Early Speech Perception Test Outcome in Children with Severe Sensorineural Hearing Loss with Unilateral Cochlear Implants Alone versus Bimodal Stimulation

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Abstract Bilateral stimulation of the auditory system has clear advantages over unilateral hearing. Hearing-impaired children are, therefore, generally fitted with hearing aids in both ears so that they can have the benefits of binaural hearing. Children who use a cochlear implant in one ear and no acoustic stimulation in the opposite ear are at a definite disadvantage. This study was undertaken to determine the advantages of bimodal stimulation in pediatric population especially in terms of speech recognition. This study comprised of 30 children between 3 and 6 years of age with profound bilateral sensorineural hearing loss with cochlear implant in one ear and fitted with digital hearing aid in non-implanted ear. Speech recognition performance was compared in unilateral cochlear implant only and with bimodal hearing stimulation in the same set of children. A statistically significant difference was found between speech reception scores in children with a unilateral cochlear implant only and those with a cochlear implant in one ear and a hearing aid in the non implanted ear in quiet surroundings. It is suggested that the use of bimodal fitting be considered as an effective management method to

obtain the advantage of binaural hearing in children who undergo unilateral cochlear implantation.

Keywords Auditory deprivation · Binaural hearing · Bimodal Stimulation · Cochlear implantee · Early Speech Perception Test

Introduction

Speech recognition is a necessary and important function of the auditory system. Acoustic information received by both the ears helps in achieving this function [1]. Hearing inputs from both ears helps to recognise speech especially in uncongenial listening situations such as in noisy surroundings or when many individuals are speaking at the same time. While binaural fittings are usually applied to hearing aids, cochlear implantation has traditionally been done unilaterally especially in government funded programmes with limited resources.

Children with profound bilateral sensorineural hearing loss with unilateral cochlear implantation are not efficient in perception and recognition of sound because of lack of balance between acoustic inputs from the two ears [2]. This shows importance of bilateral amplification to gain binaural information. Binaural hearing for these children can be provided through bilateral cochlear implantation or bimodal stimulation [3].

Various studies offer conclusive evidence of appreciable improvement in auditory spatial abilities with bilateral cochlear implantation (CI). However, the cost of having a second implant is often prohibitive. In a developing country such as ours, health care budgets are limited. In government funded programmes therefore, the emphasis is on providing usable hearing to a larger number of patients

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rather than on improving quality of life in a few. Moreover, complications of unilateral CI in children showed that complication rates varied from 2 to 16% [4]. Thus theoretically, a second cochlear implant would double the risk for complications.

A more economically viable option for bilateral stimulation of hearing is Bimodal stimulation. Bimodal stimulation is hearing stimulation by two different modes in either ear (i.e. hearing through electrical stimulation in one ear and acoustic stimulation in the other ear). This is achieved by a cochlear implant in one ear which gives electrical stimulation and a hearing aid in the other which gives acoustic stimulation [5]. The drawback of this bimodal stimulation is an atypical inter-aural difference due to two different stimuli resulting in asymmetry in the hearing of the two ears. However benefit is still seen in terms of improvement in the ability to recognise sound as compared to cochlear implant only [6].

Till date, very few studies have been performed on benefits of bimodal hearing particularly in India. From the available literature, it was found that most of the studies on benefits of bimodal hearing in the past have targeted adult population and studies on paediatric population are very few. The majority of these studies show a benefit in speech recognition and sound localization, although the magnitude of benefit and the testing procedures used differ greatly among these studies. The need for objective pediatric assessment tools for evaluation of speech perception ability is underscored by the advent of early identification and intervention programs that enable the initiation of treatment of hearing impairment in very young children. A variety of such tools are available for the evaluation and habilitation of English-speaking children with hearing aids and cochlear implants (CIs). A hierarchically structured assessment battery to evaluate early auditory awareness and subsequent speech perception from birth through adulthood is used [7]. A test battery, rather than a single test, is required because of the rapid development of speech and language during the early years after intervention. The Early Speech Perception test (ESPT) is a closed-set measure of simple speech perception tasks using words. The ESP is the first speech perception test in the hierarchy and is intended for children who are 2 or more years of age and able to select between response alternatives in a closed-set task [8].

The present study was conducted with an aim to compare the speech recognition ability in children with profound bilateral hearing loss fitted with unilateral cochlear implant with and without bimodal hearing as measured by Early Speech Perception Test Score in Hindi (ESPT).

Materials and Methods

30 children between 3 and 6 years of age with profound bilateral sensorineural hearing loss with cochlear implant in one ear were selected. Sample size calculation for significant difference in means based on a previous study by Phanindra et al. was 11 [16]. However we took a sample of 30 subjects.

