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Long-Term Effects of Cochlear Implantation on Language Skills -and Speech Intelligibility in Early-implanted Versus Late Implanted Deaf Children

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Abstract

Background: Hearing loss may affect many aspects of a person's life. The age of cochlear implantation (CI) is often considered an important predictor of language skills in children with CI, but little is known about the benefits of early CI on speech intelligibility development in these children. This study aimed to compare language skills as well as intelligibility of speech in prelingual deaf patients who received CI before the age of six years and those who received CI after the age of six years with an 8-year follow-up.

Methods: This 8-year longitudinal, retrospective case–control study was conducted in 2021 at a cochlear implant center in Tehran, Iran. Thirty-one patients were included in two groups: late cochlear implant (n = 15), and early cochlear implant (n = 16). The Test of Language Development-Primary (TOLD-P3) was used to assess the participants' language skills. The intelligibility of the participants' speech was assessed through the Persian version of the Intelligibility Context Scale (ICS) and the speech intelligibility rating (SIR).

Results: These two groups did not show a significant difference in terms of the language scores ($P>0.05$) but had a significant difference in terms of the SIR and the ICS scores ($P<0.05$). Speech intelligibility had a significantly negative correlation with the age of CI ($r = -0.57$, $P<0.001$), and a significant positive correlation with language skills ($r = 0.75$, $P<0.001$).

Conclusion: The long-term outcomes of early and late CI were similar in terms of the development of language skills but too different in terms of the intelligibility of speech. The age of CI had no effect on language development but had a significant effect on speech intelligibility.

Key Words: Cochlear Implantation, Language, Hearing Impairment, Intelligibility, Late, Speech.

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1- INTRODUCTION

Hearing is vital for children's speech and language development (1). Children with hearing loss may experience language delay and academic difficulties (1, 2). More than half of the individuals with severe to profound hearing loss undergo cochlear implants (CI) (3). Cochlear implants are used to develop the language skills in the prelingually deaf children (4, 5). Also, the development of language components including syntax and semantics is the most important criterion for measuring the efficiency of CI in these children (5, 6). In fact, deaf children have access to a significant amount of auditory information after CI, which allows them to develop their language skills more quickly than their non-implanted peers (7).

It is clear that infants who are implanted at a very young age have better language skills than those implanted after a long period of deafness (6, 8 and 9). But children who are implanted at later ages show various outcomes and rates of language development (9, 10). However, some researchers believe that any child, regardless of age, can benefit from CI (2, 9 and 11). There are limited studies comparing the linguistic outcomes of deaf children with early and late cochlear implanted (2, 9). Also, so far, no study has examined the language abilities of prelingual deaf Persian-speaking children with early and late CI. In this study, various components of language development as well as intelligibility of speech of prelingual deaf children with early and late cochlear implantation were evaluated after 8 years.

2- MATERIALS AND METHODS

2-1. Subjects and study design

An 8-year longitudinal, retrospective case–control study was conducted in 2021 to compare language skills and intelligibility of speech in pre-lingual deaf children who had CI before the age of six and those who had CI after the age of six years in Tehran, Iran. The follow-up data, in this study, were collected in February 2021, based on a mean follow-up period of 8.3 years (range 4.1-12).

Thirty-one children from a cochlear implant center in Tehran were recruited to participate in this study. They all had unilateral cochlear implants between 2009 and 2012. All participants were Persian speaking who ranged in the age range of 10 to 32 years, at the time of this study. The control group consisted of 16 children who underwent CI before the age of 6 years (early implantation). The experimental group consisted of 15 children who were implanted after the age of six years (late implantation). Although the critical age for cochlear implantation is usually considered younger (12, 13), studies have shown that CI at older ages has also had a positive effect on users' oral language (2, 14). Progressive hearing loss, complex medical conditions, family uncertainty, and geographical location have been reported as reasons for late CI (15). In addition, in Iran, due to the high cost of CI and the lack of easy access for infants in many cities, as well as the long wait for infants on the list of receiving CI, many deaf children receive CI at older ages. Accordingly, in this study, as in a similar study (2), the reference age for late and early CI was considered 6 years.

