Monaural or binaural sound deprivation in postlingual hearing loss: Cochlear implant in the worse ear

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Monaural or binaural sound deprivation in adults with postlingual hearing loss: unilateral cochlear implantation in the worse ear

ABSTRACT

Objectives: To determine whether speech recognition scores (SRS) differ between adults with long-term auditory deprivation in the implanted ear and adults who received a cochlear implant in the non sound-deprived ear either because hearing-aid-assisted or due to rapidly deteriorating hearing loss.

Methods: In this retrospective study, SRS at evaluations (3 and 14 months postimplantation) conducted with the cochlear implant alone at 60dB SPL intensity were compared in 15 patients (4 with bilateral severe hearing loss [HL], 11 with asymmetric HL, 7 of which with contralateral hearing aid), all with long-term auditory deprivation (11 monaural and 4 binaural; mean duration 16.9 years) (group A) and in 15 other patients with postlingual HL (10 symmetric and 5 asymmetric with bimodal stimulation) (controls, group B). SRS and duration of auditory deprivation were compared.

Results: Comparison of mean percentage of correctly recognized words on speech audiometry at 3 and 14 months showed improvement within each group ($P<0.05$). Between-group comparison showed no significant difference at 3 ($P=0.17$) or 14 months ($P=0.46$). Comparison of SRS in group A (bimodal stimulation [n=7] and binaural sound deprivation [n=4]) versus group B showed no significant differences in SRS at 3 (bimodal stimulation $P=0.16$; binaural sound deprivation $P=0.19$) or 14 months (bimodal stimulation $P=0.14$; binaural sound deprivation $P=0.82$).

Conclusions: SRS in monaural and binaural sound-deprived ears did not significantly differ from ears with unilateral cochlear implantation in non-sound deprived ears when tested with cochlear implant alone. Improvement in the implanted worse ear indicates that it could be a potential candidate ear for cochlear implantation even when sound deprived.

Keywords: Adults; Auditory deprivation; Choice of ear; Cochlear implant; Speech perception.

INTRODUCTION

Choosing the more appropriate ear for cochlear implantation remains a challenge for clinicians due to the lack of conclusive evidence-based recommendations. When hearing history and hearing aid use are consistent in both ears, the choice of which ear to implant is usually left to the preference of the patient or the surgeon (Morris et al., 2007). But in patients with a history of asymmetrical hearing, where one ear has been sound-deprived and the contralateral ear stimulated with a hearing aid (<50% speech recognition score in open set disyllabic words at 60 dB), which ear to implant becomes a critical choice and one not easily made.

Two different approaches can be taken. One is that the implant should be placed in the non-deprived ear to optimize outcomes when the implant is used alone (UK Cochlear Implant Study Group, 2004). The rationale behind this approach is that lack of auditory stimulation leads to often irreversible anatomical and physiological changes in the auditory pathway, with spiral ganglion degeneration and loss of neurosensorial cells, especially in the basal cochlea. Interruption of peripheral input leads to a loss of neural organization and population in the brainstem. Irreversible changes develop in the auditory pathway, resulting in auditory deprivation (Shepherd et al., 2006). Moreover, auditory deprivation can cause reorganization of the auditory cortex, leading to changes in tonotopic frequency maps (Salvi et al., 2000; Couchman et al., 2011).

But even after many years of auditory deprivation, electric stimulation of a surviving neural population of less than 5% in the spiral ganglion can allow the synaptic genesis and transmission of action potential, which has features similar to potentials spreading in normal cells (Shepherd et al., 2006). These observations support the second approach: placing a cochlear implant in the sound-deprived ear to minimize the risk of destroying useable hearing, maintain hearing aid use in the non-deprived ear (Francis el al., 2005), and maximize the potential use of binaural hearing (Perreau et al., 2007).

The duration of auditory deprivation in the implanted ear is a negative predictive factor for auditory rehabilitation (Lazard et al., 2011; Lazard et al., 2012). A study (Boisvert et al., 2012) reported statistically significant poorer performance by individuals implanted in the sound-deprived ear as compared with individuals implanted in the non-deprived ear, using the implant alone. Improved performance was noted when patients were tested in their usual listening condition (contralateral hearing aid and cochlear implant in combination).

