

Bilateral Cochlear Implantation for Children in Nagasaki, Japan

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Objectives. The number of patients with bilateral cochlear implant (CI) has gradually increased as patients and/or parents recognize its effectiveness. The purpose of this report is to evaluate the efficacy of 29 bilateral CI out of 169 pediatric CI users, who received auditory-verbal/oral habilitation at our hearing center.

Methods. We evaluated the audiological abilities 29 Japanese children with bilateral CIs including wearing threshold, word recognition score, speech discrimination score at 1 m from front speaker (SP), 1 m from second CI side SP, speech discrimination score under the noise (S/N ratio=80 dB sound pressure level [SPL]/70 dB SPL, 10 dB) at 1 m from front SP, word recognition score under the noise (S/N ratio=80 dB SPL/70 dB SPL, 10 dB) at 1 m from front SP.

Results. Binaural hearing using bilateral CI is better than first CI in all speech understanding tests. Especially, there were significant differences between the results of first CI and bilateral CI on SDS at 70 dB SPL ($P=0.02$), SDS at 1 m from second CI side SP at 60 dB SPL ($P=0.02$), word recognition score (WRS) at 1 m from second CI side SP at 60 dB SPL ($P=0.02$), speech discrimination score (SDS) at 1 m from front SP under the noise (S/N=80/70; $P=0.01$) and WRS at 1 m from front SP under the noise (S/N=80/70; $P=0.002$). At every age, a second CI is very effective. However, the results of under 9 years old were better than of over 9 years old on the mean SDS under the noise (S/N=80/70) on second CI ($P=0.04$). About use of a hearing aid (HA) in their opposite side of first CI, on the WRS and SDS under the noise, there were significant differences between the group of over 3 years and the group of under 10 months of HA non user before second CI.

Conclusion. These results may show important binaural effectiveness such as binaural summation and head shadow effect. Bilateral CI is very useful medical intervention for many children with severe-to-profound hearing loss in Japan as well as elsewhere.

Key Words: Cochlear implant, Children, Bilateral, Binaural, Binaural summation, Head shadow effect, Japan

INTRODUCTION

The clinical effects of both unilateral and bilateral cochlear implantation (CI) in children is well established internationally (1-

15), but there are only a few reported cases of bilateral CI in Japan. The number of patients with bilateral CI has gradually increased as patients and/or parents recognize its effectiveness. The following are some of the bilateral CI cases in children that we have experienced. This is a review of bilateral CI in 169 pediatric CI users, who received auditory-verbal/oral habilitation at our clinic.

This study's aim is to obtain answers to the following questions. 1) Until what age the second CI is effective for better language perception in various situations? 2) Does the use of a hearing aid (HA) on the opposite side of first CI affect the re-

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sults after second CI? 3) Is there any critical time span between the first and second CI for their progress in language perception? 4) What is the advantage of bilateral CI over unilateral CI?

MATERIALS AND METHODS

Subjects

Since we started CI surgery in 1997, out of 169 children undergoing CI rehabilitation in our clinic, 29 children (17%) had bi-

lateral CI for at least half a year before May 2011. The age of the children at the first CI operation ranged from 1 year 4 months to 15 years 5 months, whereas the age of children at the second CI operation ranged from 2 year 1 month to 15 years 10 months (Fig. 1). The most common age for the first CI was 1 or 2 years. The interval between first and second CI fitting ranged from 5 months to 10 years 1 month. This can be considered a relatively wide range, but the most frequent interval between the two CIs was under 1 year (Fig. 2). The period on non-use of their HA before the second CI is also valuable: it ranges from 0 month to

