ORIGINAL ARTICLE

Case-Control Analysis of Cochlear Implant Performance in Elderly Patients

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Objective: To characterize speech perception performance in elderly cochlear implant users compared with younger adult users.

Design: Case-control retrospective analysis from January 1, 1999, to January 28, 2008.

Setting: Tertiary care, academic practice cochlear implant program.

Patients: Medical records for 78 patients with age at implantation of 65 years or older were analyzed for ear-specific preimplantation speech perception performance, length of deafness, age at implantation, and 1-year postimplantation speech perception performance. A subset of 28 elderly patients with complete data was matched to 28 younger adult patients (age at implantation, 18-64 years) for preimplantation performance using the Hearing in Noise Test–Quiet scores (mean, 22% and 23%, respectively).

Main Outcome Measure: One-year postimplantation performance on word and sentence testing.

Results: Within the elderly cohort, the Consonant-Nucleus-Consonant and Hearing in Noise Test–Quiet scores were not affected by age. The Hearing in Noise Test–Noise scores trended downward with increasing age but did not reach statistical significance ($P = .052$). Of the matched older and younger patients, 55 of 56 showed improvement in their 1-year postimplantation compared with preimplantation Hearing in Noise Test–Quiet scores, with better preimplantation performance predictive of better postimplantation performance, independent of age at implantation ($P = .02$). Group comparisons, however, revealed poorer postimplantation scores overall for the elderly patients compared with the younger ones for the Hearing in Noise Test–Quiet (70% vs 83%; $P = .02$) and the Consonant-Nucleus-Consonant test (38% vs 53%; $P = .02$).

Conclusions: Elderly patients benefit significantly from cochlear implantation. Compared with a younger cohort matched for preimplantation performance, however, their postimplantation scores are significantly lower on some measures. These results may provide guidelines for candidacy and counseling regarding elderly patients with cochlear implants.

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Cochlear implantation has become an accepted treatment for adults with advanced presbycusis or the continued progression of early-onset sensorineural hearing loss. Older adults (ie, those ≥65 years) make up greater than 12% of the current US population, and this number is expected to double in the next 20 years.[1] As such, the number of older cochlear implant candidates is expected to increase, as well as their mean age at presentation. Issues associated with cochlear implantation in elderly patients include surgical safety, quality-of-life and cost-utility concerns, and postimplantation performance.

Surgical safety has been demonstrated, although elderly patients may require additional postimplantation observation time, additional care around the facial and chorda tympani nerves, and monitoring for urinary retention.[2-6] Improvement in quality of life in the elderly population with cochlear implants has also been consistently demonstrated.[7-10] In fact, patients aged 65 or older with severe hearing loss receive as much quality-of-life benefit from cochlear implantation as patients with mild hearing loss receive from hearing aids.[11] Objective audiologic performance measures have also demonstrated consistent improvement over preimplantation performance within the elderly population.[3-5,12] These data have supported implantation of cochlear devices in older adults as a viable rehabilitative option for significant hearing loss that is inadequately addressed with acoustic amplification.

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Despite such success, there is some indication that the performance of elderly patients may not be as strong as that of younger adults. Generally, comparisons of performance between younger adults and elderly patients have demonstrated comparable performance.[4,5,7,8,13-16] However, some recent reports[2,17] with relatively large study populations have shown lower postimplantation performance scores by elderly patients on some tests. To investigate such discrepancies, this study examined performance in a large group of cochlear implant recipients 65 years or older. Furthermore, we compared a cohort of elderly patients to a younger cohort matched for preimplantation Hearing in Noise Test–Quiet (HINT-Q) scores and duration of deafness. These results may provide guidelines for counseling the older patient regarding postimplantation expectations and prompt further investigation into factors that influence cochlear implant performance in elderly patients.

METHODS

PATIENTS

This institutional review board–approved study used a retrospective medical record review approach. We accessed records from 251 elderly cochlear implant patients currently followed up by the Koss Cochlear Implant Program at the Medical College of Wisconsin from January 1, 1999, through January 28, 2008. Patients with prelingual deafness were excluded from the analyses. Therefore, 78 patients with age at implantation (AAI) of 65 years or older (mean [SD] age, 73.3 [6.7] years; age range, 65-87 years) were included in the study. This elderly cohort was analyzed for 1-year postimplantation performance with respect to age at implantation, preimplantation hearing levels, and preimplantation speech perception.

