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Original Research Article

Correlation of auditory skills and verbal communication abilities in pediatric unilateral cochlear implants

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ABSTRACT

Background: Hearing is crucial for child's speech and language development. The child's actions during the first few months and early years are reflexive; the child's hearing directly influences the development of language and speech abilities (Robbins et al, 2000). The Meaningful Auditory Integration Scale (MAIS) (Robbins et al, 1991) and the Meaningful Use of Speech Scale (MUSS) (Robbins and Osberger, 1991) are valid and reliable parent interviewed based questionnaires were performed. The aim of the study is to correlate the auditory skills and verbal communication abilities in pediatric unilateral cochlear implant recipients.
Methods: The cross-sectional study includes the 69 unilateral cochlear implant recipients chronological aged 4 to 8 years this further divided into three groups: Group I (Implant age of <1 year), Group II (Implant age of 1 to 2 years), Group III (Implant age of >2 years).
Results: There is a significant improvement in both auditory and verbal communication outcomes with increased cochlear implant use, particularly in all three groups shows statistically significant difference ($p < 0.05$). A positive correlation between MAIS and MUSS was found in Groups I and II, but not in Group III. The correlation cannot be obtained, as there is limited verbal output present in >2 years cochlear implant recipients.
Conclusions: The study highlighted the correlation among the auditory skills and verbal communication skills in the unilateral cochlear implant recipients shows the continuum improvement with cochlear implant use.

Keywords: Unilateral cochlear implant, Auditory skills, Verbal communication

INTRODUCTION

Hearing impairment is a disability that can affect the effective functioning of the total behaviour no matter the period of onset.[1] Cochlear implant (CI) known as restorative technology that has been useful in 'restoring' the audiological skills those with severe to profound sensorineural hearing loss. The primary goal of CI is to facilitate open-set, auditory and speech understanding skills in everyday listening situations. Though significant individual outcome variance has been documented across all implant facilities worldwide, this goal is attainable for the majority of implant recipients. Certain users of unilateral CI increase the ability to talk on the phone, while others merely see expansions in their speech-reading skills.[2]

The CI procedure raises a lot of expectations in parents about the results of their child's surgery. Improved ability for communication, good social skills, academic performance, and favourable alteration in their future lives, reduced rehabilitation demand, overall contentment are some of the typical parents' expectations of their children who are in the CI procedure. Although some studies indicated that the expectations of parents have generally been fulfilled. In these situations, parents

typically possess unreasonable expectations for their kids, along with a great deal of worry and anxiety. In the later phases, dealing with the ensuing difficult rehabilitation requirements, the stress level within the family rises, particularly if they are preoperative.[3]

Parents are frequently interviewed using standardized questionnaires to measure the auditory benefits of their child receives from the implant and/or hearing aids. In the literature, they are reliable and authentic questionnaires available that are frequently use in clinics are the Meaningful Auditory Integration Scale (MAIS) and the Meaningful Use of Speech Scale (MUSS) both the scale gives important information of auditory and communication skills.[4]

According to current study, children with hearing impairments enhance their auditory and verbal communication skills after using a CI. Numerous studies describe CI's role in auditory and speech-language rehabilitation. Various studies validate the advantages of early CI, particularly when performed prior to the age of 12 months.The results of the MAIS and MUSS showed steady but notable gains in auditory integration and speech production. These results lend validity to the idea that early CI accelerates better auditory and language development which enhance age-appropriate communication skills. The purpose of the study is to correlate the auditory skills and verbal communication abilities in pediatric unilateral CI recipients.[5-7]

METHODS

Study participants

An analytical cross-sectional study was used for the present study. Data were collected using a convenience sampling method. Inclusion criteria include a child with unilateral CI has attended speech and language therapy for >6 months and the participant's caregiver/ parents who completed the consent form were considered for the study.

Exclusion criteria include children with <4 years, with other co-morbid condition and a child with unilateral CI has attended speech and language therapy for <6 months was excluded from the study. The present study consisted of total 69 paediatric unilateral CI recipients. The participants divided into three groups each group consists of 23 participants.

Ethical clearance

The study was conducted at the Sri Aurobindo institute of speech and hearing within the time period of September 2024 to July 2025, SAU, Indore, M.P. and received approval from the Institutional Review Board. Ethical considerations were strictly adhered to throughout the study.

Table 1: Distribution of participants across groups.

