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The Effects of Unilateral Cochlear Implantation on the Tinnitus Handicap Inventory and the Influence on Quality of Life

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Objectives/Hypothesis: Cochlear implantation is now the standard of care in patients with significant sensorineural hearing loss. It is well known that patients with severe hearing loss also experience disabling tinnitus. The purpose of this study was to assess the effects of cochlear implants on the perception of tinnitus using the Tinnitus Handicap Inventory (THI).

Study Design: Prospective, longitudinal study of 142 cochlear implant patients.

Methods: The THI was administered to 142 patients pre- and postimplantation. Outcome measures were obtained 12 months after the implantation. Secondary analyses to examine the correlation between changes in THI scores and outcome measures such as Hearing Handicap Inventory, Hearing in Noise Test (HINT), and short-form 36 (SF-36) quality-of-life scores were performed.

Results: Patients demonstrated statistically significant reduction of the THI scores including its subscales ($P < .001$). Prior to implantation, 37% of patients described their tinnitus as moderate to severe. Postoperatively, this percentage decreased to 10%. Cochlear implantation resulted in complete tinnitus suppression in 37% and tinnitus reduction in another 29% of patients. THI scores significantly correlated with three domains of the SF-36 quality-of-life questionnaire, namely social, emotional, and general health domains.

Conclusions: Cochlear implants have a significant suppressive effect on tinnitus in 66% of implant users. Although the reduction in the subjectively perceived tinnitus was statistically significant, it did not correlate with HINT; however, it did correlate with three quality-of-life domains, more significantly for those whose pretreatment conditions were moderate or worse.

Key Words: Tinnitus, cochlear implant, tinnitus suppression.

Level of Evidence: 2c.

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INTRODUCTION

Cochlear implantation (CI) is standard of care for those with severe to profound hearing loss who no longer derive benefit from a hearing aid. The benefits of implantation are well documented in the context of hearing improvement and validated quality of life.[1] A secondary benefit from CI is its effect on tinnitus.[2,3]

The literature suggests that a significant proportion of CI candidates report having tinnitus ranging from barely noticeable to severe. In a large survey involving over 800 CI users, more than half of the participants reported "annoying tinnitus."[4]

It is generally recognized that implants, when activated, have a suppressive effect. Total suppression of tinnitus after implantation varies from 15% to up to 83%[5,6]; nevertheless, some describe a slight risk of worsening tinnitus as a result of CI surgery.[7]

Although tinnitus suppression through CI has been reported, few have documented the subjective benefits of this reduction. The negative influence on quality of life in patients with tinnitus is also well established.[8] However, little has been written about the effect of tinnitus suppression by CI on quality of life. We hypothesize that the change of perceived tinnitus following implantation will result in a significant reduction in tinnitus-related perceived handicap using the Tinnitus Handicap Inventory (THI). We also hypothesized that quality of life would improve significantly following CI among patients experiencing moderate to severe tinnitus before their surgery. The goal of this report is to present our institutional experience with patient-perceived changes in tinnitus following implantation as measured by THI[9]; results are correlated with changes in Hearing Handicap Inventory (HHI), Hearing in Noise Test (HINT), and short-form 36 (SF-36).

MATERIALS AND METHODS

A prospective CI database is maintained that includes all patients treated at our institution. Five hundred and eighty-two CI procedures were performed for deafened adult patients

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TABLE I.
The Causes of Deafness in the 142 Patients.

Etiology	No. of Patients
Progressive idiopathic	62
Hereditary	26
Early idiopathic	20
Meniere's	7
Otosclerosis	7
Idiopathic sudden sensorineural	4
Meningitis	3
Auditory neuropathy	2
Autoimmune	2
Usher	2
Trauma	2
Diphtheria	1
Fabry's disease	1
Measles	1
Ototoxicity	1
Rubella	1

during the study period (2000–2009). No information was available for 102 patients because of questionnaires not being returned. Of the 347 patients with reported preoperative tinnitus (78%), 142 completed the pre- and postoperative questionnaires that included the THI, HHI, and SF36. Postoperative questionnaires were administered 12 months after surgery to all patients who volunteered with preimplantation tinnitus. For the purpose of the study, only preoperative and 1-year postoperative HINT scores were used. The hypothesis that a CI could change the THI score was statistically evaluated through the use of the paired group *t* test, which compares the difference between the pre- and posttest scores to zero, correcting for the dependency between the two tested measures. Additional analyses were performed to determine whether changes in HHI, SF-36, and HINT scores were correlated with changes in the THI. Pre- and posttest changes in scores were analyzed by subtracting pretest scores from posttest scores. The correlations of pre- to posttreatment changes on the THI subscales and total scores with the pre- to posttreatment changes in perceived hearing handicap and quality of life were also analyzed.

