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Original Research

Evaluation of Behavioral Characteristics After Hearing in Children with Cochlear Implants

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ABSTRACT

Objective: Cochlear implantation (CI) is an electronic device that converts mechanical sound energy into electrical signals and transmits it directly to the cochlea, allowing sound perception. These implants were applied to patients with severe sensorineural hearing loss who did not or had little benefit from the conventional hearing devices. This study aimed to investigate behavioral problems, find related factors, and determine the relationship between behavioral problems and parents' attitudes in children with CI.

Methods: The investigation involved the participation of fifty individuals, comprising 26 males and 24 females, between 4 and 18 years, with a mean age average of 4±1.56 without any neurological and developmental problems. Inclusion criteria required a minimum of one year post-CI follow-up and a corresponding minimum duration of one year utilizing CI. Achenbach's Child Behavior Checklist (CBCL) assessed behavioral aspects. Categories of Auditory Performance II (CAP) and The Speech Intelligibility Rating Scale (SIR) scales were employed to evaluate auditory performance and speech intelligibility. Parental attitudes were gauged using the Parent Attitude Research Instrument (PARI). The selection of fifty patients was accomplished through a simple random sampling technique, with no considerations for gender or social status differences during case selection.

Results: The patients who applied the CI bilaterally were more successful than the one-sided. The success rate of patients who had comorbidities was statistically significant. Aggressive behavior was less in patients operated on before age 4. There are no differences between the relations of friend circle, art, and sports-interested patients. For CAP II and SIR, there is a moderate statistical significance between the duration of use and CAP. CAP scores were analyzed high in patients who used the device for over six years. There is a moderate statistical significance between CAP and SIR correlation. Our research found a statistically significant decrease in all behavioral scales when comparing preoperative and postoperative scores. Although there was only a non-significant decrease in the delinquent behaviors score, a decrease was still observed. There were significant changes in males but no significant difference based on gender in our study.

Conclusion: The findings imply that implementing cochlear implants in younger children might yield even greater advantages. Our research adds to the expanding collection of evidence endorsing CI as a viable therapeutic choice for youngsters with hearing impairments, underscoring the necessity for continued investigations within this domain.

Keywords: Cochlear Implant, Sensorineural Hearing Loss, CBCL, CAP, SIR, PARI, Behavioral Disorder

INTRODUCTION

Hearing loss is an important public health problem affecting 32 million children worldwide and has a major impact on children's communication, social and educational development [1]. Hence, children facing severe to profound sensorineural hearing loss frequently encounter disruptions in their speech development or experience speech impairments, leading to adverse impacts on their communication skills and social interactions [2].

Important evidence has been obtained in young children indicating the effectiveness of CIs in speech perception, receptive and expressive language, and general communication skills [3]. Hearing, speaking, and language acquisition enable the child to develop independent thinking and self-control skills to maintain healthy relationships with others [4]. CI allows the child to develop the language and communication skills required to connect with peers and build effective social networks [5]. Deaf and hearing-impaired children have a higher risk of socially and emotionally negative development than their normal-hearing peers, leading to disruptive behavior problems [6].

Main Points;

- Children with severe to profound hearing loss face hurdles in speech development and social interactions, highlighting the importance of early interventions to foster proper speech and overall development.
- Cochlear implants have proven to be a transformative solution, significantly improving children's auditory perception and speech recognition, thereby aiding in robust language development and better communication abilities.
- The devices are central in enhancing a child's language acquisition, communication proficiency, and social skills, allowing them to engage more meaningfully with their environment and society.
- The study aims to explore the behavioral challenges faced by children with cochlear implants, seeking to identify the factors involved and develop insights to guide potential interventions, with the ultimate objective of enhancing these children's well-being and quality of life.
- Implementing early interventions like cochlear implants has wider public health and educational benefits, promoting inclusive education and healthier development for future generations, hence facilitating mainstreaming of children with hearing loss.

Our study aimed to investigate the behavioral problems of children with CIs aged 4-18 cross-sectionally and to find factors related to problematic behaviors.

MATERIAL AND METHODS

This study was designed at the Bozyaka Education and Research Hospital. The local ethics committee of the same hospital approved this study (approval No=03 and date 20/12/2016). Every participant's parent furnished written informed consent before engaging in the study.

Participants

Patients between 4-18 years of age who had CI surgery, followed up at our CI center, did not have any neurological and developmental problems, and were using verbal communication were included in the study.

