Cochlear Implant Outcomes in Elderly Recipients During the COVID-19 Pandemic

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Objective: To evaluate the potential significance of social distancing and quarantine precautions for COVID-19 on speech outcomes, missed appointments, wear time, and exposure to various sound environments in the first 6 months following activation for elderly cochlear implant (CI) recipients.
Study Design: Retrospective cohort.
Setting: Tertiary private practice.
Patients: Fifty cochlear implant recipients ≥65 years were evaluated. A Control Group consisted of 26 patients implanted between November 2, 2018 and February 18, 2019 while the Pandemic Group included 24 patients implanted between November 1, 2019 and February 17, 2020.
Intervention: Rehabilitative.
Main Outcome Measures: Preoperative and 6-month post-operative AzBio sentence scores in quiet were compared between groups along with the number of missed appointments as well as datalogged information regarding average CI wear time and average hours in various sound environments such as quiet, speech, and speech-in-noise.
Results: The Control Group averaged 36.5% improvement for AzBio in quiet scores while the Pandemic Group averaged only 17.2% improvement, a difference that was both statistically and clinically significant ($p=0.04$; $g=0.64$). Patients in the Pandemic Group were nearly twice as likely to miss CI programming appointments than the Control Group. The Pandemic Group wore their CI 1.2 less hours per day on average, and while the Pandemic Group spent similar times in quiet and speech environments to the Control Group, the Pandemic Group spent less time in speech with presence of background noise.
Conclusions: While social distancing and quarantine measures are crucial to limiting spread of COVID-19, these precautions may have negatively impacted early speech performance for elderly cochlear implant recipients. Missed CI programming appointments, decreased sound processor wear time, and reduced exposure to complex listening environments such as speech in the presence of background noise were more common in the Pandemic Group than in the Control Group operated the year prior. **Key Words:** Aural rehabilitation—Cochlear implant datalogging—Cochlear implant speech outcomes—COVID-19.

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INTRODUCTION

The first case of the novel coronavirus disease, COVID-19, was reported in Wuhan, China on December 12, 2019 (1). On March 11, 2020, the World Health Organization declared COVID-19 a pandemic, and following that announcement, a national emergency was declared on March 13, 2020 in the United States. On March 16, 2020, President Donald Trump along with the White House Coronavirus Task Force announced the first set of guidelines to combat COVID-19, including social distancing measures in the United States (2). COVID-19 has had an undeniable impact on health, social functioning, and the world economy. Since March 2020, the number of people infected and who have died from COVID-19 worldwide have continued to increase (3,4). Older adults are particularly vulnerable to COVID-19 related mortality due to advanced age, multiple medical comorbidities, immune compromise, polypharmacy, nutritional compromise, and isolated living conditions (5,6).

Social distancing and self-quarantine measures have been recommended by many health authorities (2,3). While such precautionary measures could save lives and reduce transmission rates, these restrictions also lead to social isolation and loneliness across various age groups. In a survey-based study on anxiety and depression caused by the COVID-19 pandemic, 66.7% of respondents reported significantly worsened quality of life with 23.1% reporting moderate to severe anxiety and nearly 10% reporting moderate to severe depression (7). Elderly patients may be particularly affected by

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loneliness; for example, the elderly are less able to mitigate the effects of isolation via technology (7–9). In fact, older adults who engage in social groups and frequently visit relatives have lower morbidity rates than those who are isolated (10). Therefore, while social distancing and quarantine may keep them safe, the elderly may be adversely impacted by such precautionary measures.