The study received institutional ethics approval before its commencement.

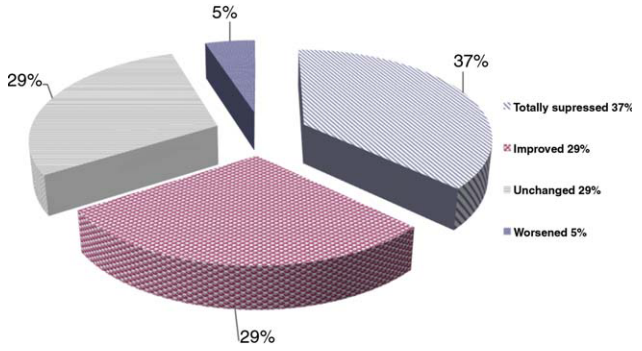

Fig. 1. Effect of cochlear implant on Tinnitus Handicap Inventory score for the whole group of 142 patients. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

RESULTS

All subjects were postlingually deafened adults. There were 57 males and 85 females, and mean age at surgery was 54.2 years (standard deviation = 14.68). The causes of deafness are shown in Table I. Three different implant devices were used on these patients, Advanced Bionics (Sylmar, CA) (n = 108, 76%), Med-El Corporation (Innsbruck, Austria) (n = 18, 13%), and Nucleus (Cochlear Ltd., Sydney, Australia) (n = 16, 11%).

CI resulted in complete tinnitus suppression in 37% (n = 53) of the study population. Twenty-nine percent (n = 41) of patients showed a reduction in the level of handicap scores with CI compared to the baseline preoperative evaluation. In 29% (n = 41) of patients, the tinnitus handicap score was unchanged. However, in 5% (n = 7) the tinnitus handicap score worsened (Fig. 1).

Because 53 patients (37%) reported complete resolution of tinnitus 1 year postimplantation, they did not fill the THI questionnaire and were excluded from THI score analysis. For those patients who experienced tinnitus postoperatively, statistical analysis demonstrated a significant improvement between pre- and postoperative THI scores ($P < .001$). The posttreatment mean was significantly lower than the pretreatment mean for all three subscales and the total score of the THI (Table II). As a group, the mean preoperative THI total score was 36.18 (standard error of mean difference = 2.3); 12 months after CI, the score was 20.18 (standard error of mean difference = 2.3).

TABLE II.
Results of Paired *t* Test of Pre- and Post-Treatment Scores on Tinnitus Handicap Inventory Subscales and Total Score.

			Differences		
		Mean	Mean	Standard Error of Mean Difference	Significance (2-Tailed)
THI Functional Subscale	Pretreatment	17.17	6.854	1.154	<.001
	Post-treatment	10.31			
THI Emotional Subscale	Pretreatment	10.90	5.708	0.815	<.001
	Post-treatment	5.19			
THI Catastrophic Subscale	Pretreatment	8.11	3.438	0.542	<.001
	Post-treatment	4.67			
THI total score	Pretreatment	36.18	16.000	2.308	<.001
	Post-treatment	20.18			

THI = Tinnitus Handicap Inventory.

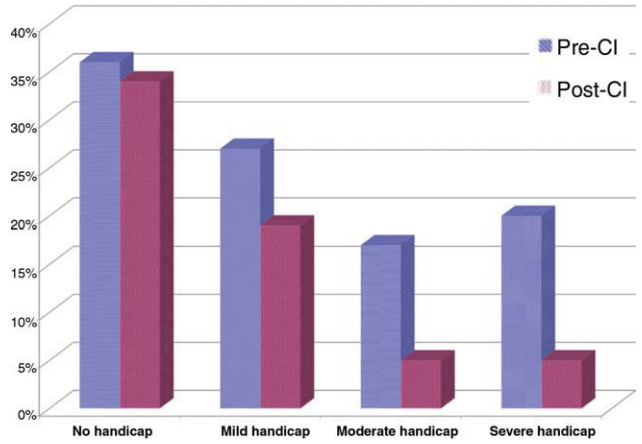

Fig. 2. Comparison between preimplantation and postimplantation Tinnitus Handicap Inventory. CI = cochlear implant. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Using guidelines recommended by Newman et al.[9] for the THI, 36% (n = 51) had a score indicating "no handicap," 27% (n = 39) had "mild handicap," 17% (n = 24) had "moderate handicap," and 20% (n = 28) had "severe handicap" before their implantation. This is compared to 34% (n = 48) who had a score indicating no handicap, 19% (n = 27) mild handicap, 5% (n = 7) moderate handicap, and 5% (n = 7) severe handicap 12 months after implant activation. Figure 2 shows the comparison between preimplantation and postimplantation THI for the 89 patients who still perceived tinnitus 12 months after implant activation.

