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Analysis of speech development and auditory performance in children after cochlear implantation

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ABSTRACT

Background: Hearing loss is a frequent congenital condition. If not treated promptly, the disease's progression may endanger newborns and young children's proper growth and development. Cochlear implants (CIs) are the only viable treatment for severe or extremely severe sensorineural hearing loss. **Aims and Objectives:** This study aimed to see how auditory performance and speech development changed after cochlear implantation in children born deaf and whether there is a link between sociodemographic parameters and the outcome. **Materials and Methods:** Analyze the improvement of speech and auditory performance in congenitally deaf children aged 1–6 years who underwent CI surgery at Government Rajaji Hospital, Madurai Medical College, Madurai, from January 2016 to June 2018. The data acquired in this study were statistically analyzed to provide detailed findings. **Results:** Among the study population with age distribution, 18 (26.87%) were in 3 years, followed by 17 (25.37%) in 4 years and least 1 (1.49%) were in 1 year. Sex distribution – 42 (62.69%) were male, and 25 (37.31%) were female children. Progress in hearing and speech was observed, which was evident from the 2-year assessment of categories of auditory performance (CAP) (2.7–4.4) and speech intelligibility rating (SIR) scores (1.04–3.67), increasing every 3 months ($P<0.001$). Scores of children in age group 2 (CAP2 and SIR 3.3) were the highest, yet differed significantly among age groups, implying that the earlier the CI implantation age, the better their language outcomes were. **Conclusion:** The importance of age at implantation and the role of family members in effective audioverbal therapy and aural stimulation at home were highlighted in this study.

Key words: Cochlear implantation; Hearing loss; Auditory rehabilitation; Congenital deafness; Auditory performance

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INTRODUCTION

Hearing loss is humans' most common sensory deficit; around 63 million people have a substantial auditory impairment. 1–3/1000 live babies have bilateral severe to profound hearing loss. They do not acquire speech but do not have a deficiency in the speech production system because they never hear any voice/sound and hence become mute. The first 5 years of life are critical for speech and language development.[1] Auditory rehabilitation should begin as soon as possible for prelingual deaf youngsters, especially as their speech and language skills develop. Cochlear implantation is a safe and effective therapy option for children worldwide with severe to profound hearing loss.[2]

The primary benefit of this medical device in youngsters is the acquisition of hearing, which is expected to facilitate communicative development.[3] It was reported that outcomes such as age at implantation, comorbidities, social determinants of health, and bilateral versus unilateral hearing had the most predictive effects. Children with

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profound deafness require pediatric cochlear implantation to hear and acquire speech understanding.[4] Cochlear implantation children reach hearing and language skills comparable to hearing children 10 years later, with word recognition scores of 85% among the top implant users.

The cochlear implant (CI) revolutionised otology and the CI revolutionised this; today, most CI patients can readily interact through cell phones. The growth has been rapid and remarkable. The most prevalent cause of deafness and severe hearing loss is damage to the sensory hair cells in the cochlea.[5] The CI bypasses damaged or absent structures by directly activating auditory nerve neurons with electrical impulses.[6] Modern CIs use an array of electrodes implanted into the cochlea's scala tympani to activate neuron subpopulations selectively.

Clinical results of CIs and related studies have provided insight into the development of childhood neurocognitive processes such as executive function and theory of mind.[7] CIs are an effective therapy choice for people with severe to profound hearing loss since they improve their surroundings.[8] A CI can help both post-lingually deafened adults and pre-lingually deafened children; however, the results vary. To successfully counsel the recipient and their family and establish acceptable and realistic expectations with a CI, the audiologist must understand what factors may play a role and impact performance results with a CI.[9]

The surgery's success depends on signal transmission through auditory pathways from the ear to the auditory cortex. Mapping is the process of programming a CI in the post-operative phase. The categories of auditory performance (CAP) and speech intelligibility rating (SIR) grading regularly evaluate implanted children's speech and auditory skills.[10] SIR is linked to articulation issues, and as a result, it can be improved with continued speaking practice.[11] CAP and SIR are basic, easy to learn, and execute for clinicians, audiologists, rehabilitation teachers, and parents unfamiliar with CI children's tests or other assessment methods. This study emphasizes the importance of implantation age, effective audioverbal therapy (AVT), and the relationship between sociodemographic parameters and surgical outcome.

Aims and objectives

This study aims to determine the association of sociodemographic factors with auditory performance and speech development in congenitally deaf children after cochlear implantation.

MATERIALS AND METHODS

This retrospective study encompassed all subjects that met the inclusion criteria from January 2016 to June 2018; researchers studied speech and auditory skills progress in congenitally deaf children (deaf-mute) who underwent CI surgery at Government Rajaji Hospital, Madurai Medical College, Madurai.

