

Effect of Preoperative Residual Hearing on Speech Perception After Cochlear Implantation

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Objective: To assess the effect of substantial preoperative residual hearing on speech perception outcomes in adult cochlear implant recipients.

Setting: Tertiary care academic referral center.

Methods: Twenty-nine patients with substantial preoperative residual hearing underwent cochlear implantation. Twenty-one implant recipients matched for age and duration of hearing loss, but without preoperative residual hearing, served as controls. Postoperative speech perception was assessed using City University of New York sentence, consonant-nucleus-consonant, and hearing in noise test in quiet and in noise (+10 dB signal to noise ratio) tests at 1, 3, 6, and 12 months after fitting.

Results: After implantation, there were no significant differences between groups for any of the tests administered. The mean change in speech perception abilities from baseline was significantly greater for the control patients than those with substantial preoperative residual hearing at a number of the test intervals across the various conditions. Moreover, at both 1 and 3 months, some patients in the residual hearing group had speech perception scores that were worse than their preoperative values. Ultimately, all of the patients with substantial residual hearing surpassed their preoperative performance.

Discussion: Patients with substantial preoperative residual hearing can gain significant benefit from cochlear implantation. Although the degree of improvement in these individuals is somewhat more modest than for those patients without preoperative residual hearing, the outcomes are still excellent. That there were no significant differences between the patient groups suggests that having substantial residual hearing before implanta-

tion does not provide a measurable performance advantage for electrical stimulation. Patients with substantial residual hearing who are contemplating cochlear implantation should be counseled regarding a possible initial decline in speech perception performance.

Key Words: Cochlear implant, residual hearing, speech discrimination.

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INTRODUCTION

Cochlear implantation is a highly effective form of auditory rehabilitation for adults with severe to profound hearing loss (HL) who gain limited benefit from conventional amplification. Previous studies suggest that the duration of HL and the residual hearing ability at the time of implantation are the best predictors of performance in these individuals, irrespective of the ear to be implanted or the age at the time of implantation.¹ Implicit in these findings is the fact that limiting central auditory deprivation is critical to successful use of a cochlear implant.

Although central auditory deprivation is clearly detrimental, are greater degrees of residual hearing predictive of incremental improvements in performance with a cochlear implant? With further clinical experience and recent improvements in implant technology, patients with substantial residual hearing are now willing to undergo implantation. The benefits of electrical stimulation alone in patients with substantial preoperative residual hearing have only recently been explored. In these small case series, excellent speech perception scores were evident after implantation, although an initial decline in performance in the early postsurgical period is commonly noted.^{2,3} Unfortunately, in none of these studies was a control group used to assess the effects of having substantial preoperative residual hearing.

Efforts to improve performance in patients with greater degrees of residual hearing have also been attempted by combining electrical stimulation with either ipsilateral or contralateral amplification.^{4,5} Indeed, clinical studies have shown that preservation of acoustic hearing is

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possible in cochlear implantation and that the combination of electric and acoustic stimuli within an ear may lead to improved speech perception scores, especially in noise.^{6,7} In these studies, within subject comparisons were made to demonstrate the beneficial effects of combined stimulation. However, the cochlear implant devices were modified in an attempt to preserve residual hearing, so these data do not provide a clear representation of the maximum benefits of electrical stimulation alone. In fact, some of these patients have ultimately elected to undergo conventional cochlear implantation after surgically induced HL, presumably because of poor performance with the hybrid device.⁸

The present study sought to assess the benefits of conventional, full-length cochlear implantation in patients with substantial preoperative residual hearing. These patients' performance scores were compared with a control group without significant residual hearing in an attempt to identify a performance advantage for subjects with significant preoperative residual hearing abilities.

MATERIALS AND METHODS

This study protocol was reviewed and approved by the local institutional review board.

Definitions and Terminology

Routine speech audiometric testing performed at our institution before and after cochlear implantation comprises following tests: City University of New York (CUNY) sentence recognition in quiet, consonant-nucleus-consonant (CNC) word recognition, and hearing in noise (HINT) sentence testing in quiet and in noise [10 dB signal to noise ratio (SNR)]. Each test was administered at 60 dB sound pressure level.

