

A Unilateral Cochlear Implant for Tinnitus

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Abstract

In recent years a growing number of Patients with unilateral hearing loss have been undergoing cochlear implantation. We provide an overview of the efficacy of cochlear implants (CIs) to rehabilitate patients with unilateral deafness with regards to sound localization, speech recognition, and tinnitus.

Although CI is not yet an FDA-approved treatment for unilateral deafness, several recent studies show improvements in speech understanding, sound localization, and tinnitus. Based on encouraging results and the unique ability to restore binaural sound processing, the benefits to many as an aid to their tinnitus, we argue that CIs should be offered as a treatment for unilateral deafness.

Keywords: hearing loss, tinnitus, electrical stimulation, cochlear implants.

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INTRODUCTION

Unilateral hearing loss implies a profound sensorineural hearing loss in one ear and no greater than a mild hearing loss in the opposite ear. Unilateral deafness is reported to affect approximately 18.1 million people in the United States¹. Common causes of unilateral deafness include sudden idiopathic sensorineural hearing loss, temporal bone trauma, Meniere's disease, and infection (labyrinthitis, mumps, and meningitis). Unilateral deafness is associated with significant audiological consequences. Patients experience difficulty localizing sounds and conversing in a noisy environment like restaurants. Patients with unilateral deafness frequently also experience tinnitus, which can have a profound impact on an individual's quality of life. Specifically, tinnitus has been associated with an increased incidence of depression, anxiety, hearing difficulties¹, difficult concentration and insomnia². In the U.S.A the FDA has not yet approved cochlear implantation in unilateral hearing loss. This paper is to review literature and argues in favor of a CI for tinnitus treatment in patients with unilateral deafness.

THE SEVERITY OF TINNITUS

Tinnitus can affect many activities of daily life, including (a) thought and emotions, (b) hearing, (c) sleep, and (d) concentration. Each person is affected differently people with tinnitus are interested in a wide variety of treatments³⁻⁶. Most would prefer a medication, but different individuals have different preferences. Many would pursue surgical options. Many are also willing to pay \$10,000 for treatments that reduce their tinnitus⁷.

TREATMENTS FOR TINNITUS

Tinnitus treatment presents a dilemma for clinicians and patients. How should a clinician approach tinnitus treatment? Middle ear tinnitus involves muscle twitching and blood vessels pulsing. This occurs, for example, in palatal myoclonus, high jugular bulb and glomus tympanicum. Sometimes these can be treated surgically. Sensorineural tinnitus involves the cochlear and/or neural response. At present, there are no approved cures⁸. There are some situations in which middle ear and sensorineural tinnitus co-exist: treatment of the underlying pathology can improve tinnitus (e.g. cholesteatoma, sudden sensorineural hearing loss, and ototoxicity). Identification of possible treatable pathology is an important reason for patients to see a physician for tinnitus. However for the vast majority of tinnitus sufferers, there is no surgery or medications have been shown to be effective or that have been approved.

Various drug regimens have been tried for tinnitus treatment. Occasionally there are encouraging reports in the literature but at present, an effective drug treatment has not identified. Some patients benefit from medications for depression or anxiety or other psychological

disturbances. It is important to note that the therapy in these situations is for depression and anxiety, not tinnitus.

As with any bothersome, common disorder that lacks understanding and effective treatments, tinnitus is an easy target for scams⁹. Thousands of purported cures can be found on the internet and people waste billions of dollars on tinnitus treatment yearly. Some scams are blatant. Others are subtle.

Of course, it is important to distinguish the tinnitus from the reactions to the tinnitus¹⁰. It is possible to treat a patient's reaction to tinnitus. Medications can be used to treat patients with depression and anxiety and to help with sleep problems. There is a variety of counseling strategies available focused on patient-centered care. For example, Tinnitus Activities Treatment includes cognitive behavior modification, including relaxation exercises, acceptance, sensory meditation for tinnitus and existential principals. In addition, patients report that they benefit from sound therapy¹¹.

CI FOR TINNITUS

At present, electric stimulation *via* a cochlear implant has proven to be a well-tolerated and effective means of restoring hearing to over 400,000 deaf individuals worldwide. However, using electric stimulation to suppress tinnitus has not been accepted worldwide to be safe and effective. In the USA it has not yet been approved by the Food and Drug Administration. There are several studies suggesting that electrical stimulation of the cochlea might help tinnitus sufferers.

