

Electrical Suppression of Tinnitus via Cochlear Implants

Richard T. Miyamoto, M.D., Michael K. Wynne, Ph.D.,
Christopher McKnight, M.D., and Brad Bichey, B.S.

Indiana University School of Medicine, Indianapolis, IN

Abstract: Electrical suppression of tinnitus via a cochlear implant is a secondary benefit for many cochlear implant recipients. In this study, a sample of 78 adult cochlear implant users were surveyed. Data was compiled from 64 completed questionnaires. A high prevalence of preoperative tinnitus was documented in profoundly deaf adult cochlear implant users. Although only a few subjects reported that their tinnitus was totally eliminated after implantation, many users reported improvement or stabilization. Duration of tinnitus appeared to be a significant factor as all subjects who reported a significant improvement had less than a 20-year history of tinnitus.

Keywords: Tinnitus, Cochlear Implants, Electrical Suppression, Tinnitus Handicap Inventory

Since the advent of cochlear implantation as a treatment for profound sensorineural hearing loss, the additional benefit of electrical tinnitus suppression in some patients has been noted by several investigators.¹⁻⁸ Some profoundly deaf cochlear implant recipients experience significant diminution of their tinnitus percepts when their cochlear implant is activated. Our interest in this area was triggered by one of our original 3M/House implant recipients who has worn her implant 24 hrs/day for over a decade as the only means of controlling her disabling tinnitus. The purpose of this retrospective study was to further explore the frequency, magnitude, and time course of cochlear implant stimulation on tinnitus suppression.

LITERATURE REVIEW

Tracking measurements of tinnitus loudness over time, McKerrow et al.⁹ reported that five of six subjects who wore cochlear implants had their tinnitus suppressed ef-

fectively with their devices on and receiving a noise input. In one patient, the tinnitus suppression occurred bilaterally even though the stimulation was delivered to only one ear. Generally, the tinnitus suppression decayed over time. Four of their six subjects perceived a reduction in their tinnitus percepts with their devices on but without any acoustic input to the speech processor. All subjects were found to have experienced some alterations in their tinnitus percept with the device on. The authors concluded that tinnitus sufferers may benefit from electrical stimulation to suppress the tinnitus percept, particularly if the device could stimulate the cochlear at the site corresponding tonotopically to the tinnitus frequency domain.

Dauman, Tyler, and Aran¹⁰ reported that the effectiveness of tinnitus reduction using electrical stimulation of the cochlear in two patients wearing cochlear implants was dependent on the site of electrical suppression along the cochlear partition. A pulse rate of 125 Hz showed the greatest efficiency needed to suppress tinnitus, as measured by the amount of current level delivered to the implant. The poorest tinnitus suppression performance occurred when their subjects used their speech processors set in the usual conditions to perceive speech as the acoustic input. This is consistent with the observations by Thedinger et al.¹¹ that patients with tinnitus receive minimal success with electrical stimulation from cochlear implants when they are implanted specifically to treat their tinnitus.

Reprint requests: Richard T. Miyamoto, M.D., Department of Otolaryngology—Head and Neck Surgery, Indiana University School of Medicine, 702 Barnhill Dr., Room 0860, Indianapolis, IN 46202-5230. Telephone: (317) 274-3556. Fax: (317) 274-6680. Presented at the American Neurotology Society Meeting, Scientific Program, Tinnitus Panel, September 28, 1996, Washington, DC.

A report by Hazell, McKinney and Aleksy¹² surveyed 808 patients with profound hearing loss referred for cochlear implantation. Of the 256 patients who were implanted, 21% had no tinnitus, 27% had tinnitus that was not bothersome, and 52% had bothersome or annoying tinnitus. One hundred ten of their patients participated in a special analysis of their tinnitus percepts. Forty-two per cent showed a significant improvement in their tinnitus after implantation as measured by a habituation score.

The purpose of the current study is to describe the frequency, magnitude and time course of the tinnitus percepts of a large group of adult cochlear implant users.

METHODS

Patients and Methods

Questionnaires were sent to active adult cochlear implant recipients who have received their cochlear implants at the Indiana University Medical Center. Sixty-four patients completed and returned their questionnaires. Fifty-five of the patients used a multichannel cochlear implant (44 used a Nucleus and 11 used a Clarion) and the remaining nine used a single channel implant. There were 39 females and 25 males in the sample. The age range encompassed all decades from the 3rd to the 8th with the majority of patients above 50 years-of-age at the time of the sampling.

