Article published online: 2020-09-02

Comparison of Speech Perception Abilities of Children using Bimodal Hearing with Children using Cochlear Implant Alone

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Ann Otol Neurotol:2021;3:72–76

Abstract

Introduction There are very few studies comparing speech perception abilities of children using bimodal hearing over monaural cochlear implant and factors related to benefit of bimodal hearing. The aim of this study is to compare speech perception abilities of children using bimodal fitting versus children using cochlear implant alone and explore factors related to benefit of bimodal hearing.

Materials and Methods In the present study, 20 cochlear implantees with the hearing age range of 3 to 8 years were included. Speech perception performance was assessed by means of Parent's Evaluation of Aural/Oral Performance of Children scale and early speech perception (ESP) test: Pattern Perception Words, Monosyllabic Words, Bisyllabic, and Trisyllabic Words Identification test. ESP test was carried out in two conditions cochlear implant with hearing aid in opposite ear (CIHA), bimodal, and cochlear implant (CI) alone. Aided audiometry was also carried out in above mentioned two conditions.

Results and Discussion On aided audiometry test, aided thresholds were improved by 5 to 6 dB in CIHA condition as compared to CI alone condition in 14 out of 20 children. Whereas on speech perception test, there was a significant improvement of 15 to 20% on domains of ESP test in these children. Factors such as implant age, chronological age, and number of hours of hearing aid usage were not significantly associated with benefit. Nevertheless aided threshold at 4,000 Hz was found to be significantly associated with bimodal benefit.

Conclusion Bimodal hearing is beneficial in most of the children than monaural hearing through cochlear implant.

Keywords
- hearing loss
- inner ear conditions
- otology

Introduction

Binaural hearing is hearing from both ears, which is an ideal hearing condition for every individual. It has many advantages such as enhanced understanding of speech in noisy situations, localization, and overall reduced listening efforts as compared with monaural hearing. Bimodal hearing means hearing from two ears but with different mode of stimulation such as electrical stimulation from cochlear implant in one ear and acoustical stimulation on other ear using hearing aid for the same individual.[1-3] In such condition, a hearing aid can provide access to low frequency acoustic cues and fine structure information which are not completely available through the cochlear implant. Past

Published online
September 2, 2020

DOI https://doi.org/10.1055/s-0040-1715930
ISSN 2581-9607.

Thieme Medical and Scientific Publishers Pvt. Ltd. A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

literature report that bimodal listening can improve speech recognition performance in quite as well noisy conditions, and may be helpful when true binaural hearing cannot be provided by means of two implants due to reasons like financial constrain or unwilling ness of parents to undergo two implants.[4,5]

Gordon et al reported that children listening through bimodal condition appears to be hearing in the middle of their head rather than in one ear.[6] Moreover, researchers suggested that use of both devices worn together offered better sound quality and localization ability. Children using bimodal listening initiate more conversation, understand more of what's being said, and require less repetition.[7,8]

Present study addresses the question of whether bimodal stimulation offers greater advantages to users of unilateral cochlear implants who have varying residual hearing of the opposite ear.

Objectives

The present study was to assess speech perception abilities in children using bimodal fitting versus children using cochlear implant alone.

Objectives: (1) The aim is to study and compare the aided thresholds for octave frequencies from 500 to 4,000 Hz and (2) to study speech perception ability using early speech perception test (ESP) in two conditions: first, children using only unilateral cochlear implant and then bimodal condition. In this study, the relationship between aided thresholds of the nonimplanted side with benefit of bimodal hearing on ESP test and functional performance in children listening through bimodal condition using Parent's Evaluation of Aural/Oral Performance of Children (PEACH) was also done. The relationship between number of years of hearing aid experience and number of hours of hearing aid usage on nonimplanted side with benefit of bimodal hearing on ESP test and PEACH score was also studied.

Materials and Methods

A detailed case history depicting information related to duration of use of hearing aid, type of hearing aid, programming parameters of hearing aids, and implant age (IA) along with demographic details was collected. Twenty children with varying chronological age from 3 to 8 years with bilateral severe to profound sensorinueral hearing loss were considered for the study. All the children were bimodal listener with varying residuals hearing capacity on the nonimplanted side. All the children were using digital hearing aid with at least four channels, and their hearing aids were suited and programmed as per the their degree of hearing loss. Children who were not able to follow test procedures, children with sensorimotor issues, and mental illness were excluded. A within-subject repeated-measures design, with each subject acting as their own control was used.

