

# Long-term follow-up of auditory performance and speech perception and effects of age on cochlear implantation in children with pre-lingual deafness

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## Abstract

**Background:** The development of auditory and speech perception ability of children with hearing loss is affected by many factors after they undergo cochlear implantation (CI). Age at CI (CI age) appears to play an important role among these factors. This study aimed to evaluate the development of auditory and speech perception ability and explore the impact of CI age on children with pre-lingual deafness present before 3 years of age.

**Methods:** Two hundred and seventy-eight children with pre-lingual deafness (176 boys and 102 girls) were included in this study, and the CI age ranged from 6 to 36 months (mean age, 19 months). Categorical auditory performance (CAP) was assessed to evaluate auditory ability, and the speech intelligibility rating was used to evaluate speech intelligibility. The evaluations were performed before CI and 1, 3, 6, 12, 18, 24, 36, 48, and 60 months after CI.

**Results:** The auditory ability of the pre-lingually hearing-impaired children showed the fastest development within 6 months after CI ( $k = 0.524$ ,  $t = 30.992$ ,  $P < 0.05$ ); then, the progress started to decelerate ( $k = 0.14$ ,  $t = 3.704$ ,  $P < 0.05$ ) and entered a plateau at the 24th month ( $k = 0.03$ ,  $t = 1.908$ ,  $P < 0.05$ ). Speech intelligibility showed the fastest improvement between the 12th and 24th months after CI ( $k = 0.138$ ,  $t = 5.365$ ,  $P < 0.05$ ); then, the progress started to decelerate ( $k = 0.026$ ,  $t = 1.465$ ,  $P < 0.05$ ) and entered a plateau at the 48th month ( $k = 0.012$ ,  $t = 1.542$ ,  $P < 0.05$ ). The CI age had no statistical significant effect on the auditory and speech abilities starting at 2 years after CI ( $P > 0.05$ ). The optimal cutoff age for CI was 15 months.

**Conclusions:** Within 5 years after CI, the auditory and speech ability of young hearing-impaired children continuously improved, although speech development lagged behind that of hearing. An earlier CI age is recommended; the optimal cutoff age for CI is at 15 months.

**Keywords:** Categorical auditory performance; Speech intelligibility rating; Cochlear implantation; Children; Pre-lingual deafness; Age at cochlear implantation

## Introduction

According to the latest WHO epidemiologic data, the number of people with hearing loss has reached 466 million worldwide, which accounts for 6.2% of the global population. This number includes 34 million hearing-impaired children, who account for 9% of the total population with hearing loss. China has the largest population of patients with hearing loss in the world. There are approximately 120,000 children with severe to profound hearing loss that occurred before 7 years of age, and 20,000 to 30,000 hearing-impaired children are born every year.<sup>[1]</sup>

For patients with severe or profound hearing loss who do not show good results even with hearing aids, cochlear implantation (CI) technology is a very effective approach to improve hearing ability and thus facilitate the patient's entry into mainstream society. Currently, approximately 400,000 people around the world have undergone CI treatment, most of which are children with pre-lingual deafness.<sup>[2]</sup> Since 1995, when the first CI procedure was successfully performed in China, more than 10,000 patients have undergone CI treatment. The number of patients undergoing this procedure is increasing by 25% to 50% every year, and 85% of the CI recipients are children under 7 years of age.<sup>[1]</sup>

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The outcomes of CI are affected by many factors, and they differ greatly among hearing-impaired children. Therefore, it is necessary to study the factors influencing these outcomes, and the CI age appears to play an important role among these factors. Many studies have assessed the effect of CI age on auditory and speech rehabilitation outcomes.<sup>[3,4]</sup> The basic principle underlying early CI is to provide appropriate auditory signal stimulation for hearing-impaired children during the sensitive period of normal speech development and the critical period of nerve connection development.<sup>[5]</sup> It has been reported that the first 3 years of life form the sensitive period of auditory development, during which brain plasticity is very strong and new neural pathways can be generated to respond to auditory stimulation, but after the age of 3 years, the auditory neural network is amplified by other nerves and cannot be fully mobilized when receiving acoustic stimulation.<sup>[6,7]</sup> Thompson *et al* reported that among 48 children who underwent CI treatment, the auditory and speech abilities in those who underwent CI treatment within the first 12 months of age were better than those who underwent the procedure within the first 18 months of age.<sup>[8]</sup> Govaerts *et al*<sup>[9]</sup> suggested that the auditory and speech development of children who underwent CI treatment at 18 months of age lagged behind that of children of the same age with normal hearing, but children who underwent CI treatment within the first 12 months of age could reach the standard levels of auditory and speech development. Other studies have shown that children who undergo CI treatment at an age younger than 4 years show better auditory and speech development than older children.<sup>[10,11]</sup> However, Geers<sup>[12]</sup> contested that early CI did not have any special advantage and that the CI age was not closely related to the abilities of speech perception, language expression, colloquialism, and reading for children who underwent CI treatment at the age of 2 to 4 years as shown by an 8-year follow-up. Thus, there is no clear conclusion regarding the optimal CI age.

At present, there is no unified rehabilitation evaluation program for the CI outcomes. However, questionnaire surveys, especially those assessing categorical auditory performance (CAP) and speech intelligibility rating (SIR), have been widely used worldwide because of their wide application scope, high repeatability, lack of limitations related to age, speech ability, coordination degree, and exclusion of subjective influencing factors. These surveys represent the fastest, easiest, and most feasible method among the many available evaluation systems.

Although many previous studies have assessed the effect of CI age on children's auditory and speech abilities, few studies conducted in our country and abroad used large samples and long-term follow-up assessments. To fill this gap in the literature, this study used the CAP and SIR questionnaires to assess the development of auditory and speech rehabilitation for pre-lingually hearing-impaired children with CI age younger than 3 years within a 5-year post-operative follow-up period and to explore the effects of CI age on the post-operative rehabilitation, thereby providing reference data and a basis for optimal selection of the CI age.

## Methods

### Ethical approval

The Ethics Review Committee in Beijing Children's Hospital approved the study protocol and written informed consent was received from the parents or legal custodians of each child prior to entry into the study.

### Subjects

Two hundred and seventy-eight young pre-lingually hearing-impaired children (176 boys and 102 girls) were included in this study. Inclusion criteria were as following: (1) pre-lingual deafness; (2) profound sensorineural deafness in both ears before CI; (3) outer, middle, and inner ear structures were bilaterally normal; (4) intraoperative electrodes were implanted; (5) native language was Mandarin; and (6) no awareness of environmental sounds, and connected speech was unintelligible before CI. Exclusion criteria included: (1) post-lingual deafness; (2) accompanied by other medical, psychologic, spiritual, intellectual, and cognitive disorders; (3) auditory neuropathy suspected or diagnosed by audiologic assessment; and (4) secondary CI surgery. These children underwent CI treatment in Beijing Tongren Hospital between 2009 and 2014. The CI age ranged from 6 to 36 months (mean age, 19 months). The patients showed no post-operative complications, other medical contraindications, or ear diseases and diseases affecting intellectual, psychologic, or physical development. The implant switch-on programming session was conducted by experienced audiologists 4 weeks after CI. Follow-up CI programming, assessment, and intensive rehabilitation were conducted for each child at certain intervals over a course of 5 years.