ELECTRICAL STIMULATION THROUGH A COCHLEAR IMPLANT

Arts et al. showed that a CI capable of providing intra cochlear electrical stimulation independent of environmental sounds appears to suppress tinnitus at least for minutes¹². The main objective was to compare the long-term suppressive effects of looped (i.e. repeated) electrical stimulation (without environmental sound perception) with the standard stimulation pattern of a CI (with environmental sound perception). It can be concluded that coding of environmental sounds is not required for tinnitus suppression with intra cochlear electrical stimulation. It is therefore plausible that tinnitus suppression by CI is not solely caused by an attention shift from the tinnitus to environmental sounds. Both the standard clinical CI and the experimental Tinnitus implant (TI) are potential treatment options for tinnitus¹³. These findings offer perspectives for a successful clinical application of the TI, possibly even in patients with significant residual hearing.

CI IN UNILATERAL HEARING LOSS AND TINNITUS

Candidacy for CI continues to evolve, but a radical

innovation has been the application of CIs to individuals with severe tinnitus and unilateral deafness (Baguley and Atlas). Previous research has indicated that tinnitus in unilateral deafness deriving from idiopathic sudden sensorineural hearing loss can be severe, and refractory to treatment. It has also been established that individuals using a CI in one ear and a hearing aid in the other are usually able to combine these two inputs to improve spatial hearing, and often to reduce troublesome tinnitus. There are a growing number of studies evaluating the effect of implantation for rehabilitation of the deficits associated with unilateral deafness over the past several years as more centers offer this treatment modality to patients with unilateral deafness¹⁴. The vast majority report improvement in sound localization, speech understanding in quiet and noise, and in tinnitus¹⁵.

A COCHLEAR IMPLANT FOR HEARING IN UNILATERAL DEAFNESS

Unilateral deafness is sometimes treated with Osseointegrated hearing implant or a CROS (contralateral routing of signal) hearing aid. This has the advantage that it picks up speech from the deaf side, but has the disadvantage that it picks up noise from the deaf side. They do not provide spatial hearing with two ears.

CI implantation for unilateral deafness has the potential to provide hearing on the deaf side, and some spatial hearing. Although the first studies of unilateral CI implantations, dating back to 1957, were in patients with bilateral deafness. CI for unilateral deafness began fortuitously in the 2000s as an experimental treatment for incapacitating and intractable tinnitus¹⁶. In addition to tinnitus suppression, users reported marked gains in sound localization and speech perception in complex listening environments. Hearing loss co-exists in up to 85% of individuals with tinnitus. This depends on definitions what constitutes a hearing loss). 0 dB HL is an average; some individuals had thresholds of -10 dB HL at age 19 years, and -5 dB HL thresholds would be a hearing loss for them. A number of unilateral CI studies have reported on substantial improvements in sound localization, hearing in noise, and quality of life measures. However, we note that the expected spatial hearing benefits are more readily predicable for bilateral CIs compared to a unilateral CI and a contralateral hearing aid¹⁵.

Van de Heyning et al. reported the first study in which CIs was primary used as an option to treat unilateral tinnitus in unilateral deafness¹⁶. In this study, 22 adults were included with unilateral severe, intractable tinnitus resulting from ipsilateral sensorineural deafness of various cochlear causes. Nine of them used a hearing aid in the non-implanted ear. Tinnitus loudness was measured with magnitude estimation. A score of 0 corresponds to 'no tinnitus', whereas a score of 10 represents a 'very loud, disturbing tinnitus'. Furthermore, the Tinnitus

Questionnaire was used to evaluate the distress caused by the tinnitus. A higher Tinnitus Questionnaire-score represents more severe tinnitus complaints. Tinnitus Questionnaire was administered 1 month prior to surgery and 1, 3, 6, 12, 18 and 24 months after the first fitting. After 24 months, this study reported complete tinnitus suppression in 14% of the participants and tinnitus improvement in 82% of the participants.

Kleinjung et al. reported a case of a unilateral deaf man suffering from ipsilateral severe tinnitus, in which tinnitus was reduced 1 month after implantation and had disappeared completely 3 months postoperatively. The Tinnitus Questionnaire was used to measure the severity of tinnitus complaints VAS was used to quantify tinnitus loudness and annoyance and Tinnitus Handicap Inventory (THI) to quantify the tinnitus-related handicap¹⁷.