Pre- to posttreatment changes on the THI total score and its subscales were statistically significantly correlated to a pre- to posttreatment changes on the HHI total score and its two subscales (social and emotional) (Table III). Change on the THI total score and on its catastrophic subscale showed a statistically significant correlation with the SF-36 general health ($r = .218$, $P < .05$) and social functioning ($r = .261$, $P < .05$) domains. There were also statistically significant correlations between changes on the THI functional subscale and the social functioning domain ($r = .268$, $P < .05$) of SF-36. Similar correlations were also found between differences on the THI emotional subscale and social functioning ($r = .287$, $P < .01$) and role emotional domains ($r = .234$, $P < .05$) of SF-36.

The modest size of the correlations observed in all patients, prompted conjecture that the correlations might be higher for those subjects who reported their conditions as being more severe before the treatment. Correlations were also analyzed for those subjects whose pretreatment conditions were rated as moderate or worse. This resulted in the score changes on total THI and on all three of its subscales being significantly correlated with change on the physical functioning and general health domains of SF-36 (Table IV).

Change in the HINT score did not significantly correlate with changes on the THI total score or its functional, emotional, and catastrophic subscales, both for the entire group and for those whose pretreatment conditions were moderate or worse.

TABLE III.
Correlations Between the Tinnitus Handicap Inventory Subscales and Total Score and the Hearing Handicap Inventory Subscales and Total Score.

	THI Change Scores			
	Functional	Emotional	Catastrophic	Total Score
HHI-social	.283	.251	.259	.293
HHI-emotional		.257		.233
HHI-total	.245	.267	.237	.274

Correlation is significant at the .05 level (2-tailed).
THI = Tinnitus Handicap Inventory; HHI = Hearing Handicap Inventory.

TABLE IV.
Significant Correlations Between the Tinnitus Handicap Inventory Subscales and Total Score and Physical Functioning and General Health Domains of Short-Form 36 for Patients Whose Pretreatment Tinnitus Was Moderate or Severe.

	THI Change Scores			
Outcome Variable Change Score	Functional	Emotional	Catastrophic	Total Score
SF-36—PF	.565*	.434*	.414*	.543*
SF-36—GH	.479*		.381†	.433*

*Correlation is significant at the .05 level (2-tailed).
†Correlation is significant at the .01 level (2-tailed).
THI = Tinnitus Handicap Inventory; SF-36 = short-form 36 quality of life; PF = physical functioning; GH = general health.

DISCUSSION

Tinnitus is a pervasive symptom that affects many people on a daily basis. The great majority of those who complain of chronic tinnitus have hearing loss, yet there is no direct correlation of symptom severity with the degree of hearing loss. Among CI candidates, studies have reported a high degree of preoperative tinnitus with prevalence rates ranging between 67% and 100% and a mean of 80%.[3] Our study of CI highlights an incidence of 78%. Although the positive effect of implantation in providing tinnitus suppression is clearly documented,[7,10–11] its impact on quality of life and long-term follow-up is not readily available.

In a self-report patient survey of 78 patients, 53 reported tinnitus before implantation. Following implantation, four patients had complete suppression of their tinnitus, and an additional 15 reported improvement in the severity of their tinnitus. Approximately 20 patients reported no change in their symptoms after implantation, and five patients reported a worsening.[7] Ito studied 60 patients who underwent CI, and more than half experienced some suppression of their tinnitus on initial activation; an additional 28% had some tinnitus suppression at 2 months of use.[11] Ruckenstein et al. published a report showing an improvement in tinnitus perception in 93% of the 38 participants, all of whom experienced tinnitus before implantation.[12]

It is unclear how many developed increased tinnitus immediately following implantation but before activation, versus increased tinnitus persisting over time. Miyamoto et al. reported worsening of tinnitus in 9% of

their populations, respectively, following implantation.[7] In addition, few papers reported the appearance of tinnitus when the CIs were activated in patients who had no tinnitus before their implantation.[2]

Recently, tinnitus suppression via CI in patients with unilateral tinnitus accompanying profound hearing loss in the same ear has been reported. Van de Heyning et al. showed a significant reduction or cessation of tinnitus in 20 of 21 patients with single-sided deafness who were implanted for incapacitating tinnitus.[13] In all patients, tinnitus loudness was reduced both with the CI switched on and with it switched off. A recent study by Buechner et al. demonstrated improvements in tinnitus using electric stimulation via CI in four of five unilaterally deaf patients.[14]

Although both studies highlight a potential new method for the treatment of severe tinnitus in selected subjects, they did not show consistent results. In addition not all patients benefited from the CI to the same degree. Tinnitus suppression using electrical stimulation via CI for single-sided deafness needs to be further evaluated.

