The effect of pre-operative developmental delays on the speech perception of children with cochlear implants

Running title: Cochlear implantation in children with developmental delays

Harukazu Hiraumi, MD, PhD, Norio Yamamoto, MD, PhD, Tatsunori Sakamoto, MD, PhD, Shinobu Yamaguchi, PhD, Juichi Ito, MD, PhD

Department of Otolaryngology-Head and Neck Surgery

Kyoto University, Graduate School of Medicine

54, Kawahara-cho, Shogoin, Sakyo-ku, Kyoto, 606-8507, Japan

Phone +81-75-751-3346

FAX +81-75-751-7225

E-mail: hhiraumi@ent.kuhp.kyoto-u.ac.jp

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CONFLICT OF INTEREST

We do not have a financial relationship with the organization that sponsored the research or any other conflicts of interest.

ETHICAL ISSUES

All the data obtained from the patients were stored in a computer with password. All patient-identifiable data are anonymized in a linkable fashion.

Abstract

Objective: The objective of this study was to evaluate the relationship between developmental delays and speech perception in pre-lingually deafened cochlear implant recipients.

Methods: This study was a retrospective review of patient charts conducted at a tertiary referral center. Thirty-five pre-lingually deafened children underwent multichannel cochlear implantation and habilitation at the Kyoto University Hospital Department of Otolaryngology-Head and Neck Surgery. A pre-operative cognitive-adaptive developmental quotient was evaluated using the Kyoto scale of psychological development. Post-operative speech performance was evaluated with speech perception tests two years after cochlear implantation. We computed partial correlation coefficients (controlled for age at the time of implantation and the average pre-operative aided hearing level) between the cognitive-adaptive developmental quotient and speech performance.

Results: A developmental delay in the cognitive-adaptive area was weakly correlated with speech perception (partial correlation coefficients for consonant-vowel syllables and phrases were 0.38 and 0.36, respectively).

Conclusions: A pre-operative developmental delay was only weakly associated with poor post-operative speech perception in pre-lingually deafened cochlear implant recipients.

Keywords: cochlear implant, developmental delay, speech perception

Introduction

The criteria for cochlear implantation in pre-lingually deafened children have recently been expanded, and many children with additional disabilities have undergone this procedure (1). Although many of these children show progress after surgery (2), the benefit they receive from cochlear implantation ranges widely. For example, progress after cochlear implantation has been shown to be low in children diagnosed with pervasive developmental disorder (2-3). Congenitally deaf-blind children also show limited development in auditory perception (2). A developmental delay is found in approximately 30% of children who undergo cochlear implantation (4-5). Previous studies have reported that deaf children with developmental delays, particularly delays in cognitive functioning, show poor development of speech perception skills after implantation (5-7). However, many reports have reached this conclusion by comparing the speech outcomes of children with developmental delays to children with normal development, and little information has been presented the relationship between the extent of a pre-operative cognitive delay and outcomes (4). Because speech perception is variable in children with cochlear implantation (6), it is not sufficient to compare speech outcomes between delayed and non-delayed children. Instead, it is necessary to examine the relationship between development and speech outcomes in each child. To determine this relationship, we created a scatter plot of developmental quotients in cognitive-adaptive areas and post-operative speech perception scores and calculated the correlation coefficients between these factors in pre-lingually deafened children receiving cochlear implantation.

Materials and Methods

Between January 1996 and December 2008, 42 pre-lingually deafened children (whose age at device implantation was younger than 60 months) underwent cochlear implantation surgery and speech habilitation therapy at the Kyoto University Hospital Department of Otolaryngology-Head and Neck Surgery. We excluded four children with an obstructed cochlea, one child with a narrow internal auditory canal and one child who spoke a foreign language. Another child failed to take both the consonant-vowel syllables and phrase perception tests for non-medical reasons and was also excluded from the analysis. In total, 35 children were included in the analysis. All children were implanted with Nucleus multichannel devices (Cochlear Ltd., Australia). The children received the most current devices and coding strategies available in Japan at the time of the surgery. Six children were implanted with CI22M, 18 children were implanted with CI24M, and 11 children were implanted with CI24R. The coding strategies used at the post-operative evaluation were SPEAK, for 8 children, and ACE, for 27 children. In all cases, all of the active electrodes were successfully inserted into the cochlea. The patients' information is shown in Table 1.