Evidence-based recommendations are lacking, however. The aim of this retrospective study was to determine whether speech recognition scores (SRS) differ between adults with long-term auditory deprivation in the implanted ear and adults who received a cochlear implant in the non-sound-deprived ear.

MATERIALS AND METHODS

The study population was 30 adults with bilateral severe to profound sensorineural hearing loss and speech recognition scores ≤50% for Italian open-set disyllabic words presented at 60 dB sound pressure level (SPL) in quiet in the best-aided condition after evaluation of optimal hearing aid fitting. The mean age at the time of implantation was 52.7 years (range 26-78). All patients underwent unilateral cochlear implantation at the ENT Department, Città della Salute e della Scienza; University of Torino between 2010 and 2013.

Preoperative petromastoid computed tomography and brain magnetic resonance imaging scans were obtained to evaluate internal ear anatomy. The cochlear implant was activated within the first month postoperative. No complications were reported. The cochlear implant was fit by a single audiologist and the rehabilitation program was carried out by a single speech therapist. Pure tone audiometry and speech recognition tests were performed regularly by a single audiologist using the same instrumentation. Four different implant devices were used: Advanced Bionics, XXX [n=1]; Cochlear, XXX [n=3]; Med El, XXX [n=24]; Neurelec XXX [n=2]. Two groups of 15 patients each were formed according to whether the patient had received a cochlear implant in the sound-deprived ear (group A) or the non-deprived ear (group B).

Patients

Group A was composed of 15 patients with a cochlear implant in the sound-deprived ear (11 females, 4 males; mean age 54.2±28.3; range 35-78). Sound deprivation refers to a condition in which the auditory system receives no auditory input for a considerable period; the duration of sound deprivation is the time in years since the onset of severe hearing loss and cannot be improved with a hearing aid. The mean length of auditory deprivation was 16.9±12.5 years (standard deviation [SD], range 3-40). Four patients (26.7%) had pre- or perilingual bilateral severe hearing loss, had been fit with bilateral hearing aids at the age of 1 to 3 years and wore them until they became unserviceable; they had bilateral and symmetrical auditory deprivation before implantation (the choice of which ear to be implanted depended on the patient's or the surgeon's preference). Seven patients (46.6%) wore a contralateral hearing aid (bimodal stimulation). Three patients had stopped wearing their hearing aid in the contralateral ear. Eleven (75%) patients reported successful use of lip reading in everyday life since the onset of significant hearing loss. One patient had a mild cochlear malformation with hypoplasia and incomplete cochlear partition, so that only 9 electrodes out of 12 (medium-size electrodes) could be correctly inserted in the cochlea. The mean pure tone audiometry (PTA) threshold at 500 – 1000 – 2000 Hz was 113.22±11.78 dB in the implanted ear and 103.08±24.05 dB in the contralateral ear. The mean PTA threshold in the hearing-aid-assisted ear in the patients with bimodal stimulation was 93.10±28.66 dB. Table 1 presents the clinical characteristics of this group.

Group B (controls) was composed of 15 patients with a cochlear implant in the non-deprived ear (8 females, 7 males; mean age 51.1±14.3 years; range 26-75). Before implantation they had symmetrical hearing loss, progressive hearing loss or received an implant within a few months after the onset of severe hearing loss. Five patients (33.3%) used bimodal stimulation with subjective benefit. The PTA threshold at 500 – 1000 – 2000 Hz was 101.54±16.15 in the implanted ear and 84.62±24.59 in the contralateral ear. The mean PTA threshold in the hearing-aid-assisted ear (with bimodal stimulation) was 84.00±21.97. Table 2 presents the clinical characteristics of this group.

Measures

Speech recognition tests were performed following the same protocol in all patients at 3 months (first follow-up) and at 14 months (second follow-up) postimplantation. The tests were conducted with the cochlear implant alone, without the contralateral hearing aid if used, and masking the contralateral ear with white noise if residual hearing present. The proportion of correctly recognized words from disyllabic word lists was noted; the patients were presented 20 recorded disyllabic words at 60 dB SPL in a quiet room via a loudspeaker placed 1 m in front of them. They were asked to repeat the words heard. All tests were performed by a single audiologist.