As in previous reports,² substantial residual preoperative hearing was defined as a CUNY test score of 60% or greater, a HINT in quiet score of 50% or greater, or a CNC word score of 20% or greater. All test scores were obtained in the best-aided binaural condition. Patients had to outscore in one of the three tests only to qualify as having residual hearing. Additionally, all patients had significant self-perceived hearing handicap using their best-aided auditory condition. All subjects were thus considered candidates for cochlear implantation. Exclusion criteria for this study included revision surgery, being a non-native English speaker, simultaneous or sequential bilateral implantations, and pre- or perilingual onset of severe-to-profound HL.

For the control group, the duration of profound HL was estimated based on biographical data and previous hearing exams. Because subjects in the study group were not profoundly deaf, the onset and duration of substantial HL were estimated based on similar factors. Specifically, patients were asked how long they had been unable to use the telephone and when their communication skills began to be severely impaired.

Identification of Subjects

A search of our cochlear implant database and associated medical records was performed. This search identified 29 subjects from our adult cochlear implant program with substantial preoperative residual hearing, as defined above. All associated surgeries were performed between September 1996 and December 2005. The search also identified a control group of 21 subjects without substantial preoperative hearing. These subjects were implanted over approximately the same interval. Subjects of each group were required to have at least one preoperative speech perception test result on record. Also, each subject had to have at least one postoperative speech perception test result at 1 year after speech processor fitting. Data beyond 1 year are not considered in this report.

Data Analysis

Data were extracted from our cochlear implant database and transferred to a spreadsheet application (Microsoft excel, Microsoft, Redmond, WA). Speech discrimination data from both groups were then compared and plotted using the application's features. Data were further analyzed using SPSS (SPSS, Chicago, IL). Specifically, scores were shown to deviate from a normal distribution (χ^2 test), and a nonparametric test (Mann-Whitney *U* test) has been used to identify statistically significant differences between the two groups.

To assess speech discrimination scores over time, postoperative results over time were compared with preoperative values of the respective test.

RESULTS

Patient Characteristics

A summary of the biographic data for both groups is shown in Table I. Audiological test results are depicted in Table II and the figures. Both groups were similar with regard to age, device model, and the ear selected for

TABLE I.
Summary of the Biographic Data of Both Groups.

	Age at Surgery	Gender	Age at Substantial HL	Estimated Duration of Substantial HL	Implant Types	Side
Study group						
Min.	23.31	10 × male	20.00	0.52	12 × Combi 40+	14 × right
Max.	82.28	19 × female	78.00	41.28	6 × Pulsar CI100	15 × left
Mean	61.34		54.41	6.93	3 × Nucleus CI24	
SD	15.33		16.29	8.43	5 × Nucleus Freedom 3 × Clarion 1.2	
Control group						
Min.	29.01	7 × male	25.00	0.56	15 × Combi 40+	11 × right
Max.	82.04	14 × female	75.00	48.72	2 × Clarion 1.2	10 × left
Mean	63.69		49.76	13.93	4 × Nucleus CI24	
SD	12.93		17.96	12.73	4 × Nucleus CI24	

TABLE II.
Statistically Significant Relationships Between Groups.

Test/Interval	Avg. Absolute Test Scores		P
	Study Group	Control Group	
CUNY			
Preoperative	72.1	8.1	.000
1 Mo	77.2	76.6	.848
3 Mo	87.4	92.1	.083
6 Mo	91.1	92.9	.568
1 Yr	94.8	95.9	.518
CNC			
Preoperative	17.9	0.1	.000
1 Mo	31.4	30.8	.990
3 Mo	42.9	41.6	.866
6 Mo	51.4	48.9	.517
1 Yr	59.0	54.8	.272
HINT in quiet			
Preoperative	41.7	2.3	.000
1 Mo	59.2	55.7	.669
3 Mo	76.4	74.7	.811
6 Mo	82.3	80.5	.499
1 Yr	86.6	88.7	.922
HINT + 10 dB SNR			
Preoperative	22.0	0.0	.000
1 Mo	46.3	40.5	.613
3 Mo	57.2	55.6	.722
6 Mo	65.7	63.7	.827
1 Yr	73.5	67.6	.328