The participants' parents filled out the demographic information form, and the educational background of the parents, professional status, and socioeconomic status were recorded five-point scale was employed to assess the extent of parental education (ranging from 1 for illiterate parents to 5 for those with postgraduate education) and professional status (ranging from 1 denoting unskilled workers to 5 representing professionals). The behavioral problems of the participants were compared with the normal hearing sample of the same age in the Turkish population. Patients and their relatives who were to participate in the study were informed about the research, and their consent was obtained.

Test materials

1. Behavioral problem scale: To assess the participants' outcomes, the study employed the Turkish adaptation of the Child Behavior Checklist (CBCL) for Ages 4-18. This questionnaire, known for its high reliability and user-friendly nature, facilitates the acquisition of psychometrically precise insights [7]. Akçakın,1985 [8] translated this questionnaire into Turkish and reliability study.

The scale comprises a set of thirteen items designed to capture behavioral and emotional issues prevalent in children and adolescents. This checklist has eight distinct subcategories: Anxious / Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Delinquent Rule-Breaking Behavior, and Aggressive Behavior. Each subcategory is scored on a 3-point scale (0 = never, 1 = sometimes, 2 = very often). The initial three subcategories contribute to the "Internalization Behavior Problem" scale, while the latter two subcategories contribute to the "Externalization Behavior Problem" scale. The cumulative score derived from these eight subcategories signifies the "Total General Behavior" level.

Raw scores transform T scores, which are adjusted based on a normative sample tailored for age and gender considerations. Elevated scores on the scales correlate with escalating behavioral challenges. The mean T score for each subcategory stands at 50 ± 10. Interpreting the T-scores, children's performances within each sub-dimension are categorized as falling within the normal range, bordering the threshold, or residing within the clinical range.

2. Evaluation of Speech Performance: The study employed the Categories of Auditory Performance (CAP) test and the Speech Intelligibility Rating (SIR) scales to gauge speech-related abilities.

The CAP test was utilized to assess the speech perception performance of children who had undergone CI. This evaluation focuses on supraliminal performance, providing a more realistic reflection of everyday auditory capabilities. The CAP test is structured as a hierarchical scale, encompassing various levels of auditory perceptual prowess. This spectrum ranges from a level of 0, representing "no awareness of environmental sounds," to a level of 7, indicative of the ability to "use the telephone with a familiar talker" [9]. (Refer to Appendix 1.)

Meanwhile, the SIR scales were employed to quantify children's speech intelligibility with CIs during spontaneous speech in everyday contexts. The SIR is a practical and efficient measure of speech intelligibility outcomes in real-life scenarios. It encompasses five distinct performance categories that span from "pre-recognizable words in the spoken language" to "connected speech intelligible to all listeners" [10]. (Refer to Appendix 2.) Notably, both scales were assessed by the same educational audiologist during the most recent follow-up visit for children who had undergone CI.

Appendix 1. Categories of the auditory performance score.

0	No awareness of environmental sound
1	Awareness of environmental sounds
2	Responds to speech sounds
3	Identifies environmental sounds
4	Discriminates speech sounds
5	Understands phrases without lip reading
6	Understands conversation without lip reading
7	Uses the telephone

Appendix 2. Speech intelligibility rate

Category 1	Pre-recognizable words in spoken language
Category 2	Connected speech is unintelligible but is developing for single words
Category 3	Connected speech is intelligible to a listener who concentrates and lip reads within a known context
Category 4	Connected speech is intelligible to a listener who has little experience of a deaf person's speech. The listener does not need to concentrate unduly
Category 5	Connected speech is intelligible to all listeners. The child is easily understood in everyday contexts

3. Assessment of Parental Attitudes: The study incorporated the Parent Attitude Research Instrument (PARI) to gauge parental perspectives regarding children with disabilities. This instrument comprises several subscales that delve into various dimensions of parental attitudes. The acceptance subscale gauges how parents embrace their child's disability and comprehend its influence on their lives. Meanwhile, the guilt subscale scrutinizes the presence of any guilt that parents might experience concerning their child's disability. The competence subscale delves into the parent's perception of their proficiency in effectively parenting a child with a disability. Lastly, the social isolation subscale evaluates the level of social isolation parents might perceive due to their child's disability [11].

Statistical Analysis

The information extracted from patient records was entered into a computer utilizing SPSS version 20.0 software from IBM Corp., located in Armonk, NY, USA. The test scores obtained from the CBCL for Ages 4-18 were subjected to statistical analysis using the Pearson Correlation coefficient and t-test. A significance level of $p < 0.05$ was adopted. The assessment involved comparing subscales of the CBCL scale, including internalization and externalization scales and total scores. The comparisons encompassed Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Delinquent Rule-Breaking Behavior, and Aggressive Behavior subscales, alongside internalization and externalization scores and total scores. Moreover, ChatGBT artificial intelligence applications were enlisted to assist in grammar correction for writing purposes.

