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Performance over Time on Adults with Simultaneous Bilateral Cochlear Implants

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Abstract

Background: Maximum performance and long-term stability of bilateral cochlear implants has become an important topic because there has been increasing numbers of recipients of bilateral cochlear implants.

Purpose: To determine the performance over time (up to 6 yr) of subjects with simultaneous bilateral cochlear implants (CI+CI) on word recognition and localization.

Research Design: Over-time investigation of word recognition in quiet (CNC) and sound localization in quiet *(Everyday Sounds Localization Test).*

Study Sample: The subjects were 48 adults who simultaneously received their cochlear implants at the University of Iowa.

Results: For word recognition, percent correct scores continuously improved up to 1 yr postimplantation with the most benefit occurring within the first month of implantation. In observing up to 72 mo, the averaged scores reached to the plateau of about 63% correct in CNC after 2 yr (N = 31). But, when we followed 17 subjects who have complete data set between 12 mo and 48+ months, word recognition scores were significantly different from 12 mo to 48+ months, which implies binaural advantages need more time to be developed. Localization test results suggested that the root mean square (RMS) error scores continuously improved up to 1 yr postimplantation with most benefits occurring within the first 3 mo. After 2 yr, the averaged scores reached to the plateau of about 20° RMS error (N = 27). When we followed 10 subjects who have complete data set between 12 mo and 48+ months, localization scores were not improved from 12 mo to 48+ months. There were large individual differences in performance over time.

Conclusions: In general, substantial benefits in both word recognition and localization were found over the first 1–12 mo postimplantation for subjects who received simultaneous bilateral cochlear implants. These benefits were maintained over time up to 6 yr postimplantation.

Key Words: Localization, simultaneous bilateral cochlear implants, speech recognition

Abbreviations: CI only = unilateral cochlear implant; CI+CI = simultaneous bilateral cochlear implants; RMS = root mean square

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Cochlear implantation has become a well-known remediation for severe-to-profound deafness. However, because of its lifelong use and its irreversible changes to the cochlea, it is important to verify the long-term benefits and stability of cochlear implantation. For the past 30 yr, researchers have inundated the literature with studies investigating the benefits and long-term performance of unilateral cochlear implants (CI only) in people with postlingual severe-to-profound hearing loss. Most of this research has focused on speech perception and has excluded localization skills, especially with regard to data over time. The studies on speech perception abilities in CI-only users have shown that most improvements occur within the first year (Helms et al, 1997; Hamzavi et al, 2003), or up to two years (Tyler et al, 1997; Ruffin et al, 2007). More recently, research has shifted to studying the benefits of bilateral cochlear implantation (e.g., Gantz et al, 2002; Müller et al, 2002; Tyler et al, 2003; Schleich et al, 2004; van Hoesel, 2004; Ramsden et al, 2005; Litovsky et al, 2006; Ricketts et al, 2006; Buss et al, 2008). However, very little research has reported on the maximum performance and long-term stability of bilateral cochlear implants. This evaluation seems crucial given that you are implanting both ears and not preserving one for future medical intervention.

Research studying the benefits of word recognition in quiet on bilateral cochlear implant users (CI+CI) during the first 6 (Laszig et al, 2004; Litovsky et al, 2006) to 12 mo (Buss et al, 2008; Mosnier et al, 2009) suggests that most users have continuous significant improvements in performance, with improvements occurring as soon as 1 mo after implantation. Furthermore, Buss et al (2008) proposed that the 1 mo score might be a rough predictor for performance after 1 yr. Eapen et al (2009) observed performance between 1 and 4 yr and showed that CI+CI users continue to improve beyond the 1 yr point up to 4 yr. Based on these results, it might be that we can expect some long-term changes in performance with CI+CI recipients that have not been observed in CI-only subjects.