Inclusion criteria for the participants were as follow:

a. Children with prelingual deafness who had a unilateral cochlear implant and at least 4 years of experience with the use of cochlear implants.

b. Children who have received language, speech, and auditory training for at least one year.

c. Children who have grown up in a monolingual environment (Persian language).

d. Children whose parents have typical hearing.

Children with additional disabilities, such as visual or motor problems or mental retardation, were excluded from the study, according to the evaluation of a speech and language pathologist (SLP).

Spoken language was the main method of communication for most participants. In fact, 6 (40%) of the participants in the experimental group in addition to oral communication used sign language and were also dependent on lip-reading. Four (25%) in the experimental group and one (6%) participant in the control group attended the deaf school, and the rest (84%) of the participants were mainstream. In fact, the participants in the two groups were matched in terms of education as well as the speech and auditory training after CI. Therefore, the participants of the two groups did not differ significantly in these respects.

2-2. Measure

In this study, the Persian version of Test of Language Development-Primary, 3rd edition (TOLD-P, 3rd) was used to examine the language abilities of the participants (16). In fact, due to the unavailability of the standard language test for children with older ages in Iran, the TOLD-P: 3 was used based on the linguistic age of the participants. The linguistic age of the participants in this study was considered to be almost equal to the duration of CI use. The duration of CI use in both groups was almost equal (CI use experience: 8.13 vs. 8.44 years) and there was no significant difference in this regard (**Table 1**). This test has 9 subtests (6 main and 3 supplemental). Furthermore, the sum of scores of some of the main subtests provides compound scores for 6 linguistic aspects (16). The Persian version of TOLD-P: 3 was carried out on 1235 Persian-speaking children. The reliability of the different subtests of this test via Cronbach's alpha was 0.74-0.94. The construct validity was 0.38-0.61 (16). Therefore, this valid test can be used as a tool to assess children's language skills and identify their weaknesses and strengths in these skills. In scoring this test, the correct answers are given a score of 1 and the incorrect answers are given a score of 0. Each subtest stops after five consecutive failures (17).

Table-1: Demographic information of all participants (N=31)

Variables	Category	Experimental Group (n=15)			Control Group (n=16)			P value
		Min	Max	Mean±SD	Min	Max	Mean±SD	
Age of CI* (year)	-	6.83	25.33	12.68±5.31	1.75	6	3.96±1.42	0.000*
Chronological age* (year)	-	13.82	32.32	20.74±4.58	10.75	15.66	12.46±1.53	0.000*
CI use experience (years)	-	4.16	11.25	8.13±2.26	5.83	12.08	8.44±1.36	0.643
Auditory training sessions after CI* (n)	-	20	30	28±4.14	30	30	30	0.064
Speech therapy sessions after CI* (n)	-	30	70	62±16.56	70	70	70	0.064
Use hearing aids after CI	Yes	1 (7%)			1 (6%)			0963
	No	14 (93%)			15 (94%)			
Sex	Male	6 (40%)			9 (56%)			0.366
	Female	9 (60%)			7 (44%)			

* *P* value is significant at the level of 0.05 based on Independent sample t-test or Chi-square as appropriate, CI: Cochlear Implantation, SD: Standard Deviation

The participants' intelligibility of speech was evaluated by the Speech Intelligibility Rating (SIR) (18) and the Intelligibility Context Scale (ICS) (19). The clinician by the SIR classifies the spontaneous speech intelligibility of the child into five categories (From 1 to 5) (18). The validity and reliability of the Persian version of the ICS has been confirmed among Persian-speaking children (20). The ICS scale is the first screening instrument to specify speech intelligibility that is scored by parents (19). This tool determines parents' perception of their child's speech intelligibility in real-life situations (19). The validity and test-retest reliability of the Persian version of the ICS has been confirmed in Persian-speaking children (2, 21). Recently, it has been proven that the ICS is also valid and reliable for assessing the speech intelligibility of children with cochlear implants (2).