A subsequent cohort was generated consisting of performance-matched elderly and younger adult implant recipients. Patients from the elderly cohort were matched to patients with an AAI of younger than 65 years (mean [SD] age, 46.7 [13.4] years; age range, 18-64 years) based first on preimplantation performance on the HINT-Q and second on duration of deafness. An analysis of variance on the younger cohort showed no significant effect of age on speech perception performance. Therefore, all younger adult patients were considered appropriate matches for the elderly cohort. There were 28 elderly patients with sufficient preimplantation and 1-year postimplantation data for the matching; therefore, this second cohort consisted of 56 patients (ie, 28 matched pairs).

ANALYSES

Clinical information was collected regarding preimplantation hearing history, preimplantation and postimplantation speech perception scores, and AAI. The speech perception test materials included single-syllable words (consonant-nucleus-consonant [CNC]) presented in quiet, sentences presented in quiet (HINT-Q), and sentences presented in speech-weighted background noise (Hearing in Noise Test–Noise [HINT-N]). Effects of age at implantation and preimplantation performance on 1-year postimplantation outcomes were analyzed for the elderly population and for the cohort of older and younger matched patients. Correlations between age and performance among individuals were assessed by linear regression. Group differences were assessed with the *t* test and the Mann-Whitney test.

RESULTS

PREIMPLANTATION DEMOGRAPHICS OF THE ELDERLY PATIENTS

There were 78 patients 65 years or older at the time of implantation, including 20 patients 80 years or older. The mean (SD) age at implantation was 74.3 (6.9) years (median, 74.5 years; age range, 65-88 years). Duration of deafness, as reported by the patient, was available for 56 patients and ranged from 1 year to 74 years (mean [SD], 15.75 [19.1] years; median, 6 years). Regression analysis comparing age at implantation with duration of deafness showed no significant correlation between these variables within this group (r=0.14, P=.32).

Preimplantation audiologic variables were analyzed as a function of AAI for this elderly group. Preimplantation hearing levels for each patient were characterized by the 4-frequency pure tone average and were compared with age at implantation. Preimplantation pure tone averages ranged from 60 to greater than 120 dB of hearing loss, with no significant relationship to AAI in this group (r=0.06, P=.61, n=67). Speech perception performance was also evaluated before implantation and compared with AAI. No significant correlations were found between preimplantation speech perception performance and AAI for HINT-Q (r=0.07, P=.72, n=30) or CNC testing (r=0.23, P=.12, n=48). Thus, within the elderly population, preimplantation audiologic measures were not influenced by age.

POSTIMPLANTATION PERFORMANCE IN THE ELDERLY PATIENTS

Postimplantation speech perception performance was evaluated 1 year after implantation and compared with AAI (**Figure 1**A-C). Age at implantation showed no correlation with postimplantation CNC scores (r=0.28, P=.13, n=30) or with HINT-Q scores (r=0.18, P=.35, n=29). For HINT-N, increased age at implantation trended toward a negative effect (r=0.40, P=.052, n=23).

To investigate whether better preimplantation performance predicted better postimplantation performance in the elderly population, the elderly group was divided into 3 groups based on preimplantation HINT-Q score (Figure 1D). Those with preimplantation HINT-Q scores below 20%, of 20% through 40%, and to 41% or greater were analyzed with respect to 1-year postimplantation HINT-Q scores. Regression analyses (graphs not shown) indicated that better preimplantation HINT-Q scores showed significant association with higher postimplantation CNC (r=0.49, P=.007), HINT-Q (r=0.44, P=.02), and HINT-N (r=0.43, P=.04) scores regardless of age.