Research studying long-term benefits of localization longer than 12 mo after implantation with CI+CI recipients is limited. Grantham et al (2007) investigated the localization abilities of a limited number of CI+CI subjects at 4 to 6 mo postimplantation and then again at 15 mo postimplantation. They found that many subjects reached a plateau in performance around 4 to 6 mo, which is quicker than the plateau demonstrated in the literature for speech perception. In contrast, Tyler et al (2006) observed a group of CI+CI subjects over time for up to 72 mo and found that patients showed a similar pattern to speech perception with improvements in localization. However, Koch et al (2009) demonstrated no significant improvement over time between 3, 6, and 12 mo with a group of CI+CI users. To better confirm the over-time benefit of localization for CI+CI recipients, a longer observation period with a larger group of subjects is needed.

The purpose of the present study was to evaluate over-time trends in word recognition and sound localization by observing data up to 6 yr postimplantation on individuals with CI+CI.

METHOD

Subjects

We studied 48 bilateral subjects who were simultaneously implanted between 1997 and 2008 all in one surgical procedure. We excluded sequentially implanted bilateral subjects. The subjects were all postlingually deafened adults with a mean age of 55.7 yr at implantation (ranging from 20 to 81 yr; SD = 14.0 yr) and a mean of duration of deafness of 7.6 yr (SD = 8.87 yr). The mean number of years of cochlear implant experience was 5.4 (ranging from 0.4 to 10.8 yr; SD = 2.9 yr). Among 48 subjects, 30 were female and 18 were male. Twenty-seven out of the 48 subjects (56%) were implanted with Advanced Bionics Corporation devices, of which the oldest version was a Clarion HiFocus 1.2. Twenty-one of the 48 subjects (44%) were implanted with Cochlear Corporation devices, of which the oldest version was a Nucleus CI 24M. Table 1 gives a summary of the internal device distribution. Twenty subjects (41.7%) experienced external device changes or upgrades during the observation period.

Word Recognition Test in Quiet

The *Consonant-Nucleus-Consonant* (CNC) test (Tillman and Carhart, 1966), presented in quiet at 70 dB(C), was used as the monosyllable word recognition test. Two lists were presented to each subject, and an average of the two was taken for the final score. All subjects were tested in a double-walled sound-treated room by experienced audiologists.

Table 1. Internal Device Distribution

Type of Device	# of subjects	% of Subjects
Clarion HiFocus 1.2/I- CII	2	4.2
Clarion HiFocus II-CII	10	20.8
Clarion HiRes 90K	9	18.8
Clarion HiRes 90K with Helix	6	12.5
Nucleus CI 24M	10	20.8
Nucleus CI 24R	4	8.3
Nucleus CI 24R(CA)	1	2.1
Nucleus CI 24RE(CA)	6	12.5
Total	48	100

Localization in Quiet

An *Everyday Sounds Localization Test* (Dunn et al, 2005) presented in quiet in a double-walled sound-treated room was used to evaluate localization abilities. This test consisted of 96 random presentations of 16 different everyday sounds (e.g., telephone ringing, instrument playing, and dog barking). The test stimuli is presented in the frontal horizontal plane using eight loudspeakers placed 15.5° degrees apart, creating a 108° arc. The signals were presented at approximately 70 dB(C). The score was derived from the RMS (root mean square) error between the source loudspeaker and the subject response loudspeaker. Chance level of this test is 43° RMS error.

RESULTS

Speech Perception: Word Recognition in Quiet

Figure 1A shows the average over-time bilateral word recognition performance for all 48 CI+CI subjects from pre-implantation (best aided) through 72 mo (6 yr) post-implantation. All subjects had over-time multiple data points; however, not all subjects had data points at every time point over time. Data from a minimum of 13 subjects was included at each averaged data point. A repeated-measures analysis of variance (ANOVA) showed that the first 12 mo after implantation showed the largest incremental improvement (8% at pre-implantation to 61% at 12 mo) in word recognition with an additional benefit of 4% between 12 and 24 mo. Over-time word recognition data after 24 mo did not show any further improvements through 72 mo. CNC scores for the 48 subjects ranged from 0 to 94%. Fifteen subjects (31.3%) scored between 80 and 94% (mean 87%). Eighteen subjects (37.5%) scored between 64 and 79% (mean 70.5%). Fifteen subjects (31.3%) scored between 0 and 63% (mean 40.8%).