### Auditory and speech ability assessment methods

The classifications performed in this questionnaire survey were based on the CAP and SIR as proposed by Nikolopoulos *et al*.<sup>[13]</sup>

The CAP classifies the auditory perception ability of deaf patients on a scale of 0 to 7 as follows: 0 = No awareness of environmental sounds; 1 = Awareness of environmental sounds; 2 = Response to speech sounds; 3 = Identification of environmental sounds; 4 = Discrimination of some speech sounds without lip reading; 5 = Understanding of common phrases without lip reading; 6 = Understanding of conversation without lip reading; 7 = Use of telephone with known listener.

Similarly, the SIR classifies the speech intelligibility of deaf patients on a scale of 1 to 5 as follows: 1 = Connected speech is unintelligible. Pre-recognizable words in spoken language, primary mode of communication may be manual; 2 = Connected speech is unintelligible. Intelligible speech is developing in single words when context and lip reading cues are available; 3 = Connected speech is intelligible to a listener who concentrates and lip reads; 4 = Connected speech is intelligible to a listener who has a little experience of a deaf person's speech; 5 = Connected speech is intelligible to all listeners. The child is understood easily in everyday contexts.

These two scales were used for the 5-year follow-up evaluations of the hearing ability and speech intelligibility of patients at pre-implantation and at 1, 3, 6, 12, 18, 24, 36, 48, and 60 months post-implantation by trained audiology professionals. The evaluators asked each question in the scale. The parents described the auditory and verbal behaviors in the daily life of the children in detail, and the evaluators rated the score according to the descriptions.

### Statistical analysis

IBM SPSS Statistics 20.0 (IBM Corp., Armonk, NY, USA) was used to conduct independent sample *t* tests and linear regression analyses on the data, that is, the CAP and SIR scores of subjects for this study at different evaluation intervals before and after CI. The statistical significance test standard was at  $P < 0.05$ .

## Results

### Development of auditory ability after CI

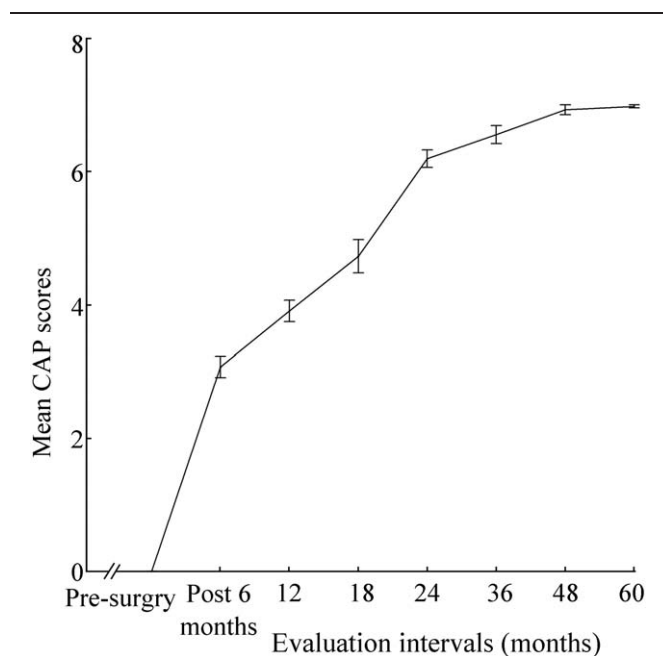
Linear regression analysis was conducted for different time intervals after CI at 0 to 6, 7 to 12, 13 to 18, 19 to 24, 25 to 36, 37 to 48, and 49 to 60 months to explore the developing trend of CAP with time after CI. The gradients were  $k = 0.524$  ( $t = 30.992$ ,  $P < 0.001$ ),  $k = 0.14$  ( $t = 3.704$ ,  $P < 0.001$ ),  $k = 0.137$  ( $t = 2.898$ ,  $P = 0.004$ ),  $k = 0.224$  ( $t = 5.814$ ,  $P < 0.001$ ),  $k = 0.030$  ( $t = 1.908$ ,  $P = 0.047$ ),  $k = 0.031$  ( $t = 2.331$ ,  $P = 0.022$ ), and  $k = 0.004$  ( $t = 1.663$ ,  $P = 0.049$ ), respectively. As the higher the gradient is, the faster the development, we found that CAP development was the fastest within 6 months after CI, showing a significant growth trend, which was followed by slower growth, and entered a plateau period at the 24th month. The CAP score growth after CI is shown in Figures 1 and 2.

### Development of speech intelligibility after CI

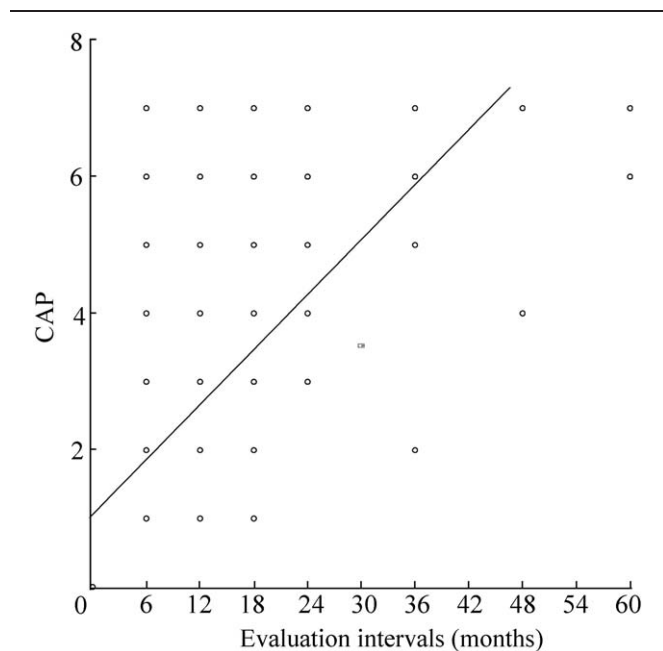
Linear regression analysis was conducted for different time intervals after CI at 0 to 6, 7 to 12, 13 to 18, 19 to 24, 25 to 36, 37 to 48, and 49 to 60 months to explore the developing trend of SIR with time after CI. The gradients were  $k = 0.072$  ( $t = 11.009$ ,  $P < 0.001$ ),  $k = 0.062$  ( $t = 3.332$ ,  $P = 0.001$ ),  $k = 0.138$  ( $t = 5.365$ ,  $P < 0.001$ ),  $k = 0.119$  ( $t = 3.645$ ,  $P < 0.001$ ),  $k = 0.026$  ( $t = 1.465$ ,  $P = 0.047$ ),  $k = 0.073$  ( $t = 2.962$ ,  $P = 0.005$ ), and  $0.012$  ( $t = 1.542$ ,  $P = 0.048$ ), respectively. As the higher the gradient is, the faster the development, we found that SIR development showed the fastest growth between the 12th and 24th months after CI, showing a significant growth trend in this period. Subsequently, the growth decelerated and entered a plateau period at the 48th month. The SIR score growth after CI is shown in Figures 3 and 4.