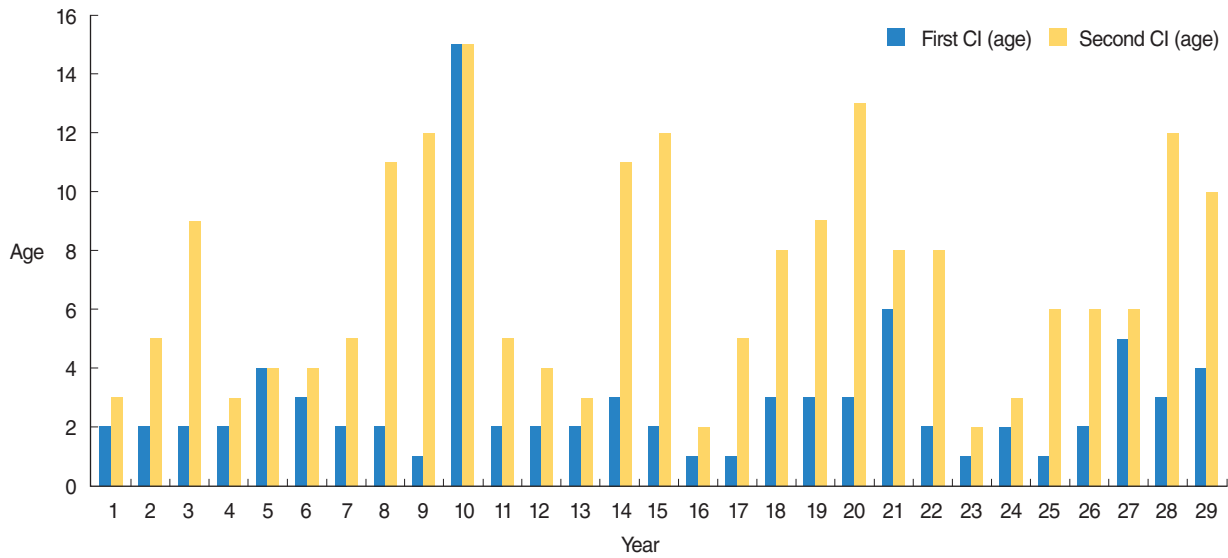


Fig. 1. Age at operation of first cochlear implantation (CI) and second CI (year).

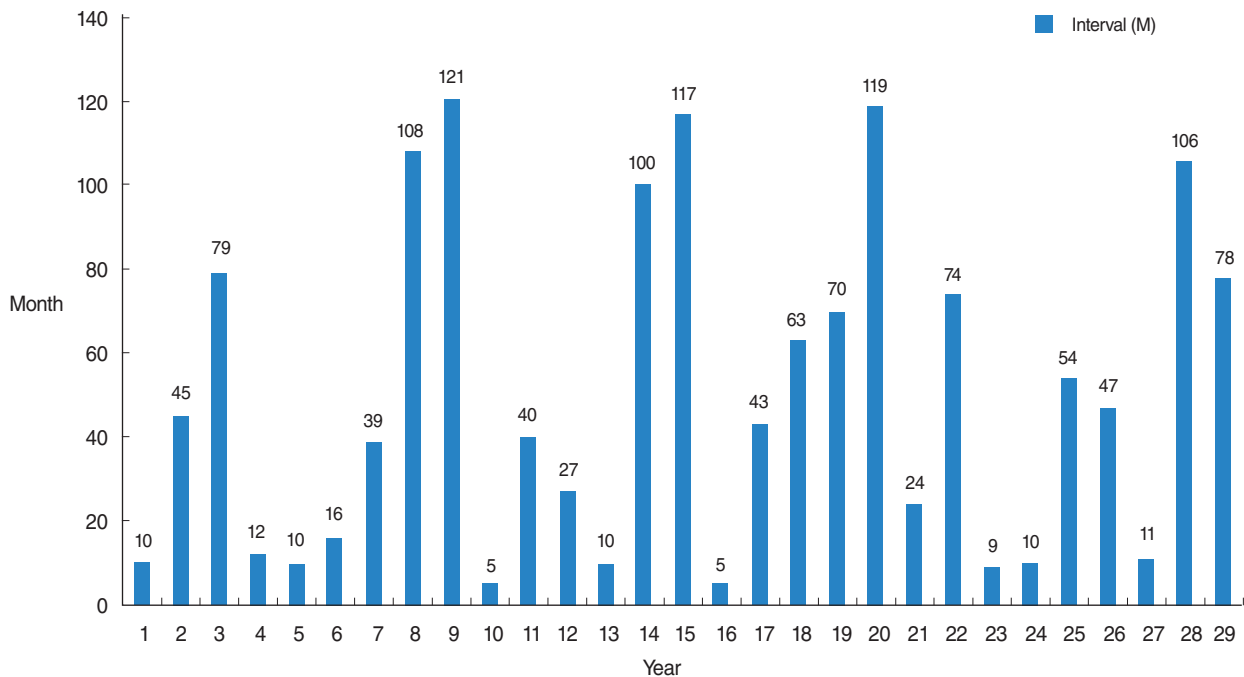


Fig. 2. Interval between first and second cochlear implantation (month).

108 months (9 years). Twelve cases did not remove their HA before the second CI (Fig. 3). Causes for deafness were described in Fig. 4. The devices used are described in Fig. 5.

We examined 19 children who acquired language with either CI or HA using various audiological tests. Children with severe anomaly or late development were not included. The children were divided into 2 groups to evaluate the amount of habilitation time after the second CI. The first group (group A) consisted of 11 children who had their second CI for at least a year. The second group (group B) included 8 children who had their second CI between 6 and 12 months.