In Figure 1B, we examined in more detail the average performance over the first 12 mo of all 48 subjects using more discreet time increments (pre-implant [0 mo], and 1, 3, 6, and 12 mo postimplantation). In this figure, a minimum of 11 subjects was averaged at each time point. Word recognition scores improved dramatically between pre-implant scores and 1 mo scores with increases from 8 to 49% (41% improvement), respectively. Furthermore, there were 5%, 1%, and 6% improvements between 1 mo and 3 mo, between 3 and 6 mo, and between 6 and 12 mo postimplantation respectively.

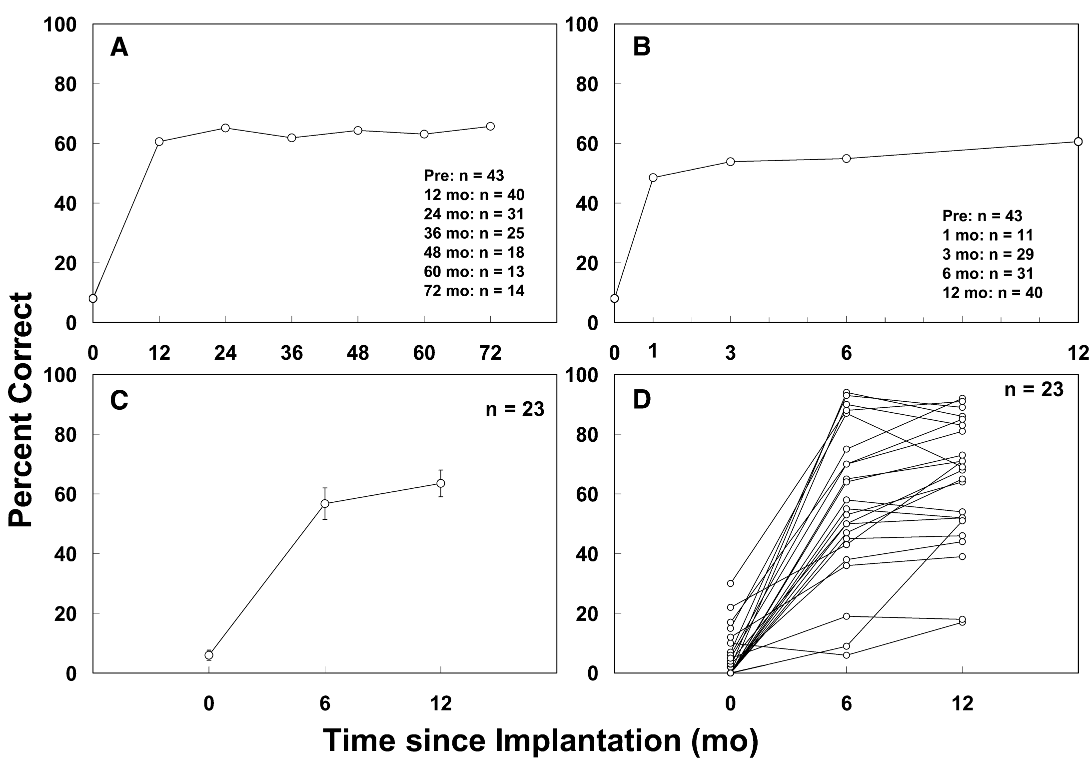

Figure 1. Word recognition performance over time. Results are expressed as percent correct, and error bars indicate standard errors. 1A shows the average over-time bilateral word recognition performance for all 48 CI+CI subjects from pre-implantation through 72 mo (6 yr) postimplantation. 1B shows the average performance over the first 12 mo for all 48 subjects with more discreet time increments. It should be noted that not all of the 48 subjects have data at each data point. 1C shows the average performance for 23 subjects who all have data at pre-implant and 6 and 12 mo postimplantation. 1D shows individual results for pre-implantation and 6 and 12 mo postimplantation for the same 23 subjects shown in 1C.