The developmental quotients were evaluated according to the Kyoto scale of psychological development, which is one of the most widely used developmental tests in Japan. In the version administered in this study, the valid age range was from 3 months to 14 years. The Kyoto scale of psychological development is highly correlated with the Stanford-Binet intelligence scale and is reported to be useful in assessing the development of small children with various disabilities (8). We routinely administer this test to children who undergo cochlear implantation surgery. This test is an individualized, face-to-face test that assesses a child’s development in the following three areas: Postural–Motor (fine and gross motor functions), Cognitive–Adaptive (non-verbal reasoning or visuospatial perceptions assessed using materials) and Language–Social (interpersonal relationships, socializations and verbal abilities). Typically, it takes approximately 30 minutes to complete the tests. A score from each of the three areas is converted to a developmental age. The developmental age for each area is divided by the child’s chronological age and multiplied by 100 to yield a developmental quotient. Of the developmental quotients for the three areas, the developmental quotient for the cognitive-adaptive area (DQCA) was used in the current study. The standard deviation of the developmental quotients in the Kyoto scale of psychological development is 10. Therefore, children with a DQCA score below 80 were considered delayed, and children with a DQCA score above 80 were considered non-delayed.

Speech perception tests were conducted 2 years after implantation. Consonant-vowel (CV) syllables and short sentences were used in the tests. In the CV syllable perception test, thirteen CV syllables, composed of thirteen Japanese consonants and the vowel /a/, were presented twice (a total of 26 CV syllables). In the phrase perception test, 40 phrases were arranged to form 10 short sentences. The CV syllable perception test was a closed set, and the phrase perception test was an open set. These parts of speech were spoken by a male professional announcer and digitized at a sampling rate of 44,100 Hz. Speech was presented through speakers at 70 dB SPL (using a PowerMac PM-7300/166 computer, Apple, USA) in a random order, and the percentage of correct answers was recorded. Some children were not able to complete the speech perception test because of poor understanding or poor expressive abilities. For these patients, the percentage of correct answers was set to a chance level (in the CV syllable perception test) or to zero (in the phrase perception test). Five children did not take the phrase perception test for non-medical reasons. These children were excluded from the phrase perception test analysis.

The association between the pre-operative DQCA and speech perception scores was analyzed in two ways. First, the speech perception scores of delayed and non-delayed children were compared using *t*-tests. Second, a correlation analysis was conducted between the pre-operative DQCA and speech perception scores. We calculated the Pearson's correlation coefficient and the partial correlation coefficient. The Pearson's correlation analysis represents an estimated linear regression line. The partial correlation analysis is a multivariate analysis that clarifies a relationship between two factors, taking into account the influence of other factors. In the current study, a partial correlation coefficient was calculated, controlling for age at the time of implantation and the average pre-operative aided hearing level. All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) 11.0 (SPSS Inc., Illinois, USA).

Results

The DQCA scores ranged from 45 to 118, with a mean value of 87. Eleven children (31%) were considered developmentally delayed, and 24 children (69%) fell into the normal development range. The age at time of implantation and the pre-operative aided hearing level were not significantly different between the delayed and the non-delayed groups ($p = 0.11$ and $p = 0.93$, respectively; *t*-test). The cause of deafness, the implant device, and the coding strategy did not differ between the two groups ($p = 0.56$, $p = 0.56$, and $p = 0.67$, respectively; chi-square test). The speech perception scores of the delayed and non-delayed groups are presented in Table 2. The CV syllable and phrase perception scores in the non-delayed group were significantly higher than those in the delayed group ($p < 0.05$ for the CV syllable test and $p < 0.05$ for the phrase perception test; *t*-test).

Scatter plots of the DQCA and speech perception scores are shown in Figures 1 and 2. The relationship between the DQCA scores and the speech perception scores was moderate (correlation coefficient = 0.48, $p < 0.01$ for the CV syllable perception test; correlation coefficient = 0.49, $p < 0.01$ for the phrase perception test; Pearson's correlation coefficient). After removing the effect of age at the time of implantation and the average pre-operative aided hearing level, we found that the relationship between the DQCA scores and the speech perception scores was weak (partial correlation coefficient = 0.38, $p < 0.05$, one-tailed, for the CV syllable perception test; partial correlation coefficient = 0.36, $p < 0.05$, one-tailed, for the phrase perception test).