A detailed history and routine ENT examination of all the children was done to rule out any middle ear pathology of recent onset or any congenital external ear malformation or acquired external ear defect. All subjects underwent cochlear implantation with Nucleus Freedom© implant with straight electrode array using posterior tympanotomy with cochleostomy surgical approach at our centre. Bimodal stimulation was started one month after implantation for all children and the duration ranged from 3 to 13 months in the study group. Of these, the duration of bimodal stimulation was up to 6 months in 18 children, more than 6 months and up to 9 months for 06 children and for more than 9 months in the remaining 06 children (Fig. 1). All participant children underwent Early Speech Perception Tests (ESPT) first with cochlear implant in one ear and then with bimodal hearing (cochlear implant in one ear and hearing aid in other ear). Hearing aids used for bimodal stimulation were optimized. It was ensured that all the children attained a stable cochlear implant map. The study design was an intervention before and after study. Early Speech Perception Tests was measured on same set of children first without hearing aid and then with hearing aid. Speech recognition ability was tested using ESPT in Hindi, a scoring system developed by Dr. Rashmi J. Bhat and Vineeta Tiwary [9].

Comparison of Early Speech Perception Test Score in Quiet Surrounding

Procedure

Each Child was made to sit in an audiometry room and test was administered at 50 dB intensity. It consisted of 2 subtests. The first subtest was PATTERN PERCEPTION TEST (Fig. 2). It consisted of a picture card with 9 pictures. It had 3 pictures each for monosyllabic, bisyllabic and trisyllabic words. Prior to the administration of test the vocabulary of child was checked and appropriate picture card was identified as per the vocabulary. The child was made to sit in a sound proof room and was given the picture card and he/she was instructed to point to the picture of the word which would be presented to him/her. The words were presented randomly at 50 dB SPL and the child was asked to point to the correct picture. A score of '2' was

Fig. 1 Duration of bimodal stimulation

Fig. 2 Picture card for pattern perception test

given if the child pointed to the correct picture. A score of '1' was given if the child pointed to a wrong picture but within the correct syllable category. A score of '0' was given if the response was incorrect and not within the same syllable category. The procedure was done on each participating child first with cochlear implant in one ear and then the same was repeated on the participant child with cochlear implant in one ear and hearing aid in non-implanted ear.

The second subtest was WORD IDENTIFICATION TEST. It consisted of 3 picture cards containing 8 pictures

each representing trisyllabic words (Fig. 3), bisyllabic words (Fig. 4) and monosyllabic words (Fig. 5) respectively. The child was made to sit in a sound proof room and he/she was given the picture card and was instructed to point to the picture of the word which was presented to him/her. The words were presented randomly at 50 dB SPL and the child was asked to point to the correct picture (Fig. 6a, b). Each correct response was scored as '1' and incorrect response was scored as '0'. The procedure was repeated on each participant child, first with cochlear implant in one ear and then the same was repeated on the

Fig. 3 Picture card of trisyllabic subset for Word Identification Test

Fig. 4 Picture card of bisyllabic subset for Word Identification Test

Fig. 5 Picture card of monosyllabic subset for Word Identification Test

Fig. 6 a and b Participants undergoing Early Speech Perception Test

child with cochlear implant in one ear and hearing aid in non-implanted ear. Scores of both subtests were tabulated to get the early speech perception score for each child in both listening conditions (cochlear implant only and with cochlear implant and hearing aid) (Table 1). These scores were subjected to the Wilcoxon sign rank test and *p* value was obtained. Mean ESPT scores were analyzed and significance value was derived.

Results

This study used Early Speech Perception Test score in quiet listening conditions to measure bimodal benefits. When ESPT score was compared in participants with cochlear implant alone and then with both cochlear implant and hearing aid conditions, out of 30 subjects 24 subjects showed a better result with addition of hearing aid along with cochlear implant while 02 showed a minimal decrease in score and 04 subjects did not show any change. The Wilcoxon sign rank test showed *W* value 19.5, Mean Difference: 7.62, sum of pos. ranks: 19.5, sum of neg. ranks: 280.5, *Z* value -3.7286 and *p* 0.0002. Hence there was a significant difference in the ESPT scores before and after the intervention with bimodal stimulation.

Mean ESPT score with use of unilateral cochlear implant only was 32.65 while with use of both cochlear implant and hearing aid it was 34.73. There was an improvement of 7.2% in mean ESPT score between cochlear implant alone and both cochlear implant and hearing aid conditions. Thus there was a significant difference in the mean ESPT score with use of cochlear implant only and mean ESPT score with use of cochlear

implant and hearing aid both (*p* = 0.049). (Table 2). The score increase was also marginally better with longer bimodal stimulation (no significant change with up to 6 months, mean increase of 3.66 for up to 9 months and a mean increase of 7.8 for those stimulated bimodally for more than 9 months.)

