



Receptive and Expressive Language in Hindi Speaking Children with Postcochlear Implantation at 6-Month Intervals

Vijay Kumar^{1,2} Rachna Mehta²

¹Department of Audiology & Speech Language Pathology, Amity University Gurgaon, Haryana, India

²Amity Institute of Neuropsychology & Neuroscience, Amity University, Noida, Uttar Pradesh, India

Address for correspondence Rachna Mehta, PhD, Amity Institute of Neuropsychology & Neuroscience, Amity University, Noida, Uttar Pradesh, India, 201301, India (e-mail: rmehta2@amity.edu).

Int Arch Otorhinolaryngol 2021;25(3):e407–e412.

Abstract

Introduction Individual variability in the language outcomes of children with cochlear implantation (CI) is a major concern. In CI rehabilitation, there is lack of a protocol regarding uniform post-CI language assessment interval duration, which can ensure better understanding of the trajectory of language growth as well as optimize language outcomes by providing feedback in fine tuning the language intervention program.

Objective To evaluate the receptive and expressive language in Hindi speaking children with up to 2 years of CI experience using revised receptive-expressive emergent language test-3ed. (REELT-3) at 6 months intervals and to compare it with that of children with normal hearing (NH).

Methods The present study included 192 children divided in 2 groups, 96 children with CI (15.8 ± 6.7 months), and 96 age-matched children with NH (22.3 ± 7.9 months). A cross-sectional, prospective study design was used to measure the language ability score (LAS) at an interval of 6 months from the time of implantation (TIA), which is 0 to 6 months, 7 to 12 months, 13 to 18 months, and 19 to 24 months of CI usage.

Results The two-way analysis of variance revealed that the LAS after 18 months of CI usage was similar to ($F(3, 92) = 8.63, p = 0.19, \eta^2 = 0.028$) that of the children with NH. However, other demographic factors, for instance, gender ($F(3, 92) = 1.73, p = 0.505, \eta^2 = 0.002$), parent's education, ($F(3, 92) = 2.05, p = 0.937, \eta^2 = 0.031$), and financial background ($F(3, 92) = 2.49, p = 0.351, \eta^2 = 0.076$) had no major impact on language.

Conclusion Eighteen months of CI usage duration can potentially stimulate receptive and expressive language up to age-matched children with NH. A protocol of periodic assessment of language, at least of 6 months, may be developed to optimize language outcomes.

Keywords

- ▶ cochlear Implantation
- ▶ receptive language
- ▶ expressive language
- ▶ language assessment
- ▶ REELT-3

Introduction

Cochlear implantation (CI) is globally considered as the standard intervention for severe-to-profound sensory-neural

hearing loss in adults and children.^{1–3} Children with congenital or acquired deafness in the early years of life are at a risk of having delayed language comprehension and expression development.^{1,4} Occurrence of congenital deafness restricts

received

April 27, 2020

accepted

July 21, 2020

published online

September 30, 2020

DOI <https://doi.org/>

10.1055/s-0040-1716570.

ISSN 1809-9777.

© 2020. Fundação Otorrinolaringologia. All rights reserved.

This is an open access article published by Thieme under the terms of the Creative Commons Attribution-NonDerivative-NonCommercial-License,

permitting copying and reproduction so long as the original work is given appropriate credit. Contents may not be used for commercial purposes, or

adapted, remixed, transformed or built upon. (<https://creativecommons.org/licenses/by-nc-nd/4.0/>)

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de

Janeiro, RJ, CEP 20270-135, Brazil

access to acoustic and phonetic elements essential for speech understanding.⁵ The outcome of CI, owing to increased access to the sound provided by it, helps children with deafness to develop language comprehension and expression skills. However, owing to individual and environmental variability, long term outcomes in children with CI are not uniform.^{6,7} The age of implantation, surgical techniques, mode of therapy, education level of parents, degree of hearing loss, continuation of therapy, and family involvement are some of the common factors that influence the CI outcomes.^{2,8-12}