Three tests were administered on every participants. First, test was a questionnaire named PEACH scale followed by aided audiogram and ESP test.

- Functional performance of children in day-to-day life was assessed using Marathi version of PEACH questionnaire in an interview manner. PEACH scale has two domains: speech perception in a quite environment and speech perception in the noisy surrounding. Score in percentage for both the domains as well as combined score were recorded. Scoring was done for each question on 0 to 4 scale. Maximum score of the scale was 44 which indicated good listening performance in day-to-day life, while low score indicated poor listening in day-to-day life.
- Aided audiometry was done either by hand raising or play audiometry method in two conditions: (1) CI only and (2) CIHA (bimodal condition). Aided thresholds at 500 Hz, 1 KHz, 2 KHz, and 4 KHz were noted in both the conditions: Testing was performed in air conditioned sound-treated rooms (ANSI S3.1–1991[R-2003]). Calibrated two channel Madson OB-922 with matched sound field speakers was used.
- ESP test in Marathi was utilized for the assessment of speech perception abilities in children with cochlear implant (Sarda and Mathew, 2012). ESP test was administered in two condition, that is, CI only and CIHA (bimodal condition). Stimulus was recorded and played through a loud speakers placed at a 45-degree angle at 1 m distance. Children were asked to point out picture as per the stimulus presented. Level of presentation was 45 dBHL. Scoring was done based on the number of correct responses. Each correct response was given one score while incorrect responses were given zero score. Speech perception scores for monosyllables, bisyllablic, and trisyllabic words as well as pattern perception were noted down. Since all the test procedures required longer time for children to pay attention, 5 to 10 minutes of intervals whenever required was provided to the children. Additionally, to avoid the familiarity effect, the sequence of test presentation—that is monosyllabic, bisyllabic, trisyllabic, and pattern perception—was randomized.

Ethical consideration: Parents were explained about the study in details both verbally and by a printed information sheet. A written consent to participate in the study was taken.

Results

Data obtained were tabulated, and Statistical Package for Social Sciences software 20.0 was used to carry out the statistical analysis to attain the objectives of the study. The Shapiro–Wilk's test of normality was used to evaluate the normalcy of distribution which revealed p <0.05 indicating non-normal distribution of data. Descriptive statistics was applied for the scores of PEACH scale, aided audiometry thresholds, and ESP test.

- PEACH scale: Information was collected from the parents of the children who were listening through bimodal condition in day-to-day life for minimum of 6 to 8 hours, and results are shown in ►**Table 1**. It can be observed from ►**Table 1** that overall performance of children in noisy situation is lower compared with quite situation

Table 1 Mean and standard deviation of Parent's Evaluation of Aural/Oral Performance of Children scale and its domains

	Mean	Standard deviation	Number of participants
PEACH in quiet	92.07% (Max. 100)	4.46%	20
PEACH in noise	86.00% (Max. 100)	8.04%	20
PEACH in combined	88.74% (Max. 100)	5.91%	20

Abbreviations: Max., maximum; PEACH, Parent's Evaluation of Aural/Oral Performance of Children.

which indicates that even though children were using bimodal listening, there was still difficulty in listening in day-to-day life.

- Aided audiometry test: Descriptive statistics was applied on the data to calculate mean and standard deviation (SD) for the aided thresholds in two conditions, that is, CI only and CIHA and is presented in ►**Fig. 1**. It can be seen from ►**Fig. 1** that there is reduction in the hearing thresholds in the bimodal condition as compared with CI alone condition, especially at 500; 1,000; 2,000 Hz; and 4,000 Hz by 2 to 3 dBHL. However, SD values are larger in CIHA condition than CI alone condition.
- ESP test: Similarly, mean and SD of various domains of ESP test is depicted in ►**Fig. 2** for bimodal and cochlear implant alone condition.

It can be observed in ►**Fig. 2** that scores on ESP are higher in CIHA condition than CI only condition across all the four domains of ESP test. Among all the domains, score was found to be improving maximally in the domain of pattern perception words, monosyllabic word identification followed by bisyllabic and trisyllabic word identification.