The mechanisms by which CI can suppress or exacerbate the intensity of tinnitus are not well understood. Electrical stimulation resulting in tinnitus suppression had its genesis 200 years ago. It was first employed by Grapengiesser in 1801. He observed a few hours residual inhibition using direct current (DC). Wreden in 1867 was the first to use alternating current (AC).

Since then, the effects of electrical stimulation on tinnitus patients have been studied by many researchers using several techniques.[15–18] Shulman et al. reported that 54% of participants experienced decreased tinnitus using a device that delivered AC current to the mastoid bone.[15] In 1986, Rothera et al., using a transtympanic route, reported tinnitus suppression by DC and AC stimulation.[16] Later on, Okusa et al. were able to suppress tinnitus via electrical promontory stimulation in 20 patients. All patients reported residual inhibition with a duration ranging from several hours to 1 week.[17] In a report that included 10 neurofibromatosis-2 patients deafened by bilateral acoustic neuroma surgery, auditory brainstem implant resulted in noticeable tinnitus reduction in six patients.[18]

It is believed that masking may be the predominant mechanism of tinnitus suppression because the attention involved in listening through the implanted device distracts attention from the tinnitus.[19] A more complex explanation may involve plasticity in the central auditory system and associated cortical areas involved with prolonged CI stimulation.[6] Some propose central mechanisms in which electrical stimulation results in contralateral residual inhibition and tinnitus suppression[20], or it may simply be due to an acoustic masking effect.[10] The acoustic masking theory, however, does not explain the suppression of tinnitus when the CI is switched off.

Tinnitus may severely affect an individual's quality of life. It has been found to be strongly correlated with negative emotional effects, distress, and depression.[21] Little has been reported in the CI literature with regard to how tinnitus and its change following surgery impact quality of life, as most studies focus on hearing-related measures.

The SF-36 is a self-administered questionnaire that measures health-related functions in eight domains: physical functioning, role limitations due to physical problems, bodily pain, vitality, general health perceptions, social functioning, role limitations due to emotional problems, and mental health.[22] Several studies have used the SF-36 to measure the impact of tinnitus on quality of life.[8] A study using the SF-36 on a group of 200 patients with tinnitus has found that for all eight domains of the SF-36, unadjusted mean scores were below the norms.[8]

A major finding in the present study was that we did not find a statistically significant correlation between the change in the THI and its subscales and change in most of the SF-36 domains. The SF-36 scales' role limitations due to social functioning, emotional functioning, and general health were the only correlated domains with the change in tinnitus handicap level. These correlations were more significant for those whose pretreatment conditions were moderate or worse.

There was, however a higher level of correlation between the total THI scores and its subscales and the total score of SF-36 in patients who had moderate or severe handicap on THI before surgery. This correlation makes sense given that our patients who experience more significantly symptomatic tinnitus have better postsurgery quality of life because of diminished tinnitus.

In this study, we did not find a significant correlation between the changes on the THI total score and on its subscales and the change in the HINT score, both for the sample as a whole and for those whose pretreatment tinnitus severity was moderate or worse. However, the change in the tinnitus-related handicap perceived by implantees postsurgery correlated significantly with the change in hearing-related handicap.

There are a number of limitations of the present study that should be considered.

The lack of a control group in the study limits the ability to draw causal inferences. The general observation that many patients first develop an increase in tinnitus awareness immediately following surgery was not captured systematically to allow a meaningful appraisal of this phenomenon and how device activation alters this perception. Documentation of the side of tinnitus was not clearly established in our database, and because of the nature of this study as a retrospective review, the distinction of CI effect on ipsilateral versus contralateral tinnitus cannot be made and considered a limitation of this work. Furthermore, the overall effect of implantation on tinnitus-related handicap would not be altered by determining the tinnitus laterality.

CONCLUSION

CIs have a significant suppressive effect on tinnitus in most CI users. Although the reduction in the subjectively perceived tinnitus was statistically significant, it

did not correlate with HINT and SF-36 scores in most implantees. A more significant improvement in quality of life was observed more frequently in patients with moderate or severe tinnitus-related handicap before CI. Although the risk of worsening tinnitus after implantation is low, mention of this possibility should be an essential part of informed consent.

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