According to the National Institute on Deafness and Other Communication Disorders, the prevalence of hearing loss increases in older adults, with one half to two-thirds of adults over 75 years experiencing difficulty hearing (11,12). Hearing loss is associated with anxiety and depression, decreases sociability, and has been identified as a highly modifiable risk factor for cognitive decline and dementia (13–18). Cochlear implants (CI) have become the standard of care for rehabilitation of hearing for those who lack benefit from conventional amplification. Improved audibility and speech perception from these implants improve social functioning and reduce loneliness, particularly in the first year after implantation (19). To maximize benefit however, CI recipients require acclimatization to the electrical signal via regular auditory inputs throughout waking hours. While dedicated aural rehabilitation has its known benefits, we hypothesized that generalized engagement with family and friends, as well as incident social contacts are also important (20). In fact, one study comparing various aural rehabilitation strategies in patients with severe-to-profound hearing loss found that group rehabilitation has significant benefits (21). Our current work sought to examine whether social distancing and quarantine measures taken during the early phase of the COVID-19 pandemic were associated with cochlear implant speech performance in patients over age 65.

MATERIALS AND METHODS

After obtaining IRB exemption for this study, a retrospective analysis was conducted on adult cochlear implant recipients at a tertiary otology/neurotology practice in Tucson, Arizona. The intent of this study was a targeted outcomes-analysis for CI recipients in their early phases of auditory experience during the pandemic, comparing those outcomes to patients unaffected by the pandemic 1 year earlier. A Control Group consisted of patients who underwent implantation between November 2, 2018 and February 18, 2019 and a Pandemic Group included patients implanted 1 year later between November 1, 2019 and February 17, 2020. All patients included in this study were English speaking adults aged 65 years and older. The Control Group consisted of 26 patients with a mean age at implantation of 75.2 years and the Pandemic Group contained 24 patients with a mean age at implantation of 77.9 years. All CI surgery was performed by the senior author (AJ) at a single hospital and did not utilize trainees; therefore, differences in outcomes due to potential differences in technique or training were eliminated. This study aims to observe the significance of COVID-19 on three areas: speech outcomes, compliance with scheduled follow up, and use parameters as determined by datalogging.

Our standardized cochlear implant protocol evaluates surgical/rehabilitative speech outcomes after cochlear implantation at 3-months, 6-months, 12-months, and annual intervals. A summary of this protocol is provided in Table 1. Data from in-house cochlear implant audiologists and our decentralized network of partnering private audiology practices that program CI were included. The 6-month AzBio sentence score in quiet was used for analysis as it was the most reliably reported metric between programming clinics and reasonably demonstrates early progress. CI-aided speech outcome testing was obtained using recorded AzBio sentences presented at 60 dBA via sound field speaker at 0° azimuth in a standard sound booth. Not all data points could be collected from all patients, due to Southern Arizona's retirement community of winter residents, especially as many patients were encouraged to socially distant themselves. Postoperative assessment data closest to the 6-month postactivation date were used (5–8 months postactivation), when available. For the Control Group and Pandemic Group, comprehensive 6-month speech outcomes were available on 22 recipients (85%) and 12 recipients (50%) respectively. Evaluation of the amount of improvement between groups only included patients with complete datasets.

TABLE 1. *Protocol for CI outcomes assessment*

Day 1 of initial activation (2–4 wk postoperative)	• Mapping and programming • Device orientation
Day 2 of initial activation (4–6 wk postoperative)	• Residual hearing, bilateral • CI-aided thresholds
1-Month	• Residual hearing, bilateral • CI-aided thresholds
3-Month	• Residual hearing, bilateral • CI-aided thresholds • AzBio sentences, quiet (*CI only*) • CNC words/phonemes (*CI only*)
6-Month	• Residual hearing, bilateral • CI-aided thresholds • AzBio sentences, quiet (*left, right, binaural*) • CNC words/phonemes (*left, right, binaural*) • AzBio sentences, +5 SNR (*left, right, binaural*)
12-Month and annual	• Residual hearing, bilateral • CI-aided thresholds • AzBio sentences, quiet (*left, right, binaural*) • CNC words/phonemes (*left, right binaural*) • AzBio sentences, +5 SNR (*left, right, binaural*)

CI, cochlear implant.