The average proportion of correctly recognized words at the first follow-up and the second follow-up was recorded. One patient in group A (6.7%) was unable to perform the speech recognition test at the first follow-up.

Statistical Analysis

Data are presented as mean, standard deviation, and median due to non normal distribution of the variables. Differences between the SRS at the first and second follow-up examinations were tested using the nonparametric Wilcoxon signed rank test. Differences between SRS for patients with and without auditory deprivation were tested using the nonparametric Wilcoxon sum rank test. Correlation was tested using Spearman's correlation coefficient. All statistical tests were performed two-sided and the significance level was set at 0.05. Analyses were performed using SAS V9.2.

RESULTS

Within group comparison of speech recognition scores

There was a significant difference between the average SRS at the first and the second follow-up evaluations, with better scores at 14 months after implantation in both groups (P=0.0002 and P=0.0001 for group A and group B; respectively) (Table 3).

Between-group comparison of speech recognition scores

There were no statistical differences in the average SRS between the two groups at the first follow-up evaluation (P=0.17), though a slightly better performance was noted for group B (0.66 [0.19] versus 0.55 [0.26]). The difference between scores was greater, albeit not significant, at the second follow-up evaluation (0.86 [0.2] versus 0.84 [0.16]; P=0.46) (Table 3).

Comparison between speech recognition scores in bimodal and bilateral hearing-deprived patients

The group A patients were further divided into two subgroups: one group (n=7) used bimodal stimulation in everyday life and were tested with the CI alone. No statistical difference was noted between their SRS and those of the group B patients at either the first or the second follow-up evaluation (P=0.16 at 3 months; P=0.14 at 14 months) (Table 4). The other subgroup included bilateral hearing-deprived patients (n=4, with pre- or perilingual hearing loss). No statistical difference was found between their SRS and those of the group B patients (P=0.19 at 3 months; P=0.82 at 14 months) (Table 5).

Speech recognition scores and duration of auditory deprivation

Spearman's correlation test was applied to determine whether a relationship existed between duration of auditory deprivation and speech recognition performance of group A (Fig. 1). No significant correlation was found at evaluation either at 3 or 14 months, though a negative trend for SRS was observed at the second follow-up (Fig. 1, panel B), with lower SRS the longer the duration of auditory deprivation (at 3 months R=0.22, P=0.43; at 14 months R=-0.23; P=0.40). Spearman's correlation test was then applied to determine whether the differences between the scores obtained at the first follow up and at the second follow up were influenced by the duration of auditory deprivation. The difference in scores obtained at the two follow-up evaluations and duration of auditory deprivation was not statistically significant but showed an obvious negative trend (R=-0.46; P=0.09) (Fig. 2).

DISCUSSION

Clinical practice has tended to act on the premise that poorer hearing outcomes are obtained when implanting a long-term sound-deprived ear (Lazard et al., 2012). The main objective of this study was to compare the SRS of patients receiving a cochlear implant (CI) in the sound-deprived ear with those of patients implanted without a history of auditory deprivation. Residual hearing in one ear may maintain a basal level of cortical metabolic activity bilaterally, which may correlate with good SRS after cochlear implantation (Boisvert et al., 2011). This is supported by auditory evoked potential studies showing an increase in activation of the ipsilateral hemisphere to stimulation in unilaterally deaf individuals as compared with normal-hearing subjects (Ponton et al., 2001). Boisvert (Boisvert et al., 2011), referring to the implanted ear, found no significant correlation between SRS and duration of auditory deprivation, percentage of lifetime auditory deprivation, and duration of sound stimulation before deprivation. Our results confirm these observations: within-group comparison of SRS at 3 and 14 months showed considerable and statistically significant improvement in both groups (p=0.0002 and p=0.0001, respectively). There was no significant difference in SRS between group A (CI in the sound-deprived ear) and group B (CI in the non-sound-deprived ear) at either follow-up assessment (Table 3), suggesting a similar development of learning in the hearing-deprived and the non deprived and a similar hearing improvement with time spent using the CI.