Questionnaire

All questionnaires allowed the subjects to remain anonymous. As a result, the questionnaires included basic demographic information such as gender, age, type of cochlear implant, and ear implanted. The question asked whether the respondent had ever experienced tinnitus, defined as "any sound or noise that seems to come from within or around the head (tinnitus is commonly known as 'ringing in the ears')." If the subject did not report any experience with tinnitus, she/he was asked to simply indicate this and return the questionnaire. For those subjects who reported any experience with tinnitus, they were asked to complete the remaining questions and then return the questionnaire. Items on the questionnaire included whether the subjects had ever sought medical attention for their tinnitus, their experiences with tinnitus before and after implantation, the nature of any current tinnitus or their recall of the nature of the tinnitus they had experienced, their percepts of the pitch and loudness of any current tinnitus, and its perceived annoyance and severity. The questionnaire was limited to four typewritten pages.

The subjects who currently had a tinnitus percept were asked to complete the Tinnitus Handicap Inven-

tory developed by Newman, Jacobson, and Spitzer¹⁴ to assess their functional, emotional and catastrophic response reactions to their tinnitus. Finally, the subjects were asked to describe, in their own words, their tinnitus.

RESULTS

Of the 64 respondents, 53 reported a history of tinnitus but only 15 of the subjects in the final sample had ever sought medical attention for their tinnitus. Figure 1 illustrates the estimated duration of the tinnitus percept prior to the implant surgery for the patients who reported any history of tinnitus before receiving the cochlear implant. Forty-four subjects experienced tinnitus before and after implantation whereas 4 subjects experienced tinnitus only prior to implantation and 5 subjects experienced tinnitus only after implantation. Three subjects recalled a severe episode of transient tinnitus during the post-operative device hook-up. Of the 44 patients who experienced tinnitus before and after implantation, 22 patients reported that the cochlear implant had no effect on the severity of their tinnitus, 18 patients indicated that the severity of the tinnitus decreased after implantation (6 indicated that they received "significant improvement" after implantation), 2 patients stated that the severity of their tinnitus increased after implantation, and 2 patients reported that no change in the severity of their tinnitus but that the tinnitus percept changed in regards to pitch and tonality. All subjects who reported a significant improvement from their implantation had less than a 20-year history of tinnitus.

Of the 49 patients who perceive tinnitus after implantation, eight patients only notice their tinnitus when their device is off and no patients reported a tinnitus percept only when their device is on. Forty-one patients reported a tinnitus percept with and without their devices, with 20 reporting no change in tinnitus severity

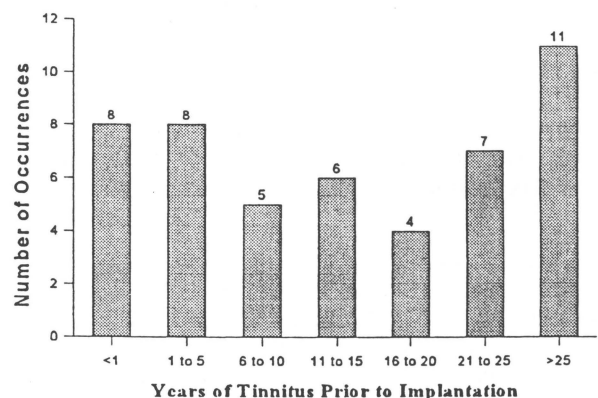


Figure 1. Estimated duration of the tinnitus percept prior to implantation.

with or without the device, 15 patients indicating that the severity of the tinnitus is less severe when their device is on, and 5 patients reported that their device appeared to increase the severity of their tinnitus. Table 1 presents the distribution of the location of the tinnitus percept for those cochlear implant users who continue to experience some tinnitus after implantation. Table 2 presents the distributions regarding the users perceptions of the annoyance and loudness of their tinnitus at the time they completed the questionnaire and when they believed that their tinnitus was at its worst.