As mentioned before, Figures 1A and 1B include a different set of subjects for each data point. This is because some subjects had not reached 72 mo of experience and because some subjects had chosen to drop out of research participation. So, in order to minimize subject variability, we selected a subset of 23 subjects who all have data at pre-implant, 6 and 12 mo postimplantation. In Figure 1C, we show averaged data from these 23 subjects. We did not include 1 and 3 mo postimplantation data because not every subject had data at those points in time. The largest increment in performance occurred between the pre-implant score (6% correct) and the 6 mo postimplantation score (57% correct) with an additional small improvement of 7% between 6 and 12 mo postimplantation. A repeated-measures analysis of variance revealed that there was a significant improvement in word recognition scores after implantation, $F(1.5, 32.3) = 108.7$, $p < .001$. Post hoc comparisons using a Bonferroni adjustment revealed a significant improvement between the pre-implant and 6 mo postimplantation score ($p < .001$) and between the pre-implant and 12 mo postimplantation score ($p < .001$). No significant difference was found between the 6 mo and 12 mo postimplantation scores ($p = .06$).

Figure 1D demonstrates individual word recognition performance during the first 12 mo postimplantation for the same subset of 23 subjects shown in Figure 1C. The results showed that for 19 of the 23 subjects, the first 6 mo led to major improvements in word recognition scores compared to pre-implant scores. Two subjects showed major improvements in the last half of the year rather than the first half of the year, and two subjects demonstrated less than a 20% improvement in scores between pre-implantation and 12 mo postimplantation.

In reviewing the data beyond 12 mo postimplantation (not shown), of the 19 subjects who showed improvements within the first 6 mo postimplantation, 12 did not show any additional changes in scores; 3 showed a 20% or more improvement (two showed an improvement at 24 mo, and one showed an improvement at 36 mo); and 4 did not have any more data after 12 mo. Of the two subjects who showed improvement between 6 and 12 mo postimplantation, no additional improvements were noted. In the two subjects who had less than a 20% improvement over the first 12 mo, one showed an additional 20% increase in scores at 36 mo, and the other showed no further improvement after 12 mo.

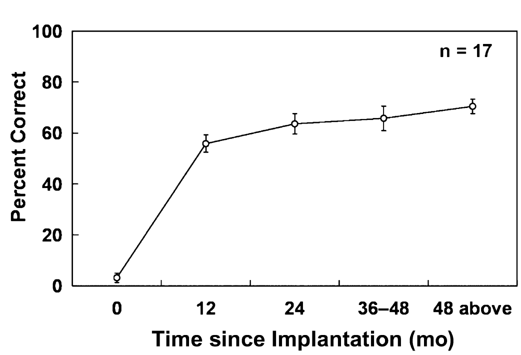

Figure 2. Word recognition performance over time for 17 subjects who all have data points at every time period except pre-implantation (6 individuals do not have pre-implant data). Results are expressed as percent correct, and error bars indicate standard errors.

In Figure 2, we studied the performance of a subset of 17 subjects who all have data points at every time period except pre-implant (6 individuals did not have pre-implant data) over the course of 4 yr. The purpose of this analysis was to study word recognition performance after the first year of implant use. A repeated-measures analysis of variance revealed that there was a significant difference in CNC scores postimplantation, $F(4, 51) = 79.24$, $p < .001$. Post hoc comparisons using Tukey adjustment revealed that pre-implant scores were significantly different to all the other time points ($p < .05$). The reason that we used Tukey adjustment instead of Bonferroni in this analysis was that Bonferroni adjustment was too conservative to be applied to the more than four group comparisons. Results for 48+ mo ($M = 69.0$, $SD = 11.1$) were significantly different from 12 mo results ($M = 54.1$, $SD = 14.1$, $p < .05$) although all the adjacent time points from 12 mo to 48+ months were not significantly different each other. While this analysis only included 17 subjects over time, we found that the average scores of all 48 subjects and the 17 subjects who have complete data set between pre-implant and 48+ months are similar.

Localization

Figure 3A shows the average over-time localization performance from a total of 47 CI+CI subjects from pre-implantation through 72 mo (6 yr) postimplantation. Again, all subjects had over-time multiple data; however, not all subjects had data points at every time point over time. Data from a minimum of 12 subjects was included at each averaged data point. This figure shows that the largest improvements occurred between pre-implantation (RMS error = 37°) and 12 mo postimplantation (RMS error = 22°). Additional benefits occurred between 12 and 24 mo with RMS error improvements from 22° to 19°, respectively. After 24 mo, the localization scores showed a plateau through 72 mo that was the same pattern as in the word recognition performance described in Figure 1. Localization scores for the 47 subjects ranged from 10° to 47°. Eighteen subjects (38.3%) scored between 10° to 15° (mean 13.2°). Fifteen subjects (31.9%) scored between 16° to 21° (mean 18.6°). Fourteen subjects (29.8%) scored between 22° to 47° (mean 30.5°).

