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Cochlear implantation performance outcomes in patients over 80 years old

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Abstract

Objective: To examine device datalogging characteristics and postoperative performance in the very elderly CI users.

Methods: Retrospective chart review of postoperative speech recognition outcomes and datalogging characteristics in patients older than 80 years old who underwent cochlear implantation and remain active users with longer than 6 months post-activation follow-up.

Results(s): The mean age at implantation was 84.8 ± 3.8 years old. Pre- and post-operative AzBio sentences in quiet scores were 12.4 ± 16.4% and 53.0 ± 23.5%, respectively ($p < .001$). Pre- and post-operative consonant-nucleus-consonant (CNC) word scores were 9.4 ± 12.8% and 40.5 ± 20.7%, respectively ($p < .001$). A nonsignificant negative correlation was noted between the age of implantation and postoperative CNC words and AzBio sentence performance. Significantly decreased performance was noted in the subpopulation with a preoperative diagnosis of dementia. Mean daily use was 10.9 h per day. When available the mean daily usage distribution was 16% speech in noise, 19.1% speech, 51% quiet, 3.8% music, and 9.6% noise. A significant positive correlation was noted between daily use and AzBio sentence and CNC word performance.

Conclusions: Very elderly patients have significant postoperative auditory performance benefits after CI. Mean daily use is comparable to previously published results in the younger population. Age of implantation does not play a significant role in overall performance. Elderly patients who are medically cleared for implantation receive significant postoperative benefits.

KEYWORDS
cochlear implant, elderly, geriatrics, hearing restoration, sensorineural hearing loss

1 | INTRODUCTION

The current life expectancy in the United States is 78.99 years and continues to steadily increase. This translates to a rise from fifteen million 80 years old and older adults in the 1950s to a hundred and ten million in 2011 and is expected to reach four hundred million by 2050. Some degree of hearing loss is essentially universal in patients over 80 years old.[1] Presbycusis, or age-related hearing loss (ARHL), is

of special public health concern due to the well-established relationship between ARHL and cognitive decline in the elderly.[2] Severe to profound ARHL has a significant negative impact on communication ability and causes cognitive decline, social isolation, and a higher incidence of depression.[3] Restoration of hearing allows for more effective communication and decreased rates of depression in the elderly.[4]

Hearing aids remain the main rehabilitative strategy for hearing loss; however, their role may be limited in cases of severe-to-profound hearing loss where cochlear implants (CI) may be the better option. CIs provide a significant improvement in speech perception in patients with severe to profound hearing loss including patients 75 years old and above.[5,6] Since there is a known association between cognitive abilities, brain plasticity, and postoperative CI speech perception some are skeptical of implantation in the very elderly or in elderly with multiple comorbidities including dementia.[7,8] The statistics are varied but some reports suggest that the elderly do not perform as well as younger counterparts, and overall health concerns often discourage the 80 plus year-olds from pursuing a CI.[6,7,9,10]

Despite expanding literature on cochlear implantation in the elderly, additional data that would help audiologists and physicians counsel the elderly on the benefits of hearing restoration by a CI are needed. A better understanding of CI use via modern recipient's sound process interrogations using processes such as "datalogging" help us better understand daily use patterns and environmental surroundings. Prior studies have correlated datalogging statistics to patient performance; however, data for the very elderly is limited.[11–13] Overall, trends suggest that older patients use their devices less frequently than their younger counterparts and daily use correlates to performance.[13] The combined knowledge of postoperative complications, CI performance, and daily use statistics in the very elderly are needed to help us counsel patients on the appropriateness of cochlear implantation. We present a clinical series reporting on presentation, postoperative complications, and postoperative performance in patients older than 80 years old. We perform a subanalysis of patients with a diagnosis of dementia with the hypothesis that these patients will not perform as well due to decreased cognitive abilities and brain plasticity.