The language learning outcome assessment in children with CI is an effective way to comment on the success of CI intervention.^{3,13} The duration of CI use in early implanted children is a robust predictor of language outcomes; a child with longer CI usage duration is likely to perform better than children with shorter CI duration.^{6,14} The development of language in children with CI has been studied using a longitudinal design, in which language assessment was conducted for a group of children with CI at certain intervals, such as 12 months after implantation,¹⁵ 24 months,^{1,16} 36 months,¹¹ 48 months,⁶ and 60 months and beyond.^{13,17} In such a scenario, post-CI language gain was compared across the baseline, which is at the time of implantation, to the performance across certain intervals of CI such as 1, 2, 3, 5, 10 and more years. There are varying results of CI success at these intervals. Nicholas (2007) observed age matched improvement in expressive language by 4.5 years in children who were implanted before 24 months and assessed at 6 and 18 months, respectively.¹² Connor (2006) investigated vocabulary and speech production outcomes in children with CI semiannually in the 1st year and once for the next 5 years and reported that children who received CI before 30 months reflected an early burst of language improvement better than children who implanted at a later age.¹⁴ Geers and Sedey (2011) also found that over 70% of children with more than 10 years of CI usage performed closer to children with normal hearing (NH) on single word vocabulary, isolated sentence comprehension and reasoning tasks.¹⁶

These findings suggest that there is lack of consistency regarding post-CI assessment interval duration. It ranged from 3 months to 5 years intervals. No study was found in which language outcomes in children with CI was evaluated at fixed, regular intervals using suitable age-matched children with CI under a counterbalanced, cross-sectional design. It is hypothesized that language assessment of

children who were implanted at early age, if assessed periodically at fixed intervals, may yield better language outcomes because the evaluation outcome will also help to fine tune the language intervention program. The findings of this study will facilitate better understanding of the trajectory of language growth in children with CI as well in customizing the speech-language stimulation plan as per the existing needs of the children within the sensitive period of language learning. Therefore, the aim of the present study was to evaluate the language learning outcome at six-monthly post-CI intervals using revised receptive expressive emergent language test-3ed. (REELT-3), which was recently tested and validated for Hindi speaking children with CI.¹⁸

Furthermore, most of the studies of CI language assessment and outcome have been done in native English-speaking children, which cannot be directly applied to children speaking different languages across the world due to structural linguistic variations across languages. Several studies have reported that non-English speaking children were excluded from the language outcome assessment study due to linguistic variations, which can be a major robust confounding factor.³ Morpho-syntactic characteristics of Hindi, one of the widely spoken languages of India, is more complex compared with English.¹⁸ The morphology of nouns, pronouns, number, and gender agreement of nouns as well as subject-verb agreement is more complex in Hindi as compared with English.¹⁹ Recent studies suggest that there may be a variable sensitive period for different levels of language.²⁰ However, until now, no study has been done to observe the development of language comprehension and production abilities in Hindi-speaking children with CI in a periodic manner and thus that was the another rationale of this study. It is hypothesized that periodic evaluation of the language at an interval of 6 months will enable us to know the language development pattern in Hindi speaking children with CI. Therefore, the present study was designed to evaluate language comprehension and production abilities in (a) Hindi-speaking children with CI; (b) two control groups of children with NH, one with chronologically age-matched children and the other with chronological age corresponding to that of CI activation; and (c) those with CI experience of up to 2 years at an interval of 6 months, such as 6, 12, 18, and 24 months of the time of implant activation (TIA).

Table 1 Mean age, standard deviation, gender, and percentage of participants across gender for normal hearing, children with cochlear implant and time of implant activation groups

	Children with normal hearing (NH) (22.3 ± 7.9 months) n = 96		Children with cochlear implant (CI) (15.8 ± 6.7 months) n = 96		Time of implant activation (TIA) (14.6 ± 8.8 months) n = 96	
	Boys	Girls	Boys	Girls	Boys	Girls
Number of Participants	48	48	57	39	57	39
Percentage of Participants	53.1%	46.9%	60.4%	39.6%	60.4%	39.6%

Table 2 Mean and standard deviation of the age of time of implant activation groups (age in months)

TIA age groups	Mean age	N (96)	Std deviation
0–6	5.95	24	3.34
7–12	11.5	24	4.22
13–18	17.0	24	1.86
19–24	21.45	24	2.43
Total	13.97		6.5

Abbreviation: TIA, time of implant activation.