### Effects of CI age on CI outcomes

For every CI age (implantation month) as a division line, children were classified into two groups: the “ $\leq$ month” group, in which the children’s CI ages were lower than or equal to the line, and the “ $>$ month” group, in which the children’s CI ages were greater than the line. A total of 29



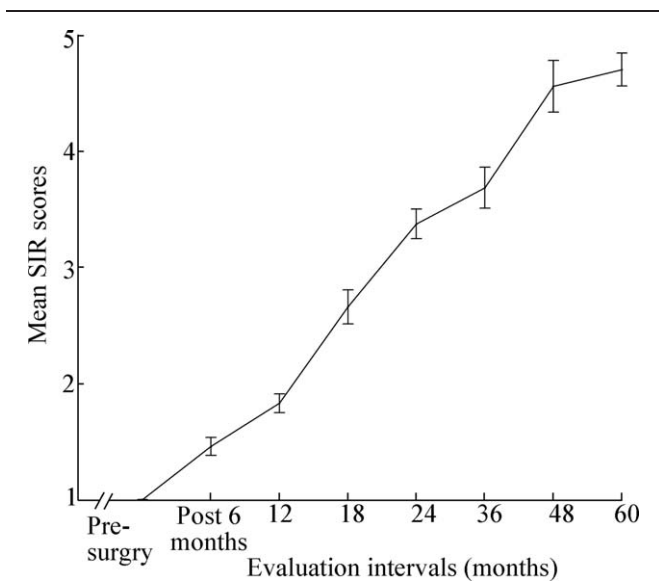
**Figure 1:** Mean CAP scores for pre-lingually young hearing-impaired children at different evaluation intervals before and after cochlear implantation for over 5 years. Results are displayed as mean scores and their standard errors. CAP: Categorical auditory performance.



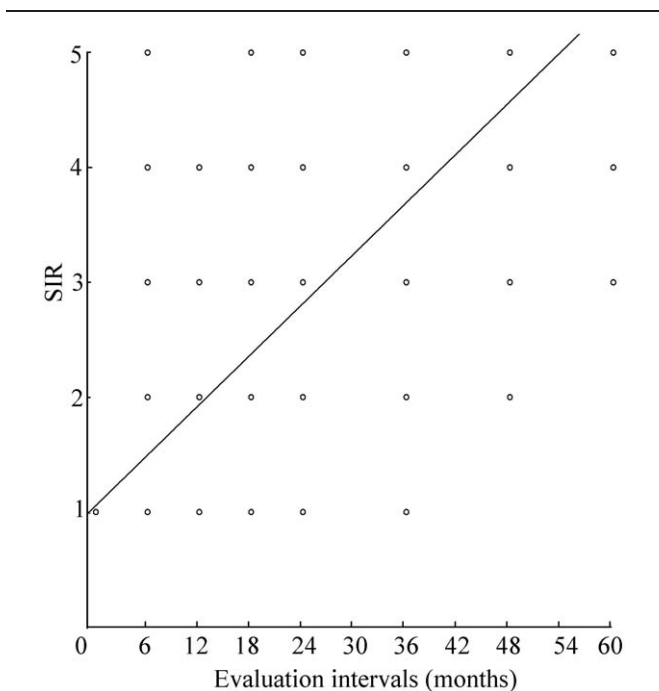
**Figure 2:** Auditory ability development trend after cochlear implantation. The CAP scores for pre-lingually young hearing-impaired children at different evaluation intervals before and after cochlear implantation for over 5 years. Results are displayed as scattered plot and the linear fitting line. CAP: Categorical auditory performance.

implantation month divisions were defined. For each division, the CAP and SIR mean scores were compared at the different follow-up evaluation intervals between the two groups, as shown in Tables 1 and 2.

Two children (1 boy and 1 girl) with CI age of 6 months were only followed up the first month and third month



**Figure 3:** Mean SIR scores for pre-lingually young hearing-impaired children at different evaluation intervals before and after cochlear implantation for over 5 years. Results are displayed as mean scores and their standard errors. SIR: Speech intelligibility rating.



**Figure 4:** Speech ability development trend after cochlear implantation. The SIR scores for pre-lingually young hearing-impaired children at different evaluation intervals before and after cochlear implantation for over 5 years. Results are displayed as scattered plot and the linear fitting line. SIR: Speech intelligibility rating.

after CI, so comparisons could not be conducted due to the lack of data for the 6th, 12th, 24th, 36th, 48th, and 60th-month follow-ups after CI.

Table 1 and Table 3 show that for the 6th-month follow-up evaluations, the mean CAP scores were significantly different ( $P < 0.05$ ) between the  $\leq$ month group and the  $>$ month group in two divisions with the 14 to 15 implantation months as the division lines and 15 divisions

with the 19 to 33 implantation months as the division lines. For the 12th-month follow-up, significant differences ( $P < 0.05$ ) were observed between the  $\leq$ month group and the  $>$ month group in the 7, 11 to 12, 20 to 24, and 26 to 31 implantation month divisions. For the 18th-month follow-up, significant differences ( $P < 0.05$ ) were observed between the  $\leq$ month group and the  $>$ month group in the 10 to 30 implantation month divisions, but there were no significant differences ( $P > 0.05$ ) between the  $\leq$ month group and the  $>$ month group in all the divisions for the 24th, 36th, 48th, and 60th-month follow-ups.

In Table 2 and Table 4, for the 6th-month follow-up evaluations, the SIR mean scores were significantly different ( $P < 0.05$ ) between the  $\leq$ month and the  $>$ month groups in nine divisions with the 12 to 20 implantation months as the division lines, two divisions with the 24 to 25 implantation months as the division lines, and three divisions with the 30 to 32 implantation months as the division lines. For the 12th-month follow-up, significant differences ( $P < 0.05$ ) were observed between the  $\leq$ month group and the  $>$ month group in the 10 to 12, 20, 22 to 24, and 26 to 31 implantation month divisions. For the 18th-month follow-up, significant differences ( $P < 0.05$ ) were observed between the  $\leq$ month group and the  $>$ month group in the 11 to 15 and 19 to 27 implantation month divisions. For the 24th-month follow-up, significant differences ( $P < 0.05$ ) were observed between the  $\leq$ month group and the  $>$ month group in the 28 to 30 implantation month divisions, but there were no significant differences ( $P > 0.05$ ) between the  $\leq$ month group and the  $>$ month groups in all divisions for the 36th, 48th, and 60th-month follow-ups.

As shown in Tables 5 and 6, most children’s CAP and SIR mean scores for each of the 7 to 15 implantation month divisions in the  $\leq$ month group were higher than those in the  $>$ month group at the 24th, 36th, 48th, and 60th-month follow-up evaluation intervals after CI, signifying that the development of hearing and speech ability in the  $\leq$ month group was faster and more pronounced. However, most children’s CAP and SIR mean scores in the  $\leq$ month group were very close to but never exceeding those of the children in the  $>$ month group for each of the 16 to 36 implantation month divisions at any follow-up evaluation interval.

**Discussion**

Data from this study showed that the auditory ability and speech intelligibility of hearing-impaired children younger than 3 years continuously improved with time after CI, but the development of speech ability lagged behind that of hearing ability in the early evaluation intervals. The CI age had no significant effect 2 years after CI, but a younger CI age is still recommended. The optimal cutoff age for CI timing is at 15 months.