We assayed reschedule, cancellation, and no-show rates in both the Control Group and Pandemic Group to determine whether compliance with follow up appointments in the first 6-months after CI activation was affected by the COVID-19 pandemic. Since our audiologic clinic remained open throughout the pandemic, only appointment data from our in-house patients was analyzed (18 in the Control Group; 17 in the Pandemic Group). Appointment data from our decentralized network of private practices was excluded as patients did not receive programming since these locations were closed for COVID-19 precautions. These rates were evaluated between March 16 and November 1, 2019 for the Control Group and March 16 to November 1, 2020 for the Pandemic Group. All missed appointments were taken into account within this time period. Refer to Table 1 for scheduling data for each cohort.

Datalogging provides an average of each patient's wear time and measures exposure to different sound environments between programming visits. Datalogging metrics were obtained to analyze whether changes in listening environments had occurred as a potential by-product of social distancing and quarantine measures. Of note, datalogging metrics are reported differently among manufacturers making it difficult to compare global differences between cohorts. Comprehensive data was available on the in-house subjects in the largest manufacturer cohort, Cochlear Americas. There were 12 patients in the Control Group (46%) and 9 patients in the Pandemic Group (38%) with such datalogging available. Data from our decentralized network of private practices was excluded as patients did not receive programming since these locations were closed for COVID-19 precautions. Since datalogging is recorded from distinct points in time (i.e., when the patient's processor is connected for programming) there are natural inconsistencies in the total number of entries per patient. Therefore, the average was taken for all data points for each cohort (67 entries for Control Group and 34 entries for Pandemic Group). Averages of CI wear time, time in quiet, time in speech, and time in speech-in-noise was measured for each group. Statistical analysis was performed using Microsoft Excel 2010 version 14.0.

RESULTS

The 6-month AzBio sentence score in quiet was used for analysis to compare pre- vs postimplantation progress and to compare outcomes between groups (Fig. 1). Preoperative and 6-month postoperative speech outcomes were available on 22 out of 26 (85%) recipients in the Control Group and on 12 out of 24 (50%) recipients in the Pandemic Group. Refer to Table 2 for speech outcome data for each cohort. The average amount of improvement among patients with complete datasets in the Control Group was 36.5% (standard deviation [SD] = 31.0, 95% CI = 23.5, 49.5) while the average improvement of the patients with complete datasets in the Pandemic Group was 17.2% (SD = 27.6, 95% CI = 1.6, 32.8). Comparative statistics was performed, which found a statistically significant difference for the amount of improvement between groups with a medium to large effect size as demonstrated through Hedges' g (t test, $p = 0.04$; $g = 0.64$).

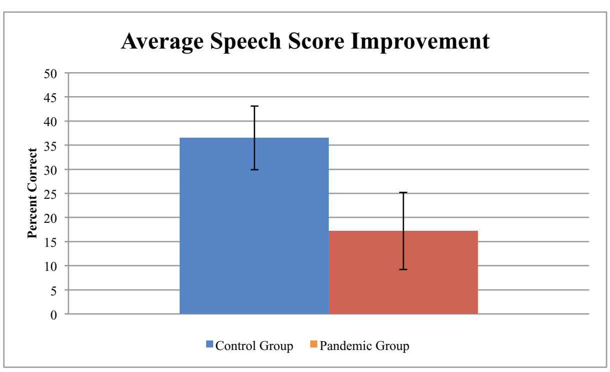

FIG. 1. Preoperative to 6-months postoperative average improvement in speech scores between groups. CI-aided speech outcome testing was obtained using recorded AzBio sentences in quiet presented at 60 dBA via sound field speaker at 0° azimuth in a standard sound booth. Comparative statistics using independent samples t test and evaluation of effect size using Hedges' g demonstrated significant difference between groups with a medium to large effect size ($p = 0.04$; $g = 0.64$). Error bars indicate standard error. CI, cochlear implant.