CUNY = City University of New York sentence test; CNC = consonant-nucleus-consonant test; HINT = hearing in noise test; SNR = signal to noise ratio.

implantation. Although the groups differed significantly for the estimated duration of substantial HL (6.93 vs. 13.93 years for the study and the control groups, respectively; $P = .05$), this difference was relatively short and all were postlinguistic. Of the 29 subjects with substantial residual hearing preoperatively, 4 (13.8%) qualified based on their preoperative CNC scores alone, 1 (3.4%) based on the HINT score alone, and 8 (27.6%) based on CUNY scores alone. Two (6.9%) subjects qualified based on both the CUNY and CNC performance, 2 (6.9%) based on CNC and HINT scores, 7 (24.1%) based on CUNY and HINT scores, and 5 (17.2%) based on all three tests scores. Of the 21 patients in the control group, none had significant open-set speech perception abilities preoperatively.

Group Comparisons

Table II shows the mean values for all speech perception test materials at the various testing intervals. The figures show the individual patient scores for CNC (Fig. 1), HINT + 10 dB SNR (Fig. 2), and the absolute change values when compared with the preoperative score (Figs. 3 and 4). Results for CUNY and HINT sentences administered in quiet are not shown because the results were compressed due to ceiling effects in the postoperative data.

As expected, comparison between the two groups of patients with and without substantial preoperative residual hearing abilities showed significant differences ($P < .05$) in mean speech perception scores for all tests administered before implantation. One year after implantation and activation, both groups of patients experienced significant improvements in speech perception abilities with mean HINT scores of 87% and 89%, mean HINT + 10 dB SNR scores of 74% and 68%, and mean CNC word scores of 55% and 59% in the study and control groups, respectively. There were no significance between group differences on any of the speech perception tests scores at any of the test intervals (Table II).

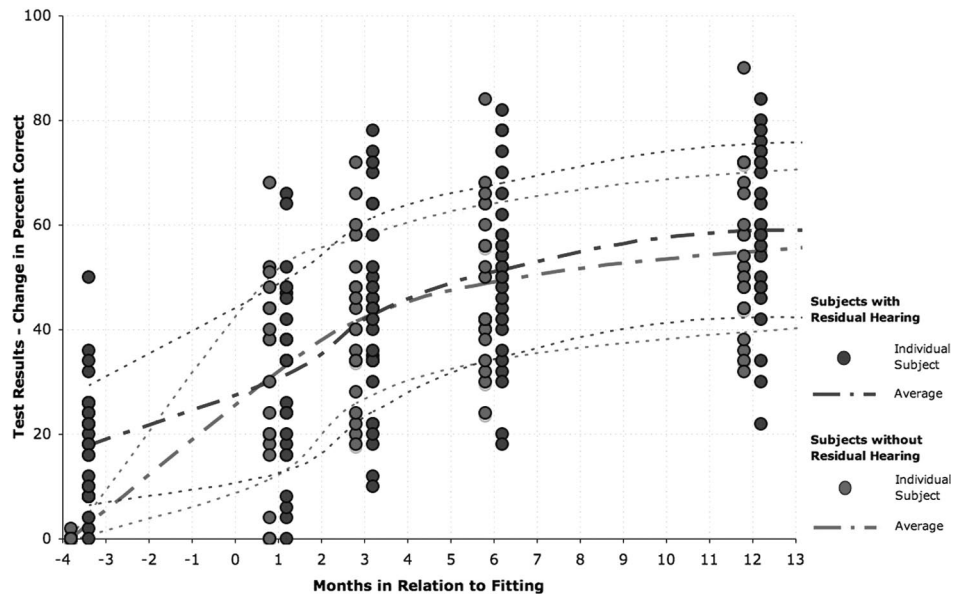
When compared with their preoperative values, patients without substantial preoperative residual hearing abilities experienced significantly greater increases in test scores than those patients with significant preoperative hearing (Table II). Importantly, some patients with residual hearing before implantation experienced decreases in performance when compared with their preoperative levels at the 1, 3, and even 6 months test intervals. All of the patients ultimately surpassed their preoperative values by the 1 year testing interval (see Figs. 3 and 4).