**Rules of CAP development**

As shown in Figures 1 and 2, the auditory ability of hearing-impaired children under 3 years of age showed a gradual growth trend after CI, but the development was



**Table 1: Comparisons of mean CAP scores between the  $\leq$ month group and  $>$ month group ( $P$  values).**

Age groups (months)	Evaluation intervals (months)						
	6	12	18	24	36	48	60
$\leq 7$ vs. $> 7$	0.177	<i>0.044</i>	0.879	0.840	0.632	0.877	0.880
$\leq 8$ vs. $> 8$	0.745	0.776	0.540	0.794	0.493	0.824	0.828
$\leq 9$ vs. $> 9$	0.108	0.282	0.158	0.794	0.493	0.824	0.828
$\leq 10$ vs. $> 10$	0.098	0.093	<i>0.005</i>	0.985	0.662	0.783	0.788
$\leq 11$ vs. $> 11$	0.172	<i>0.044</i>	<i>0.004</i>	0.539	0.752	0.714	0.692
$\leq 12$ vs. $> 12$	0.071	<i>0.027</i>	<i>0.004</i>	0.781	0.624	0.684	0.665
$\leq 13$ vs. $> 13$	0.183	0.204	<i>0.026</i>	0.563	0.349	0.602	0.588
$\leq 14$ vs. $> 14$	<i>0.012</i>	0.305	<i>0.012</i>	0.405	0.284	0.577	0.564
$\leq 15$ vs. $> 15$	<i>0.014</i>	0.269	<i>0.011</i>	0.321	0.184	0.527	0.517
$\leq 16$ vs. $> 16$	0.062	0.232	<i>0.017</i>	0.658	0.301	0.478	0.197
$\leq 17$ vs. $> 17$	0.079	0.187	<i>0.004</i>	0.550	0.515	0.215	0.220
$\leq 18$ vs. $> 18$	0.099	0.080	<i>0.005</i>	0.550	0.427	0.239	0.243
$\leq 19$ vs. $> 19$	<i>0.009</i>	0.160	<i>0.001</i>	0.179	0.414	0.264	0.266
$\leq 20$ vs. $> 20$	<i>0.003</i>	<i>0.026</i>	<i>0.005</i>	0.131	0.593	0.335	0.335
$\leq 21$ vs. $> 21$	<i>0.013</i>	<i>0.013</i>	<i>0.001</i>	0.419	0.905	0.407	0.403
$\leq 22$ vs. $> 22$	<i>0.001</i>	<i>0.010</i>	$< 0.001$	0.524	0.877	0.431	0.448
$\leq 23$ vs. $> 23$	<i>0.001</i>	<i>0.001</i>	$< 0.001$	0.315	0.877	0.431	0.448
$\leq 24$ vs. $> 24$	<i>0.001</i>	$< 0.001$	<i>0.003</i>	0.218	0.667	0.527	0.540
$\leq 25$ vs. $> 25$	<i>0.014</i>	0.269	<i>0.011</i>	0.321	0.184	0.527	0.517
$\leq 26$ vs. $> 26$	<i>0.021</i>	<i>0.001</i>	<i>0.028</i>	0.131	0.680	0.577	0.588
$\leq 27$ vs. $> 27$	<i>0.029</i>	<i>0.008</i>	<i>0.023</i>	0.133	0.692	0.629	0.638
$\leq 28$ vs. $> 28$	<i>0.017</i>	$< 0.001$	<i>0.039</i>	0.119	0.956	0.684	0.692
$\leq 29$ vs. $> 29$	<i>0.017</i>	$< 0.001$	<i>0.039</i>	0.119	0.956	0.684	0.692
$\leq 30$ vs. $> 30$	<i>0.012</i>	$< 0.001$	<i>0.039</i>	0.119	0.956	0.684	0.692
$\leq 31$ vs. $> 31$	<i>0.008</i>	$< 0.001$	0.112	0.197	0.882	0.714	0.721
$\leq 32$ vs. $> 32$	<i>0.006</i>	0.057	0.112	0.134	0.882	0.747	0.753
$\leq 33$ vs. $> 33$	<i>0.024</i>	0.083	0.068	0.134	0.319	0.747	0.753
$\leq 34$ vs. $> 34$	0.065	0.083	0.205	0.225	0.395	0.783	0.788
$\leq 35$ vs. $> 35$	0.071	0.148	0.205	0.224	0.493	0.824	0.828

The table reveals the significant difference (in italic font) of CAP between the  $\leq$ month group and  $>$ month group at different follow-up evaluation intervals from the 6th month to the 60th month after cochlear implantation. CAP: Categorical auditory performance.

not linear. The CAP scores showed the fastest change and a significant growth trend within 6 months after CI, indicating that the development of auditory ability is very important during this period. This is consistent with the findings reported previously.<sup>[14-16]</sup> We also observed that early CI, and especially rehabilitation training within the first 6 months after CI, is crucial for the development of auditory ability in young hearing-impaired children.<sup>[17]</sup>

We also found that during the period from the 6th to the 24th follow-up month after CI, auditory ability improved significantly and developed rapidly. However, the growth rate was slower than that within 6 months after CI and it entered a plateau at the 24th follow-up month. It subsequently continued to progress slowly and continuously until the 60th follow-up month. Hearing development was significantly improved in the first year after CI, and the auditory performance continued to improve 5 years after CI.<sup>[18]</sup>

### Rules of SIR development

As shown in Figures 3 and 4, speech ability gradually increased in general in young hearing-impaired children who underwent CI treatment before 3 years of age. The

fastest change in SIR scores was observed between the 12th and 24th follow-up months after CI. The subsequent growth decelerated and entered a plateau and reached a relatively stable level at the 48th follow-up month. This finding shows the periodic characteristics of initial slow growth, rapid growth in the middle stage, and steady saturation at the later stage. Different from the auditory development trend, speech ability generally lags behind auditory ability development and requires a period of accumulation. According to the development trend shown in Figures 1 and 3, progress in speech ability is slower and requires more time than that of auditory ability. Therefore, parents should be guided to prepare for and realize the importance and necessity of long-term rehabilitation training. Many scholars have come to similar conclusions.<sup>[14,16,19]</sup>

### Effects of CI age on auditory and speech ability of young hearing-impaired children after CI

Tables 1 and 2 show that the CAP mean scores differed significantly between the  $\leq$ month and  $>$ month groups ( $P < 0.05$ ) at the 6th, 12th, and 18th follow-up months after CI for most divisions, and there were no significant differences between the two groups ( $P > 0.05$ ) at the 24th