Inclusion criteria

Congenitally deaf children aged 1–6 years who received CI surgery were included in the study. The participants in this study were people with delayed speech and language impairment. Because the patients in the study had normal vision (according to an ophthalmologist's assessment before the surgical operation), the visual sensation did not need to be stimulated individually. With visual signals, auditory-verbal therapy focuses on auditory stimulation and speech-language output (real objects and flashcards etc.). Inclusion criteria were set as follows: Children with bilateral profound sensory-neural hearing loss, belonging to age group of 1–6 years and both sexes (female and male); Children with no appreciable benefit with hearing aid were also included.

Exclusion criteria

Included revision CI surgery patients and cases with lost follow-up.

The Institutional Ethics Committee approved the study protocol. Therefore, the information collected from the records was only used for the study purpose, and strict confidentiality was maintained throughout the study.

The data were collected from old hospital records from July 2020 to August 2020. The parameters analyzed included the patient's age to determine the association of age at the surgery with the outcome of auditory performance, gender, and order of live birth.

Study speech and auditory performance progress in congenitally deaf children who underwent CI surgery using CAP and SIR score.

CAP

0	No awareness of environmental sounds
1	Awareness of environmental sounds
2	Response to speech sound
3	Environmental sound identification
4	Discrimination of speech sounds without lip reading
5	Understanding common phrases without lip reading
6	Understanding conversation without lip reading
7	Telephone conversation with the known listener.

SIR

0	Connected speech is unintelligible, pre-recognizable words in spoken language
1	Connected speech is unintelligible, pre-recognizable words in spoken language
2	Intelligible speech is enveloping in single words when context lip reading cues are available
3	Connected speech is intelligible to a listener and concentrates lip reading
4	Connected speech is intelligible to a listener who has little experience of deaf persons speech
5	Connected speech is intelligible to all listeners; everyday contexts are easily understood.

All characteristics were reported with descriptive statistics. All categorical variables were evaluated with the Pearson Chi-square test. The mean frequency of speech cycles was compared with the Kruskal–Wallis test. A P≤0.05 was considered statistically significant. The data collected in the case pro forma were entered into a Microsoft Excel sheet, and data analysis was done using SPSS statistical software.

RESULTS

Seventy-three children underwent CI surgery; four (4) patients had device failure, so re-surgery has been done. Two (2) patients, even after so many instructions, did not turn up for follow-up, so only 67 implantees have been selected for the study.

Among the study population with age distribution, 18 (26.87%) were in 3 years, followed by 17 (25.37%) in 4 years, least 1 (1.49%) were in 1 year. Sex distribution – 42 (62.69%) were male, and 25 (37.31%) were female children. Of children with siblings, 51 (76.12%) had one followed by 12 (17.91%) had 0, and the least 4 (5.97%) Table 1.

The mean CAP score at 3 months was 2.76, lower than the mean CAP score at 6 months, which was 3.19, and the difference was statistically significant. The mean CAP score at 6 months was 3.19, which is lower than the mean CAP score at 9 months, which was 3.72, and the difference was statistically significant.

The mean CAP score at 12 months was 3.97, which is lower than the mean CAP score at 18 months, which was 4.4, and the difference was statistically significant. The mean CAP score at 18 months was 4.4, which is lower than the mean CAP score at 24 months, which was 4.97, and the difference was statistically significant. Finally, the mean CAP score at 3 months was 2.76, which is lower than the mean CAP score at 24 months, which was 4.97, and the difference was statistically significant. As the duration advances, CAP score increases which shows the progress of a hearing (Table 2).

Table 1: Distribution of patient's characteristics

Patient's characteristics	Frequency	Percent
Age group		
1 year	1	1.49
2 years	10	14.93
3 years	18	26.87
4 years	17	25.37
5 years	16	23.88
6 years	5	7.46
Gender		
Male children	42	62.69
Female children	25	37.31
Siblings		
0	12	17.91
1	51	76.12
2	4	5.97

Table 2: Distribution of CAP and SIR scores among the study population

Follow-up	CAP score		SIR score	
	Mean	Std. Deviation	Mean	Std. Deviation
3 months	2.76	0.7	1.04	0.21
6 months	3.19	0.78	1.28	0.52
9 months	3.72	0.71	1.79	0.62
12 months	3.97	0.78	2.39	0.76
18 months	4.4	0.7	2.97	0.94
24 months	4.97	0.85	3.67	1.04

CAP: Categories of auditory performance, SIR: Speech intelligibility rating

The mean SIR score at 3 months was 1.04, which is lower than the mean SIR score at 6 months, which was 1.28, and the difference was statistically significant. The mean SIR score at 6 months was 1.28, which is lower than the mean SIR score at 9 months, which was 1.79, and the difference was statistically significant.

The mean SIR score at 12 months was 2.39, which is lower than the mean SIR score at 18 months, which was 2.97, and the difference was statistically significant. The mean SIR score at 18 months was 2.97, which is lower than the mean SIR score at 24 months, which was 3.67, and the difference was statistically significant. The mean SIR score at 3 months was 1.04, which is lower than the mean SIR score at 24 months, which was 3.67, and the difference was statistically significant. As the duration advances, the SIR score increases such as the CAP score, which shows the progress of a hearing (Table 2).