Methods

We evaluated audiological abilities including 1) wearing threshold (WTH); 2) word recognition score (WRS, TY-89; Japanese-3 syllabic word-CD, at 60 dB sound pressure level [SPL], at 70 dB SPL); 3) speech discrimination score (SDS, 67-S; Japanese-monosyllabic word-CD, at 60 dB SPL, at 70 dB SPL) at 1 m from front speaker (SP), 1 m from second CI side SP; 4) SDS under noise (67-S; Japanese-monosyllabic word-CD, S/N ratio=80 dB SPL/70 dB SPL, 10 dB) at 1 m from front SP; 5) WRS under noise (TY-89; Japanese-3 syllabic word-CD, S/N ratio=80 dB SPL/70 dB SPL, 10 dB) at 1 m from front SP (noise: speech noise). We conducted all tests in a shielded room. Statistical analysis was done using the Student's *t*-test and paired *t*-test.

RESULTS

The mean WTH using first CI, second CI, and bilateral CI shows that all WTH is nearly the same ranging from 25 dB hearing level (HL) to 35 dB HL (Fig. 6). There were no significant differences between them. The mean WTH of their HA before the second CI was from 55 dB HL (for lower frequencies) to 65 dB HL (for higher frequencies). However, after operation the mean WTH using second CI ranges from almost 30 dB HL to 35 dB HL. There were significant difference ($P=0.03^*$) between HA and

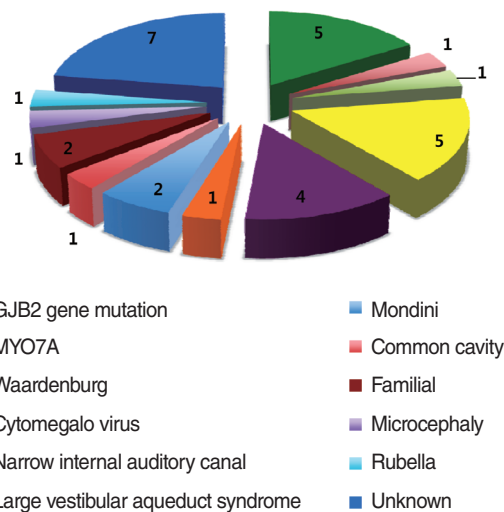


Fig. 4. Causes for deafness.

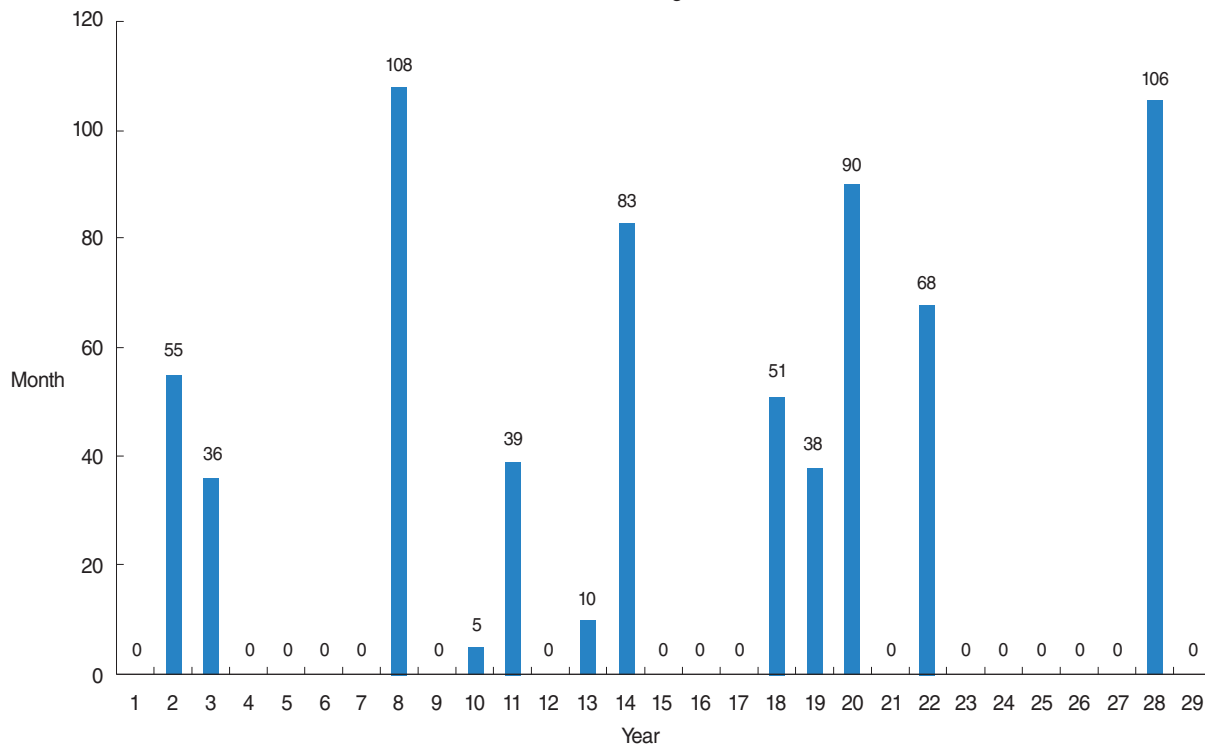
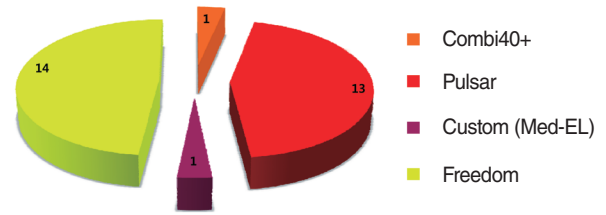
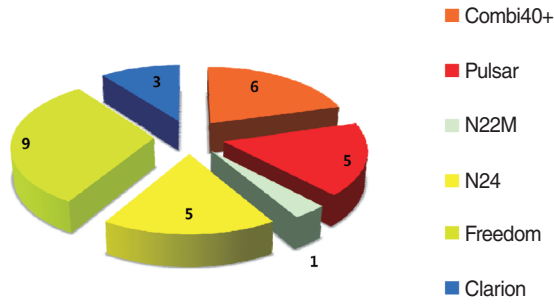


