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Auditory performance and speech intelligibility of Mandarin-speaking children implanted before age 5

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ABSTRACT

Objectives: (1) To report the auditory performance and speech intelligibility of 84 Mandarin-speaking prelingually deaf children after using cochlear implants (CIs) for one, two, three, four, and five years to understand how many years of implant use were needed for them to reach a plateau-level performance; (2) to investigate the relation between subjective rating scales and objective measurements (i.e., speech perception tests); (3) to understand the effect of age at implantation on auditory and speech development.
Methods: Eighty-four children with CIs participated in this study. Their auditory performance and speech intelligibility were rated using the Categorical Auditory Performance (CAP) and the Speech Intelligibility Rating (SIR) scales, respectively. The evaluations were made before implantation and six months, one, two, three, four, and five years after implantation. At the fifth year after implantation, monosyllabic-word, easy-sentence, and difficult-sentence perception tests were administered.
Results: The median CAP score reached a plateau at category 6 after three years of implant use. The median SIR arrived at the highest level after five years of use. With five years of CI experiences, 86% of the subjects understood conversation without lip-reading, and 58% were fully intelligible to all listeners. The three speech perception tests had a moderate-to-strong correlation with the CAP and SIR scores. The children implanted before the age of three years had significantly better CAP and monosyllabic word perception test scores.
Conclusions: Five years of follow-up are needed for assessing the post-implantation development of communication ability of prelingually deafened children. It is recommended that hearing-impaired children receive cochlear implantation at a younger age to acquire better auditory ability for developing language skills. Constant postoperative aural–verbal rehabilitation and speech and language therapy are most likely required for the patients to reach the highest level on the CAP and SIR scales.

1. Introduction

Many cochlear implant centers used subjective tests, such as the Categories of Auditory Performance (CAP) and the Speech Intelligibility Rating (SIR) scales, to evaluate auditory and speech development of children with cochlear implants (CIs) [1–4]. These "real-life" measures attract many clinicians and audiologists because they are easily administered in a busy clinical setting, such as a cochlear implant center, and can be readily applied to young deaf children over time, regardless of their intellectual or other characteristics [5–7].

Past studies have not provided a consistent opinion regarding how long an implantee needed to develop stable auditory and speech abilities. Our previous study found that approximately 80% of 21 implanted children were able to reach the highest level of both the CAP and SIR scales after 4–5 years of implant use [8]. The study suggested that most of the patients had a stabilized performance and reached a plateau level after 3 years of use. Many studies also have demonstrated that implanted children have steady progress in speech intelligibility for 3–5 years after

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Table 1
Summary of findings from studies investigating speech intelligibility of cochlear implanted children after 3 years and 5 years of implant use.

Study	*n*	Imp age	Method	Fully intelligible patients after 3 years	Fully intelligible patients after 5 years
Bakhshaee et al. [11]	47	3.5	SIR	41%	78%
Calmels et al. [2]	63	3.8	SIR	25%	34%
Allen et al. [5]	118	4.3	SIR	3%	46%
Beadle et al. [3]	30	5.3	SIR	n/a	27%
Wu et al. [8]	21	<3	SIR	Median = 5	82%
Inscoe [9]	135	n/a	Modified SIR	7%	33%
Löhle et al. [10]	33	2–14	Objective test	n/a	Imp age 2–4 years: 60–90% words intelligible

n, number of subjects; Imp age, age at implantation; n/a, not applicable or not specified.

implantation, regardless of their native language backgrounds (see Table 1 for a summary). However, Calmels et al. [2] indicated that implanted children did not significantly improve their speech intelligibility until the third year after implantation. Beadle et al. [3] further noted that more than one-third of their CI implantees did not reach a plateau after 5 years of implant use.