Materials and Methods

Participants

A total of 96 children with NH (22.3 ± 7.9 months, 48 boys and 48 girls) with no complaint of speech, language, hearing, intellectual, and developmental delay, and 96 children with CI (15.8 ± 6.7 months, 57 boys and 39 girls) participated in this study (►Table 1). Another group was formed based on the TIA (14.6 ± 8.8 months); for instance, if a child's CI activation was done at 2 years of chronological age and language assessment was conducted at 3 years of chronological age, then, his TIA age was considered as 1 year (►Table 2). Chronological age-matched controls were selected for the TIA group. All the participants were within 36 months of age and were residents of Delhi, India and nearby regions. (►Table 1) Data were collected over 2 years.

Ethical standards and considerations were maintained and adhered to while selecting the participants for this study. Institutional ethical approval was obtained before the participant's recruitment (AUUP/IEC/2018-AUG/04). The family members/caretakers of each participant were informed about the purpose and procedure of the study and written consent was acquired. Participants under the NH category were selected based on the following inclusionary criteria: target age of the language assessment tool used in this study (REELT-3); age of the participants below 36 months with no reported history of hearing loss, cognitive, or intellectual deficit, and Hindi as the primary spoken language at home. For the CI group, the pure tone audiometry finding was more than 85 dB in the better ear. There should not have been any known history of premorbid neurological illness, psychological disorders, and no other significant sensory and/or cognitive deficits for both groups. Children with CI using sign languages or whose parents were deaf did not participate in this study. Children with NH were recruited through a random sampling method and purposive sampling was used for the selection of children with CI. Based on the CI usage duration, the children with CI were further categorized under 4 categories based on implantation duration (a) between 0 and 6 months (b) 7 and 12 months (c) 13 and 19 months, and (d) 18 and 24 months.

Test Stimuli

Language comprehension and production were assessed using the REELT-3.²¹ Sixty-six test items of the REELT-3 were chosen for this study. The components of REELT-3 are 2-fold (a) receptive language and (b) expressive language. In this test, language milestones were used as test items, which were arranged in gradually increasing order of complexity. Some examples of the 66 test items of the REELT-3 are mentioned ahead. In expressive language, #7 "When hearing voices, does your baby ever vocalize back?" to receptive language #25 "Does your baby respond to simple commands or requests like 'Come here!' or 'Let's go!'?" The response was collected in a binary manner, that is, either 'Yes' or 'No'.

Procedure

The REELT-3 was used to evaluate the receptive and expressive language of children with CI and NH. Recently, we have published the validation of the REELT-3 in Hindi Speaking children with CI.¹⁸ Language ability score (LAS) was obtained for both NH and CI groups. The LAS is the combined score of the receptive language ability score (RLAS) and the expressive language ability score (ELAS), which is the standard score obtained after getting a total correct response out of the 66 questions of the REELT-3 under the receptive and expressive categories. Responses were obtained as per the feedback provided by the mother/caregiver as well as, based on the direct observation and interaction during the assessment. The test was administered, analyzed, and interpreted by trained intern volunteers of audiology & speech therapy. Participants' responses were analyzed and a score of '1', or '0' was given for every correct response with or without prompt and incorrect/no response even after prompt response, respectively.²¹ As the questions of the REELT-3 were categorized at an interval of 6 months, the average LAS for the NH group across each 6 months interval, such as 18 to 24 months, 25 to 30 months, and 31 to 36 months, were obtained and considered as a control group. The LAS of the CI group was obtained at two levels (a) overall LAS of the CI group (of 96 participants), and (b) LAS across four post-CI duration (of 0–6, 7–12, 13–18, and 19–24 months of CI usage).

Data Analysis

The response of each participant was coded, arranged, and analyzed using the IBM SPSS Statistics for Windows, Version 21.0. (IBM Corp., Armond, NY, USA). One-way and two-way analysis of variance (ANOVA) tests were used to check whether LAS across three groups (NH, CI, and TIA) and across four post-CI durations varied significantly or not. Tukey's HSD posthoc analysis was done to check out specific relations across the four CI implant durations.