DISCUSSION

In this report, we measured and compared speech perception abilities for two groups of adult cochlear implant recipients with relatively short durations of substantial HL: 1) classic candidates with little or no residual hearing and 2) those patients with substantial residual hearing before implantation. After implantation, mean and absolute speech perception scores for both groups were excellent and compared favorably with other previously reported series.^{9,10} Of interest was the finding that the speech perception scores for these two different groups of patients were not significantly different at any of the postoperative test intervals. Thus, the presence of substantial preoperative residual hearing provided no demonstrable prognostic advantage for speech perception outcomes in cochlear implantees when duration of substantial HL was relatively short. Presumably, both groups of patients had adequately surviving neural populations and intact central auditory pathways that effectively supported electrical stimulation by way of the cochlear implant.

The findings of the present study are in contrast to results previously reported by Gomaa et al.¹¹ and Rubinstein et al.¹² In these studies, shorter durations of deafness and greater degrees of preoperative residual hearing (as measured by Central Institute for the Deaf [CID] sentence scores) predicted improved performance after cochlear implantation (as measured by CNC words). Although the effect of duration of deafness was strong in their work ($P < .001$), the effect of residual hearing on postoperative performance was weak, albeit significant ($P = .029$). Thus, we believe the apparent contradictory findings in the present study are likely explained by the fact that our patients had shorter durations of deafness than those reported previously.^{11,12} Unfortunately, the results in the present study are not testable using these formulas because preoperative CID sentences were not collected in most patients.

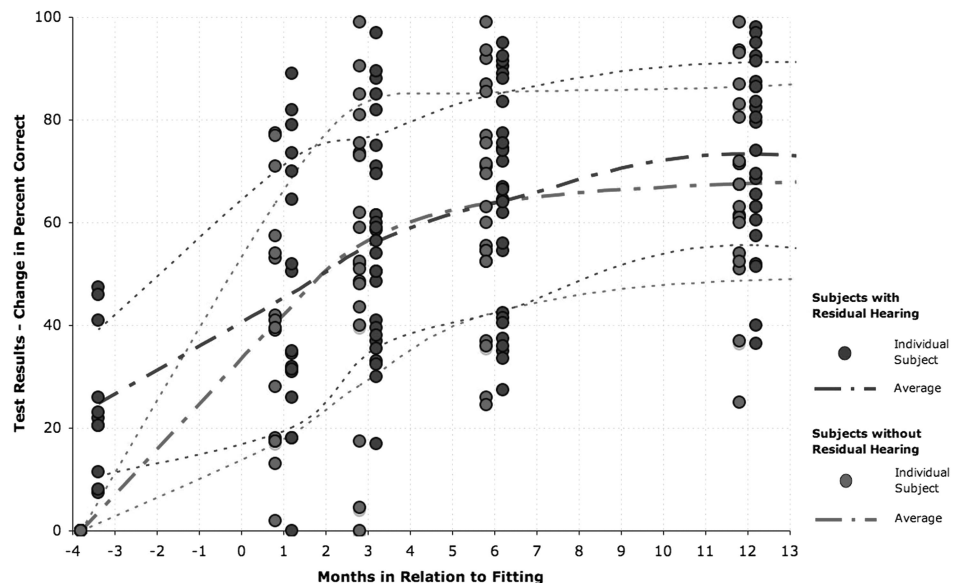
Fig. 1. Individual consonant-nucleus-consonant (CNC) scores for study group (subjects with residual hearing, dark gray dots) and control group (subjects without residual hearing, light gray dots). Data are shown for different intervals: before surgery (illustrated as being acquired between 3 and 4 months before surgery), 1 month, 3 months, 6 months, and 1 year after fitting. The bold dotted lines show the means of each group. Differences between means of both groups did not reach statistically significant levels at any test interval ($P > .05$). The thinner dotted lines delineate standard deviations for both groups.