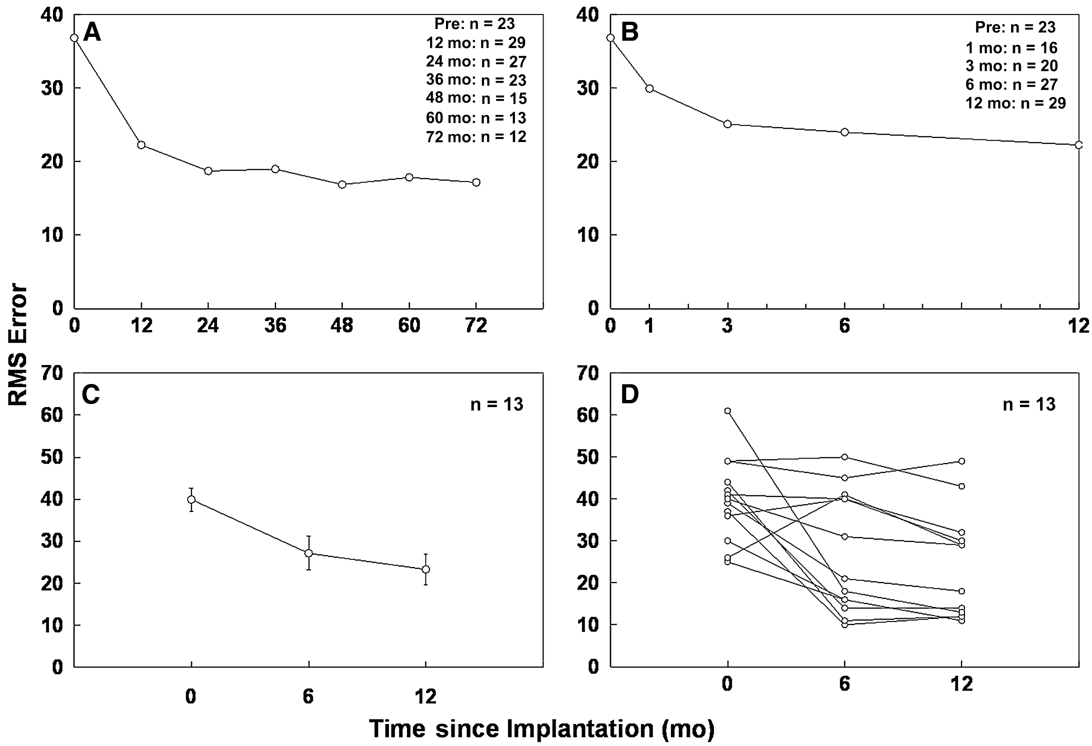

Figure 3. Localization performance over time. Results are expressed as RMS error scores, and error bars indicate standard errors. 3A shows the average over-time localization performance from a total of 47 subjects from pre-implantation through 72 mo (6 yr) postimplantation. 3B shows data from the same subjects as in 3A detailing in more discreet time increments the average performance over the first 12 mo. It should be noted that not all of the 47 subjects have data at every time increment. 3C shows average performance for 13 subjects who all have data points at pre-implant and 6 and 12 mo postimplantation. 3D demonstrates individual performance during the first 12 mo postimplantation for the same subset of 13 subjects shown in 3C.

In Figure 3B we examined in more detail the average performance over the first 12 mo of the same 47 subjects shown in Figure 3A using more discreet time increments (pre-implant [0 mo], and 1, 3, 6, and 12 mo postimplantation). In this figure, a minimum of 16 subjects were averaged at each time point. This figure shows an improvement of 7° in average performance from pre-implant (RMS error = 37°) to 1 mo postimplant (RMS error = 30°) and an additional improvement of 5° from 1 to 3 mo (RMS error = 25°). From 3 to 12 mo, a small improvement of 3° RMS error was shown.