2-3. Procedure

This study has been approved by the Ethical Committee of Baqiyatallah University of Medical Sciences (IR.BUMS.REC.1399.429). According to medical records, the children who met the inclusion criteria of this study were identified and their parents were invited by telephone for a visit to the cochlear implant center in Baqiyatallah University. On this visit, the purpose and method of the study were explained separately for each child and his parents and after obtaining informed consent, the child was sampled in a quiet room with sufficient light. Parents were also asked to complete the SIR and the ICS. The parents of all participants filled this scale in the waiting room of Baqiyatallah University.

2-4. Statistical analysis

All data were analyzed in SPSS software version 26. The normal distribution of the scores was determined using QQ plots. Descriptive methods (the mean score and standard deviation) were used to determine the score of each group, and the inferential statistical analysis (independent samples t-test or Mann-Whitney U test) was used to compare the mean scores between the two groups. In all tests, P <0.05 was considered statistically significant.

3- RESULTS

Of the 31 participants recruited, 15 (48.4%) were males, and 16 (51.6%) were females. **Table 1** shows the demographic information of the participants.

The mean score and standard deviation of the TOLD subscales, the ICS, and the SIR for the two groups are shown in **Table 2**. The participant in the control group (early implantation) scored better than the experimental group (late implantation) in all subscales of TOLD, and the ICS as well as in the SIR scale based on the mean scores. But neither the total score nor any of the TOLD subscales were significantly different between the two groups (P> 0.05). Only the mean scores of the SIR and the ICS were significantly different between the two groups (P <0.05).

Regardless of grouping based on implantation age, ICS and SIR had a significant negative correlation with cochlear implantation age and children's chronological age (P <0.05), but had a significant positive correlation with the total TOLD score (P>0.05). No significant relationship was found between the other variables (**Table 3**).

4- DISCUSSION

The present study compared the language development and speech intelligibility after an 8-year follow-up in Persian-speaking participants with prelingual deafness, who had received cochlear implantation before the age of six and after the age of six years. The results highlighted that those participants with late CI did not have poorer performance in language skills than those with early CI. The only significant difference between

the participants in early and late CI was in their speech intelligibility.

These findings suggest that deaf individuals who receive late CI have acceptable language and communication skills despite their poor speech intelligibility (**Table 2**). This is consistent with the results of previous studies, which show that deaf children who receive late cochlear implants are not significantly different from early cochlear implant children in terms of language skills (2, 22), and only have lower intelligibility of speech (2).

Table-2: The TOLD, SIR, and ICS scores and the comparison between experimental and control groups (N=31).

Measures	Experimental Group (n=15)	Control Group (n=16)	P-Value
Spoken language (M±SD)	89.6±28.05	95.75±26.24	0.533
Listening (M±SD)	103.53±19.86	103.87±17.82	0.960
Organizing (M±SD)	81.46±30.26	93.87±27.38	0.240
Conversing (M±SD)	86.60±26.88	93.06±26.86	0.509
Semantic (M±SD)	95.73±23.61	101.87±20.68	0.447
Syntax (M±SD)	86.26±27.78	93.62±27.37	0.464
Total of TOLD (M±SD)	90.53±25.5	97.01±23.79	0.470
ICS (M±SD)	3.92±0.62	4.67±0.37	0.000**
SIR (M±SD)	3.46±1.3	4.43±0.89	0.025**

CI: Cochlear Implantation, M: Mean, SD: Standard Deviation, ICS: Intelligibility Context Scale, Speech Intelligibility Rating (SIR). ** *P* value is significant at the level of 0.05 based on Mann-Whitney U test

Table-3: Spearman correlation between the intelligibility of speech (SIR & ICS), and the TOLD, with the demographic data of all the participants (N=31).