Fig. 3. Number of months child discontinued hearing aid use before second cochlear implantation.



A

B

Fig. 5. Device of first cochlear implantation (CI) (A) and second CI (B).

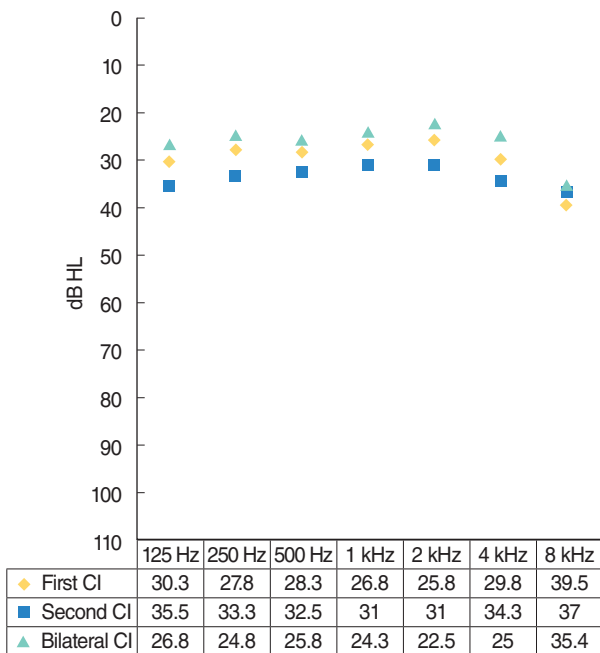


Fig. 6. The mean wearing threshold using first cochlear implantation (CI), second CI, and bilateral CI.

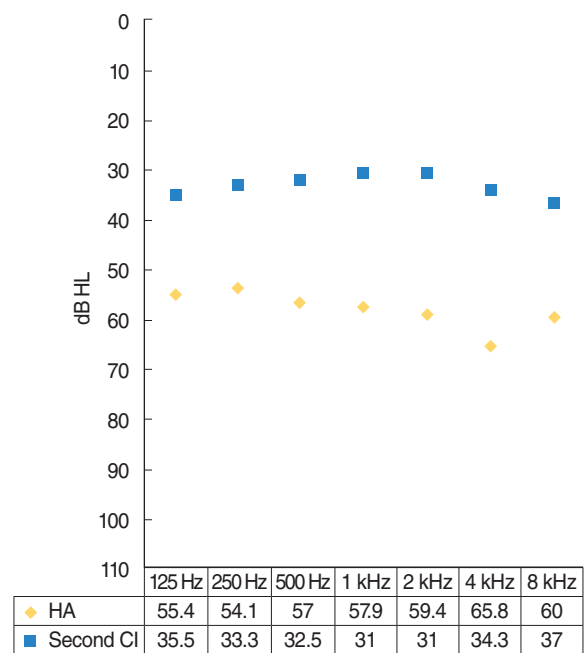


Fig. 7. The mean wearing threshold of their hearing aid (HA) before second cochlear implantation (CI) and second CI.

second CI (Fig. 7).