PERFORMANCE-MATCHED IMPLANT PATIENTS

To examine potential differences in performance between elderly and younger adult implant patients, cohorts of 28 elderly and 28 younger adult patients were matched using preimplantation HINT-Q scores and secondarily by duration of deafness. After matching, the

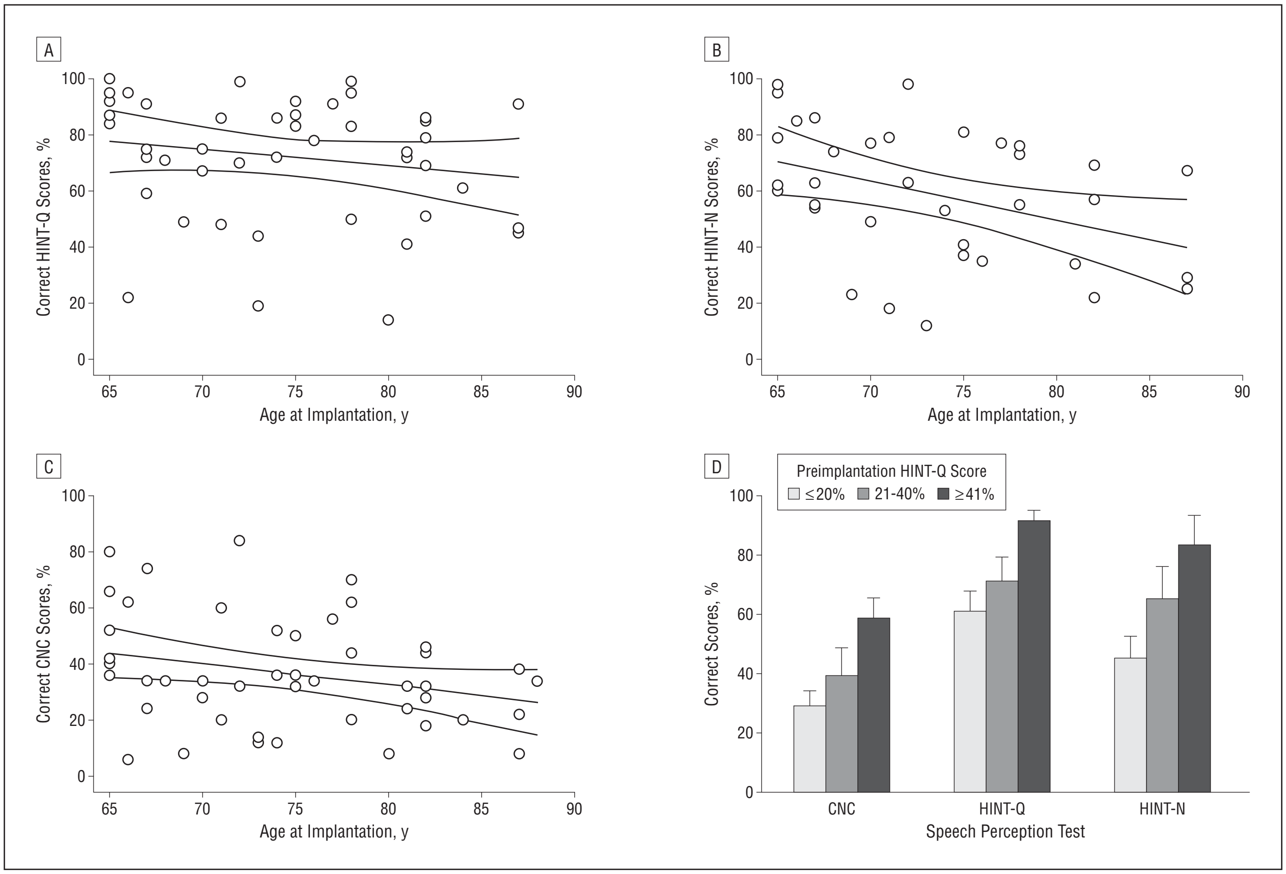

Figure 1. Postimplantation audiometric performance of the elderly patients. A, No significant correlation was found between age at implantation and Hearing in Noise Test–Quiet (HINT-Q) scores at 1-year postimplantation (r=0.18, P=.31). B, A negative trend was seen between age at implantation and Hearing in Noise Test–Noise (HINT-N) scores at 1-year postimplantation (r=0.40, P=.052). C, No significant correlation was seen between age at implantation and Consonant-Nucleus-Consonant (CNC) scores at 1-year postimplantation (r=0.28, P=.09). D, A significant improvement was seen in postimplantation performance among those with better preimplantation sentence scores. Error bars indicate SD.