2 | METHODS

This study was approved by the Western Institutional Review Board. A retrospective chart review was completed by selecting all patients who have undergone cochlear implantation at the House Ear Clinic from the start of the EMR system on June 23, 2013 to May 1, 2021 when the data was extracted. The initial search included patients who were over the age of 80 years old at the time of implantation. This initial search resulted in 189 patients. Only postlingually deafened individuals with bilateral hearing loss were included. Additional selection criteria included available preoperative and postoperative audiologic outcomes data, preoperative videonystagmography (VNG) testing including caloric testing, clinical follow-up for more than 6 months post-implantation, available operative reports, and clinical information

regarding complications. Patients with device failure, those who use electro-acoustic stimulation strategy, non-English speakers, and individuals who chose not to use their devices were excluded. This resulted in 102 patients who fit the above criteria.

All charts were reviewed for pertinent clinical data including medical comorbidities, years of hearing loss, and pre- and post-operative balance concerns. The presence of dementia as reported on intake forms or during primary care physician medical clearance was recorded, but no specific cognitive testing was performed by our clinic. Preoperative CI evaluations were reviewed for audiometric data including preoperative speech recognition scores (AzBio Sentences in quiet and/or consonant-nucleus-consonant [CNC] words). The same postoperative data were collected at the patient's last clinical visit which was at least 6 months post-activation. All speech recognition testing was presented via recorded audio in a soundproof booth at a calibrated presentation level of 60 dB SPL with the subject seated 1 m from the speaker. Data were collected with CI use only and for the combination of CI and hearing aid use in patients that used a contralateral hearing aid.

Manufacturers for all cochlear implants were recorded. In this study, device use statistics were extracted from the programing software provided by CI manufacturers. Not all participants had datalogging available. In the cases where it was available, the daily use and percentage use in various environments were collected. Datalogging statistics and extraction techniques were based on methods used by previous authors.[14] Device use statistics were updated each time a recipient's processor was connected to the programming software.

All statistical analyses were performed with the R Core Team (2020) software. Welch Two sample t test and Spearman rank correlation were used as appropriate. Statistical significance was considered with $p < .05$.

3 | RESULTS

3.1 | Patient demographics and underlying conditions

After initial data review and application of the above listed inclusion and exclusion criteria, a total of 102 patients over the age of 80 years old with active use of CI were identified. Of these, 36 were female and 66 were male with a mean age of 84.8 ± 3.8 years old. Self-identified race and ethnicity information was not included in all charts and these results are listed in Table 1. The mean length of hearing loss was 24.9 ± 15.6 years and 74% of the cohort had consistently used binaural amplification in the year leading up to implantation. The mean BMI was 26.2 ± 5.0.

Most frequent comorbidity listed on patient-completed intake forms and/or preoperative health clearance forms filled by patients' primary care physician included 46 patients with hypertension, 34 with a cardiac history, 20 with diabetes mellitus type 2, 9 with dyslipidemia, 7 with pulmonary disease (most commonly COPD), and 18 with various other comorbidities including various cancer diagnosis, bladder/

urinary diagnosis, depression, stroke, and Parkinson's disease. Of the 102, 35 patients had no listed medical comorbidities.

Sixty-five patients were implanted on the right side and 37 on the left side. Our institution implants all three of the major CI companies and the device is chosen after a discussion between the patient, audiologist, and surgeon. In our cohort, 69 had Cochlear devices, 18 Advanced Bionics, and 14 Med-El devices.

At our institution, routine preoperative balance testing for patients 65 years old and older includes bi-thermal calorics, gaze testing without fixation, and assessing spontaneous nystagmus. In the results presented, a unilateral weakness score of >20% was considered abnormal. Preoperative testing was not available for all patients, but when available showed 61 with normal function, 22 with ipsilateral weakness, 7 with contralateral weakness, and 8 with bilateral hypofunction. Additionally, 13 patients noted preoperative balance problems and 30 patients reported postoperative imbalance at their first postoperative visit. This decreased to nine patients during the 6-months visit, longer-term data was not consistently documented. Postoperative complications were noted in six patients (5.9%). These included two wound infections, one patient with vertigo resulting in a fall, one new-onset atrial fibrillation, one patient with bradycardia who was admitted overnight with spontaneous resolution, and one episode of oral bleeding which did not require additional interventions. There were no instances of facial nerve paralysis/paresis or stroke.