As mentioned before, Figures 3A and 3B include a different set of subjects at each data point. In order to minimize subject variability, in Figure 3C we show the averaged results from a subset of 13 subjects who all have data at pre-implant, 6 and 12 mo postimplantation. We did not include 1 and 3 mo postimplantation results because not all of these subjects had data at those points in time. The largest increment of improvement occurred between the pre-implant score (RMS error = 41°) and the 6 mo postimplantation score (RMS error = 29°) with an additional small improvement of 6° between 6 and 12 mo postimplantation. A repeated-measures analysis of variance revealed that there was a significant improvement in localization scores after implantation, $F(2, 26) = 12.75$, $p < .001$. Post hoc comparisons using a Bonferroni adjustment revealed a significant improvement between the pre-implant and 6 mo postimplantation score ($p < .05$) and between the pre-implant and 12 mo postimplantation score ($p < .01$). No significant difference was found between the 6 and 12 mo postimplantation scores ($p = .08$).

Figure 3D shows individual localization performance during the first 12 mo postimplantation of the same subset of 13 subjects shown in Figure 3C. The results showed that for 8 of the 13 subjects, the first 6 mo led to large improvements in localization scores compared to pre-implant scores, with three showing additional improvements after 6 mo and 10 showing a plateau in scores after 6 mo postimplantation. On the other hand, three subjects did not show an improvement in scores between pre-implant and 6 mo but did show an improvement between 6 and 12 mo postimplantation. Two subjects did not show an improvement between pre-implant and 12 mo postimplantation.

In reviewing the data beyond 12 mo postimplantation (not shown) for this subset of 13 subjects, of the eight subjects who showed major improvement within the first 6 mo, five subjects did not have additional increases in scores, and three did not have data beyond

12 mo. Of the three who showed major improvement between 6 and 12 mo, one did not show additional improvements, and two showed further improvement (one improved from 30° at 12 mo to 17° at 48 mo, and the other improved from 29° at 12 mo to 17° at 24 mo). Of the two subjects who did not have an improvement in scores between pre-implant and 12 mo, one did not have further changes in scores, and one did not have additional data.

Figure 4 shows localization results for a subset of 10 subjects who all have data over the course of 4 yr. All 10 subjects have data points in every time period except pre-implant (6 pre-implant data missing). A repeated-measures analysis of variance revealed that there is a significant difference in localization scores postimplantation, $F(4, 30) = 14.62$, $p < .001$. Post hoc comparisons using Tukey adjustment revealed that pre-implant scores were significantly different from all other time points ($M = 42.5$, $SD = 12.8$, $p < .05$). Comparisons between all other data points from 12 to 48+ months postimplantation were not significantly different from each other. As with speech perception, while this analysis only included 10 subjects over time, we found that the average scores of all 48 subjects and the 10 subjects who have complete data set between pre-implant and 48+ months are similar.

DISCUSSION

The purpose of the present study was to evaluate over-time trends in word recognition and sound localization by observing data up to 6 yr postimplantation on postlingual adults with CI+CI.

Speech Perception

The results from this study demonstrated that word recognition performance in CI+CI subjects showed substantial improvement over the first 1–12 mo postimplantation. This is consistent with previous studies that have looked at bilateral data over time (Laszig et al, 2004; Litovsky et al, 2006; Buss et al, 2008; Koch et al, 2009; Mosnier et al, 2009). Buss et al (2008) suggested that 1 mo performance might be a rough predictor of 1 yr performance postimplantation. Although we only looked at 11 subjects (Fig. 1B), most of the improvement of these 11 subjects occurred very quickly within the first month after CI+CI experience with average improvement being 41%. Litovsky et al (2006) also showed about 40% improvement in CNC words with 33 CI+CI subjects within the first month of implantation. This might suggest that attention should be placed on trying to maximize performance during the very early stages of implant experience. Several studies looking at the over-time results of CI-only subjects also report significant benefit from the cochlear implant after only 1 mo of use (Välimaa et al, 2002; Hamzavi et al, 2003). Interestingly, while Tyler et al (1997) demonstrated that CI-only subjects showed almost immediate improvement in consonant perception after switch-on, this improvement was not observed with the NU-6 word test. While we do not feel that in quiet this would result in a significant difference in scores, it should be noted that some of the comparisons used a different dB level for word presentation (e.g., Litovsky et al, 2006, used 65 dB SPL rather than 70 dB(C) as used in our study).