HINT-Q score standard deviations were within 1% between groups (**Table**). In addition, no statistically significant difference was found in average duration of deafness. Furthermore, preimplantation HINT-Q scores showed no significant correlation with age at implantation for either group. Thus, both cohorts were evenly matched on important potential predictors of postimplantation performance.

Postimplantation HINT-Q scores were compared with preimplantation performance for the individual patients comprising these cohorts (**Figure 2**A). Improvement was observed for all but 1 patient, and there was no pattern of differential improvement by age. The 1 patient whose scores did not meet preimplantation performance expectations was in the younger cohort. A statistically significant association was found between better preimplantation performance and higher postimplantation scores (r=0.31, P=.02). That said, several patients who scored 0% before implantation showed significant improvement in their scores (eg, >70%) after implantation. Comparing postimplantation performance by group showed significant improvements for both cohorts on HINT-Q performance (Figure 2B). Postimplantation performance for the elderly cohort, however, was statistically significantly poorer than for the younger group (70% vs 83%; P=.02).

The results of all speech perception tests performed at 1 year after implantation were compared between groups (**Figure 3**). The elderly cohort showed poorer performance than the younger cohort with regard to 1-year postimplantation scores for the CNC test (38% vs 53%; P=.02) and HINT-Q (70% vs 83%; P=.02). No statistically significant difference in HINT-N scores was found (P=.37), although a wider range of performance was noted within the elderly group.

To examine relative effects of advanced age on performance, the matched pairs were also analyzed for each speech perception task. Specifically, the difference in scores between the elderly and younger adult patients of the matched pair was plotted against the age of the elderly patient (**Figure 4**). Negative values indicate that the younger patient of the matched pair showed higher performance scores. For the CNC test and HINT-Q, the younger patient showed higher performance scores 64% of the time; for HINT-N, the younger patient showed higher performance scores than the elderly patient only 52% of the time. The age of the elderly patient for all tests showed no statistically significant correlation with the pair member whose scores were higher. That is, the age of the elderly patient in the matched pair did not influence the odds of the younger or elderly patient having the higher scores on the speech perception test.

Table. Demographics and Performance of Individual Elderly and Younger Adult Matched Patients

Pair No.	AAI, y	Preimplantation HINT-Q Score	1-Year Postimplantation HINT-Q Score	1-Year Postimplantation HINT-N Score	1-Year Postimplantation CNC Score
1	65	0	92	62	52
	23	0	97	70	68
2	67	0	72	63	34
	25	0	100	88	78
3	69	0	49	23	8
	29	0	11	. . .	. . .
4	70	0	75	49	28
	38	0	88	60	32
5	71	0	86	79	60
	40	0	100	9	72
6	76	0	78	35	34
	44	0	27	27	14
7	80	0	14	. . .	8
	48	0	100	95	84
8	82	0	51	. . .	18
	48	0	98	91	76
9	87	0	45	29	22
	49	0	98	88	74
10	87	0	47	25	8
	53	0	78	58	50
11	73	4	19	12	14
	55	0	95	93	38
12	66	14	95	85	62
	18	14	79	68	48
13	66	15	22	. . .	6
	36	15	74	65	34
14	75	17	83	37	32
	32	17	64	24	38
15	74	20	86	. . .	52
	48	20	91	87	56
16	67	24	59	55	24
	62	24	97	51	. . .
17	72	30	99	98	84
	35	26	43	8	36
18	68	31	71	74	34
	63	28	100	91	88
19	77	35	91	77	56
	62	38	70	54	34
20	71	37	48	18	20
	44	39	100	93	82
21	73	37	44	. . .	12
	60	40	97	67	54
22	82	38	86	69	46
	57	43	90	53	52
23	65	43	100	95	66
	64	45	94	67	40
24	65	43	100	98	80
	61	46	95	84	74
25	82	57	85	. . .	44
	42	58	50	43	12
26	78	60	83	55	44
	50	60	99	79	64
27	78	61	99	. . .	44
	59	64	95	60	40
28	67	62	91	86	74
	62	67	100	88	34
All patients ≥65 years old, mean (SD)	73.3 (6.7)	22.4 (22.0)	70.4 (25.9)	58.3 (27.6)	38.1 (23.0)
All patients <65 years old, mean (SD)	46.7 (13.4)	23.0 (23.0)	83.2 (23.9)	65.2 (25.6)	52.8 (21.6)

Abbreviations: AAI, age at implantation; CNC, Consonant-Nucleus-Consonant test; HINT-N, Hearing in Noise Test–Noise; HINT-Q, Hearing in Noise Test–Quiet. Ellipses indicate missing data.

