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COCHLEAR IMPLANTATION SURGERY IN PRELINGUALLY DEAF CHILDREN – HEARING AND SPEECH OUTCOMES

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Abstract

Objectives: The objective of the present study was to assess the hearing and speech outcomes of prelingually deaf children who underwent cochlear implantation surgery in a tertiary healthcare facility; disaggregated by age and gender. **Methods:** This was an observational prospective study conducted in the Department of Paediatrics and Otorhinolaryngology of a tertiary healthcare facility in western India between June 2019 and May 2020. We enrolled all children between 1 and 6 years of age with bilaterally prelingual deafness (with no benefit using bearing aid) who underwent cochlear implantation surgery at the tertiary healthcare facility. **Results:** The results showed that the Categories of Auditory Performance (CAP) scale score (MD 1.52, 95% CI 1.24 to 1.80), Meaningful Auditory Integration Scale (MAIS) scores (MD 7.51, 95% CI 5.59 to 9.42), Speech Intelligibility Rating Scale (SIR) scores (MD 1.68, 95% CI 1.37 to 1.99), and Meaningful Use of Speech Scale (MUSS) scores (MD 9.02, 95% CI 7.59 to 10.45) significantly ($p<0.05$) varied between children 1 to 3 years of age and children 3 to 6 years of age. However, the scores did not vary significantly by gender ($p>0.05$). **Conclusion:** The findings indicate that younger children (1-3 years) tend to achieve better outcomes compared to older children (3-6 years) highlighting the importance of early cochlear implantation for optimizing auditory performance, better speech intelligibility and meaningful auditory integration in prelingually deaf children.

Keywords: Sensory neural hearing loss, Children, Cochlear implantation, Ear, India, Speech

Introduction

Cochlear implantation surgery has revolutionized the management of prelingually deaf children, offering them the potential for improved hearing and speech outcomes.(1) Cochlear implants are electronic devices that bypass damaged or non-functioning parts of the inner ear and stimulate the auditory nerve directly, providing a sense of sound to individuals with severe to profound hearing loss.(2) Despite the increasing popularity and success of cochlear

implantation, it is crucial to assess the outcomes of this intervention in real-world settings to gain a comprehensive understanding of its effectiveness.

The incidence of congenital severe to profound sensorineural hearing loss (SNHL) which occurs before the formation of language in the child is projected to be between 0.5 to 4 per 1000 births.(3) Guidelines for selecting the appropriate candidates for implantation have been formulated by using the data available from the post operative follow up studies conducted in previously implanted children.(4) Over the period of time these guidelines have greatly evolved to encompass a greater group of beneficiaries. Selecting the ideal and deserving patients for implantation has emerged to be a vital step for ensuring a favourable result in the post operative period.

To determine whether a child is suitable for cochlear implantation several criteria have to be necessarily fulfilled.(5) These include a confirmatory diagnosis of a profound sensorineural hearing loss not benefited by any other modality of treatment, absence of medical contraindication to implantation surgical procedure, and the presence of an implantable cochlea without significant anatomical anomalies. Further evaluation of additional factors such as speech and language development of the child, developmental milestones, home environment, educational setting, and the presence or absence of other disabilities helps determining the type and extent of rehabilitation required. Additionally, assessment of other factors like duration of deafness, age at deafness onset, and the speech perception performance of the child preoperatively can hint at probable prognosis.(6, 7)

Against this background, there is a need for further research to evaluate the real-world effectiveness of cochlear implants in improving hearing and speech outcomes. Specifically, this complex procedure involves various factors, including individual characteristics, implant programming, and post-implant rehabilitation. Secondly, investigating the outcomes within 1 to 6 years of age allows for a better understanding of the impact of cochlear implantation at different stages of early childhood, potentially identifying optimal intervention strategies for specific age groups. Thirdly, understanding gender differences in outcomes. Understanding whether there are differential effects based on gender can help identify specific needs and tailor intervention approaches accordingly.