**Table 2: Comparisons of mean SIR scores between the ≤month group and >month group (P values).**

Age groups (months)	Evaluation intervals (months)						
	6	12	18	24	36	48	60
≤7 vs. >7	0.542	0.258	0.528	0.484	0.186	0.629	0.622
≤8 vs. >8	0.385	0.698	0.643	0.213	0.186	0.629	0.622
≤9 vs. >9	0.285	0.183	0.190	0.213	0.186	0.629	0.622
≤10 vs. >10	0.093	<i>0.011</i>	0.070	0.264	0.655	0.629	0.622
≤11 vs. >11	0.063	<i>0.015</i>	<i>0.016</i>	0.668	0.896	0.478	0.356
≤12 vs. >12	<i>&lt;0.001</i>	<i>0.001</i>	<i>0.040</i>	0.668	0.896	0.478	0.356
≤13 vs. >13	<i>0.004</i>	0.128	<i>0.037</i>	0.475	0.896	0.478	0.356
≤14 vs. >14	<i>&lt;0.001</i>	0.202	<i>0.022</i>	0.580	0.896	0.478	0.356
≤15 vs. >15	<i>&lt;0.001</i>	0.096	<i>0.038</i>	0.332	0.956	0.478	0.356
≤16 vs. >16	<i>0.002</i>	0.147	0.137	0.646	0.648	0.831	0.173
≤17 vs. >17	<i>0.004</i>	0.098	0.051	0.627	0.929	0.445	0.448
≤18 vs. >18	<i>0.012</i>	0.069	0.063	0.627	0.297	0.614	0.609
≤19 vs. >19	<i>0.001</i>	0.050	<i>0.024</i>	0.842	0.128	0.614	0.277
≤20 vs. >20	<i>0.045</i>	<i>0.043</i>	<i>0.024</i>	0.936	0.348	0.973	0.527
≤21 vs. >21	0.335	0.057	<i>0.007</i>	0.871	0.405	0.973	0.527
≤22 vs. >22	0.105	<i>0.028</i>	<i>0.003</i>	0.805	0.531	0.973	0.192
≤23 vs. >23	0.105	<i>0.010</i>	<i>0.003</i>	0.835	0.531	0.973	0.192
≤24 vs. >24	<i>0.024</i>	<i>0.002</i>	<i>0.010</i>	0.332	0.275	0.837	0.266
≤25 vs. >25	<i>&lt;0.001</i>	0.096	<i>0.038</i>	0.332	0.956	0.478	0.356
≤26 vs. >26	0.073	<i>0.008</i>	<i>0.033</i>	0.193	0.314	0.640	0.356
≤27 vs. >27	0.104	<i>0.006</i>	<i>0.034</i>	0.054	0.357	0.644	0.356
≤28 vs. >28	0.087	<i>0.003</i>	0.093	<i>0.043</i>	0.217	0.644	0.356
≤29 vs. >29	0.087	<i>0.003</i>	0.093	<i>0.043</i>	0.217	0.644	0.356
≤30 vs. >30	<i>0.046</i>	<i>0.003</i>	0.093	<i>0.043</i>	0.217	0.644	0.356
≤31 vs. >31	<i>0.021</i>	<i>0.014</i>	0.565	0.180	0.521	0.831	0.356
≤32 vs. >32	<i>0.011</i>	0.060	0.565	0.264	0.512	0.478	0.469
≤33 vs. >33	0.138	0.228	0.249	0.264	0.053	0.478	0.469
≤34 vs. >34	0.202	0.228	0.745	0.385	0.186	0.629	0.622
≤35 vs. >35	0.301	0.817	0.745	0.316	0.186	0.629	0.622

The table reveals the significant difference (in italic font) of SIR between the ≤month group and >month group at different follow-up evaluation intervals from the 6th month to the 60th month after cochlear implantation. SIR: Speech intelligibility rating.

follow-up month or later for all divisions. Similarly, Tables 3 and 4 show that the SIR mean scores differed significantly between the ≤month and the >month groups ( $P < 0.05$ ) at the 6th, 12th, and 18th months after CI for most divisions, and there were no significant differences between the two groups ( $P > 0.05$ ) at the 24th follow-up month or later for all divisions.

The results of the comparison between the ≤month and the >month groups showed no significant CAP and SIR differences starting at the 24th follow-up month after CI for all divisions. Scholars at home and abroad have reported similar findings.<sup>[14,15,20]</sup> It can be further seen from the results of significant differences at the 6th, 12th, and 18th follow-up months after CI that the younger the CI age, the lower the CAP and SIR mean scores, whereas the older the CI age, the higher the CAP and SIR mean scores. The reason may be that the children in the >month group have better intelligence, understanding ability, social experience, coordinating ability, and active learning ability than those in the ≤month group, and thus show greater accumulation of auditory and speech experiences, which is advantageous for the early development of hearing and speech ability after CI.<sup>[11,21]</sup> However, as shown in Tables 3 and 4, the children’s CAP and SIR mean scores

in the ≤month group reached those of the children in the >month group starting at the 24th follow-up month, signifying that hearing and speech abilities for both groups had essentially reached the same level. This indicates that the children’s hearing and speech abilities in the ≤month group developed rapidly and later reached or even exceeded those of the children in the >month group with extended use of the CI equipment, so that the advantage of children’s hearing and speech abilities in the early stage in the >month group gradually disappeared. Many studies at home and abroad have reported similar results.<sup>[14,15,22-25]</sup> In view of the rapid development of hearing and speech ability in younger children after CI, an earlier CI age is recommended.

The values in Table 5 show that the CAP mean scores in the ≤month group for each of the 7 to 15 implantation month divisions reached 7 points at the 48th and 60th follow-up months after CI, signifying that the hearing-impaired children could telephone familiar people. It can also be seen from the values in Table 6 that the SIR mean scores in the ≤month group for each of the 7 to 15 implantation month divisions also reached 5 points at the 48th and 60th months after CI, denoting that the hearing-impaired children’s speech ability could achieve a level where