3.2 | Audiometric outcomes

Audiologic evaluation results are summarized in Table 2. The mean postoperative follow-up time was 18.9 months (range 6–36 months). Audiometric data from the last clinical visit were used for the postoperative data points as long as they were at least 6 months post-initial activation. This was done based on prior results by Holden et al noting a relative performance plateau after six months of active use.[15] Not all data points were available for all patients. The implant side pre- and post-operative Az-Bio sentence score in quiet were 12.4 ± 16.4% and 53.0 ± 23.5%, respectively ($p < .001$). The AzBio sentence scores at +10 dB signal-to-noise ratio when available were 10.4 ± 16.4% and 59.50 ± 22.0%, respectively ($p < .001$). The pre- and post-operative CNC word scores in quiet were 9.4 ± 12.8% and 40.5 ± 20.7%, respectively ($p < .001$). When utilized, the mean postoperative AzBio sentence scores in the bimodal condition (combined HA and CI) were 51.68 ± 21.7%. Figure 1 shows the pre- and post-operative AzBio sentence scores and CNC word scores as subdivided by age groups. There were no statistically significant differences in performance between the 80–85, 86–90, and 90+ years old groups in either of these categories.

A Spearman's rank-order correlation was used to determine a relationship between age at implantation and performance using both AzBio sentences and CNC words in quiet scores. There was a negative correlation between age at implantation and AzBio sentence scores ($r_s = -0.015$, $p = .915$), which did not reach statistical significance. There was also a similar negative correlation using CNC word scores ($r_s = -0.032$, $p = .797$), which did not reach statistical significance.

3.3 | Impact of underlying dementia on performance

Thirteen patients were diagnosed with dementia or other underling cognitive decline condition by their primary care physician or as listed on the intake form. The outcomes of these patients ($n = 13$) were compared to the rest of the cohort without this diagnosis ($n = 89$). For this subgroup, the implant side pre- and post-operative Az-Bio

TABLE 1 Demographics of CI cohort

Characteristics	N (%)
Sex	
Male	66 (64.7%)
Female	36 (35.3%)
Race	
White	78 (76.5%)
Asian	6 (5.9%)
Hispanic	4 (3.9%)
Black	2 (2%)
Declined to answer	12 (11.8%)
Ethnicity	
Not Hispanic	90 (88.2%)
Hispanic	4 (3.9%)
Unknown	8 (7.8%)