The ranges, mean scores, and standard deviations of the total scores, functional subscale, emotional subscale, and catastrophic subscale computed from the patient's self-assessment of their tinnitus using the Tinnitus Handicap Scale is presented in Table 3. The functional subscale is reported to reflect the role limitations in the areas of mental and physical functioning thought due to the patient's tinnitus.¹³ The emotional subscale reflects the patient's broad range of affective responses to their tinnitus and the catastrophic subscale reflects the patient's perceptions of desperation, inability to escape from their tinnitus, of having a terrible disease, lack of control, and inability to cope with their tinnitus. Although the ranges were relatively large across all subscales and for the total score, the mean values were relatively low as a group. Although the mean scores for the functional subscale were only slightly higher than the mean scores for the emotional and catastrophic subscales, when adjusted in relation to the possible maximum scores, the means scores across all three subscales were judged to be equivalent.

Table 1: Distribution of the location of the tinnitus percept in respondents who reported a continued history of tinnitus after implantation.

Location of Tinnitus Percept	Number of Respondents
Left ear	10
Right ear	7
Both ears	17
Right ear > Left ear	5
Implanted right ear	3
Implanted left ear	2
Left ear > Right ear	6
Implanted right ear	5
Implanted left ear	1
Both ears equally	6
Head	13
Right side > Left side	2
Left side > right side	2
Midline	3
Unknown location	4
Outside head	2

Table 2: Distributions of the annoyance and loudness of the tinnitus percepts.

Annoyance			Loudness		
Rating	Current Percept	Worst Percept	Rating	Current Percept	Worst Percept
Not at all	21	7	Soft	18	3
A little	14	11	Comfortable	11	5
Moderately	8	16	Loud	14	25
Severe	3	14	Uncomfortable	5	12
Disabling	3	5	Painful	1	5

DISCUSSION

The data obtained from the questionnaire used in this study suggest that, as a group, there is a relatively high prevalence of tinnitus in adult cochlear implant users. Although only a few subjects reported that their tinnitus percept was eliminated after implantation, most users reported either that their tinnitus condition improved or remained stable with the cochlear implant. A small number of users reported that the severity of the tinnitus increased after implantation. There was no report of tinnitus onset corresponding with implant surgery or with the initial programming of the device. Furthermore, there was no report of the tinnitus percept being present only when the device is on.

These findings are consistent with the earlier reports that cochlear implants do suppress tinnitus in many patients.¹² The current data are not consistent with the high rates of complete or partial relief of tinnitus in both ipsilateral and contralateral ears from cochlear implantation as reported by Kim et al.¹³ They found that all of their patients with tinnitus previously reported in the implanted ear indicated complete or partial relief and the majority of the patients with tinnitus previously reported in the ear contralateral to the implant indicated some relief. There was no report of an increased tinnitus annoyance with the implantation from their subjects. However, the findings from this study indicate that although the majority of the users perceived some improvement in their tinnitus percepts after implantation, the effects of the implantation on tinnitus was not consistent across all subjects. In contrast to the Kim et

Table 3: Results of the tinnitus handicap scale.¹⁴

	Total Scale Possible: 100	Functional Scale Possible: 44	Emotional Scale Possible: 36	Catastrophic Scale Possible: 20
Mean	20.05	8.46	6.15	4.27
s.d.	20.34	7.96	7.32	3.94
Range	0-90	0-40	0-32	0-18

al.¹³ study, some users' tinnitus actually became worse after implantation. Consequently, the clinical application of cochlear implants alone as the primary means to suppress tinnitus is not supported by the current data.

When compared to the tinnitus percepts of patients participating in the validation study of the Tinnitus Handicap Scale,¹⁴ the subjects who continued to experience tinnitus in this study appeared to have lower scores across all measurement conditions (total scale, functional, emotional, and catastrophic subscales). It appears then that this group of cochlear implant users who report tinnitus are not as affected by their tinnitus as the validation group used by Jacobson and his colleagues.¹⁴ However, the differences between the mean scores are small and do not appear to be clinically significant.

As the current memories are retrospective in nature, it is possible that the patients' memories of their tinnitus percepts prior to implantation may not truly represent the actual percepts at the time of implantation. However, many of the informal descriptions of the tinnitus difficulties described by the patients suggested that they continue to have rather detailed memories of their tinnitus problems both before and after the implantation. Additional studies will approach the electrical suppression of the tinnitus percept from a prospective model while attempting to control for the strong placebo effects of tinnitus management as described by Coles.¹⁵

CONCLUSION

There is a high prevalence of tinnitus in adult cochlear implant users. Although cochlear implantation improved or stabilized the tinnitus percept for most adult cochlear implant users, only rarely did implantation result in total elimination of the tinnitus percept. Therefore, cochlear implantation is not recommended when tinnitus control is the sole therapeutic goal.