**Table 3: Comparisons of mean CAP scores between the ≤month group and >month group (*t* values, *P* < 0.05).**

Age groups (months)	Evaluation intervals (months)		
	6	12	18
≤7 vs. >7	NS	<i>t</i> = -2.049, <i>P</i> < 0.05	NS
≤10 vs. >10	NS	NS	<i>t</i> = -2.929, <i>P</i> < 0.05
≤11 vs. >11	NS	<i>t</i> = -2.046, <i>P</i> < 0.05	<i>t</i> = -3.060, <i>P</i> < 0.05
≤12 vs. >12	NS	<i>t</i> = -2.258, <i>P</i> < 0.05	<i>t</i> = -2.109, <i>P</i> < 0.05
≤13 vs. >13	NS	NS	<i>t</i> = -2.291, <i>P</i> < 0.05
≤14 vs. >14	<i>t</i> = -2.563, <i>P</i> < 0.05	NS	<i>t</i> = -2.610, <i>P</i> < 0.05
≤15 vs. >15	<i>t</i> = -2.511, <i>P</i> < 0.05	NS	<i>t</i> = -2.653, <i>P</i> < 0.05
≤16 vs. >16	NS	NS	<i>t</i> = -2.472, <i>P</i> < 0.05
≤17 vs. >17	NS	NS	<i>t</i> = -2.991, <i>P</i> < 0.05
≤18 vs. >18	NS	NS	<i>t</i> = -2.942, <i>P</i> < 0.05
≤19 vs. >19	<i>t</i> = -2.665, <i>P</i> < 0.05	NS	<i>t</i> = -3.478, <i>P</i> < 0.05
≤20 vs. >20	<i>t</i> = -3.000, <i>P</i> < 0.05	<i>t</i> = -2.262, <i>P</i> < 0.05	<i>t</i> = -2.963, <i>P</i> < 0.05
≤21 vs. >21	<i>t</i> = -2.537, <i>P</i> < 0.05	<i>t</i> = -2.540, <i>P</i> < 0.05	<i>t</i> = -3.427, <i>P</i> < 0.05
≤22 vs. >22	<i>t</i> = -3.285, <i>P</i> < 0.05	<i>t</i> = -2.644, <i>P</i> < 0.05	<i>t</i> = -3.975, <i>P</i> < 0.05
≤23 vs. >23	<i>t</i> = -3.285, <i>P</i> < 0.05	<i>t</i> = -3.864, <i>P</i> < 0.05	<i>t</i> = -3.975, <i>P</i> < 0.05
≤24 vs. >24	<i>t</i> = -3.512, <i>P</i> < 0.05	<i>t</i> = -5.100, <i>P</i> < 0.05	<i>t</i> = -3.069, <i>P</i> < 0.05
≤25 vs. >25	<i>t</i> = -2.511, <i>P</i> < 0.05	NS	<i>t</i> = -2.653, <i>P</i> < 0.05
≤26 vs. >26	<i>t</i> = -2.346, <i>P</i> < 0.05	<i>t</i> = -3.901, <i>P</i> < 0.05	<i>t</i> = -2.269, <i>P</i> < 0.05
≤27 vs. >27	<i>t</i> = -2.225, <i>P</i> < 0.05	<i>t</i> = -3.158, <i>P</i> < 0.05	<i>t</i> = -2.340, <i>P</i> < 0.05
≤28 vs. >28	<i>t</i> = -2.429, <i>P</i> < 0.05	<i>t</i> = -5.780, <i>P</i> < 0.05	<i>t</i> = -2.124, <i>P</i> < 0.05
≤29 vs. >29	<i>t</i> = -2.429, <i>P</i> < 0.05	<i>t</i> = -5.780, <i>P</i> < 0.05	<i>t</i> = -2.124, <i>P</i> < 0.05
≤30 vs. >30	<i>t</i> = -2.555, <i>P</i> < 0.05	<i>t</i> = -5.780, <i>P</i> < 0.05	<i>t</i> = -2.124, <i>P</i> < 0.05
≤31 vs. >31	<i>t</i> = -2.703, <i>P</i> < 0.05	<i>t</i> = -5.321, <i>P</i> < 0.05	NS
≤32 vs. >32	<i>t</i> = -2.806, <i>P</i> < 0.05	NS	NS
≤33 vs. >33	<i>t</i> = -2.301, <i>P</i> < 0.05	NS	NS

The table reveals *t* values where CAP is statistically significantly different (*P* < 0.05) between the ≤month group and >month group at different follow-up evaluation intervals from the 6th month to the 18th month after cochlear implantation. CAP: Categorical auditory performance; NS: No statistically significant difference.

**Table 4: Comparisons of mean SIR scores between the ≤month group and >month group (*t* values, *P* < 0.05).**

Age groups (months)	Evaluation intervals (months)			
	6	12	18	24
≤10 vs. >10	NS	<i>t</i> = -2.594, <i>P</i> < 0.05	NS	NS
≤11 vs. >11	NS	<i>t</i> = -2.486, <i>P</i> < 0.05	<i>t</i> = -2.503, <i>P</i> < 0.05	NS
≤12 vs. >12	<i>t</i> = -4.331, <i>P</i> < 0.05	<i>t</i> = -3.330, <i>P</i> < 0.05	<i>t</i> = -2.106, <i>P</i> < 0.05	NS
≤13 vs. >13	<i>t</i> = -2.966, <i>P</i> < 0.05	NS	<i>t</i> = -2.143, <i>P</i> < 0.05	NS
≤14 vs. >14	<i>t</i> = -3.644, <i>P</i> < 0.05	NS	<i>t</i> = -2.377, <i>P</i> < 0.05	NS
≤15 vs. >15	<i>t</i> = -3.621, <i>P</i> < 0.05	NS	<i>t</i> = -2.129, <i>P</i> < 0.05	NS
≤16 vs. >16	<i>t</i> = -3.176, <i>P</i> < 0.05	NS	NS	NS
≤17 vs. >17	<i>t</i> = -3.016, <i>P</i> < 0.05	NS	NS	NS
≤18 vs. >18	<i>t</i> = -2.494, <i>P</i> < 0.05	NS	NS	NS
≤19 vs. >19	<i>t</i> = -2.917, <i>P</i> < 0.05	NS	<i>t</i> = -2.338, <i>P</i> < 0.05	NS
≤20 vs. >20	<i>t</i> = -2.064, <i>P</i> < 0.05	<i>t</i> = -2.057, <i>P</i> < 0.05	<i>t</i> = -2.327, <i>P</i> < 0.05	NS
≤21 vs. >21	NS	NS	<i>t</i> = -2.831, <i>P</i> < 0.05	NS
≤22 vs. >22	NS	<i>t</i> = -2.245, <i>P</i> < 0.05	<i>t</i> = -3.172, <i>P</i> < 0.05	NS
≤23 vs. >23	NS	<i>t</i> = -2.650, <i>P</i> < 0.05	<i>t</i> = -3.172, <i>P</i> < 0.05	NS
≤24 vs. >24	<i>t</i> = -2.294, <i>P</i> < 0.05	<i>t</i> = -3.133, <i>P</i> < 0.05	<i>t</i> = -2.692, <i>P</i> < 0.05	NS
≤25 vs. >25	<i>t</i> = -3.621, <i>P</i> < 0.05	NS	<i>t</i> = -2.129, <i>P</i> < 0.05	NS
≤26 vs. >26	NS	<i>t</i> = -2.727, <i>P</i> < 0.05	<i>t</i> = -2.199, <i>P</i> < 0.05	NS
≤27 vs. >27	NS	<i>t</i> = -2.838, <i>P</i> < 0.05	<i>t</i> = -2.183, <i>P</i> < 0.05	NS
≤28 vs. >28	NS	<i>t</i> = -3.049, <i>P</i> < 0.05	NS	<i>t</i> = -2.080, <i>P</i> < 0.05
≤29 vs. >29	NS	<i>t</i> = -3.049, <i>P</i> < 0.05	NS	<i>t</i> = -2.080, <i>P</i> < 0.05
≤30 vs. >30	<i>t</i> = -2.021, <i>P</i> < 0.05	<i>t</i> = -3.049, <i>P</i> < 0.05	NS	<i>t</i> = -2.080, <i>P</i> < 0.05
≤31 vs. >31	<i>t</i> = -2.353, <i>P</i> < 0.05	<i>t</i> = -2.501, <i>P</i> < 0.05	NS	NS
≤32 vs. >32	<i>t</i> = -2.607, <i>P</i> < 0.05	NS	NS	NS

The table reveals *t* values where SIR is statistically significantly different (*P* < 0.05) between the ≤month group and >month group at different follow-up evaluation intervals from the 6th month to the 24th month after cochlear implantation. SIR: Speech intelligibility rating; NS: No statistically significant difference.