TABLE 2 Pre- and post-operative audiometric testing

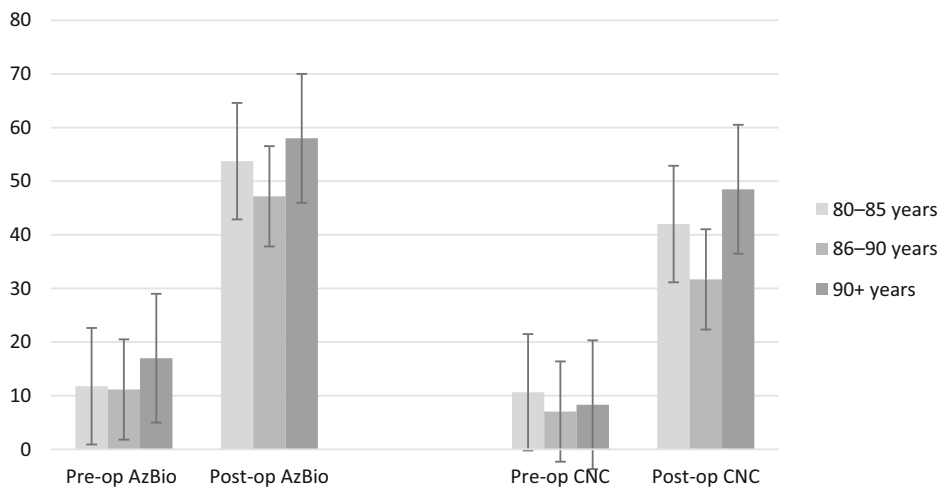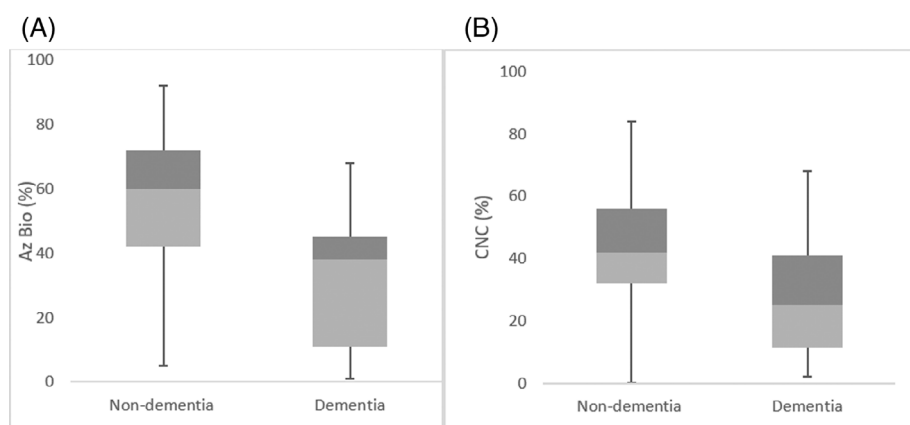|	Preoperative	Postoperative	*p*-value
Unaided PTA in dB	89.8 ± 13.9		
Unaided WRS (%)	13.3 ± 15.7		
Az-Bio sentence score in quiet (%)	12.4 ± 16.4	53.0 ± 23.5	<.001
AzBio sentence scores at +10 dB signal-to-noise ratio (%)	10.4 ± 16.4	59.50 ± 22.0	<.001
CNC word scores in quiet (%)	9.4 ± 12.8	40.5 ± 20.7	<.001

FIGURE 2 Box plots showing the mean (A) AzBio scores (%) for the subanalysis of patients with dementia diagnosis and unaffected individuals. Within each box plot, the horizontal black line represents the median value within each group. The lower and upper limits to the box correspond to the first and third quartiles (the 25th and 75th percentiles) (B) CNC scores (%).
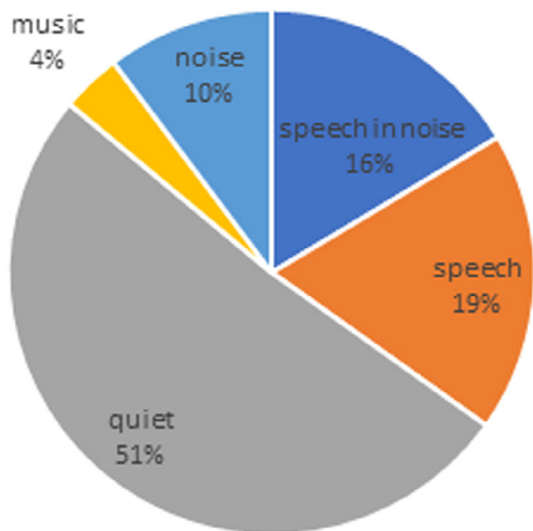

**FIGURE 3** The mean daily usage distribution using available datalogging information

sentence score in quiet were 18.1 ± 17.4% and 34.20 ± 21.1%, respectively ($p < .001$) (Figure 2). There was no statistically significant difference in age at implantation ($p = .11$). There were no differences in daily CI use ($p = .29$). The difference in postoperative performance

as measured by CNC words in quiet scores was close to but did not reach statistical significance, 28.45% vs 42.4% ($p = .06$). Postoperative performance as measured by AzBio sentence scores in quiet showed statistically significant difference ($p = .02$) with lower scores in the dementia-diagnosis cohort (34.2%) as compared to the rest of the cohort (55.6%). Data for testing in noise were limited in this group but no statistical significance was seen in AzBio sentence scores in noise ($p = .79$). Similarly, no statistical significance was noted in the bimodal condition ($p = .06$).