Discussion

In this study, 31% of implanted children were considered developmentally delayed. The incidence of developmental delays in children who have undergone cochlear implantation was previously reported to be 23-34% (4-7), and our results fell within this range. Children with a developmental delay are reported to show poor speech outcomes. Pyman et al. compared the speech perception of children with a developmental delay to that of children with normal development and found that children with developmental delays tended to progress more slowly than other children (7). In a study by Holt and Kirk, children with a developmental delay also showed slower progress in sentence recognition tests (6). In that study, the authors stressed that the intersubject variability was quite large. In the present study, children with a developmental delay in the cognitive-adaptive area showed significantly poorer speech perception than children without a developmental delay, and the intersubject variability was large, particularly in children with developmental delays.

This large intersubject variability was also observed in the correlation analysis. The correlation between the pre-operative DQCA and the post-operative speech perception scores was weak after removing the effect of other factors. This finding indicates that individual variability is large in children with similar developmental statuses. This result seems reasonable because the outcome of the cochlear implantation can be influenced by several factors, including the habilitation program, technological improvements, and family characteristics. Edwards et al. reported a high coefficient of determination between a developmental delay in cognitive areas and speech perception outcomes (4), which differs from the findings in the present study and a previous study (6). This difference in findings may be explained by the characteristics of the children included in the studies. In our study, 11 of 35 children were developmentally delayed, and many were only mildly delayed. In the Edwards et al. study, 11 of 32 children were delayed, and 3 children were significantly delayed. This specific patient population may have led to the high coefficient of determination. In the study by Edwards et al., children with a mild delay made appreciable progress (4), and this result is consistent with the present study.

In the present study, a developmental delay showed a weak but significant correlation with speech perception scores. Holt and Kirk suggested that a low speech perception score in delayed children does not necessarily indicate poor listening ability; poor knowledge of grammar or a limited vocabulary may also lead to low speech perception scores (6). In the present study, we used CV syllables and phrases to evaluate speech perception. Although the two tests require different degrees of linguistic ability, the correlation coefficients were similar. This finding suggests that the low speech recognition scores in delayed children are a result of poor listening ability. However, this result does not indicate that these children are not good candidates for cochlear implantation. Some children with developmental delays had speech perception scores that were comparable to children without developmental delays. Children with poor results may be delayed only at the stage in which they were classified at the time of examination. It is possible that these children will catch up to non-delayed children after several years.

This study showed that a pre-operative developmental delay negatively affected post-operative speech perception, but the impact was not large. Children with a similar pre-operative development status showed variable outcomes. Thus, it does not seem possible to define a developmental quotient cutoff level for the indication of cochlear implantation.

Conclusions

Pre-operative developmental delays were only weakly associated with poor post-operative speech perception two years after cochlear implantation. Outcomes varied between children with similar pre-operative developmental quotients. These results indicate that it is not appropriate to exclude children from candidacy for cochlear implantation based only on a developmental delay.

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CONFLICT OF INTEREST

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Figure 1

Scatter plot relating pre-operative DQCA scores to post-operative CV syllable perception scores. The dotted line indicates the estimated linear regression. Children with higher pre-operative DQCA scores had better post-operative CV syllable perception scores (Pearson's correlation coefficient = 0.48, $p < 0.01$; partial correlation coefficient = 0.38, $p < 0.05$). However, the outcomes varied between children with similar pre-operative developmental quotients.

Figure 2

Scatter plot relating pre-operative DQCA scores to post-operative phrase perception scores. The dotted line indicates the estimated linear regression. Many children with a normal DQCA score (above 80) scored above 80% on the post-operative phrase perception test, although the relationship between pre-operative DQCA and post-operative phrase perception scores was not strong (Pearson's correlation coefficient = 0.49, $p < 0.01$; partial correlation coefficient = 0.36, $p < 0.05$).