Palau et al. investigated three participants suffering from tinnitus who underwent cochlear implantation¹⁸. Participant 1 and 3 used a conventional cochlear implant and participant 2 used a cochlear implant with application of a noise habituator modulated *via* the audio input (specially designed for the study). Based on THI and magnitude estimation, 6 months after implantation, tinnitus disappeared completely in participant 1 and tinnitus improved in participant 2 and 3. The least tinnitus suppression was observed in the participant suffering tinnitus for more than 20 years, with application of noise habituator (participant 2).

Buchner et al. published a study including five severe to profound unilateral deaf participants suffering from ipsilateral tinnitus¹⁹. Based on an average of four magnitude estimation scores, tinnitus suppression was observed in three participants. Two of the participants reported a nearly complete tinnitus reduction. The other two indicated that tinnitus could be reduced in certain situations. In these to patients, tinnitus reoccurred due to psychological stress and noisier work environment.

Arndt et al. reported another study including 11 participants with unilateral deafness, of which 10 suffered from tinnitus²⁰. Based on magnitude estimation, at 6 months after CI activation, five of the participants reported a complete suppression of their tinnitus and three showed a tinnitus improvement. No tinnitus worsening was reported. When the CI was deactivated, tinnitus reoccurred to initial tinnitus strength. However, of the two participants in whom tinnitus did not change after implantation with the cochlear implant activated, one participant reported an increase in tinnitus when the speech processor was deactivated.

Jacob et al. published the effects of cochlear implant on the quality of hearing in unilateral deafness. Eleven of the 13 included participants suffered from tinnitus²¹. They observed an improvement in the quality of hearing due to cochlear implantation. As an additional effect, they

reported that nine participants declared that tinnitus was improved. No tinnitus worsening was reported. However, quantification of tinnitus severity was not available.

Ramos et al. performed a study including 10 participants with unilateral deafness suffering from severe-to-profound sudden-onset hearing loss and tinnitus in the affected ear, who all received a cochlear implant²². Similar T-levels and C-levels of the electrode responsible for the tinnitus pitch and the four collateral electrodes were used. THI as well as magnitude estimation was used to quantify the tinnitus handicap and loudness, respectively, at 1 and 3 months postoperatively. Two patients reported complete suppression of their tinnitus, whereas seven reported less tinnitus handicap and loudness. Again, no tinnitus worsening was observed. Interestingly, the improvement in tinnitus perception remained when the cochlear implant was deactivated.

Kleine Punte et al. published a study including 26 participants with unilateral deafness undergoing cochlear implantation, all with unilateral severe-to-profound sensorineural hearing loss and suffering from severe tinnitus²³. Twenty-two of them were already reported by Van de Heyning et al. Based on magnitude estimates, 24 months after implantation, four participants reported complete tinnitus suppression. The others reported tinnitus improvement. In 24 cases, tinnitus reoccurred at the original loudness after cochlear implant deactivation. Two participants did not experience any tinnitus within 1 day after cochlear implant deactivation. Four participants who were not described by Van de Heyning et al. were followed up to 12 months postoperatively. Effects on tinnitus loudness were comparable to those observed in 22 participant described earlier. Tinnitus loudness seemed to be stabilized after 3-6 months postoperatively. Furthermore, no differences were observed between patients suffering from pure-tone tinnitus, narrow band noise tinnitus or polyphonic tinnitus.

Zeng et al. reported a study with a study design different from the others in which they used experimental cochlear implant settings as an attempt to suppress tinnitus in one unilateral deafness participant. Here, the quality of hearing was not improved as they used an electrical stimulation pattern independent of environmental sounds. The reason why they did this is because there was no tinnitus reduction observed with the standard clinical cochlear implant settings. Based on magnitude estimates, tinnitus was completely suppressed within 6 minutes using low-rate < 100 HZ stimulus. Tinnitus reoccurred at original loudness within seconds after stopping intra cochlear electrical stimulation²⁴.

CONCLUSION

Tinnitus is a significant problem for many. At present, there is no approved pharmaceutical or surgical treatment. It is clear that CIs can help many patients with tinnitus

Indeed; there is ample evidence that CIs are appropriate for patients with severe hearing loss and tinnitus. Patients with unilateral profound deafness are an excellent starting point. Hopefully, tinnitus can be reduced substantially. However, even if the effects on tinnitus are minimal, the CI will help their hearing. Because of the major impact of tinnitus on people's well-being, private and government health insurance should provide for the device, the surgery and the fitting of the device.

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