Results

The mean LAS of Hindi speaking children with CI, NH, and TIA was obtained and it was compared across each other. The one-way ANOVA test was used to evaluate whether the language performance of these three groups differ significantly from each other. A significant difference in language

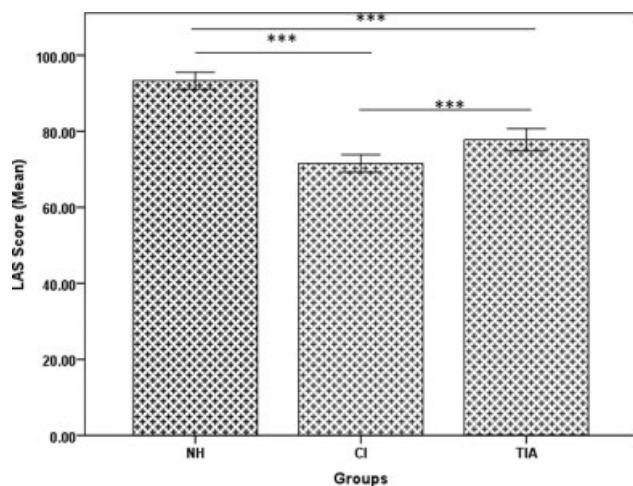


Fig. 1 Bar graph depicting language ability score across normal hearing, cochlear implant and time at implantation activation groups. * inferring statistical significance ($p < 0.001$); Abbreviations as in the text.

performance was obtained across the TIA, NH, and CI groups ($F(2, 285) = 79.530, p = 0.001, \eta^2 = 0.358$) (► **Fig. 1**). Moreover, Tukey's HSD posthoc analysis was done to test the significance between NH and CI, NH and TIA, TIA, and CI groups. It was observed that language performance differed significantly across all three conditions; (a) the language performance of children with NH was significantly better than that of children with CI ($F(1, 190) = 21.89, p = 0.001, \eta^2 = 0.495$); (b) similarly, group-wise the children with up to 2 years of TIA performed poorer than the age-matched children with NH¹⁴ for language performance task ($F(1, 190) = 15.89, p = 0.001, \eta^2 = .289$), and (c) children with up to two years of TIA performed better on language performance tasks than the children with CI ($F(1, 190) = 6.273, p = 0.004, \eta^2 = 0.037$) (► **Fig. 1**).

The LAS of the TIA group was compared across 4 CI usage windows, that are 0 to 6 months, 7 to 12 months, 13 to

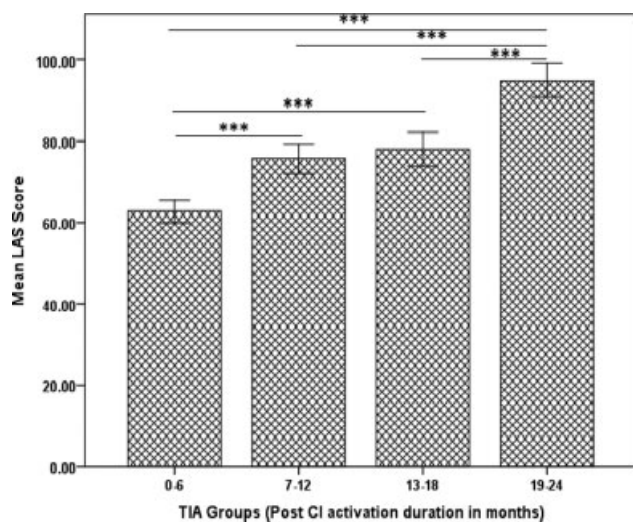


Fig. 2 Bar graph showing language ability score across four groups of time of implant activation (in months). * inferring statistical significance ($p < 0.01$); Abbreviations as in the text.

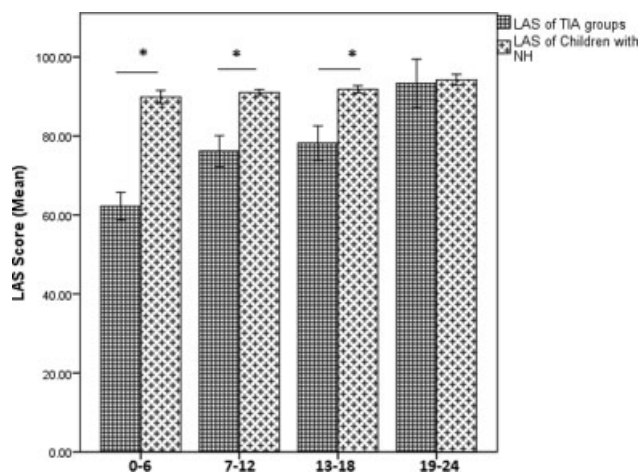


Fig. 3 Bar graph reflecting language ability score across normal hearing, cochlear implant and time of implant activation groups across gender. * inferring statistical significance ($p < 0.05$); Abbreviations as in the text.