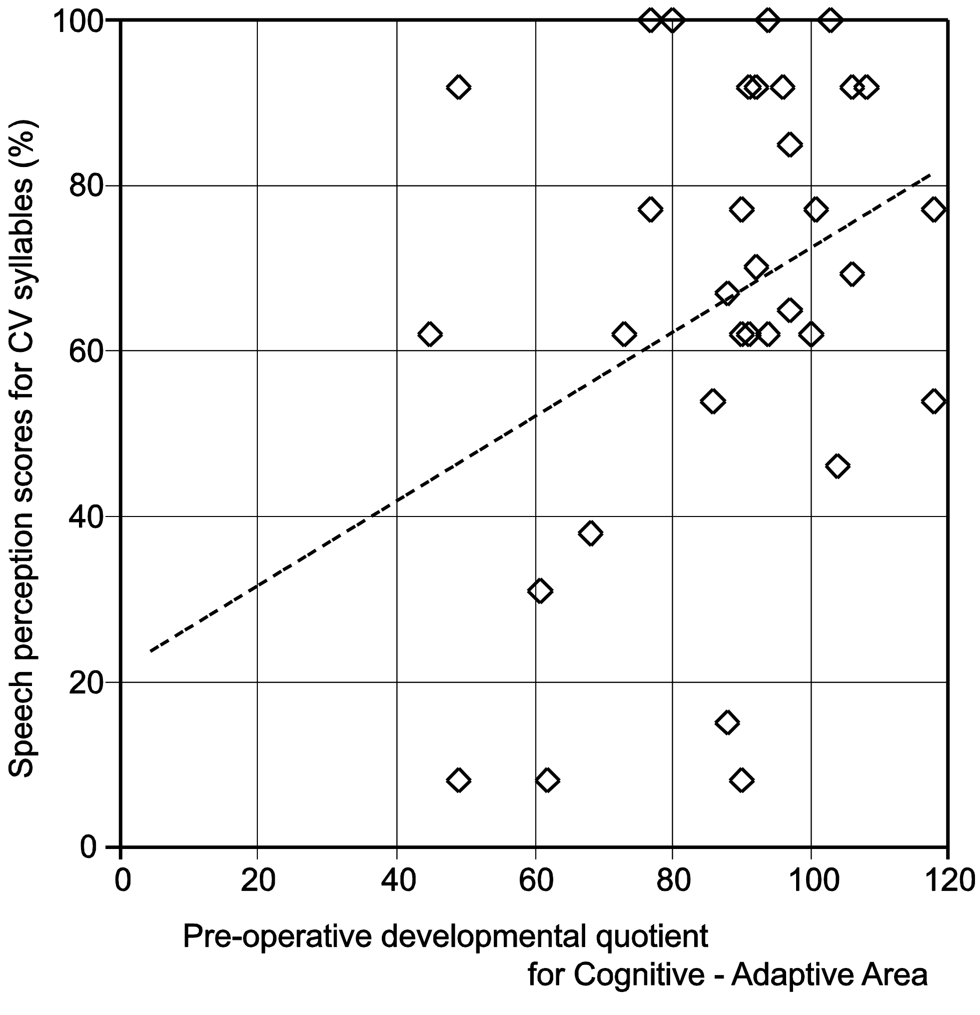
100
80
60
40
20
0
0
20
40
60
80
100
120
Speech perception scores for CV syllables (%)
Pre-operative developmental quotient
for Cognitive - Adaptive Area

Figure 1

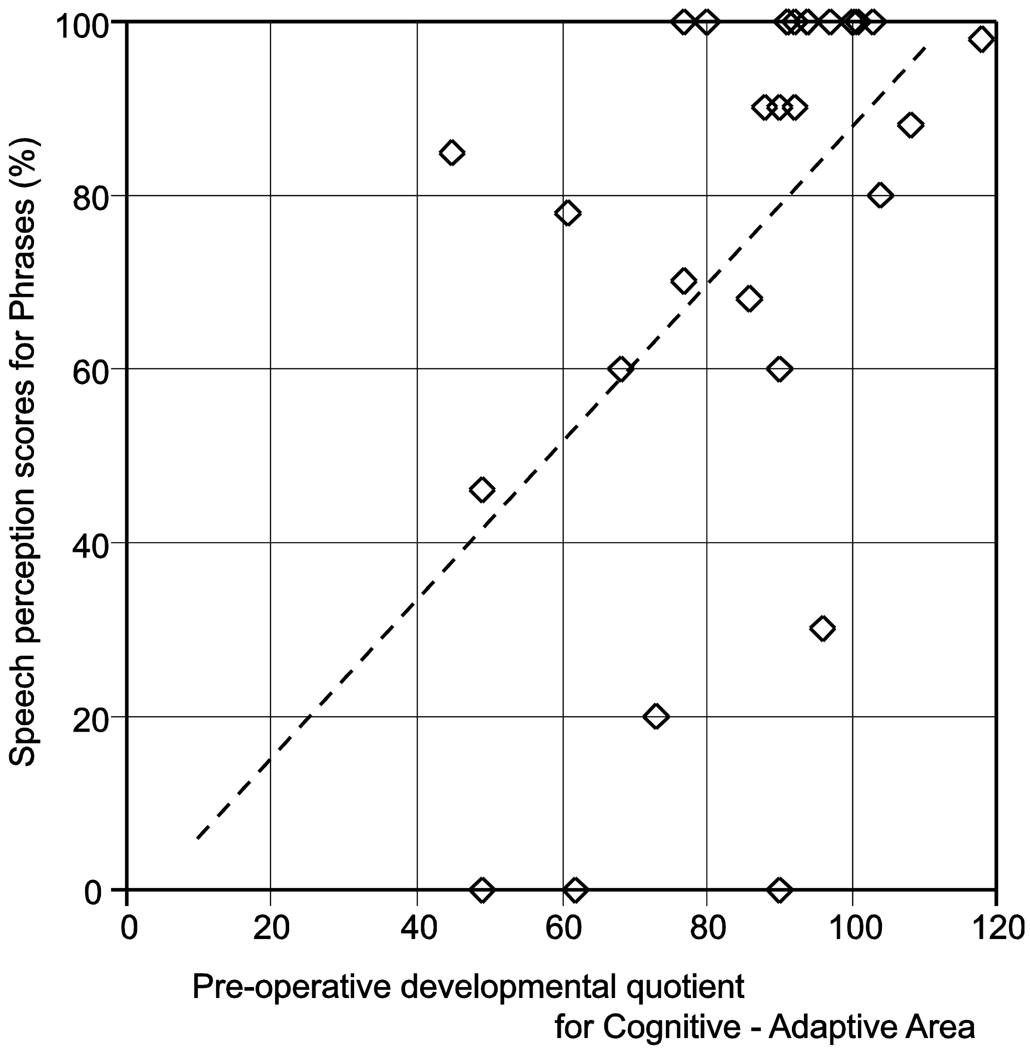
Speech perception scores for Phrases (%)
100
80
60
40
20
0
0
20
40
60
80
100
120
Pre-operative developmental quotient
for Cognitive - Adaptive Area