Group	Participants	Number of participants	Total
I	Implant age of <1 year	23	69
II	Implant age of 1 to 2 years	23	
III	Implant age of >2 years	23	

Materials used for the present study

Parents were interviewed using MAIS and MUSS questionnaires when they visit for implant programming and speech therapy sessions. Participant's parents/caregiver was informed about the research study through a participant information sheet and written consent was taken from all the participants before collecting data. A detailed case history form, occupational details of parents, medical history, pre, peri and post-natal history and speech and language details along with their age of CI and duration of speech and language therapy information was collected and used in the study.

Administration of both the scales was done on paediatric unilateral post-CI recipients to obtain scores for the auditory skills and verbal communication abilities in children of different CI age: Group I (Implant age less than 1 year), Group II (Implant age between 1 to 2 years), Group III (Implant age more than 2 years).The MAIS scale measures how well these children integrate spoken language into their daily lives and interactions, which assess following areas vocalizing behaviours, altering to sounds and deriving meaning from sounds. Scores ranged from 0 (never) to 4 (almost always) and the total score is 40. The MUSS is a tool designed to assess the functional use of speech in children, particularly those with speech and language delays or disorders. consists of 5 categories; Category 1(Use of vocalising behaviour), Category 2 (Use of Speech with family), Category 3 (Use of oral skills in social situations), Category 4 (Percentage of speech understood), Category 5 (Use of oral clarification skills). Scores ranged from 0 (never) to 4 (almost always) and the total score is 44.

RESULTS

The results of the present study highlighted the descriptive statistics, comparison of MAIS and MUSS scale followed by correlation of both the scales among three groups with their respective CI age. Demographic descriptive statistics were done to assess the mean of CI age and standard deviation among implant age of Group I, Group II, and Group III in paediatric unilateral CI recipients. Gender distribution data was assessed in percentage and total number of males and females among

the three groups. Table 2 presents key characteristics of the study participants, such as gender and CI age. Group I consisted of 23 participants, which included 12 females and 11 males.

Group II consisted of 23 participants, with 15 females and 8 males, whereas Group III also consisted of 23 participants, with 13 females and 10 males, respectively.

The CI age mean of Group I is 4.44± 0.83, Group II mean is 5.20±0.85, and Group III mean is 6.67±1.14, correspondingly.

Figure 1 illustrate the mean age of implantation and separate standard deviations (SD) of three groups. Group I held the lowest mean age of implantation at 7.83±1.26, indicating minimum variation within groups. Group II displayed the largest mean age of implantation at 16.47 ±2.79, indicating moderate variation.

Group III increases the most recent mean age of implantation of 34.13±5.69. Compare the auditory skills and verbal communication abilities outcome among the three groups. Table 3 shows the Mann-Whitney U test examined the differences between MAIS and MUSS scores across the three groups based on implant age. In Group I (implant age <1 year), the mean ranks were 31.72 for MAIS and 15.28 for MUSS, with a U value of 75.50, Z= -4.16, and p=0.000.

For Group II (implant age <2 years), the mean ranks were 31.50 for MAIS and 15.50 for MUSS, U= 80.50, Z= -4.05, P=0.000. In Group III (implant age>2 years), the MAIS mean rank was 31.52 and MUSS was 15.48, U= 80.00, Z= -4.09, P= 0.000.

These findings show a statistically significant difference between MAIS and MUSS scores in all three groups (p< 0.0001). The statistical analysis showed a significant difference in the outcome of auditory and communication skills in unilateral cochlear implant recipients among the three groups.

Table 2: Demographic distribution of mean and standard deviation of cochlear implant age and gender among the three groups.

Groups	Cochlear implant age (months)				Gender distribution		
	Mean	SD	Min	Max	Gender	N	%
Group I	7.83	1.26	7.00	11.00	Male	11	47.8
					Female	12	52.2
Group II	16.47	2.79	12.00	20.00	Male	08	34.8
					Female	15	65.2
Group III	34.13	5.69	26.00	42.00	Male	10	43.5
					Female	13	56.5