Wilcoxon signed-rank test was applied on the data to investigate if there is a statistical significant difference between aided threshold and ESP test results in CI alone and CIHA condition. Results showed statistically significant difference between CI alone and CIHA condition for aided thresholds at 1,000; 2,000; and 4,000 Hz ($p < 0.05$). Similarly, participants performed significantly higher for pattern perception subtest and monosyllabic word identification subtest of ESP in CIHA condition than CI only condition ($p < 0.05$).

To investigate if there is a significant association between aided thresholds of the nonimplanted ear and benefit score on ESP, Kendall's tau-b correlation was used. Benefit score of bimodal condition on ESP test was calculated by subtracting score of ESP in CI alone condition from score of ESP in CIHA condition. It was found that there is moderate association between aided thresholds at 4,000 Hz and benefit of bimodal hearing of pattern perception task and monosyllabic word identification task of ESP test ($r = 0.51$, $p < 0.005$; $r = 0.55$, $p < 0.02$).

To study the relationship between years of hearing aid experience and number of hours of hearing aid usage with the benefit of bimodal hearing on ESP test and PEACH score using Kendall's tau-b correlation analysis was applied. Results showed bimodal benefit is not significantly associated with IA, number of years of hearing aid usage before implantation, and number of hours of hearing aid use ($p > 0.05$). Similarly, no significant association ($p < 0.05$) observed between three factors such as IA, numbers of years of hearing aid use, and number of hours of hearing aid use with scores on functional performance in day-to-day life assessed using PEACH scale.

Discussion

The aim of the current study was to investigate whether children with bimodal hearing devices would derive benefits in speech perception and functional performance more than children using only cochlear implant. Among 20 studied participants, nine children showed bimodal benefit on aided threshold by 5 to 10 dB at 500; 2,000; and 4,000 Hz. While only six children showed bimodal benefit at 1,000 Hz. Present findings of the benefit of aided thresholds by 10 dB in nearly 50% of the studied population is in consensus with earlier studies.[5,8-10] In other words, present study has shown that benefit obtained by hearing aid is not equal

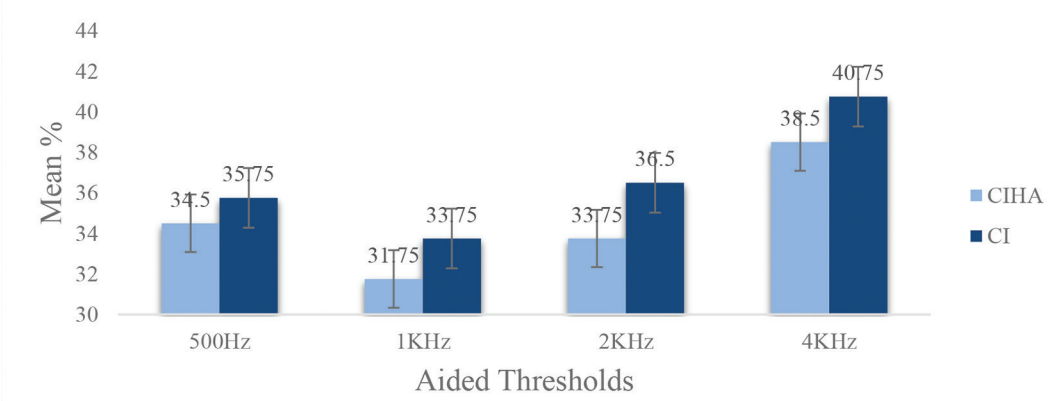

Fig. 1 Mean aided thresholds in cochlear implant and hearing aid (CIHA) and cochlear implant (CI) alone condition at octave frequencies.

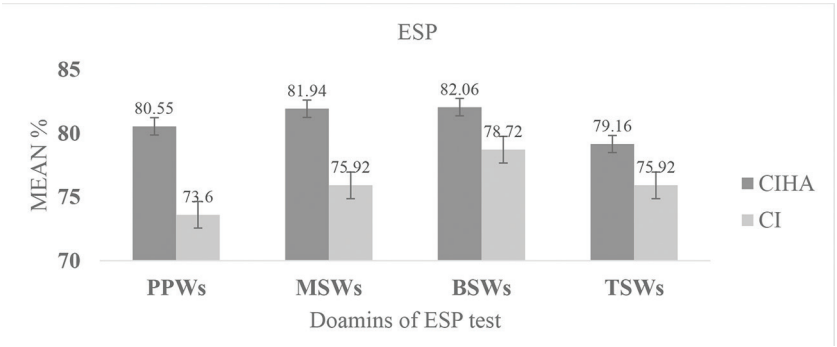

Fig. 2 Mean values of early speech perception test in cochlear implant and hearing aid (CIHA) and cochlear implant (CI) only conditions. BSW, bisyllabic words; MSW, monosyllabic words; PPW, pattern perception words; TSW, trisyllabic words.