**Table 5: Mean CAP scores in the ≤month group and the >month group.**

Age groups (months)	Evaluation intervals (months)						
	6	12	18	24	36	48	60
≤7 vs. >7	1.00, 3.09	1.00, 3.94	5.00, 4.72	6.00, 6.20	7.00, 6.54	7.00, 6.93	7.00, 6.98
≤8 vs. >8	1.50, 3.10	3.67, 3.91	5.50, 4.69	6.33, 6.18	7.00, 6.53	7.00, 6.92	7.00, 6.98
≤9 vs. >9	1.67, 3.11	3.38, 3.96	3.50, 4.83	6.33, 6.18	7.00, 6.53	7.00, 6.92	7.00, 6.98
≤10 vs. >10	2.14, 3.14	3.33, 4.03	3.00, 5.00	6.20, 6.19	6.75, 6.53	7.00, 6.92	7.00, 6.98
≤11 vs. >11	2.50, 3.15	3.32, 4.04	3.36, 5.10	6.00, 6.23	6.67, 6.54	7.00, 6.92	7.00, 6.98
≤12 vs. >12	2.44, 3.20	3.32, 4.11	3.85, 5.03	6.11, 6.21	6.71, 6.53	7.00, 6.91	7.00, 6.97
≤13 vs. >13	2.70, 3.19	3.63, 4.06	3.94, 5.12	6.33, 6.15	6.80, 6.49	7.00, 6.91	7.00, 6.97
≤14 vs. >14	2.46, 3.33	3.71, 4.04	3.95, 5.23	6.38, 6.13	6.82, 6.47	7.00, 6.90	7.00, 6.97
≤15 vs. >15	2.53, 3.35	3.71, 4.07	4.00, 5.28	6.40, 6.11	6.85, 6.44	7.00, 6.90	7.00, 6.97
≤16 vs. >16	2.72, 3.32	3.71, 4.10	4.12, 5.31	6.11, 6.24	6.75, 6.45	7.00, 6.89	6.94, 7.00
≤17 vs. >17	2.77, 3.33	3.70, 4.13	4.04, 5.44	6.10, 6.26	6.67, 6.48	6.81, 7.00	6.94, 7.00
≤18 vs. >18	2.81, 3.34	3.66, 4.22	4.07, 5.46	6.10, 6.26	6.42, 6.64	6.82, 7.00	6.94, 7.00
≤19 vs. >19	2.73, 3.57	3.73, 4.19	4.03, 5.64	6.00, 6.36	6.43, 6.65	6.83, 7.00	6.95, 7.00
≤20 vs. >20	2.74, 3.71	3.67, 4.44	4.21, 5.67	6.00, 6.40	6.48, 6.63	6.86, 7.00	6.95, 7.00
≤21 vs. >21	2.82, 3.69	3.68, 4.60	4.24, 6.00	6.10, 6.32	6.54, 6.57	6.88, 7.00	6.96, 7.00
≤22 vs. >22	2.79, 3.95	3.70, 4.71	4.21, 6.23	6.13, 6.30	6.54, 6.58	6.88, 7.00	6.96, 7.00
≤23 vs. >23	2.79, 3.95	3.67, 4.88	4.21, 6.23	6.09, 6.37	6.54, 6.58	6.88, 7.00	6.96, 7.00
≤24 vs. >24	2.81, 4.18	3.69, 5.08	4.35, 6.09	6.08, 6.44	6.59, 6.47	6.90, 7.00	6.97, 7.00
≤25 vs. >25	2.53, 3.35	3.71, 4.07	4.00, 5.28	6.40, 6.11	6.85, 6.44	7.00, 6.90	7.00, 6.97
≤26 vs. >26	2.91, 3.93	3.77, 4.90	4.49, 6.00	6.08, 6.54	6.59, 6.46	6.90, 7.00	6.97, 7.00
≤27 vs. >27	2.92, 3.92	3.80, 4.88	4.50, 6.14	6.10, 6.60	6.58, 6.45	6.91, 7.00	6.97, 7.00
≤28 vs. >28	2.93, 4.09	3.81, 5.17	4.57, 6.50	6.11, 6.71	6.55, 6.57	6.91, 7.00	6.97, 7.00
≤29 vs. >29	2.93, 4.09	3.81, 5.17	4.57, 6.50	6.11, 6.71	6.55, 6.57	6.91, 7.00	6.97, 7.00
≤30 vs. >30	2.93, 4.20	3.81, 5.17	4.57, 6.50	6.11, 6.71	6.55, 6.57	6.91, 7.00	6.97, 7.00
≤31 vs. >31	2.93, 4.33	3.82, 5.20	4.63, 6.33	6.13, 6.67	6.56, 6.50	6.92, 7.00	6.97, 7.00
≤32 vs. >32	2.94, 4.57	3.84, 5.25	4.63, 6.33	6.13, 6.80	6.56, 6.50	6.92, 7.00	6.97, 7.00
≤33 vs. >33	2.99, 4.75	3.85, 5.33	4.63, 7.00	6.13, 6.80	6.51, 7.00	6.92, 7.00	6.97, 7.00
≤34 vs. >34	3.01, 4.67	3.85, 5.33	4.68, 7.00	6.15, 6.75	6.52, 7.00	6.92, 7.00	6.98, 7.00
≤35 vs. >35	3.02, 5.00	3.88, 6.00	4.68, 7.00	6.16, 7.00	6.53, 7.00	6.92, 7.00	6.98, 7.00

Data are shown as the mean CAP scores in the ≤month group and >month group at different follow-up evaluation intervals from the 6th month to the 60th month after cochlear implantation. Data in italic fonts show that the mean CAP scores in the ≤month group are higher than those in the >month group. CAP: Categorical auditory performance.

coherent speech could be understood by all listeners in the context of normal daily language activities. However, the CAP and SIR scores in the ≤month group for each of the 16 to 36 implantation month divisions never reached the full score after CI. Therefore, 15 months can be used as the optimal cutoff age for children with hearing impairment to select the best time for CI. Future studies with larger samples are needed to verify the results of this study.

The previous studies on the optimal CI age have reported conflicting results. Some scholars contest that the hearing ability of infants and young children under the age of 3 years develops rapidly within 1 year after CI, and the development speed of hearing ability is unrelated to the CI age.<sup>[20]</sup> children with CI age under 2 years can achieve faster hearing ability development.<sup>[26]</sup> CAP scores in children with CI age under 2 years were close to the normal values. It required approximately 3 years for the CAP scores of children with CI age from 2 to 4 years to reach the normal levels after CI. However, it is very difficult for children with CI age higher than 4 years to achieve a normal CAP score after CI.<sup>[9]</sup> Although there is no unified conclusion on the critical CI age that can achieve the best implantation effect, generally speaking,

the younger the CI age, the better the surgical effect, which is consistent with the results of this study. However, the child's weight is also an important factor to consider, as the criteria for CI surgery include a minimum weight limit; a low weight increases the risks of anesthesia and surgery.<sup>[21]</sup>

In conclusion, the CAP and SIR questionnaires are suitable for the assessment of hearing and speech development after CI. The results of this study showed that the hearing ability and speech intelligibility of patients who underwent CI treatment under the age of 3 years continuously improved along with the passage of time within 5 years after CI, but the development of speech ability lagged behind the development of hearing ability at the early stage. There was no significant difference in hearing and speech abilities among the young hearing-impaired children starting at 2 years after CI. However, considering the rapid development of hearing and speech abilities in younger children, it can be suggested that the earlier the CI age, the better. The optimal cutoff age for CI timing is at 15 months; CI after this time may not be equally beneficial. To better assess the hearing and speech development of children after