18 months, and 19 to 24 months. One-way ANOVA analysis was done to test whether the language performance of these four groups significantly varied from each other. It was observed that language performance across four CI usage durations was significantly different across each other ($F(3, 92) = 6.620, p = 0.001, \eta^2 = 0.178$) (► **Fig. 2**). Tukey's HSD posthoc analysis was done to identify the rate of improvement across four CI usage durations and to test whether these durations differed significantly. It was observed that the language performance of the TIA group having more than 18 months of CI usage was significantly higher than TIA groups of 0 to 6, 7 to 12, and 12 to 18 months. However, no significant difference was observed between children having CI usage experience of 7 to 12 months and 13 to 18 months (► **Fig. 2**).

Besides, the LAS of children of the TIA group from 0 to 2 years of CI usage were compared across age-matched children with NH. The two-way ANOVA revealed that the language performance of children with CI for 0 to 6 months durations was significantly lower than children with NH ($F(3, 92) = 30.1, p = 0.008, \eta^2 = 0.028$) (► **Fig. 3**), while in the 18 to 24 months group, the language performance in the CI usage approached that of the NH group ($F(3, 92) = 8.63, p = 0.19, \eta^2 = 0.028$). Language development pattern in boys and girls with CI was also evaluated for the NH, CI, and TIA groups. The two-way ANOVA test was computed to test whether the language performance of children with CI was different from each other across gender during four phases of assessment at 6 months interval. No significant difference in overall language gain across boys and girls was obtained for NH, CI, and TIA ($F(3, 92) = 1.73, p = 0.505, \eta^2 = 0.002$) (► **Fig. 4**).

Similarly, the language outcome was tested across the socioeconomic-educational perspective. Parents of the CI group who had less than 12 years of formal education were compared across more than 12 years of educated parents. The one-way ANOVA test was computed to test whether the language performance of these three groups

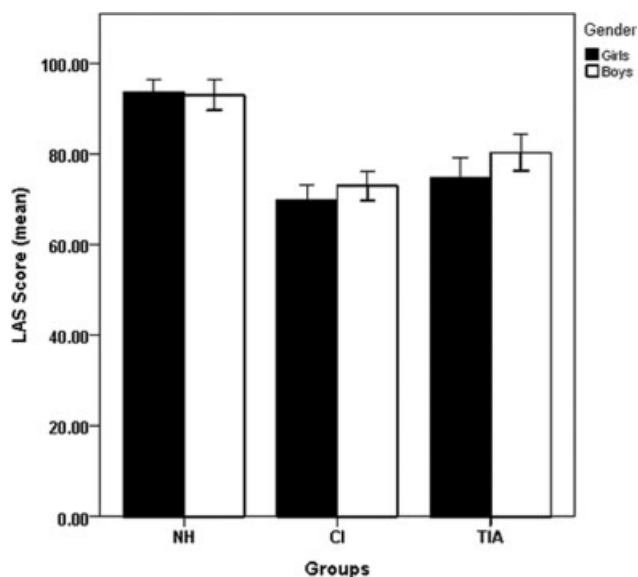


Fig. 4 Bar graph reflecting language ability score of children with normal hearing across children with cochlear implant of time of implant activation groups across four assessment conditions at an interval of 6 months. * inferring statistical significance ($p < 0.05$); Abbreviations as in the text.

differed, and it was observed that the educational background of parents does not significantly influence language outcomes ($F(3, 92) = 2.05, p = 0.937, \eta^2 = 0.031$). Parents of the CI group whose monthly income was lower than the Indian Rupees 10,000 were compared to parents who earned more than the Indian Rupees 10,000. The one-way ANOVA test was computed to test whether the language performance of these two groups differed significantly, and it was also observed that the financial background of parents does not influence language outcomes significantly in children with CI ($F(3, 92) = 2.49, p = 0.351, \eta^2 = 0.076$).