The CAP score change between 3 and 24 months of the subjects with age distribution. Three years age group had a higher mean of CAP score change with three followed by 2 years with 2.8 and least in 4 years with 1.88; the difference is statistically significant (P=0.001) (Table 3).

The SIR score changed between 3 and 24 months of the subjects with age distribution. 2-year age group had a higher mean SIR score change with 3.3, followed by 3 years with

Table 3: Distribution of CAP score change with age distribution in the study population

Age	CAP score change			P-value
	N	Mean	Std. Deviation	
1 year	1	2	0	0.001
2 years	10	2.8	0.79	
3 years	18	3	0.77	
4 years	17	1.88	0.86	
5 years	16	1.5	0.89	
6 years	5	1.6	0.55	
Total	67	2.21	1.01	

CAP: Categories of auditory performance

Table 4: Distribution of SIR score change with age distribution in the study population

Age	SIR score change			P-value
	N	Mean	Std. Deviation	
1 year	1	1	0	0.003
2 years	10	3.3	0.48	
3 years	18	3.05	0.93	
4 years	17	2.52	1.06	
5 years	16	2.12	0.71	
6 years	5	2	1.22	
Total	67	2.62	0.99	

SIR: Speech intelligibility rating

3.05 and least in 4 years with 2.52, and the difference is statistically significant (P=0.003). The above data analysis clearly shows that the earlier age has good hearing and speech intelligibility (Table 4).

DISCUSSION

CIs are beneficial in treating severe to profound hearing loss by enhancing auditory access. The current study emphasizes implantation age, AVT success, and the relationship to surgical outcomes. Totally, 73 children underwent CI surgery at Government Rajaji Hospital, Madurai. Out of the 67 children who come under the inclusion criteria, the remaining six children fall on the exclusion criteria, i.e., four children underwent revision surgery due to device failure, even after extensive preop counselling and education on the importance of AVT, two children did not come for AVT after CI surgery.

The study's subjects were 3.5-year-old on average. The majority of individuals were under the age of 3 years. Fitzpatrick et al., found that the average age of infants during implantation was 3.[12] In terms of sex distribution, male children outnumber female children. Pulsifer et al., and Zheng et al., also revealed a male preponderance among all age groups of children studied.[13,14] Subjects with one sibling outnumber those without, similar to the observation made by Fink et al.[15]

Post-operatively, patients were scored using the CAP scale for 2 years, every 3 months. Three months after the half-yearly score, the mean CAP increased from 3.19 to 3.72 (P=0.001). After 2 years, the CAP score increased to 3.67. Yang et al., found that the 1st-year CAP score post-CI implantation surgery was 3.93.[16] As evidenced by our 1st-year CAP score, the children went from being unconscious of environmental sounds to being aware of and responsive to speech sounds. According to Bakhshaee et al., 11 out of 47 individuals developed the ability to respond to speaking voice after CI surgery.[17] Guo et al., found similar CAP score improvement kinetics in years 1 and 2.[18] Despite a small difference (0.57) in the fourth quarter mean CAP scores, the development was 4.4–4.97 (P=0.001). The normal group of individuals in the Yang et al., study improved rapidly to 5.86 by year 2.[16] This means the subjects could converse and understand without lip reading. Each year after 3 months of implantation, a SIR score evaluation was performed every 3 months. The SIR score increased from 1.79 (year 1) to 3.67 at the end of year 2, suggesting a continuous improvement in CI functioning. Bakhshaee et al., previously showed a statistically significant increase in SIR scores over the evaluation years.[17]

CAP score change and age were correlated during the evaluation period. Based on the scores, the change in CAP scores within the 1st year of evaluation increased faster in subjects aged three than in those aged 4. However, CAP ratings varied greatly among age groups (P=0.001). These findings imply that implantation age influences auditory and later speech development. According to Liu et al., the earlier a child receives cochlear implantation, the better their hearing and speech abilities.[19] The age distribution of SIR scores also significantly varied from 1 to 6. (P=0.003). The 2-year age group had the highest mean SIR score change with 3.3, followed by 3 years with 3.05, and 4 years with 2.52, which is statistically significant (P=0.003). In this study, children with CIs had higher CAP and SIR ratings as they grew older. As many studies have shown, this suggests that cochlear-implanted toddlers aged 1–3 may benefit from better rehabilitation.[3]

Limitations of the study

Limitations of this retrospective study include reliance on old hospital records, a small sample size, limited geographical representation, a short follow-up period, and a lack of consideration for specific sociodemographic factors. Other relevant factors and individual effects were not explored, potentially limiting the study's comprehensive understanding.

CONCLUSION

The importance of age during cochlear implantation surgery and the role of family members in returning the kid to near-normal activities with effective AVT and auditory stimuli at home was highlighted in this study. Our findings imply that children who follow the prescribed post-operative mapping and auditory-verbal treatment program have superior hearing perception and speech intelligibility, regardless of gender.

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