3.4 | Datalogging results

Datalogging was available for 79 patients with a daily mean use of 10.9 h per day (range 0.3–21.9). There was a negative correlation between hours of CI use and age at implantation ($r_s = -0.190$, $p = .090$), which did not reach statistical significance. When available the mean daily usage distribution was 16% speech in noise, 19.1% speech, 51% quiet, 3.8% music, and 9.6% noise (Figure 3). The daily use was compared to CI outcomes using AzBio sentence and CNC words in quiet scores (Figure 4). There was a positive correlation between daily use (h/day) to AzBio sentence scores ($r_s = 0.405$, $p = .001$) which by normal standards is considered significant. Similar

FIGURE 4 Correlation between mean daily CI use and auditory outcomes. (A) Positive correlation between daily use (h/day) and AzBio scores ($r_s = 0.405$, $p = .001$). (B) Positive correlation between daily use and CNC in quiet scores ($r_s = 0.341$, $p = .004$).
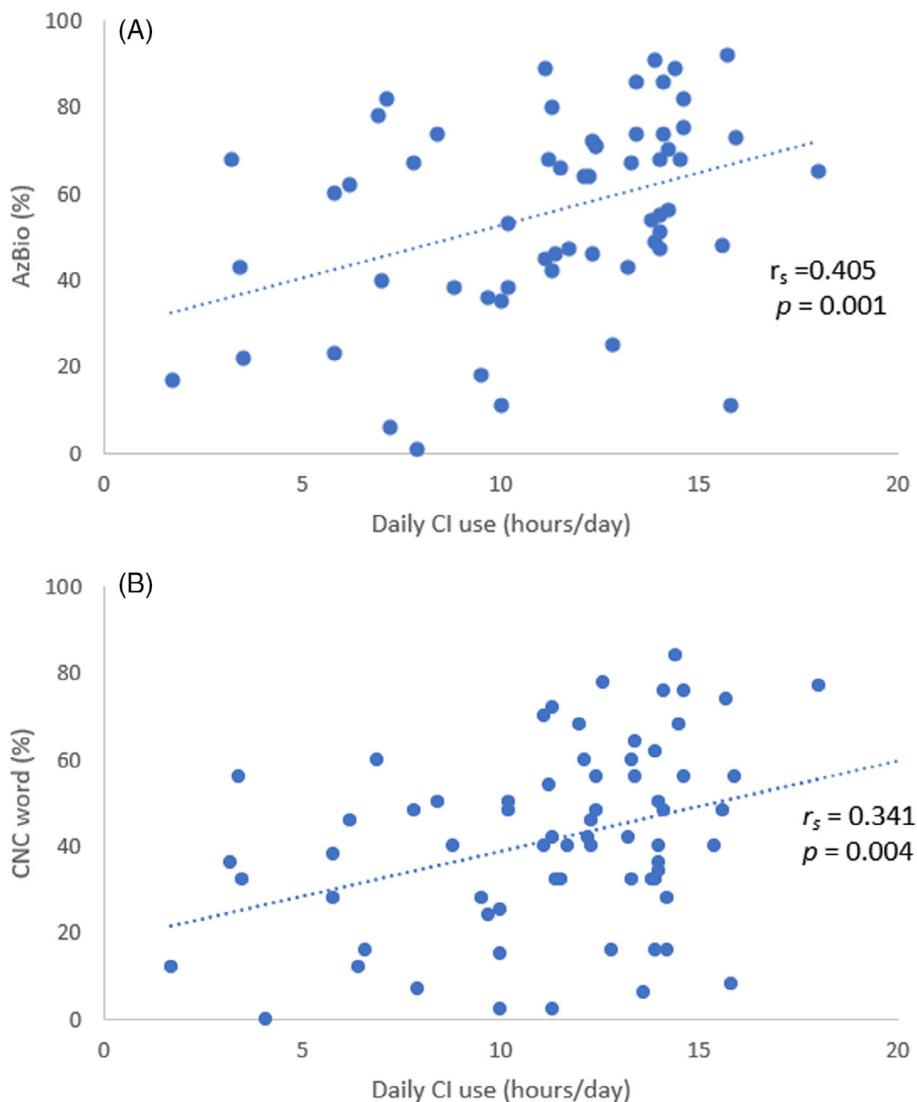
statistically significant positive correlation was seen when comparing daily use to CNC words in quiet scores ($r_s = 0.341$, $p = .004$). Both indicate that daily use is a possible predictor for overall patient performance.

