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TINNITUS IN THE PROFOUNDLY HEARING-IMPAIRED AND THE EFFECTS OF COCHLEAR IMPLANTS

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Of the 82 adult patients implanted in the Department of Veterans Affairs Cooperative Studies Program 304, 22 patients (27%) reported a bothersome tinnitus preoperatively. The tinnitus handicap experienced preoperatively in this profoundly deaf population is greater than that reported by mildly to severely hearing-impaired patients. The magnitude of their handicap was not correlated with age or preoperative hearing loss. After 2 years of cochlear implant use, a reduction in the tinnitus handicap was reported in 9, and an increase was noted in 3 of the 22 patients. In addition, 3 patients experienced a "severe" tinnitus 2 years after receiving a cochlear implant, whereas they had not reported a "bothersome" tinnitus preoperatively. One patient reported a tinnitus immediately after the surgery, but it subsided within a few days.

KEY WORDS — cochlear implant, profound deafness, tinnitus.

INTRODUCTION

Tinnitus is one of the most debilitating symptoms that accompanies sensorineural hearing loss. Unfortunately, there are few treatments that have been shown to help significantly large numbers of patients (for a recent review, see that by Tyler and Babin[1]).

One promising area for tinnitus treatment is electrical suppression. Several studies have shown that extracochlear electrical stimulation can be effective in reducing tinnitus.[2-7]

Other investigators have reported tinnitus reduction using intracochlear stimulation in cochlear implant patients. For example, Berliner et al[8] reported that 53% of 65 patients using the House single-channel cochlear implant observed that their tinnitus was improved when they were using their cochlear implant, although 11% reported that their tinnitus got worse. Similarly, Hazell et al[9] found that 54% of the 28 patients who had received the single-channel intracochlear implant developed in London reported some relief from their tinnitus while listening through their speech processor. Gibson[2] produced some, good, or complete relief in 39% (16 of 41) Nucleus patients, Bredberg et al[5] were able to decrease the annoyance in 55% patients (12 of 22; with single and multichannel implants), and Zwolan et al[4] reported that 28% (12 of 43) Nucleus patients noted a decreased tinnitus annoyance.

Tyler and Kelsay[10] noted that 34 of 42 (81%) of some of the better cochlear implant users reported that their tinnitus was reduced while they were using their implant. One patient reported that the tinnitus got worse. A variety of single-channel and multichannel, intracochlear and extracochlear cochlear implants were used.

In addition to these surveys, a few patients have been implanted specifically to reduce tinnitus. J. W. House[11] reported that W. F. House implanted 5 severely to profoundly hearing-impaired patients for tinnitus relief. Only 1 reported a reduction in the tinnitus while listening to speech through the cochlear implant. Sininger et al[12] measured tinnitus reduction in 1 patient implanted with the 3M/House implant. The subject had normal low-frequency hearing and a moderate to severe high-frequency hearing loss. Sinusoids between 400 and 16,000 Hz were ineffective in reducing tinnitus, but a biphasic pulse train was effective in 6 of 15 conditions tested. Sininger et al suggested that the current may have been insufficient to reduce tinnitus in most conditions because of loudness intolerance induced by bone conduction or electrophonic hearing. Also noteworthy is the observation that the short (6 mm) intracochlear electrode resulted in little change in the residual hearing of this patient. This suggests that intracochlear electrodes may eventually be designed for tinnitus suppression in mildly to moderately hearing-impaired patients.

Hazell et al[9] tested 6 totally deaf patients who received an intracochlear implant. They were able to reduce the tinnitus in all 6 patients using a 100-Hz sinusoid.

In the present investigation we have evaluated the tinnitus in patients participating in a multicenter evaluation of cochlear implants sponsored by the Department of Veterans Affairs Cooperative Studies

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TABLE 1. BIOGRAPHICAL DATA OF 22 PATIENTS REPORTING BOTHERSOME TINNITUS PREOPERATIVELY