Although implantation of patients with substantial residual hearing was ultimately effective, some of these patients experienced decreases in performance at their 1, 3, and even 6 month intervals when compared with their preoperative values. The fact that speech perception abilities declined in these patients is an important finding. Patients with substantial residual hearing abilities, as defined in this study, who are contemplating cochlear implantation should be counseled appropriately regarding this issue. Specifically, a more prolonged rehabilitation period might be anticipated before realizing improvements in speech perception abilities. In patients with slowly progressive HL, delaying implantation until further HL occurs should also be considered. Ultimately, these decisions must be individualized for the patient in the context of their current quality of life issues.

Is conventional cochlear implantation without hearing preservation as good as ipsilateral electric-acoustic stimulation (EAS)^{4,5,13} in patients with substantial residual hearing? This question remains to be answered. The subjects in the present study with substantial residual hearing would likely have been EAS/hybrid candidates in some of the previously reported trials.⁴⁻⁷ Although the benefits of hearing in noise using the combined electrical and acoustic signals seem evident in the EAS trials, the performance comparisons between the cochlear implant alone situation and that using combined stimulation are hampered by the fact that most EAS patients are implanted with a compressed array, which has a reduced number of electrodes.^{8,14} It is notable that subjects in the present study demonstrated significantly improved hearing in noise after standard cochlear implantation without

Fig. 2. Individual, mean scores, and standard deviations for the hearing in noise test (HINT) battery at +10 dB SNR presentation level. Each dot represents a single subject's score at each test interval. Intervals are: before surgery (illustrated as being acquired between 3 and 4 months before surgery), 1 month, 3 months, 6 months, and 1 year after fitting. Differences between mean values (bold dotted lines) of both groups do not reach statistically significant levels at any interval ($P > .05$). The thinner dotted lines delineate standard deviations for both groups.