After 5 years of implant use, 27–46% of the children were indicated as being fully intelligible in past studies done before year 2007 that used subjective rating scales [2,3,5,9]. Löhle et al. [10] adopted objective measures and reported that children implanted at an age between 2 and 4 years were 60–90% intelligible in the words they produced after 5 years of implant use. Bakhshaee et al. [11] and Wu et al. [8], both utilizing the SIR scale, obtained a more satisfactory result, with approximately 80% of their subjects becoming fully intelligible after 5 years of use. The latter two studies used children implanted at a younger age and wearing more advanced CI devices, which may have contributed to the better results.

It should also be noted that few studies have investigated the relation between subjective rating scales and objective speech perception tests to estimate the proportion of words/sentences the patients in certain CAP/SIR categories might be able to recognize. Calmels et al. [2] demonstrated that, after 5 years of implant use, their subjects obtained a median score of 93.7% on the closed-set sentence perception test and 76.3% on the open-set sentence test, whereas their median SIR score was 4. It was reported that the open-set perception scores did not improve visibly until the second year after implantation and did not reach a plateau after 4–5 years of use.

Although it appears that most implanted children were able to improve their auditory and speech abilities over time, past studies have indicated that post-implantation outcomes were chiefly influenced by the age at implantation rather than the length of implant use [4,12–16]. Children implanted at a younger age were more likely to develop a satisfactory level of auditory and speech performance.

Therefore, the objectives of this study were (1) to report the auditory performance and speech intelligibility of 84 Mandarin-speaking prelingually deaf children after using cochlear implants for one, two, three, four, and five years to understand how many years of implant use were needed for them to reach a plateau-level performance; (2) to investigate the relation between subjective evaluations (CAP and SIR scales) and objective measurements (speech perception tests); and (3) to understand the effect of age at implantation on auditory and speech development.

2. Materials and methods

2.1. Participants

A total of 110 severe-to-profoundly deafened children who were implanted during the years 2000 and 2007 and had used the implants for at least 5 years were recruited from the cochlear implant center of Chang-Gung Memorial Hospital. Those who had neurological/developmental disorders (5 patients) or were post-lingually deafened (21 patients) were excluded, leaving 84 prelingually deafened children (42 boys and 42 girls) to participate in this study. They received cochlear implantation between the age 1.1 and 5.0 years (mean = 3.0, SD = 1.5) and had used the CIs for a mean duration of 5.1 years by the time they received the fifth follow-up visit. The average duration of postoperative aural–verbal rehabilitation they had undertaken was 4.0 years. The nucleus 24 device with an ACE (Advanced Combination Encoder) coding strategy was used by all subjects. Most of the participants were born deaf with unknown etiologies. The study protocol and written informed consent form were approved by Chang-Gung Memorial Hospital Ethics Committee for Human Studies. All written informed consent forms signed by guardians on the behalf of the children participants involved in our study were obtained before the test procedures.

2.2. Test materials

2.2.1. CAP and SIR

The Categories of Auditory Performance (CAP) scale was developed by the Nottingham group to assess the auditory performance of deaf children. It is a nonlinear hierarchical scale consisting of eight performance categories (from 0 to 7). The categorizing criteria are described in Table 2. The reliability of the scale has been proven [7]. The Speech Intelligibility Rating (SIR) scale was also designed by the Nottingham group for quantifying the speech production capabilities of linguistically compromised children who are profoundly deafened. It classifies the children's spontaneous speech intelligibility into five categories (from 1 to 5). The criteria are listed in Table 3. Its reliability has also been confirmed [5,17]. The two scales have been used in many Asian studies as well (e.g. [18,19]).

2.2.2. Speech perception tests

Three open-set speech perception tests were administered at the fifth year after implantation. The easy-sentence test, developed by Lin et al. (unpublished materials) according to the Central

Table 2
Categorical Auditory Performance (CAP) criteria.

Rating scale	Criteria
7	Use of telephone with known listener
6	Understanding of conversation without lip-reading
5	Understanding of common phrases without lip-reading
4	Discrimination of some speech sounds without lip-reading
3	Identification of environmental sounds
2	Response to speech sounds
1	Awareness of environmental sounds
0	No awareness of environmental sounds