Implant Type	Patient No.	Suspected Cause of Hearing Loss	Age (y)	Age at Profound Hearing Loss (y)	Years of Profound Hearing Loss	Hearing Thresholds (dB HL) Left 250 Hz	Left 500 Hz	Right 250 Hz	Right 500 Hz	Implanted Ear
3M/Vienna	1	Other	64	40	24	>	>	>	>	L
	2	Meningitis	57	40	17	>	90	80	>	L
	3	Infection, trauma, or noise	39	38	1	>	>	>	>	R
Ineraid	4	Infection	61	44	17	>	>	>	>	L
	5	Trauma	65	63	2	100	>	>	>	R
	6	Mumps or measles	66	37	29	85	95	95	100	L
	7	Meningitis	41	38	3	>	>	85	90	L
	8	Noise or ototoxicity	49	24	25	100	95	90	95	L
	9	Meningitis, otosclerosis, or noise	51	38	13	>	>	85	110	R
	10	Hereditary	81	77	4	100	95	100	95	R
	11	Noise	56	49	7	100	115	105	120	L
	12	Trauma	34	28	6	>	105	>	>	L
	13	Noise	65	62	3	90	115	100	100	R
Nucleus 22-channel	14	Ototoxicity	53	32	21	>	105	105	95	L
	15	Otosclerosis	62	51	11	>	>	>	115	L
	16	Noise or hereditary	58	45	13	>	100	>	100	R
	17	Unknown	47	36	11	>	100	>	110	L
	18	Other	67	59	8	80	100	90	>	R
	19	Unknown	65	58	7	>	>	>	>	R
	20	Ototoxicity	50	23	27	85	85	>	100	L
	21	Trauma	66	61	5	>	>	>	>	L
Nucleus 1-channel	22	Meningitis	68	68	3	>	109	>	>	R

HL — hearing level, > — response beyond limits of audiometer (typically 110 dB HL at 250 Hz and 120 dB HL at 500 Hz).

Program 304. One focus of the present report is to quantify the handicap of tinnitus in this profoundly hearing-impaired population. The second focus is to provide further documentation on the reduction of tinnitus in cochlear implant patients, and to provide preliminary observations about the effectiveness of tinnitus reduction for the single-channel 3M/Vienna, the multichannel Nucleus, and the Ineraid cochlear implants.

METHOD

Patients were part of a larger investigation of the effectiveness of different cochlear implants that began in January 1987. Seven hospitals worked under a common protocol. The patients received the 3M/Vienna, Nucleus, or Ineraid device in a randomized order. One patient received a single-channel extracochlear Nucleus implant because of a fibrous round window that prevented the introduction of the electrode into the scala tympani.

Prior to implantation, all candidates were asked whether they had "bothersome" tinnitus. If they answered affirmatively, they were administered the Tinnitus Handicap Questionnaire of Kuk et al.[13] The scale contains 27 questions that can be separated into three factors or subscales (loosely labeled tinnitus, hearing ability, and the patient's view of tinnitus). The reliability of the Tinnitus Handicap Scale, as determined by Cronbach's α, is .93. The Tinnitus Handicap Questionnaire was also administered at the first stimulation, 3 and 12 months poststimulation, and at yearly intervals thereafter.

All patients in this study, whether they initially reported bothersome tinnitus or not, were asked to rate their tinnitus on a five-label scale (absent, mild, moderate, severe, intolerable) at their initial stimulation and at 3, 12, 24, and 36 months postimplantation.

All surgeons and audiologists were asked to list complications arising from the surgery, including the exacerbation or occurrence of tinnitus.

Three measures were obtained to quantify different aspects of the Patient Quality of Life Form (this suppl, pp 37-40), the Index Relative Questionnaire Form (this suppl, pp 41-43), and the Performance Inventory for Profound Hearing Loss Answer Form

TABLE 2. TINNITUS HANDICAP SCALE SCORES OF 22 PATIENTS REPORTING BOTHERSOME TINNITUS PREOPERATIVELY

Implant Type	Patient No.	Tinnitus Handicap Scale		
		Preop	12-mo	24-mo
3M/Vienna	1	0/0/50 8	70/17/100 62	80/71/88 79
	2	73/67/38 66	0/0/25 4	7/0/44 11*
	3	20/31/75 32	5/6/63 14	3/20/50 15
Ineraid	4	19/0/70 27	27/25/50 30	36/20/63 37
	5	0/0/5 1	0/0/33 5	0/0/13 2
	6	65/86/59 69		35/10/30 28*
	7	8/13/5 9	4/0/13 5	
	8	32/66/54 44	3/20/48 14	0/0/50 8
	9	10/42/38 22	7/10/25 10	7/0/38 10
	10	11/58/53 29	40/70/50 49	19/66/53 35
	11	38/21/50 36	0/0/67 8	
	12	38/25/50 37	22/2/67 23	15/8/38 17
	13	13/80/60 37		11/80/73 38
Nucleus 22-channel	14	3/3/50 11	11/92/31 33	5/13/25 10
	15	83/83/88 84	59/64/90 65	52/75/63 59
	16	68/97/73 76	57/94/56 66	51/88/53 60
	17	14/4/50 17		
	18	3/5/60 13	5/0/25 7	
	19	1/2/30 6	0/0/50 8	
	20	0/0/75 12	0/0/50 8	0/0/48 8
	21	37/0/50 30	23/0/50 23	
Nucleus 1-channel	22	73/67/33 67	48/54/69 53	

Data are three scores and mean.
*Thirty-six-month data (24-month data not obtained).

