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

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

1. 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.

2. 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

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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.

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 min 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).

3. 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 Figs. 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).

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.
* $p < 0.05$.