The primary objective of the present study was to assess the hearing and speech outcomes of prelingually deaf children who underwent cochlear implantation surgery in a tertiary healthcare facility; disaggregated by age and gender.

Materials and methods

This was an observational prospective study conducted in the Department of Paediatrics and Otorhinolaryngology of a tertiary healthcare facility in western India between June 2019 and May 2020. The study was approved by the Institutional Human Ethics Committee (IHEC). The contents of Participant Information Sheet (PIS) in local language (Hindi) was provided to the parents and/or guardians' and contents were read to them in their own language to their satisfaction. The study subjects were enrolled in the study after obtaining written informed consent (from parents and/or guardians). We enrolled all children between 1 and 6 years of age

with bilaterally prelingual deafness (with no benefit using bearing aid) who underwent cochlear implantation surgery at the tertiary healthcare facility. However, we excluded post lingually deaf children, children with neurological defects, syndromic children, children with anatomical defects of the middle ear, inner ear or eighth nerve, and children already using hearing aids with benefit.

We computed the minimum required sample size to be 100. Children suspected of having hearing loss (from outpatient department, referrals, from routine neonatal screening of high-risk babies) underwent preliminary auditory evaluation. These children were then subjected to Otoacoustic Emissions test (OAE)(8) and if found absent they underwent BERA,(9, 10) followed by behavioural audiometry to confirm the presence of bilateral severe to profound sensory neural hearing loss (SNHL) of less than 90dB.(11) We then provided them with a hearing aid trial and recorded the aided response. Other audiological evaluations conducted were impedance audiometry and speech reception threshold. Radiological investigations included high resolution CT scan (HRCT) of the temporal bone and MRI of the inner ear; and routine laboratory investigations were conducted. Preoperative psychological evaluation of the child was done to estimate the IQ. Preanesthetic workup, preoperative, intraoperative and post operative management was followed in accordance with existing standards. Specifically, Electrical Stapedial Reflex Telemetry (ESRT) and Neural Response Telemetry (NRT) was done to ensure the proper placement and working of the device.(12, 13) The placement of the external device (consisting of the microphone, speech processor, and transmitter) and the initial activation or "switching on" of the device was done three weeks after the surgery. For rehabilitation and training, a training program was planned out for the child, incorporating both Ausplan (Auditory, Speech, and Language) and St. Gabriel's curriculum for training paediatric population with cochlear implants.(14) The number of classes were scheduled over a period of one year – based on convenience of both the parent and therapist.

Evaluation: Throughout the training program child's performance was continuously monitored, evaluated to assess the outcomes (final evaluation is done at the end of one year); focusing one four areas of development namely,

1. Audition – Categories of Auditory Performance (CAP) scale (hearing awareness)(15) and Meaningful Auditory Integration Scale (MAIS, use in home environment)(16)
2. Speech – Speech Intelligibility Rating Scale (SIR, precision of speech),(17) Meaningful Use of Speech Scale (MUSS, use in home environment), Monosyllabic Trochee Polysyllabic (MTP, measures the ability of the child to identify different syllable patterns),(18) Common Object Token Test (COT, ability of the child in the area of complex closed-set speech awareness),(19) integration of the auditory cues with motor skills and auditory memory), and Glendonald Auditory Screening Procedure (GASP, ability of the child to understand simple sentences).(20, 21)

Statistical analysis: The data collected in the present study (n = 100) was manually entered into Microsoft Excel and analysed using STATA v16. Descriptive analysis was presented using numbers and percentages for categorical variables; mean (standard deviation) or median (interquartile range) for continuous variables. Chi square test of significance (two-sided) was

applied to test for association between categorical variables and independent "t" test was used to test for association between (or non-parametric Mann-Whitney test) between continuous variables. Statistical significance was taken as $p<0.05$.

Results

The present study included a total of 100 children between 1 and 6 years of age with bilaterally prelingual deafness (with no benefit using bearing aid) who underwent cochlear implantation surgery at the tertiary healthcare facility. More than half the children (52.0%) were between three and six years of age; whereas 48.0% were between one and three years of age. Regarding distribution of gender, majority (58.0%) were males, followed by 42.0% females.