(this suppl, pp 44-48).[14] The Beck Depression Scale[15] and the Wechsler Adult Intelligence Scale (nonverbal)[16] were also used.

A factor analysis[17] was used to determine a single estimate of speech perception performance. This is referred to here as the speech perception composite index.

RESULTS

Tinnitus and Profound Hearing Loss. Prior to implantation 22 of 82 (27%) profoundly hearing-impaired patients reported bothersome tinnitus. Table 1 shows some biographical data on each patient. All reported bilateral tinnitus. All patients were men (in this Veterans Administration study) except for 2 female patients, numbered 6 and 7. The average age of the tinnitus patients was 57.5 years (SD = 11.0), the average age at onset of profound deafness was 45.8 years (SD = 14.5), and the average length of profound deafness was 11.7 years (SD = 8.9). To characterize the preoperative hearing thresholds, hearing thresholds at 250 and 500 Hz are shown for each patient in each ear. In all cases, hearing at higher frequencies was poorer than that shown for 500 Hz. At 500 Hz, 8 patients had some measurable hearing in both ears, an additional 3 had hearing on the right, and an additional 5 had hearing on the left.

To document the severity of tinnitus in this profoundly deaf population, the Tinnitus Handicap Scale scores for each patient are shown in Table 2. Preoperatively, some patients experienced only mild tinnitus handicap (eg, patients 1, 5, 19, and 20), whereas others reported a severe handicap (eg, 2, 6, 15, 16, and 22). Preoperatively, the overall score averaged 42.3% (SD = 24.7; range, 8 to 84), the factor 1 (emotional consequences of tinnitus) score averaged 42% (SD = 27.9; range, 0 to 83), the factor 2 (tinnitus and hearing ability) score averaged 34% (SD = 34.7; range, 0 to 96.7), and the factor 3 (patient's view of tinnitus) score averaged 50.6% (SD = 20.6; range, 5 to 87.5).

We also explored whether the degree of the tinnitus handicap in this population could be predicted by other variables. Table 3 shows that no biographical, audiological, or communication efficacy questionnaires correlated significantly with tinnitus handicap.

It is also of interest to compare profoundly hearing-impaired patients who have tinnitus and those who do not. Table 4 contrasts a variety of measures in these two groups. No significant differences were found between these groups before implantation on measures of quality of life, intelligence, depression, or hearing handicap. Of interest, the group with tinnitus obtained somewhat higher speech perception scores than the group without tinnitus.

Tinnitus and Cochlear Implants. One patient who did not have tinnitus prior to implantation reported an "extreme" tinnitus within 72 hours of surgery. He was 41 years old, was 27 years old when he acquired

TABLE 3. PEARSON CORRELATION COEFFICIENTS AMONG PREOPERATIVE BIOGRAPHICAL DATA AND TINNITUS HANDICAP SCALE AND ITS THREE FACTORS

Tinnitus Handicap Scale	*Age*	*Age at Profound Deafness*	*Years of Profound Deafness*	*500-Hz Hearing Threshold in Implanted Ear*	*Speech Perception Index*	*Communication Handicap Scale Score*
Factor 1	.09	.02	.08	.22	−.12	−.50
(stress)	(.68)	(.92)	(.74)	(.32)	(.60)	(.02)
Factor 2	.20	.11	.07	−.14	.12	−.24
(hearing)	(.37)	(.64)	(.74)	(.54)	(.60)	(.29)
Factor 3	.008	−.20	.33	−.08	.24	−.30
(perception)	(.97)	(.38)	(.13)	(.71)	(.28)	(.18)
Total	.14	.03	.12	.11	−.02	.07
	(.55)	(.90)	(.59)	(.64)	(.93)	(.75)

In each case, N = 22. Shows p values in parentheses.

a profound deafness from ototoxicity, and had experienced a profound hearing loss for 14 years. A few days postoperatively it was reported that the tinnitus was "not persistent," and on the patient's 12- and 24-month visits the tinnitus was absent.