However, in a previous study (Boisvert et al., 2012) poorer results were observed in monaural deprived patients using a contralateral hearing aid when they were assessed with the CI alone. The patients with a CI in the aided ear performed significantly better than those with CI in the sound-deprived ear when tested with the CI alone; the results were similar in the hearing-deprived and the non-deprived only when testing was performed in usual listening conditions, fitted with a contralateral hearing aid in the patients used to wearing it. Moreover, 3 hearing-deprived patients stopped using the CI and preferred using only the hearing aid alone. In contrast, we found that even in the 7 patients with bimodal stimulation (one subgroup A) the SRS obtained using the CI alone did not differ from the SRS obtained by the group B patients (P=0.16 at 3 months; P= 0.14 at 14 months); none of these 7 patients stopped using their CI.

Strong correlations have been reported between SRS and duration of bilateral significant hearing loss, percentage of lifetime bilateral significant hearing loss, and duration of stimulation before onset of bilateral significant hearing loss, (Boisvert et al., 2011; Matterson et al., 2007). These studies underscore the role of overall auditory deprivation and support the idea that the most important factor in cochlear implantation is bilateral hearing deprivation. In our study, 4 patients (other subgroup A) had pre- or perilingual bilateral hearing loss and long-term bilateral deprivation. Their SRS were initially lower than those of group B at 3 months (0.40 versus 0.66) but became similar at 14 months (0.85 versus 0.86). The differences were not statistically significant at either assessment (P=0.19 at 3 months; P=0.82 at 14 months). This observation raises the question whether poor outcomes are to be expected in individuals with prelingual deafness (Su et al., 2004) and bilateral auditory deprivation (Blamey et al., 1996). Our patients could be successfully implanted because the auditory pathways were stimulated with hearing aids for severe hearing loss in early childhood; thus the stimulation of the auditory pathway occurred during the so-called “critical period”, between the second and third years of life, when sound stimuli must reach the auditory pathway in order to create the basic organization of the central auditory system (Ryugo et al., 2009). Moreover, the majority of our patients (75%) who received a CI in the sound-deprived ear had developed good lip reading ability, which may be considered a positive predictive factor good outcome. It has been demonstrated that degraded phonological representation correlates with low speech recognition performance after cochlear implantation. Lip reading can maintain auditory memory alive, so that visual-sound correspondences in the postimplant period are easily rebuilt (Tyler et al., 1996).

Finally, a negative, albeit non significant correlation emerges between the duration of auditory deprivation and the improvement in the SRS of group A between 3 and 14 months. This suggests that long-term auditory deprivation has a greater negative effect on the development of learning: the longer the duration of auditory deprivation, the less the improvement in speech recognition.

In conclusion, our findings suggest that outcomes after cochlear implantation in the sound-deprived and in the non-sound-deprived ear are similar. There were no significant differences in SRS between the long-term sound-deprived patients with bimodal stimulation and the non-sound-deprived patients, even when tested with the CI alone. However, we found that the longer the duration of auditory deprivation, the less the improvement in SRS at 14 months. These results may have implications in guiding preoperative decision of surgery. Monaural and binaural auditory deprivation are not necessarily contraindications to cochlear implantation, though a CI should be placed as soon as possible after the onset of severe hearing loss.

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Tables and figures

TABLE 1. Clinical characteristics of the auditory-deprived adults (group A).

Age at CI	CI ear	Sex	Cause (onset)	Use of hearing aids in past	Years of auditory deprivation**	Electrode insertion
35	right		prenatal CMV infection (perilingual)	bilateral since age 3 ys	15	CP
38	right°		unknown (prelingual)	bilateral since age 1 y	25	RW
43	right*		unknown	never used	22	RW
44	left		congenital malformation (prelingual)	bilateral since age 2ys	5	RW
45	left		middle ear infections	bilateral	5	RW
47	right		unknown (prelingual)	bilateral since age 3 ys	3	CP
49	left		viral infection	bilateral	6	CP
53	right°		sudden hearing loss	bilateral	5	CP
56	left°		ototoxicity	bilateral	40	CP
61	left°		unknown	contralateral	10	RW
62	right		unknown	never used	10	CP
65	left°		sudden hearing loss	bilateral	30	CP
67	left°		otosclerosis	contralateral	16	CP
70	right*		unknown	bilateral	21	RW
78	left°		middle ear infections	contralateral	40	RW

* bilateral CI refers to patients with cochlear implant placed in the sound-deprived ear.