Discussion

In the present study, language comprehension and expression abilities were tested using the REELT-3 to compare NH, CI, and TIA Hindi speaking children. It was observed that the LAS of the CI group was significantly different compared with that of the NH group; however, no significant difference was obtained across the CI & TIA and TIA & NH groups. Thus, it can be inferred that the language development in the TIA group occurred in the same patterns as that of age-matched NH children. The mean age of the TIA group was 21.45 months, which suggests that auditory stimulation of more than 14 months is critically required and enough to bridge the gap in language performance between the CI and NH groups. These findings suggest that the prolonged auditory period in children with CI increases the morphological and phonological awareness skills that are requisite for language development and expression.^{1,14} Moreover, longer duration of CI usage enhances mother-child interaction and helps in building additional social-cognitive connection with the surroundings, which is essential for language development.¹⁴

Depending on the duration of CI usage, the development of language learning was also measured across four time frames, between 0 and 6 months; 7 and 12 months; 13 and 19 months; and 18 and 24 months. The results revealed that the language performance of CI children increased significantly after 18 months of CI usage compared with the other three time frames. Moreover, a significant difference was also observed for language development between 0 and 6 months and 13 and 18 months of the TIA group. This finding suggests that a minimum of 1 year is required to observe a significant difference in language development among various TIA groups, thus justifying the need for early implantation.^{12,22,23} Early implantation ensured early access to sound for the CI children resulting in a shorter sound deprivation period, which is required for language development.¹¹ It was also observed that early CI ensures auditory neural reorganization corresponding to exposure of sound or verbal input.^{24,25} These findings also support the existence of an early sensitive period through early and ongoing plasticity of central auditory pathways for receptive and expressive language learning in children with CI.¹⁴ Furthermore, the present study also supports the age range of less than 2.5 years as the most sensitive critical age for neuroplasticity and central auditory nerve development responsible for the growth of language, as the mean age of the TIA group in this study was 14.6 months.^{25,26} However, the critical time range of less than 2.5 years may vary for different speech and language components.²⁷ Also, the results revealed that even after 24 months of CI use, the group-wise gap on language performance tasks was not bridged completely between the Hindi speaking CI and NH groups. However, after 18 months of CI usage, the language performance of children with CI appeared in the range of that of children with NH. Owing to morphosyntactic complexity, especially in person, gender, number, subject-verb agreement, etc., language learning in children with CI cannot completely approach the learning abilities of children with NH. This further justifies the need for a longitudinal study for more than 24 months of activation of CI.

Furthermore, the language performance was also compared among the CI, TIA, and NH groups across gender, family income, and parental education, separately. The rationale for doing such analysis was to check whether these confounding variables have any impact on the outcome of the present study. No significant difference was observed for any of these three conditions. Prolonged CI usages and early implantation enables re-networking of the central auditory pathway, which is essential for intact language comprehension and production.²⁵ Thus, it may be possible that demographic-related issues, such as gender, family income, and parental education, would not have impacted the language learning outcomes. Moreover, although the status of language in children in the CI and NH groups was quantified using parents' feedback along with direct observation and interaction, the potential bias in the parents' information may not be ruled out completely.

Conclusion

The present study reveals that language development in children with CI improves significantly during the 2nd year of CI usage. The present findings justify the need for early implantation to ensure a reduced sound deprivation phase. Periodic assessment of language outcomes at an interval of 6-months in the children with CI can facilitate the understanding of the pattern and trajectory of language development. The inclusion of more language domains for assessment beyond 2 years, using a longitudinal design, may yield better outcomes. From a theoretical point of view, this study allows us to understand the nature of linguistic difficulties in children with CI that may manifest across the different duration of CI usage across languages. Clinically, the dynamics of language development in children with CI can be used as feedback in developing a target-based therapeutic intervention plan.

Conflict of Interests

The authors declare that there is no conflict of interests.

Acknowledgment

The support and research facilities provided by the Amity University are acknowledged.

