertigo following cochlear implantation.

Keywords: Cochlear implant, Cochlea, Cochleostomy, Vertigo, Vestibular therapy

INTRODUCTION

The cochlear implant is considered as one of the marked innovations in auditory rehabilitation since its first experience was done by Eyries and Djourno in 1957.¹ The cochlear implantation is a standard and safe surgical procedure with low minor and major complications postoperatively like facial nerve palsy, infection, dysgeusia, and skin alterations.² With the broadened indications and widespread use of cochlear implantation, it is now becoming more important to analyze critically and evaluate the risks and possible side effects of this surgical intervention in deaf patients.³ The occurrence of vertigo or dizziness following cochlear implantation is one of the most commonly found complications and usually transient. Auditory and vestibular systems have

close proximity to each other along with their embryologic and physiologic interaction.⁴ So, this anatomical and physiological closeness of the vestibulo-auditory systems may face trauma during any surgical procedure nearer to it such as cochlear implantation.⁵ Cochlear implant (CI) is a standard tool for the rehabilitation of patients with severe to profound hearing impairment.⁶ Bilateral cochlear implantation, particularly in the pediatric age group, has also been an established concept. Currently broadened indications and widespread use of cochlear implantation, it has become more crucial to analyze and evaluate the risk and possible side effects of this procedure. Cochlear implantation may result in trauma to labyrinthine structures during the insertion of electrodes into cochlear turns.⁷ Regarding cochlea which is obviously at risk, the vestibular structures may also be negatively affected by this surgery. One possible side

effect with considerable impact on the daily life of the patient is vertigo. There is paucity of literature for vertigo in cochlear implant patients. This review article discusses the details of the epidemiology, etiopathology, clinical manifestations, diagnosis, treatment of vestibular symptoms such as vertigo following cochlear implant.

LITERATURE SEARCH

Multiple systematic methods were used to find current research publications on vertigo following cochlear implantation. We started by searching the Scopus, PubMed, Medline, and Google Scholar databases online. This search strategy recognized the abstracts of published publications, while other papers were discovered manually from the citations. A search strategy using PRISMA (Preferred reporting items for systematic reviews and meta-analysis) guidelines was developed. Randomized controlled studies, observational studies, comparative studies, case series, and case reports were evaluated for eligibility. There were total numbers of articles 69 (31 case reports; 28 cases series; 10 original articles). This paper focuses only on vertigo following cochlear implantation. The search articles with any manifestations other than vertigo following cochlear implantation are excluded in this review article. Review articles with no primary research data were also excluded. This paper examines the epidemiology, etiopathogenesis, clinical manifestations, diagnosis, and treatment of vertigo following cochlear implantation. This analysis provides a foundation for future prospective trials for vertigo after cochlear implantation. It will also catalyze additional study of vertiginous symptoms following cochlear implantation, allowing early detection and treatment.

EPIDEMIOLOGY

Over the last thirty years, cochlear implantation has become a standard tool for rehabilitation of the patients with severe to profound hearing impairment.⁸ Before the cochlear implant era, the patients were required to be almost completely deaf. However, in current times more liberal indications have to lead to cochlear implantations in less severely deaf patients achieving inadequate results with hearing aids. Bilateral cochlear implantation at an early age is now considered an established concept. Vertigo following cochlear implant surgery was not described in the early days of the cochlear implantation. As people were more careful about movement disorders, clinicians started to observe vertigo among cochlear implant patients in the early 1990s where few patients showed a severe form of vertigo.⁹ The frequency of vertigo following cochlear implantation varies widely and it ranges from 0.33 to 75% cases.¹⁰ The vertiginous symptoms in 90% of the cases with cochlear implantations were due to otogenic origin.¹¹ Many authors documented vertigo following cochlear implantation. One author reported 47% of 55 patients with multichannel cochlear implants experienced

subjective vertigo and that 8% presented prolonged vertiginous symptoms.¹² One study revealed postoperative vertigo found in 36% of the cases and one-third only found in immediate post-op period. Half of the post-operative vertigo is directly attributable to cochlear implantation.¹³

