

Factors Affecting the Effectiveness of Auditory and Speech Development in Pre-Lingual Deaf Children After Cochlear Implantation

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ABSTRACT

Introduction: A cochlear implant (CI) is an electronic device provided for deaf patients. Congenitally deaf children generally have delayed speech and language development due to hearing impairment. The aim after implantation is for patients to have speech development the same as normal-hearing children and to be able to communicate with other people by verbal language. However, some children provided with a CI at Siriraj Hospital were still unable to use spoken language and had delayed speech and language development. This study aimed to examine factors that affected the outcomes after cochlear implantation at Siriraj Hospital.

Methods: Sixty pre-lingual deaf children with CI were included in the research, which was a retrospective study. Three main related factors, consisting of age at implantation, duration of hearing deprivation, and multiple disabilities, were reviewed that affected the development in CI patients. The data were collected from Siriraj's outpatient department (OPD) documents between 1 January 2014 and 31 October 2022. The auditory and speech developments of participants in this study were compared with developmental milestones.

Results: The findings showed that 14 patients had auditory and speech developments similar to children with normal hearing (23.3%), and 46 samples experienced delayed developments (76.7%). The duration of auditory deprivation showed significant differences between successful and unsuccessful patients (p -value<0.05), while ages at implantation and multi-disabilities were not statistically different.

Conclusion: The significant factor affecting the auditory and speech development of CI patients from Siriraj Hospital was the duration of auditory deprivation. Samples who had periods of auditory deprivation more than or equal to 1.5 years tended to be more unsuccessful than those ages less than 1.5 years by 5.5 times.

Keywords: Cochlear implant, Auditory deprivation, Hearing loss, Pre-lingual Deafness, Speech development

Introduction

Hearing loss is the inability to hear sounds appropriately, leading to difficulty in understanding speech sounds. It can occur in one ear (unilateral) or both ears (bilateral). The capability to comprehend a conversation depends on the severity of hearing impairment, which can be categorized by hearing levels. People with mild to moderate hearing loss may have difficulty understanding words, especially in a noisy environment. In contrast, people with severe to profound deafness cannot hear anything, even in quiet situations [1]. ASHA (2011) states a profound hearing loss is hearing thresholds over 90 decibels [2]. In the past, Thai speech-language, and hearing association

(THAISHA) followed ASHA's criteria. However, in 2022, the criteria changed to WHO's criteria. WHO (2008) classified a profound hearing impairment at hearing thresholds of more than 80 decibels [3].

Children with severe to profound hearing loss principally have delayed speech and language development. This is because they cannot perceive sounds to develop their auditory skill, which is the principle of speech and language development [4]. When children are diagnosed with hearing impairment, children will be required to fit a hearing aid to motivate inner ear function. If children do not have any benefit from traditional amplification devices, cochlear implantation (CI) will be considered [5]. The limitation of traditional hearing devices for deaf patients is they

can hear sounds but do not understand meaning, especially speech sounds. Unfortunately, some cases who have total deafness are incapable of hearing any sound, even when hearing aids are set at full-on gain. These limitations may result in delayed speech and language development. Therefore, cochlear implantation is an alternative opportunity to improve children's development. The main purpose of cochlear implantation is so children can communicate with other people by using verbal language [6]. However, the perception of speech sounds between CI and normal-hearing children is incompatible. Sounds that children with CI hear are dissimilar to natural sounds.

For this reason, auditory training is exceptionally recommended for children after implantation to develop their speech and language skills to be equal to children with normal hearing [7]. At Siriraj Hospital, the number of children with CI has increased over the years. Some patients can use spoken language to communicate with other people and have speech and language development similar to normal-hearing children, while others cannot and have delayed speech and language development.

According to Patni et al [8] and Niparko et al [9] factors affecting the outcome of children with CI were the age at implantation and the duration of auditory deprivation. According to the study by Gaurav et al [10] patients wearing CI under five years had better speech and language development than patients over five years. Additionally, the research of Karltorp et al [11] revealed that children with the age at implantation under 5 to 11 months had speech and language development similar to children with normal hearing. Furthermore, other factors affecting the CI results were patients who had multiple disabilities such as autistic spectrum, learning disorder, or cerebral palsy. These factors can cause delayed speech and language development after implantation [12-13]. This study aimed to retrospectively explore factors that affect the outcome of pre-lingual children after cochlear implantation (CI) at Siriraj Hospital.

Methods

This research was a retrospective study. It was approved by the International Review Board (IRB) under the Faculty of Medicine, Siriraj Hospital, Ethics

Framework 717/2022 (IRB4). The data were collected using information from out-patient-department (OPD) documents of Siriraj Hospital between 1 January 2014 and 31 October 2022. The inclusion criteria were children with pre-lingual deafness, having congenital profound hearing loss in both ears, and experiencing CI for at least two years.