Spearman Correlation	CI use experience		Chronological age		Age of CI		Auditory training after CI		Speech therapy after CI		TOLD	
	r	*P* value	*r*	*P* value	*r*	*P* value	*r*	*P* value	*r*	*P* value	*r*	*P* value
SIR	-.037	.844	-.508	.004*	-.463	.009*	.118	.529	.118	.529	.752	0.00*
ICS	.061	.746	-.566	.001*	-.577	.001*	.168	.367	.168	.367	.438	.014*
TOLD	-.196	.291	-.135	.470	-.036	.850	-.024	.896	-.024	.896	1	-

* *P* value is significant at <0.05, CI: Cochlear Implantation, ICS: Intelligibility Context Scale, SIR: Speech Intelligibility Rating

The results of a review study also showed that many of these children achieve age-appropriate language in a long-term follow-up (5). Although in general most studies have found that the earlier cochlear implants are performed, the better is the result for language skills (5, 23). However, sometimes even children who receive cochlear implants at a very young age cannot achieve the appropriate language for their age (24). Apart from the age of cochlear implantation, other factors seem to be involved in the development of language abilities. For example, a study showed that regardless of cochlear implantation age, children with cochlear implantation can acquire age-appropriate language skills, if they have moderate or higher cognitive skills (25). Also, the residual hearing before cochlear

implantation is effective in determining language skills (26). In this study, the cognitive skills of the participants and the residual hearing before CI were not examined and compared, so it is possible that the cognitive skills or the residual hearing in the two groups are different. However, Wie et al. showed that most children with CI after 4 years do not show significant differences in language skills with their hearing counterparts (6). Though our results can in a way confirm the claims of Wie et al., we should be careful in generalizing the results, since we did not have a group of children with normal hearing.

The lack of a significant correlation between language skills and cochlear implantation age (**Table 3**) may indicate that the development of language skills in these children is not dependent on the age of CI. Therefore, all deaf people of any age can benefit from cochlear implants. This result is consistent with the results of recent studies (2, 27), and contradicts the results of older studies which believed that the development of language skills is sensitive to the age of CI (28, 29).

The results of this study (**Table 2**) showed that the speech intelligibility based on both scales (ICS and SIR) was significantly different in participants with early CI and late CI. This finding is consistent with the results of various previous studies (2, 30, 31).Furthermore, as shown in **Table 3**, there was a significant negative correlation between age of CI and speech intelligibility score based on both of these scales (ICS and SIR), indicating that the age of CI is a critical factor in determining speech intelligibility. This is consistent with the results of all previous studies (2, 30-33). That is, the younger the child at the time of cochlear implantation, the more likely it is that the child will have a more intelligible speech later. Because speech performance is not dependent on residual hearing before cochlear implantation (26), it can be concluded that one of the long-term results of early CI versus late CI is the better speech intelligibility development.

Also, considering that all the results related to speech intelligibility in this study are completely consistent in both scales (SIR and ICS), it seems that the ICS has simultaneous validity and can be used for preliminary evaluation of speech intelligibility in patients with cochlear implants. This is consistent with the results of a recent study on the use and validity of the ICS in people with CI (2). In general, increasing knowledge and assessment tools in this area helps to develop the necessary rehabilitation programs to improve language skills in children with CI.

The present study had some limitations: First, for a more accurate comparison, we did not have a group with normal hearing. Second, the language skills and speech intelligibility were not assessed prior to CI. Third, the sample size of this study was limited and the design was retrospective. Fourth, the culture and socio-economic status of the participants were not taken into account, while these factors also affect the long-term outcome of CI. Finally, the participants' use of CI during the day and the remaining hearing before CI were not considered. Therefore, caution should be exercised in interpreting and generalizing the results of this study. Further studies should prospectively evaluate the impact of early and late CI on language skills with large sample sizes.

5- CONCLUSION

The long-term outcomes of early and late CI were very different in terms of speech intelligibility, but they were not different in terms of language skills development. The age of CI had no impact on language skills. Although no differences in language skills were observed, better development of speech intelligibility seems to be one of the long-

term consequences of early CI versus late CI. These results should be considered for more accurate planning of rehabilitation programs in these children before and after CI.

6- ACKNOWLEDGMENTS

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7- Conflict of Interest

There is no conflict of interest.

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