* SD=Standard Deviation, Min. =Minimum, Max.=Maximum

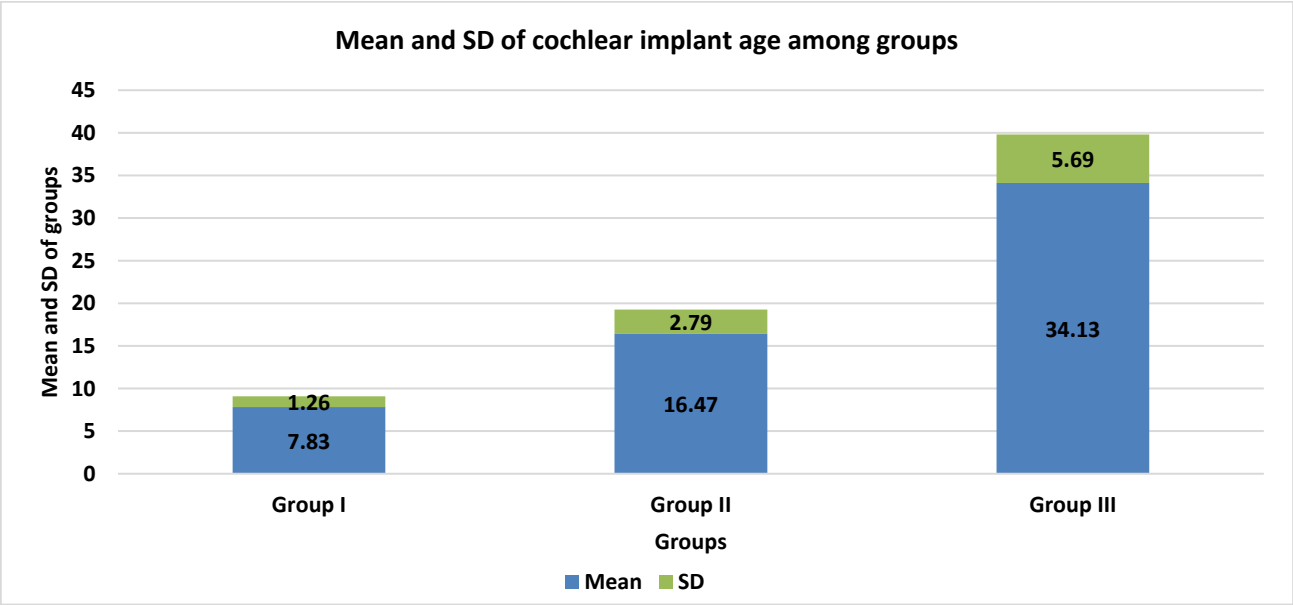

Figure 1: Distribution of mean and standard deviation of cochlear implant age among group I, group II and group III.

Table 3. Results of comparison between MAIS and MUSS scores using Mann-Whiteny U test.

Group	Scales	Mean rank	Mann-Whiteny U test		
			U	/Z/-value	P value
Group I	MAIS	31.72	75.50	-4.16	0.00
	MUSS	15.28			
Group II	MAIS	31.50	80.50	-4.05	0.00
	MUSS	15.50			
Group III	MAIS	31.52	80.00	-4.09	0.00
	MUSS	15.48			

Table 4. Results of correlation of MAIS and MUSS among the three groups by using the Spearman Rank Correlation test.

Group	Tests	N	Correlation coefficient	P value
Group I	MAIS	23	0.618	0.000
	MUSS			
Group II	MAIS	23	0.666	0.001
	MUSS			
Group III	MAIS	23	0.141	0.521
	MUSS			