ETIOPATHOLOGY

The exact etiopathology of vertigo after cochlear implantation is controversial. Many theories have been suggested for explaining vestibular impairment following cochlear implantation resulting in vertigo. There are multiple factors associated with the causation of vertigo following cochlear implantation. Traumatic injury to labyrinth during insertion of the electrode, perilymph loss during surgery, post-operative perilymph fistula, foreign body reaction with labyrinthitis, endolymphatic hydrops, and electrical stimulation of the labyrinth by the implant are proposed mechanisms for causing vertigo in cochlear implantation.^{14, 15} The impact of the electrical vestibular stimulation by the implant on the inner ear/labyrinth is also considered as the cause of vertigo.¹⁶ Furthermore, benign paroxysmal positional vertigo, autoimmune Ménière's syndrome, and Tullio phenomenon have also been documented after cochlear implantation.¹⁷ During performing cochleostomy, bone dust particles may fall into the cochlea, by way of microinjury/rupture of the basilar membrane, which goes into the endolymphatic compartment of the scala media and then moves into the semicircular canal, resulting in canalolithiasis and causing BPPV.¹⁸ The vibrating trauma to the cochlea during cochleostomy plays an important role in causing paroxysmal vertigo in patients with a cochlear implant. In addition, vibrations affecting the cochlea are enough to dislodge otoconia, as documented in the literature in the case of dental implantation with the use of osteotomes.¹⁹ Another theory suggests that dislodgment of an otolith by electrical stimulation can happen during initial fitting where the first fitting session may cause a triggering effect.²⁰ Intracochlear misdirection of the electrode may occur even with intraoperative measurements seem to be normal. If a patient presents with unexplained vertigo after cochlear implantation with poor functioning of the cochlear implant, a misdirected active electrode must be thought. A new high-resolution three-dimensional imaging technique before surgery helps avoid such failures of electrode insertion.

The types or designs of electrodes in cochlear implants do not influence vestibular outcomes. One study showed no correlation between the brand of cochlear implant and vestibular dysfunction following cochlear implantation by comparing two brands of the implant such as Cochlear and Med-EI.²¹ Pre-operative impaired visual fixation suppression is an important risk factor for the development of vertigo after cochlear implantation. Other than direct trauma of the labyrinth by electrode insertion, other etiologies have also been documented in the literature such as post-operative endolymphatic hydrops,

benign paroxysmal positional vertigo, and direct electrical stimulation of vestibular receptors by the cochlear implant.^{22,23}

Histopathological studies of the temporal bone

The insertion of an intra-scalar electrode array at the time of cochlear implantation may cause immediate injury to the inner ear and result in delayed onset damage which may affect the neuronal stimulation. Histopathological studies of petrous bone specimens reveal that other neighboring organs are also affected in addition to the cochlea.²⁴ Insertion of the cochlear implant may result in trauma to the basilar membrane, the spiral lamina, and the spiral ligament. The electrode may cause a rupture of the basilar membrane. Structural alterations have been demonstrated in the utricle, saccule, and semicircular canal, and functional changes seen in peripheral vestibular receptors.²⁵

CLINICAL MANIFESTATIONS

The symptoms of dizziness reported by patients following cochlear implantation can be quite diverse. Vertigo is one of the commonest minor complications following cochlear implantation surgery and is usually transient.²⁶ The occurrence of dizziness following cochlear implantation is often difficult to predict by the surgical team and may develop into an invalidating situation. Some patients present vertigo just after surgery whereas others take a few weeks or months to develop vertigo.²⁷ Different vestibular function tests have not satisfactorily identified the cause for such symptoms of vertigo.²⁸ On the timing of vertigo, this symptom may be early-type (occur within 2 weeks of cochlear implantation), prolonged type (ongoing symptoms), and delayed-type (occur for more than 2 weeks after cochlear implantation).²⁹ One study showed that one-third of cochlear implant patients presented vertigo only more than one month after surgery.¹⁴ In this study, many patients experienced vertigo after one year of cochlear implantation.¹⁴ Another study reported a high prevalence of vertiginous symptoms found after cochlear implantation.²⁷ These patients had presented vertigo relatively late (months to a year) after cochlear implantation. The vestibular symptoms range from mild unsteadiness or lightheadedness to immediate, brief attacks of vertigo.³⁰ Several mechanisms have been suggested to explain cochlear implantation associated vertigo, the majority of them are due to postoperative Ipsilateral vestibular hypofunction, caused either by surgical injury, disruption of normal cochlear physiology, or ensuing endolymphatic hydrops.³¹ BPPV has been documented as a complication of surgery affecting the cochlea such as stapedectomy, stapedotomy, and cochlear implantation.³² In one study, although many patients with cochlear implants develop BPPV, no common risk factors like age of the patient, types of the implant, causes of deafness and anatomical variations in cochlea and labyrinth except all were female patients.³³ The age of

these patients was more than 60 years in half of the study participants. In three quarters of these patients, paroxysmal vertigo with irregular frequency and duration with seconds to minutes.²⁷ The classical concomitant symptoms were tinnitus, fluctuating hearing loss, and vegetative reactions. However, the prodromal symptoms were uncommon. The presence of vertigo immediately after cochlear implantation suggests direct damage to vestibular structures by insertion of the electrode.³⁴ Despite microscopical and functional damage to the vestibular organs, not all patients with cochlear implantation present with post-operative vertigo. Different studies showing vertigo following cochlear implantation in Table 1.