The mean WRS at 1 m from the front SP at 70 dB SPL is shown in Fig. 8. The mean score for the second CI in group A was similar to the mean score for the first CI. The mean score on the WRS for all cases shows that there were no significant differences between the results of the first CI and the bilateral CI at 70 dB SPL ($P=0.13$).

The mean WRS at 1 m from the front SP at 60 dB SPL is described in Fig. 9. The mean score for the second CI in group A was similar to the mean score for the first CI. For all cases, there were no significant differences between the results of the first CI and bilateral CI at 60 dB SPL ($P=0.05$).

The mean SDS at 1 m from the front SP at 70 dB SPL is described in Fig. 10. The mean score for the second CI in group A was similar to the mean score for the first CI. The SDS results show that there were significant differences between the results

of the first CI and the bilateral CI at 70 dB SPL ($P=0.02^*$).

The mean SDS at 1 m from the front SP at 60 dB SPL is described in Fig. 11. There were no significant differences between the results of the first CI and the bilateral CI at 60 dB SPL ($P=0.24$).

The mean SDS at 1 m from the second CI side SP at 70 dB SPL is described in Fig. 12. The mean score for the second CI in group A was similar to the mean score for the first CI. There were no significant differences between the results of the first CI and the bilateral CI at 1 m from the second CI side SP on all cases at 70 dB SPL ($P=0.25$).

The mean SDS at 1 m from the second CI side SP at 60 dB SPL is described in Fig. 13. The mean score for second CI in group A was superior to the mean score for first CI. There were significant differences between the results of first CI and bilateral CI at 1 m from second CI side SP on all cases at 60 dB SPL ($P=0.02^*$).

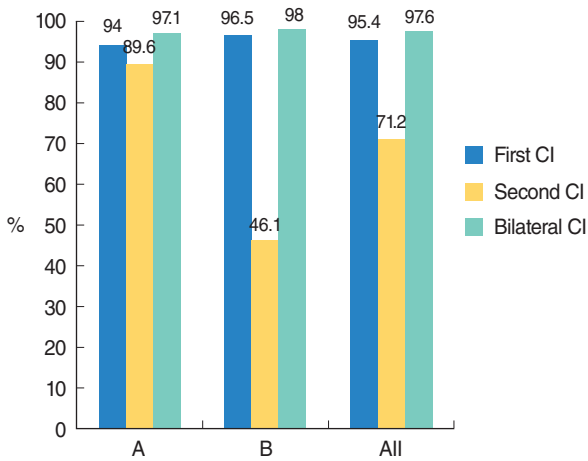


Fig. 8. Mean word recognition score at 1 m from front speaker at 70 dB SPL (0.13). CI, cochlear implantation; SPL, sound pressure level.

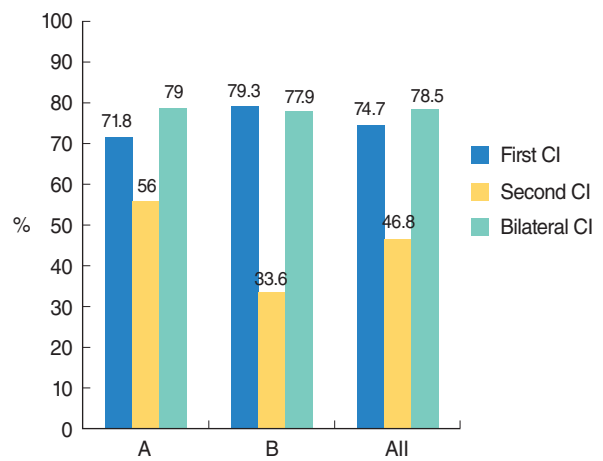


Fig. 11. Mean speech discrimination score at 60 dB SPL ($P=0.24$). CI, cochlear implantation; SPL, sound pressure level.

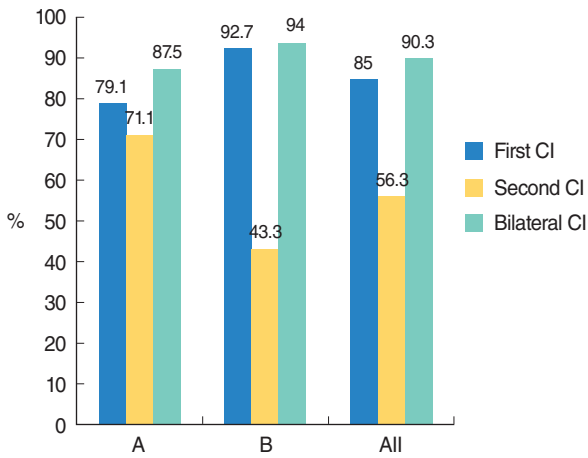


Fig. 9. Mean word recognition score at 1 m from front speaker at 60 dB SPL ($P=0.05$). CI, cochlear implantation; SPL, sound pressure level.