Audition and speech by age groups: The results of the present study showed that the mean (SD) Categories of Auditory Performance (CAP) scale score was 5.11 (0.69) and 3.59 (0.74) among children 1 to 3 years and 3 to 6 years respectively. The mean difference (95% CI) was found to be 1.52 (1.24 to 1.80) – statistically significant at $p<0.05$. The mean (SD) Meaningful Auditory Integration Scale (MAIS) scores among children 1 to 3 years and 3 to 6 years was 34.92 (2.29) and 27.41 (6.31) respectively; a statistically significant difference (MD 7.51, 95% CI 5.59 to 9.42).

The mean (SD) Speech Intelligibility Rating Scale (SIR) scores were 3.99 (0.58) and 2.31 (0.91) among children 1 to 3 years and 3 to 6 years respectively. This was a statistically significant difference of 1.68 (95% CI 1.37 to 1.99) at $p<0.05$. The mean (SD) Meaningful Use of Speech Scale (MUSS) scores were 32.83 (2.33) among children 1 to 3 years and 23.81 (4.46) among children 3 to 6 years – a statistically significant difference.

Audition and speech by gender: The results of the present study showed that the mean (SD) Categories of Auditory Performance (CAP) scale score was 4.41 (1.32) and 4.29 (1.11) among male and female children respectively. The mean difference (95% CI) was found to be 0.12 (-0.38 to 0.62) – statistically insignificant ($p>0.05$). The mean (SD) Meaningful Auditory Integration Scale (MAIS) scores among male and female children was 31.62 (4.67) and 30.58 (5.35) respectively; a statistically insignificant difference (MD 1.04, 95% CI -0.96 to 3.04).

The mean (SD) Speech Intelligibility Rating Scale (SIR) scores were 3.21 (1.14) and 2.99 (1.43) among male and female children respectively. This was a statistically insignificant difference of 0.22 (95% CI -0.29 to 0.73) at $p>0.05$. The mean (SD) Meaningful Use of Speech Scale (MUSS) scores were 27.91 (6.48) among males and 28.38 (5.82) among females – a statistically insignificant difference (MD 0.47, 95% CI -2.03 to 2.97).

Discussion

The results of the present study indicate significant differences in the Categories of Auditory Performance (CAP) scale scores and Meaningful Auditory Integration Scale (MAIS) scores between children aged 1 to 3 years and those aged 3 to 6 years who underwent cochlear implantation surgery. The CAP scale is commonly used to assess the auditory performance and development of children with cochlear implants.(22) Higher CAP scores indicate better auditory abilities and speech perception.(23) In this study, the mean CAP score was 5.11 (SD

0.69) for children aged 1 to 3 years and 3.59 (SD 0.74) for children aged 3 to 6 years. The mean difference between the two age groups was found to be 1.52 (95% CI 1.24 to 1.80), which is statistically significant ($p<0.05$). So, on an average child implanted before 3 years is able to "understand phrases without lip reading" whereas those implanted after 3 years are only able to "discriminate between speech sounds" at the end of 1 year after rehabilitation. These findings suggest that younger children (1-3 years) who received cochlear implants demonstrated better auditory performance compared to older children (3-6 years). This result aligns with previous research showing that early implantation during the critical period of language acquisition provides better outcomes in terms of speech perception and language development.(24, 25) Early intervention allows for optimal brain plasticity, enabling the development of auditory skills and language processing abilities.(24) The MAIS is a questionnaire-based assessment that evaluates the functional auditory skills and auditory development of children with cochlear implants. Higher MAIS scores indicate better auditory integration and meaningful use of hearing in everyday life.(26) In the present study, the mean MAIS score was 34.92 (SD 2.29) for children aged 1 to 3 years and 27.41 (SD 6.31) for children aged 3 to 6 years. The mean difference between the two age groups was 7.51 (95% CI 5.59 to 9.42), indicating a statistically significant difference. The results suggest that younger children (1-3 years) demonstrated better meaningful auditory integration compared to older children (3-6 years). These findings are consistent with previous research demonstrating that younger children tend to exhibit more rapid progress in auditory skill development and everyday communication outcomes after cochlear implantation.(27, 28) The age-related differences observed in both the CAP and MAIS scores can be attributed to various factors. Firstly, younger children may have a shorter duration of deafness, allowing for better preservation of auditory pathways and more efficient neural adaptation to the cochlear implant.(27) Secondly, younger children may have fewer pre-implantation experiences with non-auditory communication methods, resulting in a more significant impact of auditory input on their overall development.(29) It's important to note that despite the differences observed between the age groups, both the younger and older children in this study demonstrated positive outcomes in terms of auditory performance and meaningful auditory integration. Cochlear implantation remains a valuable intervention for improving hearing and speech outcomes in prelingually deaf children, regardless of age.