TABLE 2. *Patient demographics*

	Control Group (n = 26)	Pandemic Group (n = 24)
Age range, years	66–93	65–93
Mean age, years	75.2	77.9
Male	15	16
Female	11	8
Left ear implanted	18	7
Right ear implanted	8	17
Cochlear Americas	20	13
Advanced Bionics	3	7
MED-EL	3	4
Total patients with comprehensive speech scores	22	12
Mean preoperative speech score	27.7	25.3
Mean 6-month postoperative speech score	64.2	42.5
Mean speech score improvement	36.5	17.2
Total missed appointments	25	43
Average missed appointments	1.5	2.5

The Control Group underwent implantation between November 2, 2018 and February 18, 2019. The Pandemic Group underwent implantation between November 1, 2019 and February 17, 2020. To compute average speech score improvement between groups, only patients with comprehensive datasets were included. For total and average missed appointments, only in-house patients were included.

To assess missed appointments, data was available for 18 patients (69%) in the Control Group and 17 patients (71%) in the Pandemic Group. As demonstrated in Figure 2, a total of 25 missed appointments (M = 1.5) were measured for the Control Group and 43 missed appointments (M = 2.5) for the Pandemic Group, which is a statistically significant difference with a medium to large effect size ($p = 0.03$, $g = 0.62$). Patients in the Pandemic Group were 1.72 times more likely to reschedule their appointments.

To evaluate average hours of CI use via datalogging, data was available for 12 patients (46%) in the Control Group and 9 patients (38%) in the Pandemic Group. The average wear time was 12.5 hours (SD = 3.4, 95% CI = 11.7, 13.3) for the Control Group and 11.3 hours (SD = 1.6, 95% CI = 10.8, 11.8) for the Pandemic Group. A statistically significant difference was found between groups with a medium effect size, which demonstrates that the Pandemic Group was wearing their device for less time per day ($p = 0.01$; $g = 0.41$) (Fig. 3).

To investigate whether a reduction in diverse listening environments contributed to the reduced speech scores in the Pandemic Group, an analysis was performed on the datalogs to evaluate average time in the three most common listening environments: quiet, speech, and speech-in-noise. Average time in quiet was 6.6 hours a