among children with severe to profound hearing loss on nonimplanted side. Moreover, benefit is not similar across all octave frequencies even though diagnosis was same across all the children. This can be attributed to the fact that most of the children were diagnosed to have severe to profound hearing loss based on click evoked auditory brainstem response, which does not assess residual hearing at different frequencies above 80 dBHL. However, when these children were assessed using visually reinforced audiometry or conditioned play audiometry which could pinpoint their exact residual hearing at different frequencies and then hearing aids were programed based these results more than 50% of these children were found to have benefit of bimodal advantage.

For studying speech perception, ESP test was administered. Only 18 out of 20 children were able to perform on ESP test. On statistical test, CIHA group performed significantly better than CI alone group on pattern perception test and monosyllabic words identification task of ESP test. Present reports support the earlier studies by Hua et al who stated that adults with CI and HA on the unimplanted ear perform superior than CI alone condition.[11]

Additionally, in the present study, it is also noted that benefit was more on pattern perception test and trisyllabic word identification test. This could be due to the fact that pattern perception is much easier to perceive than word identification as a child has to only follow the pattern and respond for the stimulus. Present finding has been also supported by Dunn et al stating that longer stimulus is easier to perceive than shorter stimulus due to temporal integration and more extrinsic cues associated with it.[10]

Furthermore, positive moderate association between aided thresholds at 4,000 Hz and benefit of bimodal hearing on pattern perception task and monosyllabic word identification task of ESP test was observed. Bimodal benefit has been observed at 1,000; 2,000; and 4,000 Hz. Nevertheless, the association of speech perception using ESP is found only with aided thresholds at 4,000 Hz. This is supported by other investigators—such as Cutler et al, Bonatti et al, and Owren and Cardillo—who have reported that information at high frequency is more important for speech perception than information at mid and low frequency.[12-14] This would have resulted into stronger association between aided thresholds at 4,000 Hz with speech perception performance on ESP test among these young children. However, present findings are in contrary to Mok et al who have reported that information provided by the hearing aid at higher frequencies interfere with the speech perception of cochlear Implant. Contradictory finding in the present study could be because in the current study many children had significant hearing benefit at 4,000 Hz compared with earlier studies by Mok et al who reported few children having any significant benefit of bimodal hearing at 4,000 Hz. Mok et al found significantly positive correlation between bimodal benefit and aided threshold at 1 and 2 KHz. At 4 KHz, the correlation with bimodal benefit scores were not significantly positive.[15]

Functional performance of children using cochlear implants along with hearing aid was assessed using PEACH scale. It was found that scores on PEACH scale were higher in quite situation as compared with noisy situation. This supports the earlier findings by Gifford et al and Ching et al who have reported that children with cochlear implant perform superior in quite than in noise.[8]

Present finding of no association between number of hours of hearing aid usage with bimodal benefit is supporting the earlier reports of Ching et al, who have stated no significant difference in speech perception performance between individually who use hearing aid for longer versus shorter duration.[16] However, present results are in contrary to Armstrong et al, (1997) who reported greater binaural benefits for people with better residual hearing and who habitually wore hearing aids for longer time with cochlear implants.[7] The discrepant findings in the present study could be related to differences in the time since hearing aid has been fitted among the studied population, motivation level of parents etc. If hearing aid and therapy is taken for long time before implantation then children get habituated to hearing aids and then continue to use for longer time irrespective of its benefit. In the current study, there were few children using hearing aid for more than 1 year and few less than 1 year.

Study can be done in future on larger data and using more objective tests such picture identification in noise for pediatric population. If clear correlations are eventually found,

then guidelines could be established regarding the success or difficulty that may be expected for individuals who receive bimodal stimulation.

Conclusion

Bimodal hearing is beneficial in most of the children than monaural hearing through cochlear implant.

Conflict of Interest
None declared.

Acknowledgment
We would like to thank all the participants of the study and Bharati Vidyapeeth University to allow us to conduct the current study.

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