°bimodal stimulation

**time spent in absolute absence of auditory input in the implanted ear

CP= cochlear promontory RW = round window

TABLE 2. Clinical characteristics of the non- auditory-deprived adults (group B).

Age at CI	CI ear	Sex	Cause	Hearing aid experience	Electrode insertion
26	left		unknown	bilateral (for 20 years) until CI	CP
32	right°		MELAS syndrome	bilateral until CI	CP
37	left°		unknown	bilateral (for 5 years) until CI	CP
37	left°		middle ear infections	contralateral	CP
42	right		middle ear infections	bilateral (for 2 years) until CI	CP
45	right		Ménière’s disease	never used	CP
51	left		ototoxicity	never used	CP
53	right		Ménière’s disease	never used	RW
53	right		sudden hearing loss	ipsilateral (for 8 years) until CI	CP
58	left		unknown	contralateral until CI	CP
63	right°		sudden hearing loss	bilateral until CI	CP
64	right		otosclerosis	never used	CP
65	left		middle ear infection	bilateral (for 40 years) until CI	CP
66	right°		unknown	bilateral until CI	CP
75	right		unknown	contralateral until CI	CP

° bimodal stimulation; CP denotes cochlear promontory; RW round window

MELAS syndrome: Mitochondrial myopathy, encephalopathy, lactic acidosis, and stroke

TABLE 3. Comparison of speech recognition scores within the auditory-deprived group and the non-auditory-deprived group separately and between the two groups at each follow up exam.

	Auditory-deprived	Non-auditory-deprived	P-value**
Percentage of recognized words at 3 months (SD)	0.55 (0.26)/ 0.60	0.66 (0.19) / 0.70	0.17
Percentage of recognized words at 14 months (SD)	0.84 (0.16)/ 0.90	0.86 (0.20) / 1.00	0.46
P-value*	0.0002	0.0001	

SD standard deviation.

The percentage of recognized words at 60 dB SPL.

Data are presented as the means ±SD/ median.

*Performed with the Wilcoxon signed rank test.

**Performed with the Wilcoxon sum rank test.

TABLE 4. Comparison between the speech recognition scores in the auditory-deprived patients normally using bimodal hearing and the scores in the non-auditory-deprived patients.

	No. of patients	Percentage of recognized words at 3 months (SD)	Percentage of recognized words at 14 months (SD)
D bimodal	7	0.53 (0.27) / 0.50	0.77 (0.16) / 0.80
Non-auditory-deprived	15	0.66 (0.19) / 0.70	0.86 (0.20) / 1.00
P-value		0.16	0.14

D bimodal refers to auditory-deprived patients who normally use bimodal hearing but tested wearing the CI alone.

Data are presented as the means ±(SD/ median.

Performed with the Wilcoxon sum rank test.

TABLE 5. Comparison between speech recognition scores of the patients with bilateral auditory deprivation and scores of the non-auditory-deprived patients.