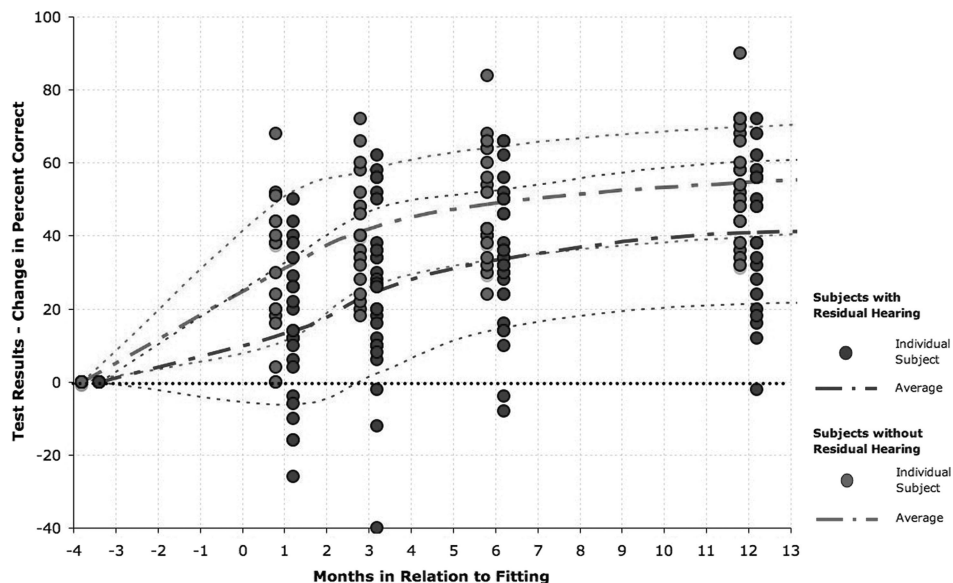


Fig. 3. Changes over time after cochlear implant fitting in individual scores, average performance, and standard deviations for the consonant-nucleus-consonant (CNC) monosyllabic word test. Each dot represents changes of each subject's individual scores over time (before surgery, 1 month, 3 months, 6 months, and 1 year after fitting). The thinner dotted lines delineate standard deviations for both the study and the control groups. Some subjects of the study group show decreased scores compared with preoperative values early after speech processor fitting (below the no change line). During the course of cochlear implant usage, however, those subjects generally surpass their preoperative values. Of note, one subject's scores at the 12-month interval are almost equal to his preoperative CNC word scores. This subject had a preoperative CNC score of 50% and reached 48% at 1 year after implantation. He surpassed preoperative scores on all other tests and continues to be a satisfied cochlear implant user.

hearing preservation. Only future comparison studies, possibly using the presently reported results as a control group, will serve to answer these questions more thoroughly.

Although the effects of contralateral amplification were not formally studied in this patient population, beneficial effects of such an intervention have been demonstrated by others.^{15,16} Anecdotally, many of the patients in the present study rejected the use of the contralateral hearing aid shortly after beginning to use the cochlear

implant. The reasons for this remain unknown, but may be related to difficulties in fusing two dissimilar signals. Further work is needed in this area.

CONCLUSIONS

Patients with substantial preoperative residual hearing can gain significant benefit from cochlear implantation. Although the degree of improvement in these individuals is somewhat more modest than in those patients without preoperative residual hearing,

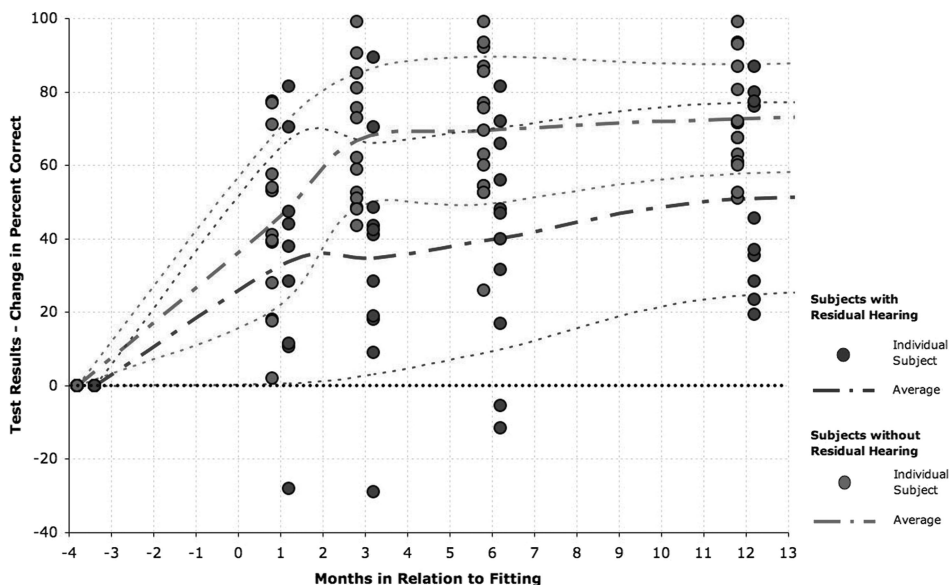


Fig. 4. Changes over time after cochlear implant fitting in individual scores, average performance, and standard deviations for the hearing in noise test (HINT) battery at +10 dB SNR presentation level. Each dot represents changes of each subject's individual scores over time (before surgery, 1 month, 3 months, 6 months, and 1 year after fitting). The thinner dotted lines delineate standard deviations for both the study and the control groups. Similar to test results observed with the CNC test, some subjects of the study group show decreased scores compared with preoperative values early after speech processor fitting (below the no change line).

the outcomes are still excellent. The finding that there were no significant differences between the patient groups suggests that having substantial residual hearing before implantation does not provide a measurable performance advantage for electrical stimulation. Patients with substantial residual hearing who are contemplating cochlear implantation should be counseled regarding a possible initial decline in speech perception performance.

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