Figure 2

Table 1

Subject characteristics

Characteristics			
Male / Female			21 / 14
Mean (range) age at cochlear implantation (in months)			37 (18 – 58)
Mean (range) average aided hearing threshold (dBHL)			75.0 (55.0 – 110.0)
Etiology of deafness			
	Congenital	Unknown	27
		Inner ear malformation	5
	Acquired	Bacterial meningitis	1
		Viral infection	2
Device			
	CI22M		6
	CI24M		18
	CI24R		11
Coding strategy			
	ACE		27
	SPEAK		8

Male / female ratio, etiology of deafness, implant device, and coding strategy are reported as the number of children included in these groups.

Table 2

Speech perception scores of delayed and non-delayed children

	Mean	SEM	Significance
CV syllable perception score			
Delayed group	44%	11%	0.02*
Non-delayed group	70%	5%	
Phrase perception score			
Delayed group	52%	14%	0.03*
Non-delayed group	84%	7%	

Mean speech perception scores of delayed and non-delayed children are reported as percentages. The delayed group scored significantly lower than the non-delayed group in CV syllable and phrase perception tests (t - test).

SEM: standard errors of the means

*: $p < 0.05$

References

1. Kim LS, Jeong SW, Lee YM, Kim JS. Cochlear implantation in children. Auris Nasus Larynx. 2010 Feb;37(1):6-17.
2. Daneshi A, Hassanzadeh S. Cochlear implantation in prelingually deaf persons with additional disability. J Laryngol Otol. 2007 Jul;121(7):635-8.
3. Edwards LC. Children with cochlear implants and complex needs: a review of outcome research and psychological practice. J Deaf Stud Deaf Educ. 2007 Summer;12(3):258-68.
4. Edwards LC, Frost R, Witham F. Developmental delay and outcomes in paediatric cochlear implantation: implications for candidacy. Int J Pediatr Otorhinolaryngol. 2006 Sep;70(9):1593-600.
5. Wiley S, Meinzen-Derr J, Choo D. Auditory skills development among children with developmental delays and cochlear implants. Ann Otol Rhinol Laryngol. 2008 Oct;117(10):711-8.
6. Holt RF, Kirk KI. Speech and language development in cognitively delayed children with cochlear implants. Ear Hear. 2005 Apr;26(2):132-48.
7. Pyman B, Blamey P, Lacy P, Clark G, Dowell R. The development of speech perception in children using cochlear implants: effects of etiologic factors and delayed milestones. Am J Otol. 2000 Jan;21(1):57-61.
8. Koyama T, Osada H, Tsujii H, Kurita H. Utility of the Kyoto Scale of Psychological Development in cognitive assessment of children with pervasive developmental disorders. Psychiatry Clin Neurosci. 2009 Apr;63(2):241-3.