Of those 22 patients with tinnitus preoperatively, 3 patients received the 3M/Vienna device, 10 received the Ineraid device, 8 received the intracochlear Nucleus device, and 1 received an extracochlear Nucleus device.

The effectiveness of cochlear implants at reducing tinnitus in individual patients is shown in Table 2 and the Figure. Table 2 shows their preoperative, 12-month, and 24-month postoperative overall scores for the Tinnitus Handicap Scale. A scattergram is shown in the Figure, in which we contrast the preoperative Tinnitus Handicap Scale score to the postoperative Handicap score at 12 months and 24 months. Points falling below the diagonal line indicate that the tinnitus handicap has decreased following use of the cochlear implant.

TABLE 4. PREIMPLANT COMPARISON OF PATIENTS WITH PROFOUND HEARING LOSS WITH TINNITUS (N = 22) AND THOSE WITHOUT TINNITUS (N = 60)

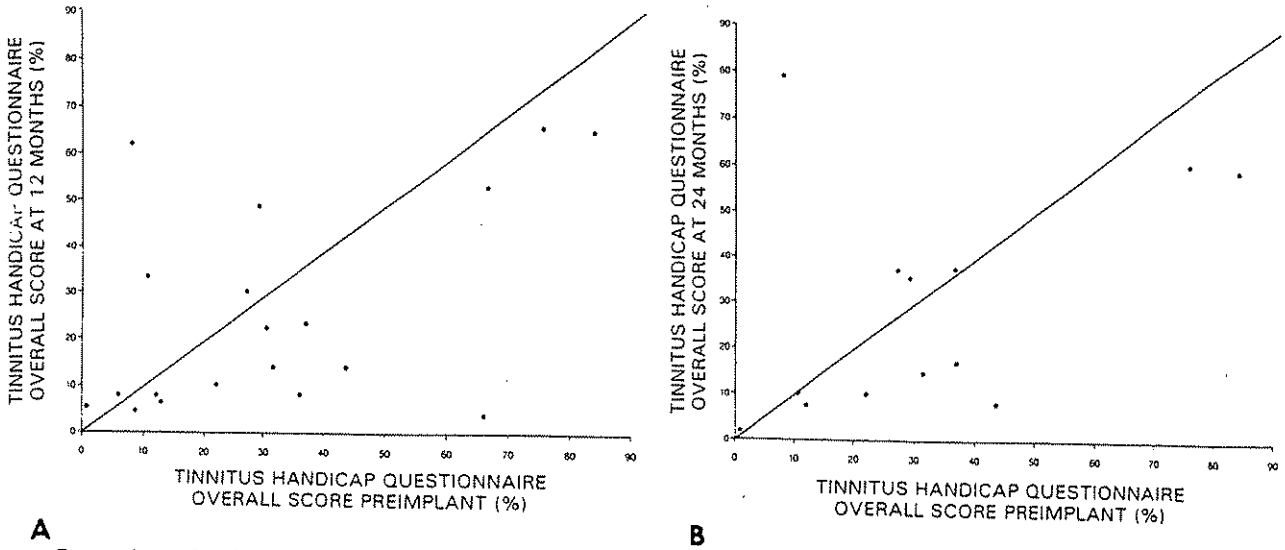
Patient Group	*Profound Hearing Loss and No Tinnitus*	*Profound Hearing Loss and Tinnitus*
Age (y)	59.9 ± 10.4	57.5 ± 11.0
Length of profound deafness (y)	15.7 ± 13.4	11.7 ± 8.9
Age at onset of deafness (y)	29.0 ± 11.4	35.9* ± 14.8
Quality of Life Questionnaire	60.6 ± 11.3	60.1 ± 10.2
Index Relative Questionnaire	66.9 ± 10.8	65.2 ± 11.3
Performance Inventory for Profound Hearing Loss	53.6 ± 13.8	51.2 ± 12.7
Speech Perception Index	8.65 ± 3.0	11.69 ± 4.86
Wechsler Adult Intelligence Scale (nonverbal)	101.8 ± 14.8	104.3 ± 14.9
Beck Depression Scale	6.7 ± 5.7	7.5 ± 6.9

*p = .03.