RESULTS

Demographic Data

A total of 50 patients, 26 males (52%) and 24 females (48%), between 4 and 18 years, with a mean age average of 4± 1.56, were included in the study. The demographic information of the patients is in Table 1. CIs were implanted in 35 patients (70%) at the age of 4 years or younger and 15 patients (30%) older than 4 years of age. The number of patients with 0-2 years of CI use was 4 (8%), the number of patients with 3-5 years of CI use was 11 (22%), and the number of patients with 6 years or more of CI use was 35 (70%). CIs were placed on the right side in 29 (58%) patients, on the left side in 16 (32%) patients, and bilateral in 5 (10%) patients. 7 (14%) patients had additional disabilities (disarticulation, spelling mistakes and word understanding). The socioeconomic status of the 18 (36%) parents was at the lower level, 27 (54%) of the parents were at the intermediate level, and 5 (10%) of the parents were at the upper level. The mean duration of CI use was 8.4 ±1.78 years, with a minimum of 1 and a maximum of 15 years. (Table 1.)

Table 1. Demographic Information

Demographic Information	Number of Patients	Percentage
Total Patients	50	100%
Male	26	52%
Female	24	48%
Age at Implantation		
≤4 years	35	70%
>4 years	15	30%
Duration of Cochlear Implant Use		
0-2 years	4	8%
3-5 years	11	22%
≥6 years	35	70%
Side of Implantation		
Right	29	58%
Left	16	32%
Bilateral	5	10%
Additional Disabilities	7	14%
Socioeconomic Status of Parents		
Lower	18	36%
Intermediate	27	54%
Upper	5	10%
Duration of Cochlear Implant Use (years)		
Mean	8.4	
Minimum	1	
Maximum	15	

CBCL, CAP, SIR, and PARI

The test scores obtained from the 4-18 Age CBCL were evaluated using the Pearson Correlation coefficient and t-test. The significance level was accepted as $p <0.05$. Subscales of the CBCL scale, internalization scale, externalization scale, and total scores were compared.

These comparisons were made among Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Delinquent Rule-Breaking Behavior and Aggressive Behavior subscales and internalization scores, externalization scores, and total scores. The average time for receiving special education is 6.08 ±1.42 years, ranging from 0 to 13 years. No notable difference was observed between the duration of special education and involvement in sports, art, or friendship relations. However, a statistically significant positive correlation was discovered between special education and CAP duration. A strong statistically significant positive correlation was also observed between CAP and SIR. Furthermore, a significant difference was found between the duration of implant use.

Patients with bilateral implants were observed to have a significantly higher success rate than patients with unilateral implants. Success status was also significantly correlated with comorbidities. Regarding behavioral outcomes, aggressive behavior was significantly lower in patients who underwent surgery before the age of 4 years. Moreover, those who had a duration of implant use of 6 years or more had significantly higher CAP scores. (Table 2.A and B)

Table 2 presents the mean ranks and sum of ranks for various factors of two age groups, 0-5 years and > six years, and the total sample size. The mean rank for each factor is higher for the >6 years group than the 0-5 years group. The only exception is the CAP factor, which has a lower mean rank for the > 6 year group. The highest mean ranks are observed for Withdrawal and Aggression scores, respectively. The Wilcoxon test results indicated significant differences between the two groups for CAP (Z=-2.398, p=0.017). However, the two groups had no significant differences in other factors (p > 0.05). The results suggest that the two age groups did not significantly differ on most factors except for CAP. The test statistics in the table refer to the Mann-Whitney U and Wilcoxon W tests, which were conducted to compare the ranks of the different variables between the two age groups (0-5 years and >6 years). The Z score and Asymp. Sig. (2-tailed) values are also provided to indicate the significance of the differences observed.

Table 2. B shows all the test statistics for various factors between two age groups (0-5 years and >6 years). The factors included in the table are Factor 1, Factor 2, Factor 5, CAP, SIR, Total Score, Aggression Score, Anxiety Score, Socialization Score, and Attention Score. The table provides valuable information on the significance of differences between the two age groups for each factor, which can aid in further analysis and interpretation of the data. Based on the values in the "Asymp. Sig. (2-tailed)", there are some statistically significant differences between the groups for certain variables. Specifically, there is a significant difference between the 0-5 year and > 6-year groups for the "CAP" variable (p=0.017). There are no other significant differences between the groups for the other variables. The table presents the Mann-Whitney U and Wilcoxon W test results, the Z-score, and the asymptotic significance level (2-tailed) for each factor and score. The grouping variable is 0-5 years and >6 years.