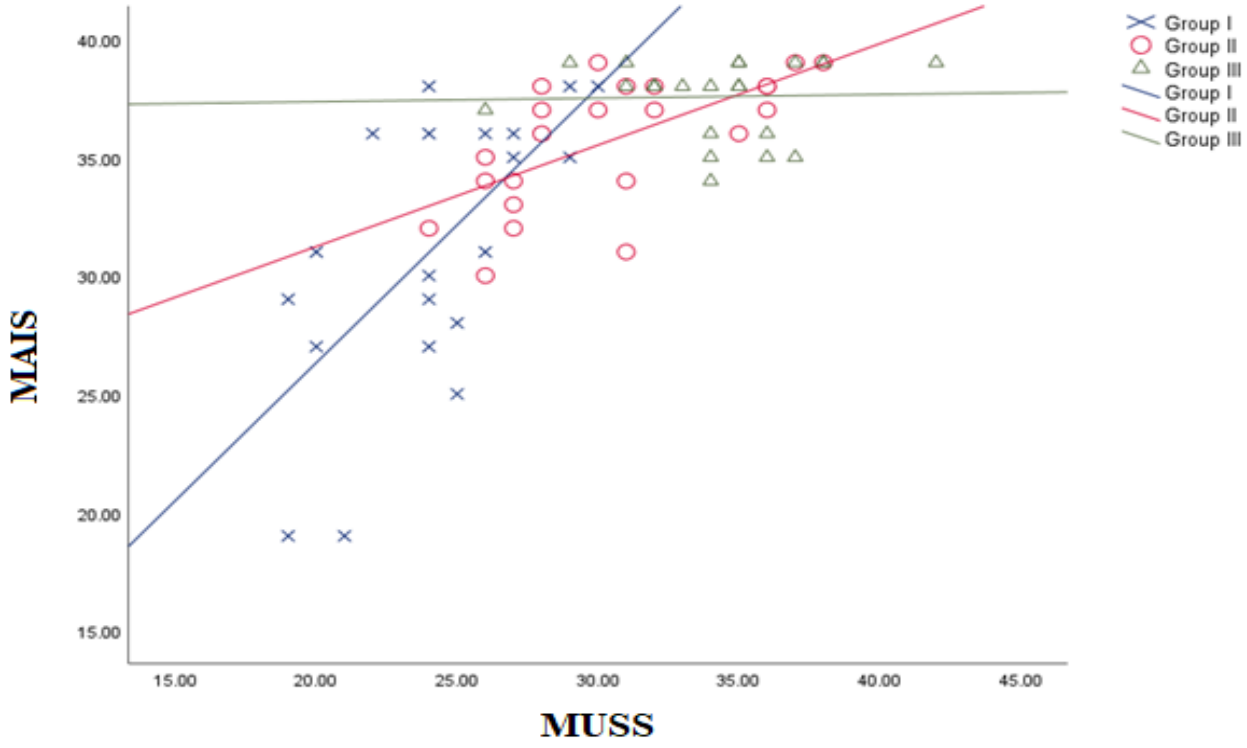

Figure 2: Scatter plot shows correlation of MAIS and MUSS in overall groups.

Correlate the auditory skills and verbal communication abilities among the three groups The score of the MAIS and MUSS scale was noted as per the parental perspective. The MAIS scale measures vocalizing behaviours, alerting to sounds, and deriving meaning from sounds, whereas the MUSS scale highlights the Use of vocalising behaviour, Use of Speech with family, Use of oral skills in social situations, Percentage of speech understood and Use of oral clarification skills. Total score determines the auditory skills and oral spoken difficulty by adding the scores of each probe.

Spearman Rank Correlation test is used to measures the strength and association between MAIS and MUSS scores across all the groups combined, as well as for each group individually in peadiatric unilateral CI recipients in

aged 4 to 8 years. Table 4 represents Spearman Rank Correlation coefficient and its significance level (p value) among the three groups.

Table 4 demonstrate the overall correlation of MAIS and MUSS among the group I, group II and group III the correlation using the Spearman Rank Correlation test the R value is 0.693 in MAIS and MUSS indicated strong positive correlation. In the overall correlation between MUSS and MAIS, a significant correlation was observed (R=0.689, P=0.000). The group wise assessment, a significant correlation was observed for group I and II (GI: R=0.618, P=0.002; GII: R=0.666, P=0.001) except for Group III (R=0.141, P=0.52).

Figure 2 displays a scatter plot showing the relationship between the three groups' MAIS and MUSS total scores. The distribution of data points demonstrates a clear positive trend, indicating that higher MAIS scores are associated with higher MUSS scores. This observation is supported by the Spearman Rank Correlation coefficient of ρ=0.693, indicating a strong positive correlation among the two variables in the combined dataset. Statistical findings showed a significant correlation between auditory and speech skills across groups, except in Group 3.

DISCUSSION

The study examined the outcome of post CI in a group of congenitally-deaf children with CI as reported by parents. The auditory and speech scale performance comparison was determined in between the three groups and was analyzed using SPSS version 20. The results indicated that there are notable differences in the outcomes of auditory and verbal communication abilities among the three groups (Group I, Group II, and Group III). A strong correlation was found between Groups I and II, however Group III, which has more than two years of CI experience, shows no significant The findings are consistent with existing literature, conducted a study using two scales the MAIS and the MUSS are standardized parental-report tools designed to assess a child's auditory skills and speech usage in everyday environments, providing valuable insights from the parents' perspective. These scales help in capturing functional communication abilities that are evident in clinical assessments. In the present study, similar significant results were observed, further supporting the effectiveness and clinical utility of MAIS and MUSS in evaluating real-world auditory and speech outcomes in children with hearing impairment.[5-8]