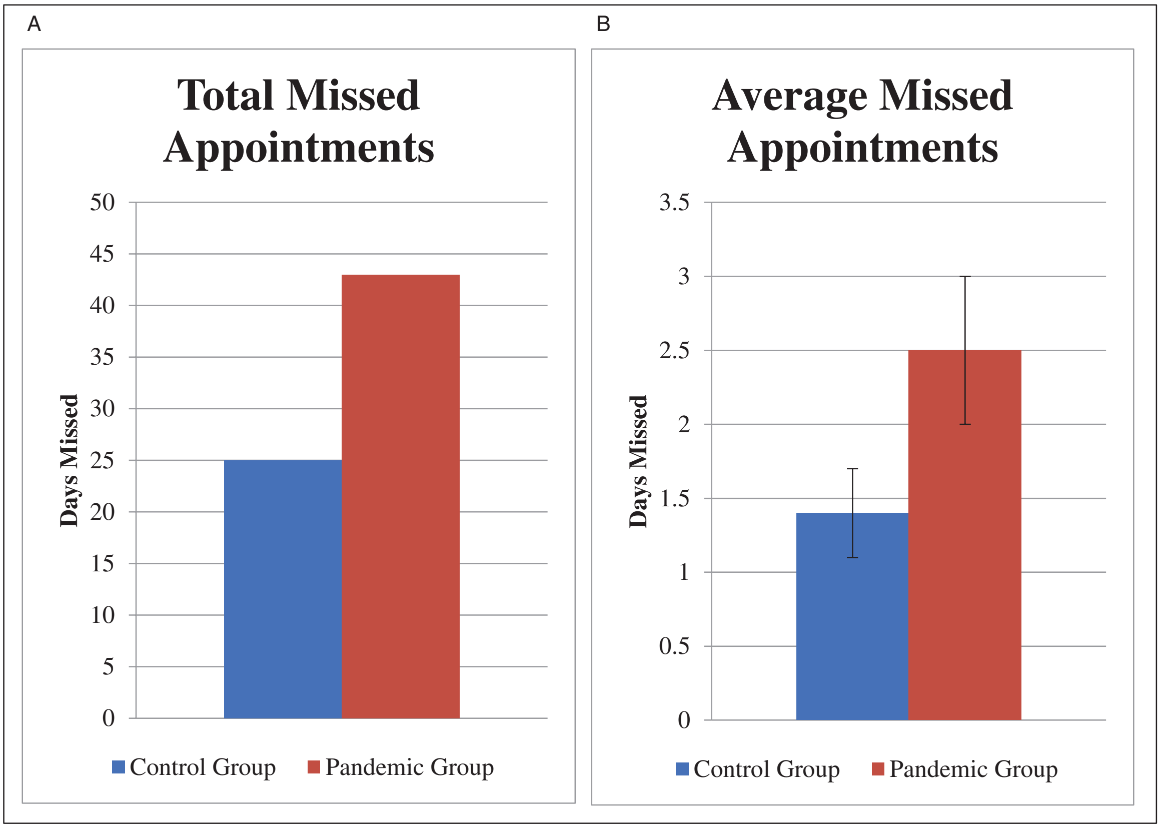

FIG. 2. *A*, Total rescheduled, cancelled, and no-show appointments for each group. Comparative statistics using independent samples *t* test and evaluation of effect size using Hedges' *g* demonstrated significant difference for total missed appointments between groups with a medium to large effect size ($p = 0.03$; $g = 0.62$). *B*, Average rescheduled, cancelled, and no-show appointment rate for each group. Error bars indicate standard error.

day (SD = 2.8) for the Control Group and 6.3 hours a day (SD = 2.2) for the Pandemic Group. Average time in speech was 0.7 hours a day (SD = 0.5) for both the Control Group and Pandemic Group. There was no statistically significant difference between groups for either the quiet ($p = 0.31$) and speech ($p = 0.33$) listening environments. However, for speech-in-noise, the average time was 2.4 hours a day (SD = 1.7, 95% CI = 2.0, 2.8) for the Control Group and 1.7 hours a day (SD = 1.2, 95% CI = 1.3, 2.1) hours for the Pandemic Group, which demonstrated a statistically significant difference between groups with a medium effect size ($p = 0.007$; $g = 0.45$) indicating that patients spent less time in speech-in-noise once social distancing measures were enacted (Fig. 4).

DISCUSSION

In its broadest sense, aural rehabilitation aims to reduce hearing loss induced deficits of function, activity, participation, and quality of life through sensory management, instruction, perceptual training, and counseling (22). Regardless of the type of assistive technology utilized, the need for aural rehabilitation increases with advancing age. Declines in hearing and speech intelligibility are particularly common in the elderly; for example, one study found that about 32% of patients 60 years of age report problems understanding speech while up to 64% have such problems by age 80 (23). Once assistive listening devices and hearing aids are no longer adequate, cochlear implantation has become the modality of choice for improving audibility, speech understanding, autonomy, quality of life, and even cognitive function (24–27). After surgery, however, patient- and clinician-driven therapy programs help maximize CI performance (28–30). This requires access to implant audiologists for programming as well as personal investment and initiative by the CI recipient for dedicated practice with their device. The importance of environmental sound inputs and day-to-day social interaction as a means of passive aural rehabilitation is less clear; however, the idea that exposure to sound in all its different ways is valuable makes intuitive sense.

The COVID-19 pandemic has had profound physical, psychological, psychosocial, and economic consequences worldwide. While everyone has been affected in different ways, we hypothesized that precautionary self-isolation measures designed to protect our older population may have adversely affected elderly CI recipients within the first year after cochlear implantation.