References

- 1 Caselli MC, Rinaldi P, Varuzza C, Giuliani A, Burdo S. Cochlear implant in the second year of life: lexical and grammatical outcomes. *J Speech Lang Hear Res* 2012;55(02):382–394
- 2 Pisoni DB, Kronenberger WG, Harris MS, Moberly AC. Three challenges for future research on cochlear implants. *World J Otorhinolaryngol Head Neck Surg* 2018;3(04):240–254
- 3 Baldassari CM, Schmidt C, Schubert CM, Srinivasan P, Dodson KM, Sismanis A. Receptive language outcomes in children after cochlear implantation. *Otolaryngol Head Neck Surg* 2009;140(01):114–119
- 4 Levitt H, McGarr N, Geffner D. Development of language and communication skills in hearing-impaired children. *Introduction. ASHA Monogr* 1987;(26):1–8
- 5 Svirsky MA, Teoh S-W, Neuburger H. Development of language and speech perception in congenitally, profoundly deaf children as a function of age at cochlear implantation. *Audiol Neurotol* 2004;9(04):224–233
- 6 Bradham T, Jones J. Cochlear implant candidacy in the United States: prevalence in children 12 months to 6 years of age. *Int J Pediatr Otorhinolaryngol* 2008;72(07):1023–1028
- 7 Cruz I, Quittner AL, Marker C, Desjardin JL, Team CICDaCI Investigative Team. Identification of effective strategies to promote language in deaf children with cochlear implants. *Child Dev* 2013;84(02):543–559
- 8 Tomblin JB, Barker BA, Spencer LJ, Zhang X, Gantz BJ. The effect of age at cochlear implant initial stimulation on expressive language growth in infants and toddlers. *J Speech Lang Hear Res* 2005;48(04):853–867
- 9 Brito Rd, Bittencourt AG, Tsuji RK, Magnan J, Bento RF. Cochlear implantation through the middle fossa: an anatomic study for a novel technique. *Acta Otolaryngol* 2013;133(09):905–909
- 10 Leigh J, Dettman S, Dowell R, Briggs R. Communication development in children who receive a cochlear implant by 12 months of age. *Otol Neurotol* 2013;34(03):443–450
- 11 Geers AE. Speech, language, and reading skills after early cochlear implantation. *Arch Otolaryngol Head Neck Surg* 2004;130(05):634–638
- 12 Nicholas JG, Geers AE. Will they catch up? The role of age at cochlear implantation in the spoken language development of children with severe to profound hearing loss. *J Speech Lang Hear Res* 2007;50(04):1048–1062
- 13 Ruben RJ. Language development in the pediatric cochlear implant patient. *Laryngoscope Investig Otolaryngol* 2018;3(03):209–213
- 14 Connor CM, Craig HK, Raudenbush SW, Heavner K, Zwolan TA. The age at which young deaf children receive cochlear implants and their vocabulary and speech-production growth: is there an added value for early implantation? *Ear Hear* 2006;27(06):628–644
- 15 Miyamoto RT, Hay-McCutcheon MJ, Kirk KI, Houston DM, Bergeson-Dana T. Language skills of profoundly deaf children who received cochlear implants under 12 months of age: a preliminary study. *Acta Otolaryngol* 2008;128(04):373–377
- 16 Geers AE, Sedey AL. Language and verbal reasoning skills in adolescents with 10 or more years of cochlear implant experience. *Ear Hear* 2011;32(01):39S–48S
- 17 Geers AE. Factors Affecting the Development of Speech, Language, and Literacy in Children With Early Cochlear Implantation. *Lang Speech Hear Serv Sch* 2002;33(03):172–183
- 18 Kumar V, Mehta R. Adaptation and validation of receptive expressive emergent Language Test-3: Evidence from Hindi speaking children with cochlear implant. *Int J Pediatr Otorhinolaryngol* 2020;132:109891
- 19 Dayal V. Incorporation: Morpho-syntactic vs. semantic considerations. The syntax and semantics of pseudo-incorporation: Brill; 2015:47–87
- 20 Houston DM, Miyamoto RT. Effects of early auditory experience on word learning and speech perception in deaf children with cochlear implants: implications for sensitive periods of language development. *Otol Neurotol* 2010;31(08):1248–1253
- 21 Bzoch KR, League R, Brown VL. Receptive-expressive Emergent Language Test: Examiner's Manual: Pro-ed. 2003
- 22 Clark JH, Wang N-Y, Riley AWCDaCI Investigative Team. et al; {#,46}. Timing of cochlear implantation and parents' global ratings of children's health and development. *Otol Neurotol* 2012;33(04):545–552
- 23 Ertmer DJ, Young NM, Nathani S. Profiles of vocal development in young cochlear implant recipients. *J Speech Lang Hear Res* 2007;50(02):393–407
- 24 Gordon KA, Papsin BC, Harrison RV. Activity-dependent developmental plasticity of the auditory brain stem in children who use cochlear implants. *Ear Hear* 2003;24(06):485–500
- 25 Sharma A, Dorman MF, Spahr AJ. A sensitive period for the development of the central auditory system in children with cochlear implants: implications for age of implantation. *Ear Hear* 2002;23(06):532–539
- 26 Locke JL. A theory of neurolinguistic development. *Brain Lang* 1997;58(02):265–326
- 27 Bates E. Language and the infant brain. *J Commun Disord* 1999;32(04):195–205