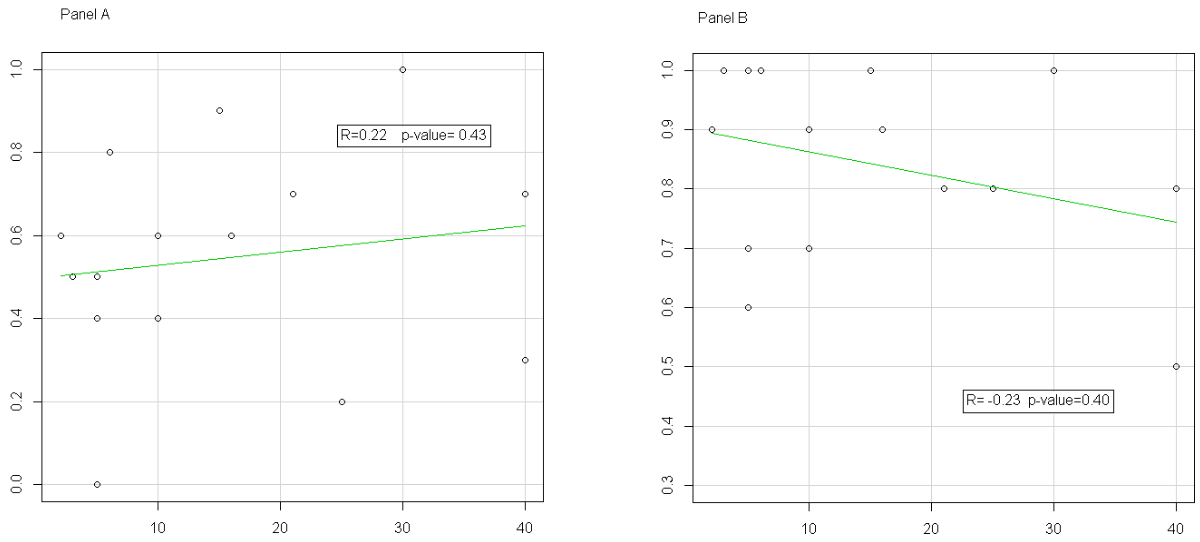
	No. of patients	Percentage of recognized words at 3 months (SD)	Percentage of recognized words at 14 months (SD)
Bilateral D	4	0.40 (0.39) / 0.35	0.85 (0.19) / 0.90
Non-auditory-deprived	15	0.66 (0.19) / 0.70	0.86 (0.20) / 1.00
P-value		0.19	0.82

Bilateral D refers to patients with bilateral auditory deprivation.

Data are presented as the means ±SD/ median.

Performed with the Wilcoxon sum rank test

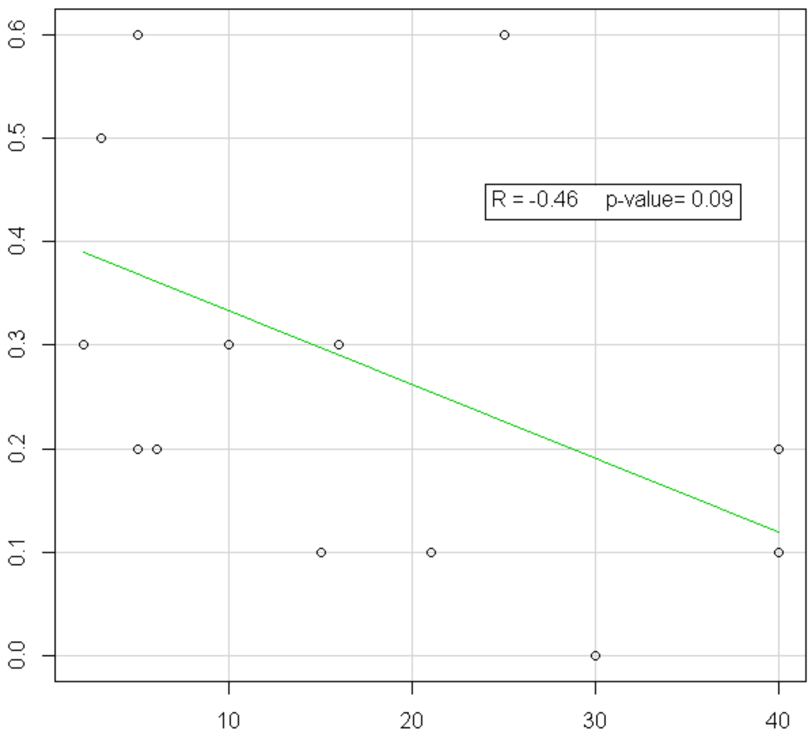
Figure 1.



Panel A: Correlation between years of auditory deprivation and speech recognition scores at 3 months after implantation.

Panel B: Correlation between years of auditory deprivation and speech recognition scores at 14 months after implantation.

Figure 2.



Spearman's correlation between differences in scores obtained through follow up (3-14 months) and duration of auditory deprivation.