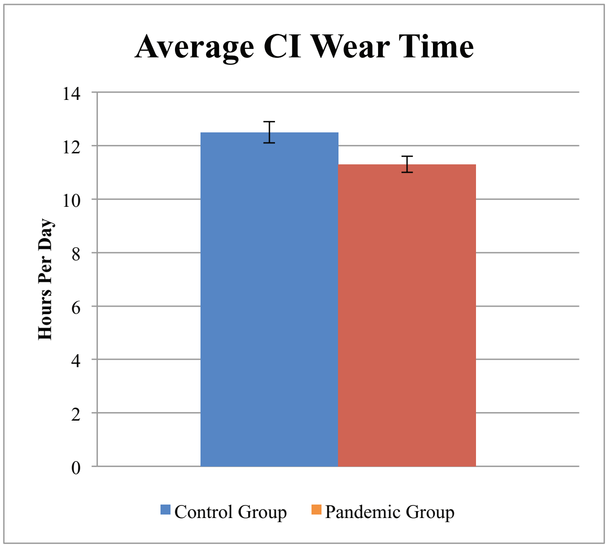

FIG. 3. Datalogging data was analyzed to determine average hours of CI wear time between groups. Comparative statistics using independent samples *t* test and evaluation of effect size using Hedges' *g* demonstrated significant difference for average hours of CI wear time between groups with a medium effect size ($p = 0.01$; $g = 0.41$). Error bars indicate standard error. CI, cochlear implant.

Aural rehabilitation is particularly important in this first year where technical challenges with implant equipment, access to audiologists for programming, active cognitive and listening exercises, as well as passive rehabilitation via social interaction and/or environmental sound exposure are necessary.

There have been few studies to date regarding COVID-19 and CI recipients. Ayas et al. examined the impact of COVID-19 on cochlear implantation utilizing an online questionnaire sent to parents of 31 pediatric cochlear implantees (31). Twenty-four parents responded to the questionnaire and all of them reported a significant impact on access to hearing health services, particularly CI mapping, 96% had trouble with home training methods, and 71% could not participate effectively in remote learning. Gordon, et al. utilized CI datalogging data to demonstrate that 45 pediatric CI recipients were in quiet environments more frequently after COVID-19 precautions were enacted in March 2020 as compared to measurements taken prior to March 2020 (32). This increase in quiet was associated with a decrease in access to spoken communication which is a detriment to children's development. Lastly, Dunn et al. (2021) used ecological momentary assessment to assess the psychosocial effects of COVID-19 on CI recipients (33). While they reported their subjects spent more time in quieter environments, consistent with our results, they also found that these recipients had lowered anxiety and social isolation levels due to social distancing measures suggesting that being in controlled home environments were more relaxing.

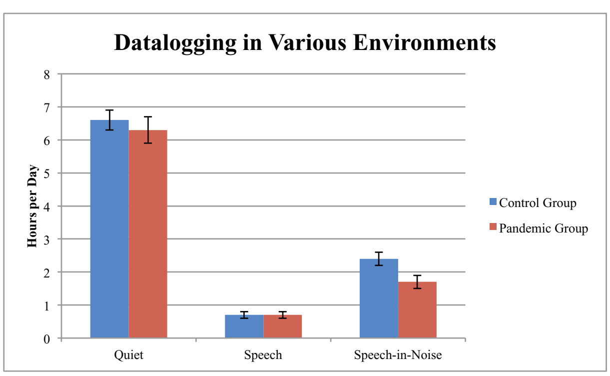

FIG. 4. Datalogging data was analyzed for time in quiet, time in speech, and time in speech-in-noise for the Control Group and Pandemic Group. Comparative analysis utilizing independent samples *t* test and evaluation of effect size using Hedges' g was performed. There were no significant differences between groups for the quiet and speech environments ($p = 0.31$; $p = 0.32$). There was a significant difference between groups for the speech-in-noise environment with a medium effect size ($p = 0.007$; $g = 0.45$). Error bars indicate standard error.