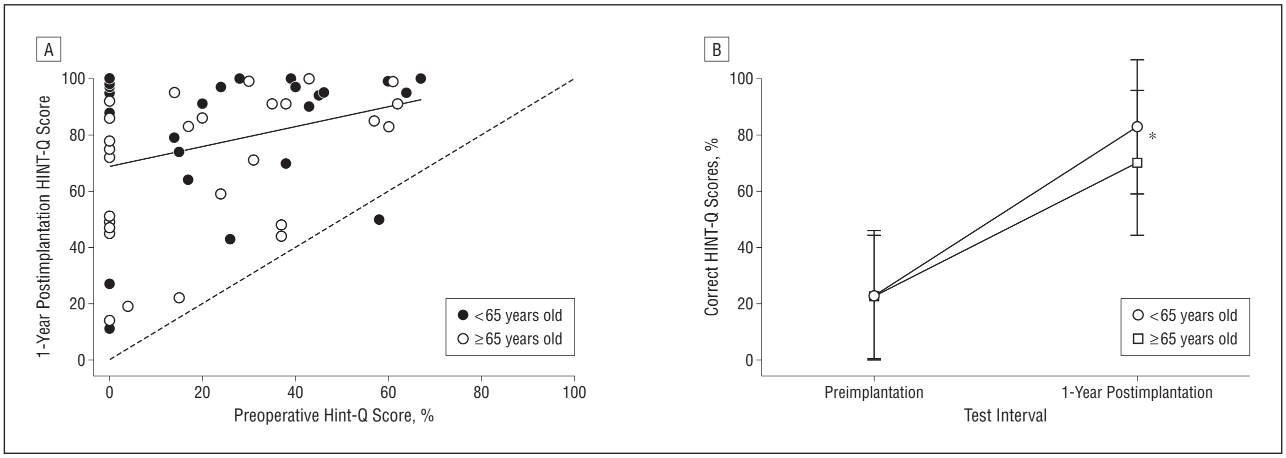

Figure 2. Postimplantation audiometric performance of 56 patients (28 younger adult and 28 elderly) matched for preimplantation Hearing in Noise Test–Quiet (HINT-Q) scores. A, Comparison of preimplantation to postimplantation HINT-Q performance (r=0.31, P=.02). There was improvement in 55 of 56 patients at 1-year postimplantation. B, Group comparison of postimplantation HINT-Q performance (P=.02, Mann-Whitney test). Although both groups improved, a statistically significant difference was found in audiometric scores between the elderly and younger adult matched cohorts. Error bars indicate SD; asterisk, a statistically significant difference between groups.