The sample size was calculated by using the Rule of Thumb. From previous studies, there were three main factors related to the development of CI recipients: age at implantation, duration of hearing deprivation, and multiple disabilities. For this study, the researcher required five patients per one factor, so the number of successful and unsuccessful samples was $3 \times 10 = 30$. The percentage of successful patients at Siriraj Hospital was roughly 20. Therefore, the appropriate number of samples was $100 \times 30/20 = 150$. However, 60 CI children were recruited from all 110 patients for this study. Patients with post-lingual deafness, having progressive hearing loss, having operated CI for less than two years, and receiving some benefits from hearing aids before implantation were excluded from this study. The duration of data collection was around six months.

Statistical analysis

An unpaired t-test was used to analyze factors affecting speech and language development of CI children compared with Developmental Milestones for each independent variable. The Mann-Whitney U test was used for continuous data, and Chi-square or Fisher's exact tests were used for grouped data. Multiple logistic regression was used to analyze the relationship between dependent and independent variables. Moreover, an odds ratio (OR) was used to report the association between two events with a 95% odd ratio.

Results

The average patient age in this study was approximately 8.58 ± 2.32 years. The impairment was diagnosed at the age of around 1.44 ± 0.64 years. The implantation and duration of CI ages were about 2.88 ± 1.13 and 5.83 ± 2.37 years, respectively (Table 1).

Table 1 General information of samples

	Mean	SD	Median	Min	Max
Patient age	8.58	2.32	8.67	4.5	16.08
Diagnostic age	1.44	0.64	1.58	0.25	2.5
CI implantation age	2.88	1.13	2.87	0.92	5.17
Duration of CI age	5.83	2.37	5.25	2.33	14.58

Speech development was used to classify patients into two groups. From the total number of 60 CI patients in this study, 14 CI patients (23.3%) had speech and language development similar to children with normal hearing, which were categorized into successful groups, while 46 patients with CI (76.6%) had delayed speech and language development, classified into unsuccessful groups (Table 2).

Table 2 Percentage of successful and unsuccessful patients

Outcome	n	%
Successful patients	14	23.3
Unsuccessful patients	46	76.7
Total	60	100

The successful group's average CI implantation age was roughly 2.17 ± 0.94 years. The duration of auditory deprivation was about 0.98 ± 0.62 years (the period before fitting a hearing aid). Three children had other disabilities regarding visual problems, which was 21.43% of the total group. One sample had an auditory nerve problem (7.14%) (Table 3).

The total number of unsuccessful patients was 46. They were operated on for CI implantation at around 3.10 ± 1.10 years. The duration of auditory deprivation was higher than the successful group, which was approximately 1.59 ± 0.98 years. There were five patients with other disabilities and ten auditory nerve problems (10.87% and 21.74% of this group), respectively. In this group, seven children attended a mainstream school, and 13 participants lost follow-up from the hospital (Table 3).

Table 3 Comparison between successful and unsuccessful groups

Factors	Successful (n = 14)	Unsuccessful (n = 46)	p-value
CI implantation age	2.17 ± 0.94	3.10 ± 1.10	0.319
Duration of auditory deprivation	0.98 ± 0.62	1.59 ± 0.98	0.016*
Duration of auditory deprivation (years)			
< 1.5	12 (85.7%)	24 (52.2%)	0.025*
$\geq 1.5^{\#}$	2 (14.3%)	22 (47.8%)	
Multiple disabilities	3 (37.5%)	5 (62.5%)	0.374
Auditory nerve problems	1 (9.1%)	10 (90.9%)	0.430

[#]Odds ratio (95% CI) = 5.50 (1.11, 27.37); *Significant level at $\alpha=0.05$

The duration of auditory deprivation was statistically significant when comparing the results of successful and unsuccessful patients (p-value < 0.05). The average auditory deprivation for the successful group was about 0.98 years, while for the unsuccessful group, it was roughly 1.59 years. Children who had auditory deprivation more than or equal to 1.5 years had an opportunity to be unsuccessful patients by 5.5 times of ages under 1.5 years. On the other hand, other factors, including CI implantation age, multiple disabilities, and auditory nerve problems, had no statistical significance (p-value > 0.05). Moreover, no factors affected speech and language development after implantation when analyzing data with multiple logistic regression (Table 3).