The variable influence of cochlear implantation on tinnitus remains unexplained. This may be due, in part, to a lack of residual inhibition of tinnitus in patients using multichannel implants. It also seems apparent that tinnitus production is not entirely dependent on cochlear disease processes. Significant central, cognitive, and/or emotional components also contribute.¹² The observations that improvements in tinnitus percepts in both the ipsilateral and contralateral ears may occur after implantation and can even occur independently of whether the device is on or off provide further evidence that central influences are operational.¹³

The management of tinnitus complaints is a difficult task, particularly for patients with severe and profound hearing loss. Additional basic and clinical research is needed to address whether different management strat-

egies are required for patients who use or are candidates for cochlear implants.

REFERENCES

1. Brackmann DE: Reduction of Tinnitus in Cochlear-Implant Patients. *Journal of Laryngology and Otology* 95 (Supplement 4):163-165, 1981.
2. House JW, Brackmann DE: Tinnitus: Surgical Treatment. In: Tinnitus. Ciba Foundation Symposium 85. D Evered, G Larensen, G Pitman, London, England. pp 204-216, 1981.
3. Douek E: Electrical Stimulation of the Inner Ear—Auditory; Tinnitus Suppression Results and Speech Discrimination. *Journal of Laryngology and Otology* (Supplement 9):137-138, 1984.
4. Berliner KI, Cunningham JK, House WF, House JW: Effect of the Cochlear Implant on Tinnitus in Profoundly Deaf Patients. In: Proceedings of the Third International Tinnitus Seminar. H Feldman, Harsch, Karlsruhe, FDR. pp 451-453, 1987.
5. Battmer RD, Heermann R, Laszig R: Suppression of Tinnitus by Electrical Stimulation in Cochlear Implant Patients. *HNO* 37:148-152, 1989.
6. Tyler RS, Kelsay D: Advantages and disadvantages reported by some of the better cochlear-implant patients. *American Journal of Otology* 11:282-289, 1990.
7. Gibson WPR: The effect of electrical stimulation and cochlear implantation on tinnitus. In: Proceedings of the Fourth International Tinnitus Seminar. JM Aran, R Dauman, New York, NY. pp 403-408, 1992.
8. Zwolan TA, Kileny PR, Souliere CR Jr, Kemink JL: Tinnitus suppression following cochlear implantation. In: Proceedings of the Fourth International Tinnitus Seminar. JM Aran, R Dauman, New York, NY. pp 423-426, 1992.
9. McKerrow WS, Schreiner CE, Snyder RL, Merzenich MM, Toner JG: Tinnitus suppression by cochlear implants. *Annals of Otology, Rhinology, & Laryngology* 100(7):552-558, 1991.
10. Dauman R, Tyler R, Aran JM: Intracochlear Electrical Tinnitus Reduction. *Acta Otolaryngologica* 113:291-295, 1993.
11. Thedinger B, House WF, Edgerton BJ: Cochlear implant for tinnitus. Case reports. *Annals of Otology, Rhinology, & Laryngology* 94:10-13, 1985.
12. Hazell JWP, McKinney CJ, Aleksy W: Mechanisms of tinnitus in profound deafness. *Annals of Otology, Rhinology & Laryngology* 166 (Supplement):418-20, 1995.
13. Kim HN, Shim YJ, Lee HK, Kim YM, Kim ES: Effects of Electrical Stimulation on Tinnitus in the Profoundly Deaf. In: Proceedings of the Fifth International Tinnitus Seminar. GE Reich, JA Vernon, Portland, OR. pp 508-517, 1996.
14. Newman CW, Jacobson GP, Spitzer JB: Development of the Tinnitus Handicap Inventory. *Archives of Otolaryngology-Head and Neck Surgery* 122 (2):143-148, 1996.
15. Coles RRA: Placebo Effects and Placebo Treatment. In: Proceedings of the Fifth International Tinnitus Seminar. GE Reich, JA Vernon, Portland, OR. pp 6-8, 1996.