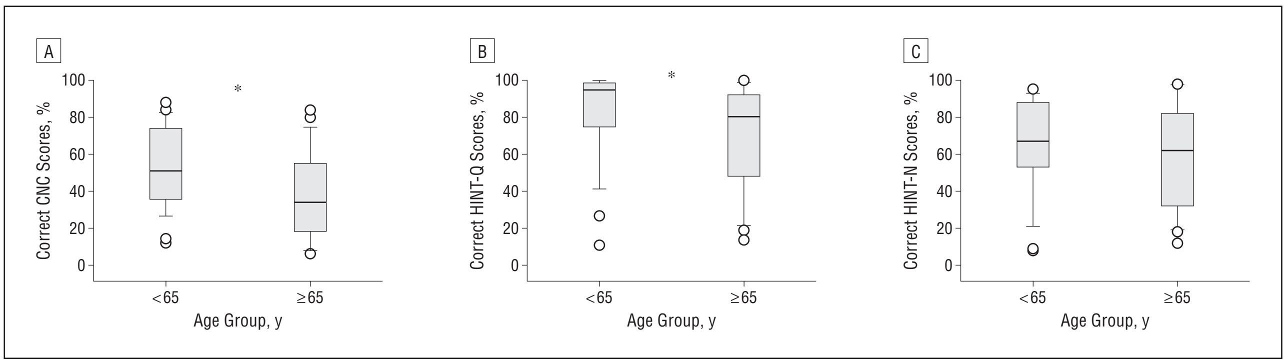

Figure 3. Audiometric performance of the elderly and younger adult performance-matched cohorts. A, Consonant-Nucleus-Consonant (CNC) scores correct at 1-year postimplantation (P=.02, t test). B, Hearing in Noise Test–Quiet (HINT-Q) scores correct at 1-year postimplantation (P=.02, Mann-Whitney test). C, Hearing in Noise Test–Noise (HINT-N) scores at 1-year postimplantation (P=7.05, t test). The CNC and HINT-Q scores were statistically significantly lower in the elderly population than in younger adults. The HINT-N scores showed a broader range of performance in the elderly group, but the mean score was no different than that of the younger adult group. Error bars indicate SD; asterisk, a statistically significant difference between groups.

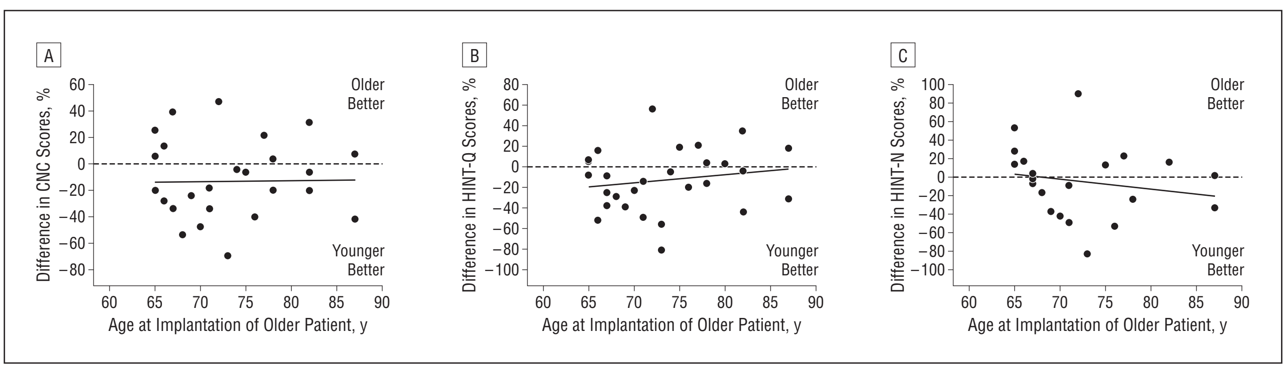

Figure 4. Performance of each matched pair: the difference in scores between the elderly and younger adult patients of the pair was plotted against the age of the elderly patient. A, Correct Consonant-Nucleus-Consonant (CNC) scores; B, correct Hearing in Noise Test–Quiet (HINT-Q) scores; and C, correct Hearing in Noise Test–Noise (HINT-N) scores. The solid line shows the linear regression curve fit for the elderly patients. Dots above the dashed line indicate that the elderly patient performed better at 1 year than the younger adult matched patient. Dots below the dashed line favor the younger adult patient. Younger adult patients typically performed better on all tests, but this finding did not reach statistical significance.

COMMENT

This study demonstrates that the scores of elderly recipients of cochlear implants improve significantly on all standard speech perception tests when comparing preimplantation with 1-year postimplantation scores. However, by controlling for preimplantation HINT-Q scores and duration of deafness, this study also shows that on some tests elderly patients should not be expected to have scores as high as those of younger adults with similar preimplantation characteristics. One explanation for these results is that the elderly patient may have a prolonged adaptation phase and reach levels attained by younger users at 1-year postimplantation at a later point. Alternatively, elderly patients may have inherent limitations in processing the high-rate stimulation paradigms used in current cochlear implants. Central cognitive or associative processes may also influence the performance in the population of elderly patients.