Table 1: Study of incidence of vertigo following cochlear implantation.

Study	Percentage of patients presenting with vertigo following cochlear implantation (%)
Enticott et al ⁷	32
Filipo et al ⁹	67
Steenerson et al ²³	75
Todt et al ²⁵	53
Klenzner et al ³⁴	12

PREOPERATIVE AND POSTOPERATIVE INVESTIGATIONS

The vestibular functions should be evaluated systematically in clinics before performing cochlear implantation as it can influence the choice of a side of cochlear implantation in cases of bilateral symmetrical hearing loss. Vestibular function tests are usually organ-specific and cannot evaluate the global function of the whole vestibular system.³⁵ After cochlear implantation, the investigations can be repeated and alterations of the test results can sometimes be found.³⁶ The most commonly otolithic function is impaired following cochlear implantation. In 80% to 100% of cases, cervical vestibular evoked myogenic potential (c VEMP) are usually lost as per the meta-analysis by Krause et al.³⁷ These findings correlate with histopathological findings where these severe in saccule and utricle than in the semicircular canals.³⁸ One meta-analysis shows post cochlear implant cVEMP sensitivity is very low, at 0.32, and this result is not very contributive, despite the histological lesions.³⁹ The warm water caloric test may be used to assess the vestibular function, as this procedure is helpful to check the ear separately.⁴⁰ The caloric test may be carried out preoperatively and postoperatively. The advanced vestibular tests like video head impulse tests (vHIT), subjective visual vertical (SVV), or ocular vestibular evoked myogenic potential (oVEMP) are very useful tests preoperatively and post-operatively to reveal vertigo in cochlear implantation surgery.⁴¹ Injury to peripheral vestibular receptors has been demonstrated following cochlear implantation by using posturography and rotator chair testing.⁴² This explains that direct injury

as a result of electrode insertion into the labyrinth is of fundamental role in the cause of the post-operative vertiginous symptom. A postoperative CT scan is useful to find out misdirection placed electrodes of the cochlear implant into the vestibular part of the inner ear.⁴³ A deformed implant should be removed and reimplanted successfully with enlarged and reshaping of the cochleostomy to prevent post-operative vertigo.

TREATMENT

Post cochlear implant patients developing vertigo require vestibular evaluation by a vestibular therapist. Vestibular rehabilitation is an effective mode to control vertigo occurring in patients with cochlear implantations. Acute peripheral vestibulopathy like vestibular neuritis and temporal bone fracture resulting in vertigo can be overcome by central compensatory mechanisms. Vestibular sedatives can be prescribed for reducing the acute onset vertigo after cochlear implantation.⁴⁴ In this situation, the interaction between vestibular and visual systems plays an important role. Visual stimuli are usually able to suppress the vestibular afferences by inactivating the parieto-insular vestibular cortex, so stabilizes the equilibrium performance.⁴⁵ This mechanism can compensate the vestibular malfunction after cochlear implantation. With help of pre-operative visual fixation suppression testing and counseling for patients with risk of post-cochlear implantation vertigo, such patients can be planned for vestibular rehabilitation training even before surgery.⁴⁶ During cochleostomy of cochlear implantation, drilling should be done on the promontory as far as the blue line of the endosteum and raise the endosteum so as not to allow the bone dusts to enter inside the cochlea. One study documented the effective technique for atraumatic electrode insertion of the cochlear implant with optimal conservation of residual inner ear function. Slow painstaking insertion of electrodes and topical application of corticosteroids intraoperatively are helpful for efficacy towards residual hearing and also for vestibular function.⁴⁷ Insertion of electrodes into the scala tympani is a better option than inserting into the scala vestibule for preserving vestibular receptors.⁴⁸ The lesions in the vestibule often occur by dislocation between the two scalas leading to perilymphatic fluid leakage followed by fibrosis. The vestibular protection is better with the insertion of electrodes through a round window in comparison to cochleostomy.⁴⁹ So, the risk of vestibular trauma is more when inserting electrodes into the scala vestibule in comparison to inserting through cochleostomy. The depth of insertion of the electrode does not seem to affect the vestibular function or present vertigo.⁵⁰

CONCLUSION

Vertigo following cochlear implantation is a well-known complication. The injury of electrode insertion results in morphological and functional alterations in the inner ear. Cochlear implantations may induce long-term vertigo.

Positional vertigo is a common sequel following multichannel cochlear implant patients. Post-cochlear implant vertigo responds well to vestibular therapy. A more global study is needed for vestibular function before and after cochlear implantation which will improve the understanding of the pathophysiology of vertigo by cochlear implantation. It can be assumed that impairment in the peripheral vestibular receptors results in vertigo only in the presence of insufficient central compensatory mechanisms.

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