Discussion

Hearing is critical for the development of speech, language, communication skills and learning. Binaural hearing cues are important for better speech perception and recognition. In children with profound bilateral sensorineural hearing loss, providing bilateral hearing stimulation is often a challenge especially in developing nations. Bimodal stimulation could be a viable alternative to bilateral cochlear implantation in such situations without much compromise of hearing outcomes. Our study compared the speech recognition ability in children with profound bilateral hearing loss fitted with unilateral cochlear implant with and without bimodal hearing as measured by Early Speech Perception Test Score in Hindi (ESPT). Early Speech Perception Test is a closed-set, picture pointing task comprised of 1-, 2- or 3-syllable targets used to assess detection, pattern perception and word identification ability. It is used in an auditory-only presentation format with Low-verbal and standard options depending on developmental ability of child [8].

Our study showed a significant difference in the ESPT scores before and after the intervention (*p* = 0.002) and an improvement of 7.2% in mean ESPT score between cochlear implant alone and both cochlear implant and

Table 1 ESPT scores before and after intervention (n = 30)

S.no	ESPT score with unilateral cochlear implant (CI) only	ESPT score with cochlear implant and hearing aid (CI + HA)
1.	21	28
2.	26	26
3.	15	24
4.	20	28
5.	19	28
6.	36	38
7.	35	36
8.	30	30
9.	33	30
10.	38	38
11.	35	36
12.	39	42
13.	42	41
14.	36	38
15.	33	32
16.	30	38
17.	36	38
18.	29	30
19.	40	40
20.	41	41
21.	36	38
22.	35	38
23.	28	32
24.	32	34
25.	38	38
26.	35	38
27.	31	36
28.	40	42
29.	24	30
30.	30	34

W value 19.5, mean difference: 7.62, sum of pos. ranks: 19.5, sum of neg. ranks: 280.5, Z value = 3.7286 *p*: 0.0002

hearing aid conditions which was also statistically significant ($p = 0.049$). A study on speech recognition performance in children with unilateral cochlear implant and bimodal hearing done by Rathna kumar et al. [10] showed that there was not much improvement in speech

recognition performance with bimodal hearing compared to cochlear implant alone in quiet surrounding. However, this study showed a significant improvement in speech recognition score with bimodal fitting in a noisy environment [10]. An increase in duration of bimodal hearing also affected the outcome positively. Tyler et al. [11] also showed only a marginal improvement with the bimodal hearing. Luntz et al. studied the hearing progress in patients using cochlear implant along with hearing aid in contralateral ear for the first 3 years after implantation in 13 subjects. The study showed that the speech identification scores improved as the subjects continuously used hearing aid in the contralateral ear though the mean scores obtained using cochlear implant alone and cochlear implant and hearing aid in the contra lateral ear were statistically not significant [12]. However, many other studies done on adult and paediatric populations showed results similar to our findings. Ching et al. [5] and Potts et al. [13] showed a significant improvement in speech perception test score with bimodal stimulation in adult cochlear implant recipients. Hamzavi et al. [14] reported higher speech recognition scores in subjects with bimodal fitting than the subjects with a unilateral cochlear implant alone. Ching et al. [15] found that speech perception was significantly better in children with a unilateral cochlear implant and hearing aid both than with unilateral cochlear implant alone. Phanindra et al. [16] reported that the mean speech identification scores were better in cochlear implant with hearing aid condition than cochlear implant alone in both noisy and quiet listening situations.

Although, the test method used to measure speech perception in this study does not simulate conditions experienced in real life, it is nevertheless useful to look for possible improvement in understanding speech with a bimodal hearing condition. This study concludes that despite the difference in mode of auditory stimulus, the paediatric cochlear implant recipients achieved statistically significant difference in speech recognition score with bimodal conditions as compared to unilateral cochlear alone, in quiet surroundings.

Hence the use of bimodal fitting device is recommended as an effective management option especially in developing nations with a limited health budget and government funded programmes in order to obtain binaural hearing and

Table 2 Mean Early Speech Perception Test Score with unilateral cochlear implants and with both cochlear implants and hearing aid respectively

	N	Mean	Std. Deviation	<i>p</i> value
ESPT score with unilateral cochlear implant only (CI) total score: 42	30	32.12	6.93	0.049
ESPT score with cochlear implant and hearing aid (CI + HA) total score: 42	30	34.73	5.07	

to prevent the effect of auditory deprivation in children with unilateral cochlear implants.

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Compliance with Ethical Standards

Conflict of interest Dr Ajith Nilakantan, Dr Poonam Raj, Dr Sachin Saini, Dr Ruchika Mittal declares that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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