The slight negative impact of age found in this study emerges when comparing preimplantation matched groups of elderly and younger implant patients. This is similar to the findings by Leung and colleagues,[14] who examined more than 250 patients who underwent implantation after the age of 64. When they matched patients for preimplantation performance on Central Institute for the Deaf sentence tests and duration of deafness, the older group scored an average of 4.6% less than the younger group on CNC testing ($P < .05$). A similar analysis by Chatelin and colleagues[2] also identified a performance gap in elderly patients. Although not matched for preimplantation performance, a group of 65 elderly patients had significantly worse performance scores on the 1-year postimplantation CNC test and HINT-Q than 101 randomly selected younger individuals. The CNC scores had a difference of 9% and the HINT-Q scores had a difference of 17%. Our study showed a difference of 28% at 1 year after implantation for CNC scores and approximately 15% for HINT-Q scores.

Other studies have reported no statistically significant difference in postimplantation performance between elderly and younger adult patients on various word and sentence tests. There is wide variability across these studies as to whether the control group was matched to the elderly group (eg, by preimplantation performance or duration of deafness), the definition of *elderly* (eg, >55 years or >65 years), the range of ages in the elderly cohort, and the reporting interval (eg, <1 year, 1 year, or >1 year). Despite these differences and the reported lack of statistical significance, a review of studies[4,8,13,15,16,18] reporting at least 1-year data indicates that the mean performance of the elderly cohort was less than that of the younger adults on 18 of 19 word, sentence, and speech performance tests. The only instance in which an elderly cohort demonstrated a higher mean score than a younger group was on Central Institute for the Deaf sentence tests, which showed a performance difference of 1.1%.[4] The elderly cohort in that study included individuals between 60 and 65 years of age, an age group that is often included in the younger cohort in other studies.

Individual patient data are not available for most reports, and a formal meta-analysis could not be performed. However, such results raise the issue of whether most studies are underpowered to identify a performance gap between elderly and younger adult cochlear implant users. Even if we can conclude that on average elderly implant users have less robust performance scores than younger adults, the clinical significance of such a gap may be inconsequential given that the performance scores of virtually all patients show significant improvement over those from the preimplantation period. However, if elderly patients have unique performance outcomes after cochlear implantation, this would be an important component in preimplantation counseling so that an informed decision for surgery can be made.

An important consideration in analyzing outcomes in elderly patients is the difference between chronologic and physiologic age. Chronic disease (eg, cardiovascular, metabolic, or neurologic) is more prevalent in elderly patients and can affect physical and cognitive abilities. Individuals of the same chronologic age, but with significantly different medical histories, may have physiologic differences that influence central auditory processing and thus performance after cochlear implantation. Such differences would be less pronounced in younger adults in whom such diseases are less prevalent. Indeed, we saw a greater variability in performance on sentence tests, both in quiet and in noise, in elderly patients, which may reflect central processing issues and the differential effect of age-related disease. Larger cohorts would be needed to distinguish performance differences among those with various systemic diseases.

To distinguish central from peripheral effects on performance, this study matched elderly and younger patients for cochlear function by preimplantation scores on HINT-Q. Thus, differences in postimplantation performance are unlikely to be related to inherent function of the cochlea. By default, such differences would reflect deficits in the auditory nerve or central auditory system. Regarding the former, there is little correlation between auditory nerve ganglion cell survival and cochlear implant performance.[19] In addition, electrophysiologic studies indicate that age-related changes in speech perception are primarily because of impaired temporal acuity of the cortical as opposed to the peripheral auditory system.[20,21] Thus, we postulate that the performance gaps and greater variability seen in the elderly population in our study are consistent with central processing deficits. Current testing in our laboratory is under way to compare peripheral and central measures of auditory perception in elderly cochlear implant users.

By using a cohort matched for preimplantation performance, this study demonstrated that elderly patients have performance scores that are strong but less so compared with their younger counterparts. These data may better provide guidelines for preimplantation counseling regarding postimplantation expectations for the elderly candidate. This study also found that better preimplantation performance predicts better postimplantation scores in the elderly and younger patient. These data question whether implant criteria in elderly patients should be expanded. This would allow those with significant progressive presbycusis (ie, destined to meet implant criteria) to undergo implantation earlier, thus maximizing their postimplantation performance. Additional studies are being conducted to assess whether gains in elderly patients after cochlear implantation are resistant to continued age effects.

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