Table 3 shows the CAP variable's central tendency and dispersion measures in two age groups: 0-5 years and >6 years. The median CAP score for the >6 years group (8.00) is higher than the median for the 0-5 years group (6.00). The standard deviation for the 0-5 years group is 2.031, and for the >6 years group is 1.991, indicating that the scores are more dispersed in the younger age group. Both groups' minimum and maximum scores are 1 and 9, respectively.

Table 2. PARI data corelation with age

A.

	0-5 years		**>6 years**		**Total**
Factor 1	N=15	Mean Rank=20.67	N=35	Mean Rank=27.57	N=50
Factor 2	N=15	Mean Rank=20.00	N=35	Mean Rank=27.86	N=50
Factor 5	N=15	Mean Rank=20.03	N=35	Mean Rank=27.84	N=50
CAP	N=15	Mean Rank=18.23	N=35	Mean Rank=28.61	N=50
SIR	N=15	Mean Rank=21.40	N=35	Mean Rank=27.26	N=50
Total Score	N=15	Mean Rank=25.77	N=35	Mean Rank=25.39	N=50
Aggression Score	N=15	Mean Rank=26.33	N=35	Mean Rank=25.14	N=50
Withdrawal Score	N=15	Mean Rank=26.97	N=35	Mean Rank=24.87	N=50
Anxiety Score	N=15	Mean Rank=21.00	N=35	Mean Rank=27.43	N=50
Socialization Score	N=15	Mean Rank=24.37	N=35	Mean Rank=25.99	N=50
Attention Score	N=15	Mean Rank=23.87	N=35	Mean Rank=26.20	N=50

B.

Test Statistics	Factor 1	Factor 2	Factor 5	CAP	SIR	Total Score	Aggression Score	Withdrawal Score	Anxiety Score	Socialization Score	Attention Score
Mann-Whitney U	190,000	180,000	180,500	153,500	201,000	258,500	250,000	240,500	195,000	245,500	238,000
Wilcoxon W	310,000	300,000	300,500	273,500	321,000	888,500	880,000	870,500	315,000	365,500	358,000
Z	-1.537	-1.764	-1.740	-2.398	-1.388	-0.085	-0.266	-0.472	-1.437	-0.369	-0.523
Asymp. Sig. (2-tailed)	0.124	0.078	0.082	0.017	0.165	0.932	0.791	0.637	0.151	0.712	0.601

Table 3. CAP

	0-5 years	>6 years
N	15	35
Median	6.00	8.00
Std. Dev	2.031	1.991
Minimum	1	1
Maximum	9	9
25%	5.00	7.00
50%	6.00	8.00
75%	7.00	9.00

DISCUSSION

The hearing status of the hearing-impaired children and the resulting verbal language delays are thought to be associated with behavioral problems due to difficulty in perceiving the environment and events and the inability to express themselves adequately. The majority of the literature has reported higher rates of internalization problems (e.g., anxiety and depression) and externalization problems (e.g., hyperactivity and behavioral problems) in children with hearing loss compared to normal hearing children [12,13]. One of the important effects of behavioral problems in children is that they can limit the audiological benefit they receive from their implants. Behavioral problems can make it difficult for children to adapt to implant use and speech education. Children presenting with behavioral problems benefit less from the CI. It can be thought that the audiological benefits of CI can also lead to greatly improved cognitive abilities [14-16]. It is completed with findings a strong statistically significant positive correlation was observed between CAP and SIR after the CI surgery.

In addition to studies showing that they exhibit behavioral problems even after successful hearing aid use or CI interventions, studies indicate a significant decrease in behavioral, emotional, and social problems after CI implants in deaf and hard-of-hearing children [15,16]. Preschool children with CIs have been reported to perform similarly to their hearing peers in CBCL measurements after one year of implant use [17]. It has also been reported that deaf children successfully cope with social and school-life demands, regardless of their speech and language success after CI [17-20]. Our study shows a significant difference between the CAP variable's 0-5 year and > 6-year groups (p=0.017).

It was observed that they actively participate in school and sports activities, as in the normal-hearing student group [18]. Language deficiencies can lead to communication difficulties and consequently trigger social problems and aggressive behavior. SIR of auditory performance test scores (i.e., CAP) can be considered determinants of social and aggressive

behavior problems. The study by Wei-Chieh Chao et al. showed that the CAP scale scores of CI patients were correlated with all CBCL test contents except "Somatic Complaints" and "Thought Problems." Children with more problematic behaviors had lower CAP / SIR scores [20-25]. It has the same correlation in our study.