4 | DISCUSSION

Hearing loss is a common finding in the elderly and CIs are becoming a more frequently sought-after treatment option as life expectancy increases. A recent metanalysis concluded that CIs in the elderly improve autonomy and quality of life.[16] CI outcomes in the general population are highly variable due to various methods of reporting results and multiple factors affecting overall performance. In literature, postoperative CNC word scores range from 40% to 70% in adults.[12,17–19] The mean postoperative CNC word scores in our cohort were 40.5 ± 20.7%, placing our results on the lower range of the spectrum. Outcomes specific to the very elderly are scarce, but prior reports showed similar performance levels.[5,6] Despite, lower

overall performance, multiple prior studies and our results show a significant change in audiometric scores when comparing pre- and postoperative performance.[5,17,20]

Given lower overall performance levels in our cohort, the age of implantation was correlated with performance to see if predictive trends exist. Leung et al previously found that slightly lower scores were seen in patients implanted after being older than 65 years, but these findings were not clinically significant.[21] More recently Bourn et al noted lower post-implantation performance in patients 90+ years old, with nonsignificant decreases in performance when comparing the 80–84 year and the 85–90 year groups.[6] Figure 1 demonstrates that our cohort did not replicate this trend. On the contrary, there was a slightly better performance in the 90+ year cohort when compared to the younger 86–90 year which did not meet statistical significance. The overall trend in our data showed similar negative correlations between the age of implantation and overall performance. These trends did not reach statistical significance. Duration of deafness may be a more significant factor affecting outcomes than the age at implantation.[21,22] Given the imprecise duration of deafness

responses in our cohort, we did not perform such correlation calculations. Our data and preceding findings suggest that age should not be used as an independent factor during CI evaluation. These findings should be stressed to patients who are discouraged from considering a CI due to their advanced age.

Advanced age, increased frailty, and perceived risk of complications both related to anesthesia and surgery are common concerns of the elderly.[23] Prior studies suggest possible perioperative cognitive dysfunction in the elderly after general anesthetic.[24] Implantation under local anesthesia is one possible consideration for those with underlying comorbidities.[25] In our cohort, all procedures were completed under general anesthesia after appropriate work-up and medical clearances as indicated. Despite general anesthesia, our complication rates were low at 5.9% with only three patients experiencing symptoms possibly related to the anesthetic. These included new-onset atrial fibrillation, bradycardia, and oral bleeding. Increased awareness of low complication rates and novel options including local anesthesia among primary care providers may facilitate referral for CI evaluation in the geriatric population.

Balance problems were a common concern (noted in 12.7% of the very elderly in our cohort preoperatively). Postoperative disequilibrium was reported in 29.4% of patients during the first clinical visit. Preoperative VNG identified a unilateral weakness in 29.6% of the patients, of these 7.1% were implanted on the side opposite of weakness after a thorough discussion between the patient, surgeon, and audiologist. Key considerations were duration of hearing loss, active ear disease, better hearing ear, and other specific clinical situations. Comparable findings of 28% unilateral preoperative weakness were also noted by Wong et el in a preoperative CI cohort of patients older than 75.[5] Despite these findings, Wong et al concluded that the benefit of improved speech perception after CI is significant and postoperative complications including disequilibrium should not be a major limitation when advising the elderly.[5] Vestibular rehabilitation and a close working relationship with occupational therapy may help alleviate postoperative imbalance symptoms and avoid falls and injury.[26]