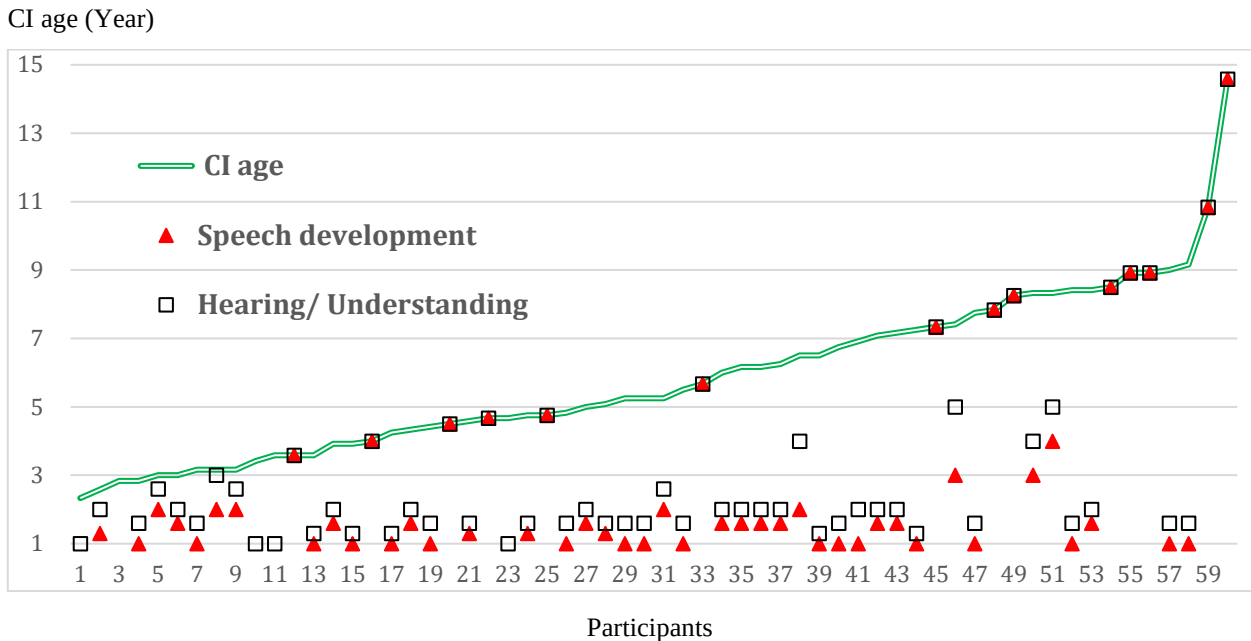


Figure 1 Auditory and speech development of participants comparing CI ages.

Discussion

CI is an optional surgery for deaf patients who do not derive any benefits from hearing aids. The outcomes after implantation rely on several factors. The objective of this study was to explore factors that affect the effectiveness of auditory and speech development after cochlear implantation at Siriraj Hospital to recommend appropriate advice before implantation and to design a proper intervention after implantation for each patient. Figure 1 illustrates the development of each participant in terms of auditory and speech skills. A total of 60 patients were included in this study. The green line represents the ages of using CI. Squares and triangles mean hearing and speech development of each participant, respectively. There were 14 patients with auditory and speech development equal to CI ages (23.3%, square and triangle overlap green line) and 46 samples with delayed speech and language development (76.7%, square and triangle under green line). Developmental milestones in this study are at a maximum of 4 years. Participants with auditory and speech development over four years were grouped as successful. This is because they can understand speech and communicate with other people.

In addition, understanding the language of some participants in Figure 1 was better than speech because receptive language is generally developed faster than expressive language [14]. Receptive language is the capacity to comprehend language from hearing or reading. It is the elementary step before expressing language through verbal or nonverbal communication [15]. Therefore, some children are better able to develop receptively than expressively. The researcher used speech development in this study to categorize successful and unsuccessful groups. Overall,

the CI ages of the successful group were approximately under five and over seven years.

According to other related studies, three main factors affected speech and language development after cochlear implantation. The most relevant factor was the duration of auditory deprivation, followed by ages receiving CI and multiple disabilities, respectively. The significant difference between successful and unsuccessful patients from this study was the duration of auditory deprivation. The result of this study demonstrated that the average of the successful group had a lower period of auditory deprivation than that of the unsuccessful group. Furthermore, the average CI implantation ages in the successful group were likely lower than in the unsuccessful group, but there was no statistical difference. In addition, other disabilities and auditory nerve problems in the successful group tended to be lower than in the unsuccessful group, but there was no statistical difference. This is because the sample size in this study was too small to analyze the data. If there are more samples in the research, some results might differ significantly.

Additionally, this study was a retrospective study, so some aspects may not have been able to be recruited into this study. This is the restriction of this research. For example, the consistency of intervention after implantation and family support may affect the outcome after implantation, but these factors were not included in this study. Some children attended auditory training at other hospitals, so the OPD document would not record this information. Therefore, further studies may include more factors related to auditory and speech development effectiveness after cochlear implantation.

Conclusion

For this study, the duration of auditory deprivation affected children's development in terms of auditory and language skills in pre-lingual deafness children after cochlear implantation, which was significantly lower than that of unsuccessful patients. Children with auditory deprivation over or equal to 1.5 years would experience delayed speech and language development rather than those under 1.5 years. Other factors, including ages with CI and multiple disabilities, were not statistically different between successful and unsuccessful groups. In the future, if the number of CI patients at Siriraj Hospital increases, more factors might be included in further studies.

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