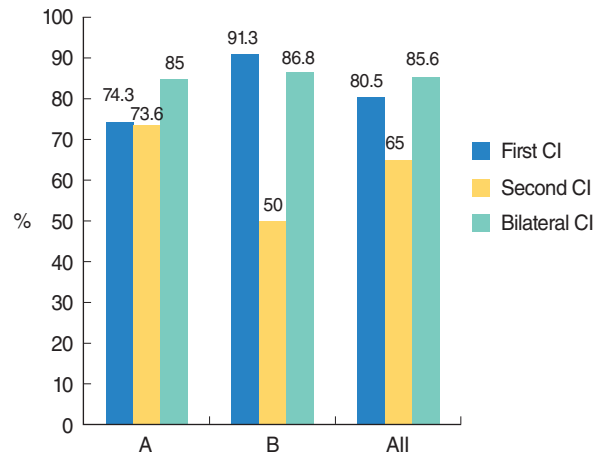


Fig. 12. Mean speech discrimination score at 1 m from second cochlear implantation (CI) side speaker at 70 dB SPL ($P=0.25$). SPL, sound pressure level.

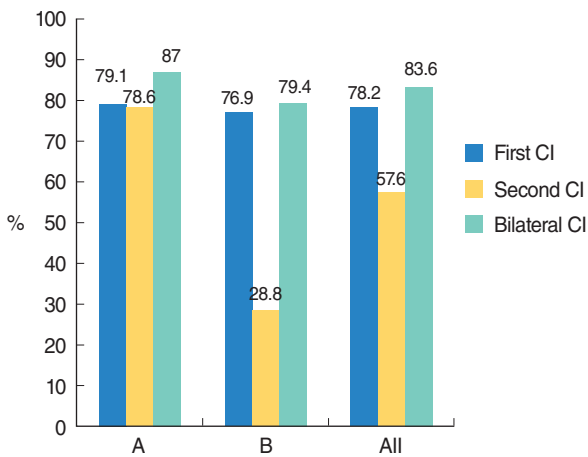


Fig. 10. Mean speech discrimination score at 70 dB SPL ($P=0.02^*$). CI, cochlear implantation; SPL, sound pressure level.

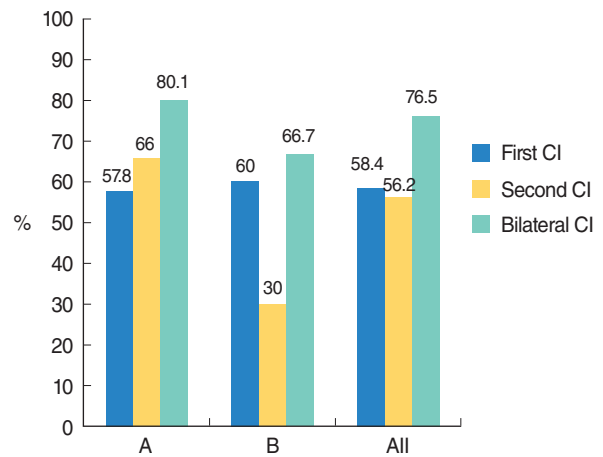


Fig. 13. Mean speech discrimination score at 1 m from second cochlear implantation (CI) side speaker at 60 dB SPL ($P=0.02^*$). SPL, sound pressure level.

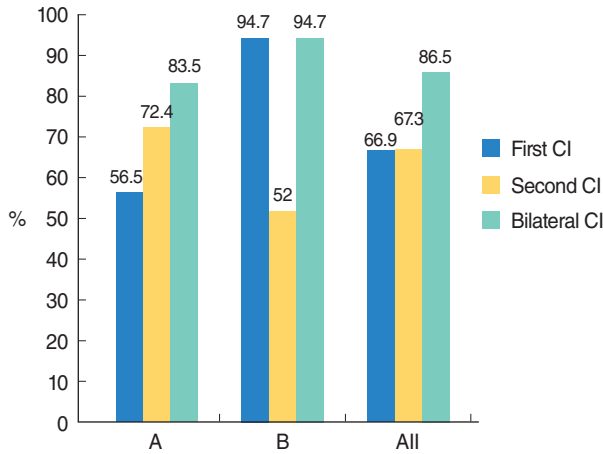


Fig. 14. Mean word recognition score at 1 m from second cochlear implantation (CI) side speaker at 60 dB SPL ($P=0.02^*$). SPL, sound pressure level.