Prior studies show that mental health pointedly improves after implantation in the elderly. Specifically, depressive symptoms in the geriatric population improved after rehabilitation with either CI or hearing aid use, with sustained outcomes in the CI cohort only.[27] There is also a well-known link between underlying hearing loss and cognitive decline.[2] Rehabilitation of hearing in the elderly results in improved scores during subsequent cognitive testing.[18] Due to these known links, a subanalysis of patients with preoperative dementia was performed. Despite underlying dementia, patients in our cohort were using their CI at the same rates as unaffected peers ($p = .29$). Even though the performance of patients with dementia was noted to be significantly lower when comparing AzBio sentence scores to the rest of the cohort, patients still had significant improvements when compared to preoperative scores. A similar trend was noted with CNC words in quiet scores but did not reach statistical significance. Future studies including long-term follow-up and subjective feedback from patients will be crucial in helping us further understand the perceived benefit in this population.

The availability of datalogging helps us understand the relationship between daily use and performance. The overall cohort daily mean use was 10.9 h per day, which is consistent with findings by Holder et al reporting a 10.2 h per day mean use.[12] Schvartz-Leyzac et al specifically evaluated daily use in a small subgroup of 30 patients older than 80 years old noting a daily use of 10.97 h per day.[13] In their study, they further noted a negative correlation between age and daily use. Despite a similar negative correlation between hours of CI use and age of implantation, their findings did not reach statistical significance. In contrast, regardless of age, increased daily use showed a significant positive correlation to performance as measured by AzBio sentences and CNC words in quiet scores. This resonates with prior assertion by Holder et al that the highest speech recognition outcomes are correlated with greater than 10 h of CI use per day.[12] Results showing that performance in the very elderly significantly improves with increased daily use are valuable counseling tools to be used by audiologists as they counsel their elderly patients in the post-implant period. It is essential to note that no conclusions can be drawn by these findings as correlation does not convey causation. It remains unknown whether longer daily use promotes better performance, or if better performing individuals are more likely to wear their CI more often.

In our elderly cohort, the mean daily usage distribution showed more than half of the time implants were used in quiet. Speech (19%) and speech in noise (16%) were the second and third most commonly listened in environments. This distribution is similar to prior findings by Schvartz-Leyzac noting 48.53% of time spent in quiet in the general CI population.[13] These findings are important when combined with the prior knowledge of perceived loneliness in the elderly.[28] Contrera et al noted a significant improvement in loneliness scores in the ≥50 years old population up to 12 months after implantation as compared to hearing aid users.[29] This knowledge along with the known versatile usage of implants by the elderly can be used as an additional counseling point by audiologist when working with the geriatric implant population.

There are several limitations of this study including the retrospective nature of data collection and incomplete audiometric data in some cases. The majority of our patients were Caucasian which could be partly due to selecting only English-speaking patients for inclusion. Additionally, the presence of dementia in the subanalysis was based on self-reported intake forms or as marked by primary care physicians without specific cognitive testing. Future studies with larger sample sizes and direct cognitive function testing will allow for more generalizable results. The causality of any of the correlations cannot be assumed due to multifactorial relationships. Additional quality of life data in addition to objective outcomes will be essential for the very elderly to fully understand the extent of benefits of implantation in this population.

5 | CONCLUSION

Results demonstrate that even the very elderly have meaningful use of their implants. Significant improvement is noted when comparing

pre- and post-operative performance scores. Patients with underlying dementia show lower performance scores, but still show meaningful improvement after implantation. Overall, the complication rates in this elder population are very low. Mean daily use is comparable to previously published results in the younger population. Age of implantation does not play a significant role in CI performance. The combination of these results has important implications for the counseling and rehabilitation of the very elderly considering CI.

CONFLICT OF INTEREST

No conflict of interest.

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