The results of the present study revealed significant differences in the Speech Intelligibility Rating Scale (SIR) scores and Meaningful Use of Speech Scale (MUSS) scores between children aged 1 to 3 years and those aged 3 to 6 years who underwent cochlear implantation surgery. The SIR is a scale used to assess the intelligibility of speech produced by individuals with cochlear implants.(30) Higher SIR scores indicate greater speech intelligibility. In this study, the mean SIR score was 3.99 (SD 0.58) for children aged 1 to 3 years and 2.31 (SD 0.91) for children aged 3 to 6 years. The mean difference between the two age groups was 1.68 (95% CI 1.37 to 1.99), which is statistically significant ($p<0.05$). So, it can be inferred that a child implanted before 3 years of age are able to produce speech which "is intelligible to a listener who has little experience of deaf persons speech, and the listener need not concentrate unduly" whereas in those implanted between 3 and 6 years showed a SIR score corresponding to a speech "intelligible to listener who concentrates and lip reads within a known context" at the end of 1 year training program.(31) The findings suggest that younger children (1-3 years)

demonstrated better speech intelligibility compared to older children (3-6 years). This is consistent with previous research indicating that earlier cochlear implantation and intervention contribute to more favourable speech outcomes in terms of intelligibility and articulation skills.(29) Early implantation provides children with the opportunity to develop age-appropriate speech production skills and benefit from the sensitive period for language acquisition.(24) The MUSS is a scale used to evaluate the meaningful use of speech in daily life by individuals with cochlear implants. Higher MUSS scores indicate greater functional and communicative use of speech. In the present study, the mean MUSS score was 32.83 (SD 2.33) for children aged 1 to 3 years and 23.81 (SD 4.46) for children aged 3 to 6 years. The mean difference between the two age groups was statistically significant. The results indicate that younger children (1-3 years) demonstrated better meaningful use of speech compared to older children (3-6 years). This finding aligns with previous research highlighting the advantages of early intervention in promoting functional communication skills and social integration.(28, 32) Early access to sound and speech input allows children to develop the necessary auditory and linguistic foundations for effective communication.(33) It is crucial to consider that individual variations, such as the child's motivation, parental involvement, and ongoing therapy, can influence the outcomes of speech intelligibility and meaningful use of speech.