Our study, the first of its kind, aimed to examine the significance of COVID-19 in elderly CI recipients within the first 6 months of their aural rehabilitation process. When comparing 6-month speech outcomes, the Control Group revealed greater improvements in speech scores, gaining an average of 36.5 percentage points compared to the Pandemic Group which gained 17.2 percentage points (Fig. 1). While exact causes for this significant difference cannot be completely discerned, one can speculate that (1) use-time and (2) a decrease in complex social interactions as determined by time spent in background noise may be contributing factors. In the audiology clinic, patients and caregivers anecdotally acknowledged less participation in aural rehabilitation exercises and noted being primarily at home in quiet environments. In theory, recipients had more time available to do their listening exercises with quarantine measures in place; however, many of them informally reported that the stress of the pandemic and upheaval of their typical lives resulted in less motivation.

As noted in Figure 2, a significant difference was found in missed appointments between groups, as patients were 1.72 times more likely to miss an appointment in the Pandemic Group. We hypothesize this was due to social distancing and quarantine measures encouraging patients to stay at home to minimize exposure to the virus. The Pandemic Group had only 50% of the data points used for calculating speech scores despite the fact that both groups had a similar number of patients implanted during their respective time periods. However, when patients miss visits, they miss valuable programming sessions and do not prioritize their aural rehabilitation needs. This can result in frustration for the patient and treating audiologists, as recipients are not progressing as desired.

Datalogging measures found a statistical difference in CI wear time between the Control Group and Pandemic

Group (Fig. 3). Despite that difference being small at just over 1 hour per day, the cumulative effect over several months is substantial, especially during recipients' critical period of acclimatization and central remodeling. We encourage our patients to wear their device for at least 10 hours a day, ideally during all waking hours.

As demonstrated in Figure 4, datalogging indicated that patients in the Control Group and Pandemic Group spent equal time in quiet and speech environments; however, consistent with social isolation measures, recipients spent less time in speech with presence of background noise. This reduced social interaction may have been detrimental to early progress as varied auditory experience may be especially important for neural plasticity.

We would like to acknowledge a few limitations of our study. First, there is inconsistency between datalogging measures; in fact, it became readily apparent that data is logged differently between the three CI manufacturers. Two manufacturers collect data through averages for different environments at different intensity levels. However, we found it unclear how this data is then divided into their respective categories for quiet, speech, and speech-in-noise since those algorithms are proprietary to each manufacturer. As such, separation of stimuli into these categories may not be a completely accurate representation of each patient's exact listening environments (34). Furthermore, some of this collected data is excessive, which obfuscates the intentional purpose of datalogging which is to measure wear time and listening environments. The last CI manufacturer collects data cumulatively, which makes direct comparisons impossible. In addition, not all sound processors collect datalogging in any manner. Perhaps, collaboration between manufacturers to create a single methodology for datalogging may be of benefit in future clinical research. The other limitations of our study relate to its retrospective nature. While our intent was to recognize the striking performance differences in a Pandemic Group as compared to a Control Group from 1 year prior, it is conceivable that observed differences were related to reasons outside the pandemic. Therefore, while missed CI programming appointments, decreased sound processor wear time, and reduced exposure to complex listening environments such as speech in the presence of background noise were observed in the Pandemic Group, a cause-and-effect relationship to worsened speech performance cannot be formally established.

CONCLUSION

Social distancing and self-quarantine have been critical to limiting the spread of COVID-19, especially within our elderly communities. However, such precautionary measures have also had some unintended consequences. Compared to a Control Group from 1 year prior, our work demonstrates reduced speech performance for our elderly cochlear implant recipients implanted in the months just prior to the pandemic, which may be temporally correlated with missed/rescheduled CI programming appointments, decreased sound processor wear time, and reduced exposure to complex listening environments such as those with background noise. Based on these findings, our practice now emphasizes the importance of postoperative follow up for CI mapping even more than we did in the past, and we recommend additional active practice time each day for all our CI recipients.

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