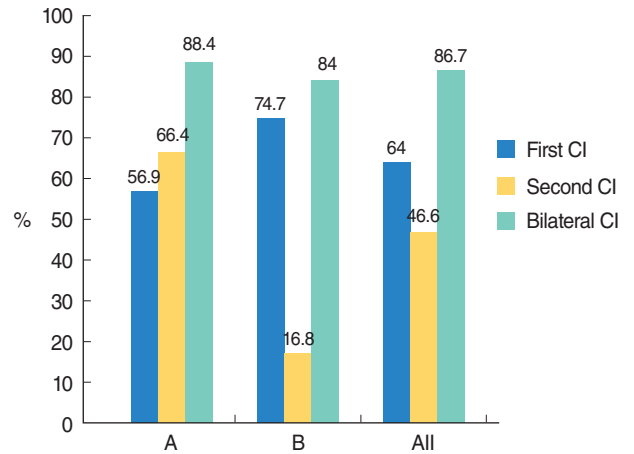


Fig. 16. Mean word recognition score at 1 m from front speaker under the noise ($S/N=80/70, +10; P=0.002^{**}$). CI, cochlear implantation.

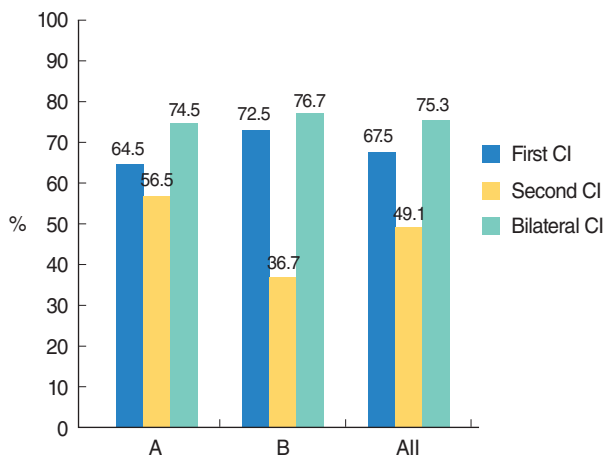


Fig. 15. Mean speech discrimination score at 1 m from front speaker under the noise ($S/N=80/70, +10; P=0.01^*$). CI, cochlear implantation.

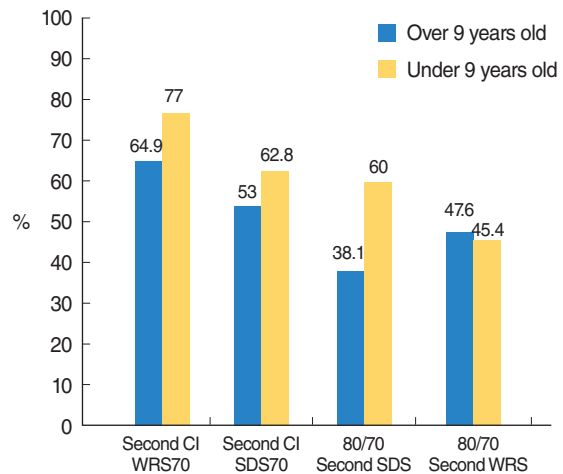


Fig. 17. Comparison of the mean word recognition score (WRS) and speech discrimination score (SDS), at 70 dB SPL at 1 m from front speaker, the mean SDS and WRS under the noise ($S/N=80/70$) on second cochlear implantation for over and under 9 years old. SPL, sound pressure level.

The mean WRS at 1 m from second CI side SP at 60 dB SPL were described in Fig. 14. The mean score for second CI in group A was superior to the mean score for first CI. There were significant differences between the results of first CI and bilateral CI at 1 m from second CI side SP on all cases at 60 dB SPL ($P=0.02^*$).

The mean SDS at 1 m from front SP under the noise ($S/N=80/70, +10$) were described in Fig. 15. The mean score for second CI in group A was similar to the one for first CI. There were significant differences between the results of first CI and bilateral CI under the noise at 1 m from front SP on all cases ($P=0.01^*$).

The mean WRS at 1 m from front SP under the noise ($S/N=80/70, +10$) were described in Fig. 16. The mean score for second CI in group A was superior to the mean score for first CI. In all cases, there were significant differences between the results of first CI and bilateral CI under the noise at 1 m from front SP ($P=0.002^{**}$).