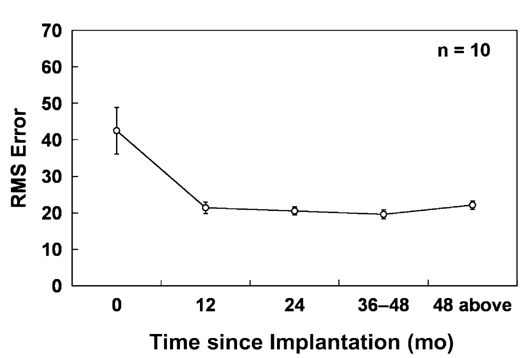

Figure 4. Localization performance over time for 10 subjects who all have data points in every time period except pre-implantation (6 individuals do not have pre-implant data). Results are expressed as RMS error scores, and error bars indicate standard errors.

Studies observing performance up to 6 mo after implantation (Laszig et al, 2004; Litovsky et al, 2006; Buss et al, 2008; Mosnier et al, 2009) have shown improvements in this 6 mo stage of implantation. Other studies observing performance through 12 mo have shown that performance continues to improve in the later stage (6–12 mo) as well (Koch et al, 2009; Mosnier et al, 2009; Buss et al, 2008). In this study, we demonstrated a significant improvement in CI+CI performance from pre-implant to 6 mo postimplantation ($p < .001$) in the same subjects. From 6 to 12 mo postimplantation, improvement also approached a significant level ($p = .06$).

After 24 mo, in our study, on average as a group ($n = 31$) there was no further significant improvement in word recognition. We did find that performance was stable after 24 mo, which was similar to the trend found with some CI-only results (Hamzavi et al, 2003). More specifically, Ruffin et al (2007) found no major improvement or decrement after 24 mo postoperation in CI-only subjects in an analysis of subjects over 120 mo postimplantation.

When we analyzed individual data over time, we observed that some subjects had improvements up to 24 mo and then plateaued while others showed improvements even later up to 48 mo postimplantation. Eapen et al (2009) analyzed CNC scores of CI+CI subjects from 1 to 4 yr postimplantation. They found binaural scores were significantly improved over time every year. In our study, when we observed the same subjects (n = 17) over time through 48+ months, we also found significant improvement in word recognition, but only when comparing 12 mo data to the 48+ months data. Most improvements in bilateral scores occurred within 1 yr postimplantation. However, when the same subjects were observed over time, we revealed that there can be a significant improvement after more than 4 yr of use of CI+CI.

When we look at the most recent CI+CI average word recognition scores in this study and compare these results to the literature on CI-only subjects, we find an interesting difference. In our study, the CNC scores for CI+CI subjects were 61% at 12 mo (N = 40) and 66% at 72 mo (N = 14) postimplantation. This is consistent with Litovsky et al (2006), who reported 60% in CI+CI scores in CNC words at 6 mo, and Eapen et al (2009), who reported 70% correct at a 4 yr point in time. However, Helms et al (1997) reported about 50% correct in monosyllable word recognition at 12 mo postimplantation in 25 CI-only subjects, and Hamzavi et al (2003) reported 41% correct for monosyllable words at 24 mo in 45 CI-only subjects. Ruffin et al (2007) reported the CNC performance for different age groups, which can be averaged from age 20 to 80 as 55% correct at 24 mo. Thus, it seems that CI+CI scores are 5–20% better than CI-only scores. We also observed that about one-third of the total number of subjects showed higher than 80% correct in CNC test.