**Table 6: Mean SIR scores in the  $\leq$ month group and the  $>$ month group.**

Age groups (months)	Evaluation intervals (months)						
	6	12	18	24	36	48	60
$\leq 7$ vs. $> 7$	1.00, 1.46	1.00, 1.84	2.00, 2.67	<i>4.00, 3.36</i>	<i>5.00, 3.65</i>	5.00, 4.53	<i>5.00, 4.69</i>
$\leq 8$ vs. $> 8$	1.00, 1.47	1.67, 1.84	3.00, 2.65	<i>4.00, 3.33</i>	<i>5.00, 3.65</i>	5.00, 4.53	<i>5.00, 4.69</i>
$\leq 9$ vs. $> 9$	1.00, 1.47	1.50, 1.86	2.00, 2.72	<i>4.00, 3.33</i>	<i>5.00, 3.65</i>	5.00, 4.53	<i>5.00, 6.69</i>
$\leq 10$ vs. $> 10$	1.00, 1.49	1.40, 1.93	2.00, 2.77	<i>3.80, 3.33</i>	<i>4.00, 3.67</i>	5.00, 4.53	<i>5.00, 4.69</i>
$\leq 11$ vs. $> 11$	1.08, 1.51	1.47, 1.94	2.00, 2.85	<i>3.50, 3.35</i>	<i>3.75, 3.68</i>	5.00, 4.50	<i>5.00, 4.64</i>
$\leq 12$ vs. $> 12$	1.06, 1.54	1.41, 1.98	2.15, 2.84	<i>3.50, 3.35</i>	<i>3.75, 3.68</i>	5.00, 4.50	<i>5.00, 4.64</i>
$\leq 13$ vs. $> 13$	1.17, 1.55	1.67, 1.92	2.24, 2.88	<i>3.55, 3.32</i>	<i>3.75, 3.68</i>	5.00, 4.50	<i>5.00, 4.64</i>
$\leq 14$ vs. $> 14$	1.14, 1.59	1.71, 1.92	2.25, 2.93	<i>3.50, 3.33</i>	<i>3.75, 3.68</i>	5.00, 4.50	<i>5.00, 4.64</i>
$\leq 15$ vs. $> 15$	1.16, 1.62	1.68, 1.95	2.32, 2.93	<i>3.57, 3.29</i>	<i>3.67, 3.69</i>	5.00, 4.50	<i>5.00, 4.64</i>
$\leq 16$ vs. $> 16$	1.21, 1.64	1.71, 1.95	2.44, 2.88	<i>3.29, 3.42</i>	<i>3.56, 3.74</i>	4.67, 4.54	4.40, 4.83
$\leq 17$ vs. $> 17$	1.23, 1.67	1.70, 1.97	2.38, 2.96	<i>3.45, 3.32</i>	<i>3.67, 3.70</i>	4.33, 4.70	4.57, 4.80
$\leq 18$ vs. $> 18$	1.27, 1.66	1.70, 2.00	2.41, 2.96	<i>3.45, 3.32</i>	<i>3.46, 3.84</i>	4.43, 4.67	4.43, 4.78
$\leq 19$ vs. $> 19$	1.25, 1.76	1.71, 2.03	2.38, 3.05	<i>3.45, 3.40</i>	<i>3.40, 3.94</i>	4.43, 4.67	4.56, 4.88
$\leq 20$ vs. $> 20$	1.33, 1.71	1.72, 2.08	2.42, 3.12	<i>3.38, 3.36</i>	<i>3.53, 3.87</i>	4.56, 4.57	4.64, 4.83
$\leq 21$ vs. $> 21$	1.41, 1.58	1.74, 2.10	2.42, 3.29	<i>3.39, 3.35</i>	<i>3.56, 3.86</i>	4.56, 4.57	4.64, 4.83
$\leq 22$ vs. $> 22$	1.39, 1.68	1.74, 2.18	2.41, 3.38	<i>3.40, 3.33</i>	<i>3.60, 3.83</i>	4.56, 4.57	4.58, 5.00
$\leq 23$ vs. $> 23$	1.39, 1.68	1.73, 2.25	2.41, 3.38	<i>3.35, 3.41</i>	<i>3.60, 3.83</i>	4.56, 4.57	4.58, 5.00
$\leq 24$ vs. $> 24$	1.79, 1.82	1.72, 2.38	2.46, 3.36	<i>3.29, 3.57</i>	<i>3.57, 4.00</i>	4.60, 4.50	4.62, 5.00
$\leq 25$ vs. $> 25$	1.16, 1.62	1.68, 1.95	2.32, 3.93	<i>3.57, 3.29</i>	<i>3.67, 3.69</i>	5.00, 4.50	<i>5.00, 4.64</i>
$\leq 26$ vs. $> 26$	1.40, 1.79	1.75, 2.40	2.52, 3.38	<i>3.28, 3.67</i>	<i>3.58, 4.00</i>	4.64, 4.40	4.64, 5.00
$\leq 27$ vs. $> 27$	1.41, 1.77	1.76, 2.50	2.53, 3.43	<i>3.26, 3.89</i>	<i>3.60, 4.00</i>	4.50, 4.75	4.64, 5.00
$\leq 28$ vs. $> 28$	1.41, 1.82	1.76, 2.67	2.59, 3.50	<i>3.27, 4.00</i>	<i>3.59, 4.20</i>	4.50, 4.75	4.64, 5.00
$\leq 29$ vs. $> 29$	1.41, 1.82	1.76, 2.67	2.59, 3.50	<i>3.27, 4.00</i>	<i>3.59, 4.20</i>	4.50, 4.75	4.64, 5.00
$\leq 30$ vs. $> 30$	1.40, 1.90	1.76, 2.67	2.59, 3.50	<i>3.27, 4.00</i>	<i>3.59, 4.20</i>	4.50, 4.75	4.64, 5.00
$\leq 31$ vs. $> 31$	1.40, 2.00	1.78, 2.60	2.64, 3.00	<i>3.31, 3.83</i>	<i>3.64, 4.00</i>	4.54, 4.67	4.67, 5.00
$\leq 32$ vs. $> 32$	1.40, 2.14	1.79, 2.50	2.64, 3.00	<i>3.33, 3.80</i>	<i>3.64, 4.00</i>	4.50, 5.00	4.67, 5.00
$\leq 33$ vs. $> 33$	1.43, 2.00	1.81, 2.33	1.63, 3.50	<i>3.33, 3.80</i>	<i>3.60, 5.00</i>	4.50, 5.00	4.47, 5.00
$\leq 34$ vs. $> 34$	1.44, 2.00	1.81, 2.33	2.65, 3.00	<i>3.34, 3.75</i>	<i>3.65, 5.00</i>	4.53, 5.00	4.69, 5.00
$\leq 35$ vs. $> 35$	1.44, 2.00	1.83, 2.00	2.65, 3.00	<i>3.35, 4.00</i>	<i>3.65, 5.00</i>	4.53, 5.00	4.69, 5.00

Data are shown as the mean SIR scores in the  $\leq$ month group and  $>$ month group at different follow-up evaluation intervals from the 6th month to the 60th month after cochlear implantation. Data in italic fonts show that the mean SIR scores in the  $\leq$ month group are higher than those in the  $>$ month group. SIR: Speech intelligibility rating.

CI, it is necessary to assess a larger sample over a longer period in a prospective longitudinal study.

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### Conflicts of interest

None.

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