We attempted to determine until what age the second CI is effective for better language perception in various situations. We

compared the results of over 9 years old with the results of under 9 years old, analyzing the mean WRS and SDS at 70 dB SPL at 1 m from the front SP, the mean SDS and WRS under the noise ($S/N=80/70$) on second CI (Fig. 17). The mean SDS under the noise ($S/N=80/70$) for the second CI ($P=0.04^*$) shows significant differences between the over 9 years old and the under 9 years old.

We compared children that had not used their HA for over 3 years before the second CI with those that had used their HA within 10 months before the second CI using various speech understanding tests (Fig. 18). The mean WRS and SDS revealed better scores for HA usage within 10 months before the second CI than for those who stopped using their HA 3 years or more before the second CI. Especially on the WRS and SDS under the noise, there were significant differences between these two groups ($P=0.01^*$ on SDS and $P=0.04^*$ on WRS).

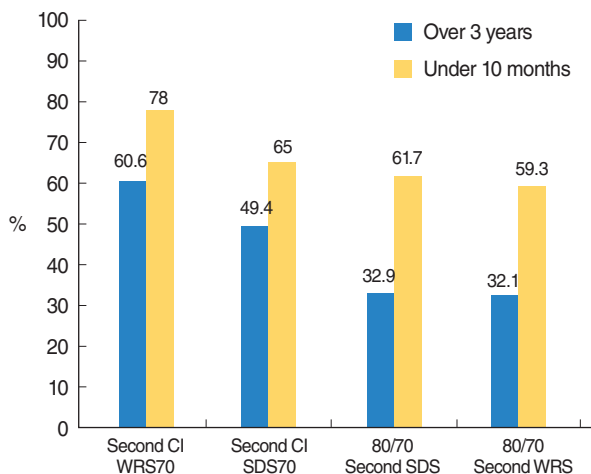


Fig. 18. Comparison of the mean word recognition score (WRS) and speech discrimination score (SDS) at 70 dB SPL at 1 m from front speaker, the mean SDS and WRS under the noise (S/N=80/70) on second cochlear implantation (CI) for those that had not used their hearing aid (HA) for over 3 years before second CI with those that had used their HA within 10 months before second CI. SPL, sound pressure level.

DISCUSSION

In all children, the WTH using the second CI was almost the same using the first CI ranging from 25 to 35 dB HL. Also, the WTH using the second CI recovered compared to the WTH using HA before their second CI ($P=0.03^*$). A previous report (6) also describes that aided thresholds give better performance.

At every age, a second CI is very effective. However, the results of under 9 years old were better than the results of over 9 years old on the mean SDS under noise (S/N=80/70) on the second CI ($P=0.04^*$). These results may be due to brain plasticity of the children for acquiring speech understanding under the noise (10, 14).

About use of a HA in their opposite side of first CI, on the WRS and SDS under the noise, there were significant differences between the group of over 3 years and the group of under 10 months of HA non user before second CI ($P=0.01^*$ on SDS and $P=0.04^*$ on WRS). We recommend wearing hearing aids on the opposite side after first CI. As the Japanese language uses lower frequencies, a little wearing threshold of usable frequencies remains. Also, the input from the hearing aid is very important. It is a waste to remove the HA and let the input on the opposite side of the first CI.

Most of the speech understanding scores (WRS and SDS) for children who have undergone at least 1 year habilitation after first CI and now have been fitted with a second CI show similar results to the first CI. Though the second CI eventually caught up with the first CI, it took nearly over one year.

Binaural hearing using bilateral CI is better than the first CI in all speech understanding tests. Especially, there were significant

differences between the results of the first CI and bilateral CI on: 1) SDS at 70 dB SPL ($P=0.02^*$); 2) SDS at 1 m from second CI side SP at 60 dB SPL ($P=0.02^*$); 3) WRS at 1 m from second CI side SP at 60 dB SPL ($P=0.02^*$); 4) SDS at 1 m from front SP under the noise (S/N=80/70, +10) ($P=0.01^*$); 5) WRS at 1 m from front SP under the noise (S/N=80/70, +10; $P=0.002^{**}$).

These results may show important binaural effectiveness such as binaural summation (1, 4, 5) and head shadow effect (2, 3).

Binaural summation (1, 3, 4, 7) and head shadow effect (2-5) are very likely to be important phenomena providing effective binaural advantages. Furthermore, binaural squelch (2, 4, 5) and sound localization (8, 9) are also well known to yield binaural advantages. In particular, in infancy there are many cases where the ability of hearing under the noise is very important for speech/language development.

The improvement of sound localization and hearing under noise that is provided in binaural hearing shows strong effectiveness in a typical infant environment and for children in a classroom setting (14). Bilateral CI is a very useful medical intervention for children with severe-to-profound hearing loss in Japan and elsewhere.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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