Age at implantation reported to affect the outcomes for deaf children. The younger the age of implantation, the better the outcomes However, consistent with some variability was observed, particularly with the MUSS and SIR, which capture more complex speech and language skills. This reflects the multidimensional nature of speech development, which depends not only on auditory access but also on environmental, parental, and behavioral factors. Contrastively, study also reported enhanced auditory performance and speech intelligibility post-CI, as reflected in the MAIS, CAP, and SIR scores. However, their findings showed no significant differences between groups when evaluated with the MUSS and SIR, which specifically measure speech and language abilities.[9-11]

The long- term benefit of continuous use of implant and evaluated surgical outcomes using MAIS, MUSS, and aided hearing assessments in matched groups based on gender, age at implantation, hearing age, and rehabilitation duration. The responses were obtained in the following categories: recognizing and responding to speech sounds, demonstrating the ability to discriminate spontaneously between two speakers, and associating vocal tones. Similar patterns were observed in the present study, reinforcing the impact of these factors on post-implantation success. The interaction of age and time post-implantation was also noted in, where auditory skills improved progressively within the first three years, with some children requiring longer durations to plateau. Our findings similarly demonstrate that auditory and speech gains continue over time, with MAIS and MUSS scores reflecting sustained improvements. Moreover, our study supports the bidirectional relationship between hearing and speech development, whereby auditory function facilitates speech perception and production, and speech use reinforces auditory responsiveness, creating a positive developmental cycle.[12-15]

Parental involvement and educational background also emerged as key predictors of outcome. Studies by Bosco et al (2005), Robins et al (2003), and Swami et al (2012) emphasized the role of parental input in monitoring auditory and speech progress, with findings showing that cochlear morphology, hearing deprivation duration, and family support all significantly influenced MAIS and MUSS outcomes. Similarly, Umat et al (2010) demonstrated a strong correlation between auditory performance and spontaneous speech, highlighting verbal communication as a central goal of CI.[3,16-18]

Hence, to summarize the above findings it can be suggested as the CI age increases, child's auditory skills enhance such as auditory awareness, discrimination, identification and comprehension. Parallel to auditory skills, verbal communication abilities also improve, in terms of use of vocalizing behavior, use of speech with family, and use of oral skills in social settings but percentage of speech understood by listener and use of oral clarification skills may or may not be affected because both the skills require the richness of vocabulary, the number of words and grammatical content, spontaneous speech, voice control, and communication flexibility for effective verbal communication. Hence, the CI increases the availability of auditory stimulation which results in improve speech production skills in CI recipients.

Clinical implications of this research include the following the current study advances our knowledge of the connection between children with CI communicative development and auditory processing which offers valuable qualitative and quantitative insights that can inform the design of targeted intervention strategies aimed at enhancing real-world auditory functioning additionally speech and language outcomes. Additionally, the research serves as an important resource for parents and caregivers, helping to increase their awareness and understanding of their child's auditory capabilities and communicative development, thereby encouraging more active participation in the rehabilitation process.

However limitations of our study are small sample size was used, which would have limited the findings' applicability to the larger group of children who use CI. The research did not incorporate detailed linguistic or language structure assessments, such as measures of syntax, morphology, or narrative discourse, which are crucial to understand the language development.

Future studies should focus onto improve the generalizability of findings across various demographic and linguistic groups, future research should aspire to replicate the study with a bigger and more diverse sample and incorporating standardized language assessment tools alongside auditory scales such as the MAIS and MUSS would offer an all-encompassing comprehension of the child's overall communication profile, including syntax, semantics, and pragmatic skills.

CONCLUSION

The results of the statistical analysis revealed significant differences among the three groups, with a clear positive correlation between the MAIS and MUSS scores. These findings suggest that children who demonstrated stronger auditory integration abilities also showed higher levels of meaningful speech use, indicating that auditory skills directly influence the development of verbal communication. Additionally, the data demonstrated that children who had their CI earlier in life performed noticeably better on speech and auditory tests, highlighting the significance of early cochlear implantation CI in fostering the best possible language results. Overall, the study supports the use of MAIS and MUSS as useful instruments for evaluating progress and developing customized aural rehabilitation techniques and offers insightful information about the importance of auditory input in language development among children with hearing impairment.

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