The results of the present study indicate that there were no statistically significant differences in the Categories of Auditory Performance (CAP) scale scores and Meaningful Auditory Integration Scale (MAIS) scores between male and female children who underwent cochlear implantation surgery. In this study, the mean CAP score was 4.41 (SD 1.32) for male children and 4.29 (SD 1.11) for female children. The mean difference between the two genders was 0.12 (95% CI -0.38 to 0.62), which is statistically insignificant ($p>0.05$). Similarly, the mean MAIS score was 31.62 (SD 4.67) for male children and 30.58 (SD 5.35) for female children. The mean difference between the two groups was 1.04 (95% CI -0.96 to 3.04), which is also statistically insignificant. These findings suggest that there were no significant gender-based differences in the auditory performance and meaningful use of auditory skills among children with cochlear implants in this study. This aligns with previous research that has reported no significant gender differences in outcomes following cochlear implantation.(34) The lack of gender differences in the outcomes of cochlear implantation can be attributed to several factors. Firstly, cochlear implant technology provides a standardized approach to auditory rehabilitation, which may mitigate any potential gender-related variations in outcomes.(27) Secondly, the underlying etiology of deafness and individual differences in motivation and engagement may play a more significant role in outcomes than gender.(35) The results of the present study indicate that there were no statistically significant differences in the Speech Intelligibility Rating Scale (SIR) scores and Meaningful Use of Speech Scale (MUSS) scores between male and female children who underwent cochlear implantation surgery. These findings suggest that there were no significant gender-based differences in speech intelligibility and the meaningful use of speech among children with cochlear implants in this study.(36) This aligns with previous research that has reported no significant gender differences in speech outcomes following cochlear implantation. It is essential to note that while this study did not find any significant gender differences, it is important to consider that individual variations,

such as age at implantation, duration of deafness, and therapy participation, can impact outcomes in children with cochlear implants.(28)

While the present study provides valuable insights into the hearing and speech outcomes of prelingually deaf children who underwent cochlear implantation, it is important to consider its limitations. Firstly, the study may have a relatively small sample size, which could limit the generalizability of the findings. The study may have a relatively short follow-up duration, which may limit the assessment of long-term outcomes. Cochlear implantation is a lifelong process, and evaluating outcomes over an extended period would provide a more comprehensive understanding of the benefits and challenges associated with the procedure. The study may not have accounted for various external factors that could influence the outcomes, such as socioeconomic status, educational opportunities, and parental involvement. The study's reliance on subjective measures, such as rating scales, introduces the possibility of observer bias and subjectivity in the assessment process.

Conclusion

The present study highlights the importance of early cochlear implantation for optimizing auditory performance, better speech intelligibility and meaningful auditory integration in prelingually deaf children. The findings indicate that younger children (1-3 years) tend to achieve better outcomes compared to older children (3-6 years). These results align with previous research emphasizing the benefits of early intervention in maximizing speech perception and language development in children with cochlear implants. However, it's important to consider individual variations and the need for ongoing support and therapy to optimize outcomes for all children with cochlear implants.

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Table 1: Distribution of study participants

Study variables		**Number (n)**	**Percentage (%)**
Age (in years)	**1 to 3**	48	48.0
	3 to 6	52	52.0
Gender	**Male**	58	58.0
	Female	42	42.0

Table 2: Audition and speech by age groups

Variables	**Age (in years)**	**Mean**	**SD**	**MD (95% CI)**	**p value**
CAP	**1 to 3**	5.11	0.69		<0.001*

	3 to 6	3.59	0.74	1.52 (1.24 to 1.80)	
MAIS	**1 to 3**	34.92	2.29	7.51 (5.59 to 9.42)	<0.001*
	3 to 6	27.41	6.31		
SIR	**1 to 3**	3.99	0.58	1.68 (1.37 to 1.99)	<0.001*
	3 to 6	2.31	0.91		
MUSS	**1 to 3**	32.83	2.33	9.02 (7.59 to 10.45)	<0.001*
	3 to 6	23.81	4.46		
*Statistically significant at p<0.05					

Table 3: Audition and speech by gender

Variables	**Gender**	**Mean**	**SD**	**MD (95% CI)**	**p value**
CAP	**Male**	4.41	1.32	0.12 (-0.38 to 0.62)	0.553
	Female	4.29	1.11		
MAIS	**Male**	31.62	4.67	1.04 (-0.96 to 3.04)	0.182
	Female	30.58	5.35		
SIR	**Male**	3.21	1.14	0.22 (-0.29 to 0.73)	0.773
	Female	2.99	1.43		
MUSS	**Male**	27.91	6.48	0.47 (-2.03 to 2.97)	0.372
	Female	28.38	5.82		
*Statistically significant at p<0.05					