Early initiation of hearing rehabilitation with hearing aids or CIs improves language development and social-emotional adaptation [20]. It has been stated that early implantation in children with hearing loss has an important effect on the development of hearing due to the development of early neuronal plasticity, allowing the development of speech perception and verbal language acquisition [21]. Prolonged CI usage time, better performance in early-age implantation, and auditory speech perception affect the performance of expressive and receptive verbal language [26-28]. In our study, the number of patients with 0-2 years of CI use was 4 (8%), the number of patients with 3-5 years of CI use was 11 (22%), and the number of patients with six years or more of CI use was 35 (70%). The mean duration of CI use was 8.4 years, with a minimum of 1 and a maximum of 15 years. There were significant changes between the CI using period and behavioral status.

Compared with the normative language acquisition process, it shows that these children develop expressive and receptive oral language skills and have linguistic skills patterns under their chronological age. The language skills of children who were implanted after one year old were shown to decrease [23]. In addition, the implantation age of CI users, children's hyperactivity and attention deficit disorder, and behavioral problems negatively correlate with [24]. In recent years, a significant increase in the number of children undergoing CI with significant disabilities, in addition to their deafness, was seen. Additional problems are known to decrease these children's language and auditory performance levels compared to deaf children with CIs without additional problems. This situation is much more important in children with CIs with more than one additional disability. However, CI helps them improve their communication skills [25].

High family income has been associated with better language performance before CI and accelerated improvement in language understanding after CI [26]. In early communication interactions, maternal sensitivity has been shown to affect language outcomes positively [29, 30]. In our study, the socioeconomic status of 18 (36%) parents was at the lower level, 27 (54%) of the parents were at the intermediate level, and 5 (10%) of the parents were at the upper level. Patients with bilateral implants were observed to have a significantly higher success rate than patients with unilateral implants. Success status was also significantly correlated with comorbidities. Regarding behavioral outcomes, aggressive behavior was significantly lower in patients who underwent surgery before the age of 4 years, and it is associated with other literature regarding the ''parent and children'' relation in different situations and diseases [31, 32]. Moreover, those who had a duration of implant use of 6 years or more had significantly higher CAP scores.

Our study suggests that socioeconomic factors, including the 36% of parents from lower socioeconomic backgrounds, potentially affected children's access to quality rehabilitation services and specialized education, influencing behavioral outcomes measured by the CBCL scale. The education and professional level of the parents, assessed on a five-point scale, might have significantly dictated the parental involvement in the children's recovery process. This is exemplified by the finding of reduced aggressive behavior in children who underwent surgery before the age of four, indicating possible better access to early intervention resources. Thus, socioeconomic disparities appear to have a notable impact on post-surgery outcomes.

There are several positive aspects of this study. The study provides valuable insights into the behavioral outcomes of children with CIs, which can help inform clinical decision-making and improve the quality of care for this patient population. Using standardized measures, such as the CBCL, CAP II, and Speech Intelligibility Rating Scale, enhances the validity and reliability of the findings. The study provides evidence for the effectiveness of CI in improving speech perception and language skills in children with hearing loss, which can lead to improved communication and social interactions. Additionally, the study highlights the importance of early detection and treatment of hearing loss in reducing the risk of behavioral problems in children with hearing loss. Finally, the study emphasizes the need for a multidisciplinary approach to caring for children with CIs, including specialized education and support services for the child and their family.

Limitations

There are several limitations to this study. The sample size was relatively small, which may limit the generalizability of the results to larger populations. Additionally, the study design was cross-sectional, which limits the ability to establish causal relationships between CI and behavioral outcomes. Longitudinal studies are needed to examine the long-term effects of CI on behavioral outcomes over time. The study only included patients who were using verbal communication, which may exclude patients who are nonverbal or use sign language as their primary mode of communication. The study did not include a control group of children with hearing loss who did not receive CIs. This makes it difficult to determine whether the observed improvements in behavioral outcomes are specifically related to CI or other factors, such as access to specialized education and support services. Future research should consider these factors to understand better the complex interplay between hearing loss, CI, and behavioral outcomes in diverse populations

CONCLUSIONS

Our study underscores the value of early CIs in enhancing speech and reducing aggressive behavior in children with hearing loss. The key to success is early surgery, ideally before age 4, and a multidisciplinary approach encompassing specialized education and family support. This work adds to the mounting evidence that CIs are a viable treatment option, spotlighting the necessity for further research.

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Ethical Approval: This study was designed at the University of Healt Sciences, Izmir Bozyaka Education and Research Hospital. The ethics committee of the approved this study (approval number: 03 and date 20/12/2016).

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