One patient showed a dramatic increase in the tinnitus handicap, and 2 others showed a small increase. One patient (patient 1) showed an increase from 8% to 62% and 79%, preoperatively to 12 and 24 months postoperatively. Another (4) showed an increase from 27% to 37% from preoperatively to 24 months postoperatively. The third patient (10) went from 29% to 49% from preoperatively to 12 months postoperatively, but his score decreased to only 35% by 24 months. Thus, 2 of 22 patients (9%) showed an increase in their tinnitus after 24 months of cochlear implant use.

Nine patients (41%) show a clear (greater than 10%) decrease in their tinnitus handicap: from 66% to 11% (patient 2), from 32% to 15% (3), from 69% to 28% (6), from 44% to 8% (8), from 22% to 10% (9), from 36% to 8% (11), from 37% to 17% (12), from 84% to 59% (15), and from 76% to 60% (16).

Three patients who did not report their tinnitus as bothersome preoperatively later reported a severe tinnitus postoperatively. Two of these subjects had moderate tinnitus preoperatively, and reported a severe tinnitus at 24 months postimplantation. One patient reported mild tinnitus preoperatively, severe tinnitus at 12 months, moderate tinnitus at 24 months, and severe tinnitus at 36 months. Unfortunately, preoperatively these patients were not asked to rate their tinnitus on this none-mild-moderate-severe-intolerable scale; they were only asked if they experi-



Comparison of preimplant versus A) 12-month and B) 24-month postoperative scores on Tinnitus Handicap Questionnaire.

enced "troublesome" tinnitus or not. If we consider their preoperative, nontroublesome tinnitus to be equivalent to mild or moderate, then the cochlear implant precipitated a marked increase in tinnitus in all 3 patients.

DISCUSSION

In the present investigation, 27% (22 of 82) of the profoundly hearing-impaired patients reported bothersome tinnitus before receiving a cochlear implant. This number is considerably lower than that reported by other studies of cochlear implant patients. Tinnitus was observed in 85% (44 of 52) by Gibson,[2] 86% (18 of 21) by Bredberg et al,[5] and 85% (28 of 33) by Zwolan et al[4] in their cochlear implant patients. This apparent discrepancy is likely a result of our stipulation of bothersome tinnitus. Our 27% estimate of bothersome tinnitus compares with an incidence of about 8% of the general population reporting a moderately or severely annoying tinnitus.[18] Axelsson and Ringdahl[19] found that about 14% of the general population reported that they suffered from tinnitus "often or always," and that this number increased to about 25% when only men between 50 and 59 years of age were considered. Brown[20] estimated about 21% of the general population of men between 55 and 64 years old to have tinnitus "every few days" or that "bothers them quite a bit" (see also Meikle and Griest[21]). Thus, it appears that the profoundly hearing-impaired population in the present study have an incidence of tinnitus much larger than that of the general population, but not substantially larger than that of other men of similar ages with less severe hearing losses.

We also quantified the handicap caused by the tinnitus in this population. Kuk et al[13] normed the Tinnitus Handicap Scale on 275 patients with mild to severe hearing loss who were attendees at otolaryngology and audiology clinics. Their patients averaged 32.4% on the overall score, 31.2% on the factor 1 score, 28.4% on the factor 2 score, and 46.1% on factor 3. The patients in the present study, with profound hearing losses, had similar overall scores (32%), slightly lower factor 1 scores (27%), and higher factor 2 and 3 scores (34% and 50%). Thus, our preliminary conclusion based on this small sample size is that patients with profound hearing loss generally experience a similar overall handicap from their tinnitus as do patients with lesser degrees of hearing loss.

The tinnitus was reduced in about 41% of our patients. This is in about the middle of the range of the 8% to 80% success rate reported by the studies reviewed in Introduction. In addition, tinnitus was exacerbated in about 1% of our patients — an observation also occasionally made by others. It is also true that cochlear implantation has the potential to produce tinnitus in a patient who did not experience tinnitus preoperatively. Therefore, one of the advantages of cochlear implantation experienced by most patients is a reduction of tinnitus. It is also important to alert cochlear implant candidates that there is a 1 in 100 chance that their tinnitus may be increased, in our experience.

Additional work is needed to explore the effectiveness of intracochlear electrical stimulation for the reduction of tinnitus. Differences between analogue and pulsatile stimulation and deep or shallow electrode insertion might be critical. Dauman et al[22] have reported some preliminary results suggesting that cochlear implant patients might benefit from a continuous pulse train presenting in the background while they are listening to speech.

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