However, a possible caveat to this comparison that should be considered is the technological change that might influence the performance. Krueger et al (2008) longitudinally followed more than 20 yr of CI-only patients and divided them into five groups according to device generation. The performance discrepancy is as big as about 45% between the earliest devices (around 10% correct) and the newest devices (around 55% correct) both at 12 mo postimplantation. The earliest devices were Nucleus 22 systems using an F0/F2 strategy while the newest devices were CII or HiRes90K (Advanced Bionics), Freedom (Cochlear), or C40+ and Pulsar (Med El) systems. The subjects in this study were using the newer devices. Thus, technology could be a contributing factor in the difference in scores shown between the CI+CI scores from our study and CI-only findings in the literature.

We also cannot overlook the influence of test materials. Research has shown that test materials can influence the range of results. Tyler et al (1997) discussed the difference in improvement with regard to duration of cochlear implant use due to the different test materials used. Wackym et al (2007) found that more challenging tests or test conditions can show more binaural benefits for bilateral cochlear implant patients compared to easier test conditions. It has also been proposed that we need specially designed tests for bilateral patients to adequately measure performance (Tyler et al, 2006).

Localization

As with word recognition, we observed that CI+CI subjects showed substantial improvement in localization over the first 1–12 mo postimplantation. We found that the greatest improvement in localization (decreased 7° RMS error scores) occurred after only 1 mo of implant use. This is similar to the improvement we witnessed with word recognition performance. However, with localization we observed additional improvements between 1 and 3 mo (decreased 5° RMS error scores) postimplantation after the greatest improvement found at 1 mo. With word recognition, we did not find as much improvement between 1 and 3 mo postimplantation. This is consistent with earlier work that showed benefits in localization for some postlingually deafened adults at 3 mo postimplantation (Tyler et al, 2002). Grantham et al (2007) found that the majority of their patients showed improvement in localization within 6 mo postimplantation, which they felt was faster growth than speech perception results. However, in our data, speech perception performance improves faster than localization although both listening skills improve significantly within 6 mo postimplantation.

Overall duration of improvement for localization was similar to word recognition. Major improvement occurred within 6 mo, and for some subjects localization improvement extended to 24 mo. When we compared pre-implant and 6 and 12 mo data in the same subjects (n = 13), we could find significant improvement up to 6 mo and an insignificant difference between 6 and 12 mo (p = .008) postimplantation performance. Grantham et al (2007) reported that many CI+CI subjects reached a plateau in performance around 4 to 6 mo for localization. On the other hand, Nopp et al (2004) indicated that some subjects showed extended improvement over 12 mo postimplantation. However, they reported that the major improvement still occurred within 12 mo, as similar to speech perception. Interestingly, Koch et al (2009) demonstrated no significant improvement in localization over time between 3, 6, and 12 mo with a group of CI+CI users.

After 24 mo postimplantation, our study showed that localization scores leveled off and were consistent with 72 mo postimplantation performance. However, if you look at individual data, we found several subjects who showed an extended improvement period up to 48 mo. Unlike with word recognition, there was no improvement present from 1 to 4 yr postimplantation.

In this study, we observed how the bilateral listening performance changed over time. This observation is important when tailoring rehabilitation programs for

CI+CI users. This study suggests that it might be beneficial to provide adult CI+CI users with focused auditory rehabilitation training during the first 12 mo postimplantation in an attempt to further increase the improvements that are seen naturally with general listening experience. However, a controlled comparison study of the benefits of auditory training in the early stages following implantation would be needed to directly show this benefit.

SUMMARY

In the present study, we observed many trends that were consistent with previous studies (Nopp et al, 2004; Dunn et al, 2005; Ching et al, 2007). In short, improvement patterns can vary. We found a range of performance with some subjects reaching a performance plateau at 1 mo postimplantation and others who continuously improved until 48 mo postimplantation. Although individual results showed a variety of performance, in general, the largest improvement occurred within 6 mo postimplantation for both localization and speech perception.

The results of this study can be valuable to counsel eligible candidates of simultaneous bilateral implantation preoperatively. In addition to this, these can be valuable information for the professionals who are planning postoperative aural rehabilitation program for this population.

In this study we looked at the bilateral performance over time and not necessarily the binaural advantage. This could provide some evidence of binaural advantages of simultaneous bilateral implantation albeit indirect. Future studies with specially designed tests looking at the binaural advantage over time would be interesting and beneficial.

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