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Original Research Article

Listening skill progress in children with cochlear implants in the first three months after implantation

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ABSTRACT

Background: Development of auditory skills is triggered as soon as cochlear implantation is done. Very few studies have reported development of listening skills in cochlear implanted children in the immediate period following the implantation. The present study aims to profile the development of auditory skills in children with cochlear implants during the first three months following implantation.
Methods: The tool used is Listening Progress Profile (LiP) which was used to collect information about listening skills one week prior to cochlear implantation, within a week of switch on and once every two weeks till the end of three months after implantation. Twelve children in the age range of one year to five years with congenital bilateral profound hearing loss, who were scheduled for unilateral cochlear implantation were included as participants.
Results: Results indicate a statistically significant improvement in LiP scores at each test interval. No significant difference was found in the listening skill progress for children implanted before and after three years of age. Younger male participants performed consistently better than older males and younger and older females.
Conclusions: LiP can be used as a major tool for assessing the development of listening skills in young children during the immediate post implantation period as it provides detailed information regarding the auditory performance towards a variety of stimuli.

Keywords: Listening skills, Listening progress profile, Cochlear implantation

INTRODUCTION

Cochlear implants (CI) have evolved into an accepted standard of care for adults and children with severe to profound hearing loss. Pediatric cochlear implantation has provided the profoundly congenitally deaf children with greater access to sound, which has promoted an increase in the auditory skills, speech understanding, and oral linguistic development. Early restoration of auditory input provided by a CI enables children to substantially improve their verbal language-learning trajectory.[1]

The potential benefits of a cochlear implant are to improve the auditory perception especially in terms of listening skills, the perception of environmental sounds, to aid in lip reading, and also to aid in monitoring one's own voice. It provides the ability to discriminate pitch and loudness. It permits the use of telephone and also the enjoyment of music. Cochlear implantation also enhances the quality of life. The outcomes associated with cochlear implantation span a range and depend on many complex and interactive factors such as age at implantation, pre-implant duration of deafness, age at onset of deafness, cause of deafness, status of the cochlea, amount of residual hearing preoperatively, duration of implant experience, number of electrodes in use, age appropriate sign or spoken language competence, family support and motivation, cochlear implant technology, appropriate programming of the device, additional special needs and

quality and consistency of educational and habilitative environment.[2]

Age at the time of implantation is an important factor in predicting listening as well as language outcomes for prelingually deaf children. Researchers have reported that the use of cochlear implants in early childhood leads to a shorter period of deafness and is linked to better performances than many children implanted later in childhood on measures of speech, language and reading.[3-7] The earlier the implantation, the more likely the child will develop hearing, speech, language and cognitive skills at a level similar to a normal hearing child. They can be educated in mainstream schools leading to the same career opportunities.[8] Also, children implanted earlier develop intelligible speech compared to hearing aid users.[9] It has also been reported that children implanted before 3.5 years of age had evoked cortical responses within the normal range. These normal cortical responses were not seen in children implanted after 3.5 years of age.[10] Sensitive periods of neural development exist during the first 3 years of life and are critical for the establishment of auditory mechanisms, including speech understanding and language. Early auditory deprivation can lead to reallocation of perceptual resources in the auditory cortex. Conversely, electrical stimulation with ongoing use of the implant can result in neural survival and developmental changes in the central auditory system. In general, congenitally deaf children who undergo implantation as adolescents do not demonstrate the open-set speech perception abilities seen in younger children who use CIs.[11]

Listening is the first behaviour developed and the most influenced behaviour by cochlear implantation. Stacey, Fortnum, Barton and Summerfield stated that short term outcomes from cochlear implantation which emerge soon after the implantation are mainly in the domain of auditory performance which includes auditory receptive capabilities and in speech communication skills which includes the perception, production and the use of spoken language.[12] They reported the medium and long term benefits of cochlear implantation to be in the domains of functional language development, educational achievements and quality of life. Educational achievements included academic abilities like reading, writing, number concept, money concept etc and the CI user's participation and attention in education while the quality of life had been judged in terms of feelings, behaviour, well-being, sociability, etc.

Development of auditory skills is triggered as soon as the implantation is done. Several studies have looked at the progress in listening skills after cochlear implantation in children.[13-15] Auditory performance of cochlear implanted (CI) children was assessed with the Listening Progress Profile (LiP) and the Monosyllabic-Trochee-Polysyllabic-Word Test (MTP) following the EARS protocol on 140 prelingually deafened children from various clinics and centers worldwide implanted with a MEDEL COMBI 40/40+ where the analysis of LiP data showed a significant increase of auditory performance after one month of CI use compared to preoperative scores ($p<0.01$).[16] Analysis of MTP data revealed a significant improvement of word recognition after 6 months ($p<0.01$), thus with both tests, children's auditory skills improved up to 2 years and the amount of improvement was negatively correlated with age at implantation. Anderson et al evaluated outcomes of 37 children implanted under the age of two and compared them to children implanted at a later age. Outcomes were assessed using the LiP, MTP tests and the meaningful auditory integration scale (MAIS) and meaningful use of speech scale (MUSS) questionnaires pre-operatively and then at initial fitting, 1, 3, 6 and 12 months after first fitting and then annually thereafter.[17] Statistical analysis demonstrated that these children's scores improved significantly over time and they suggested that there may be a distinct advantage of early implantation for severe to profoundly hearing impaired children particularly for the skills necessary for development of receptive and expressive language skills. Such studies provide a chronological estimate of the development of listening skills after cochlear implantation, which led to the development of various scales and guidelines for the assessment as well as for the monitoring of auditory skills in children after cochlear implantation.

Studies in the Indian context on the progress of listening skills are few and those published have monitored the improvement in listening skills from a minimum period of 3 months after implantation with testing intervals of three to six months.[18] Information regarding the progress in listening skills in the immediate period after implantation is not available. Hence this study is taken up with the aim of profiling the progress in listening skills of children in the first three months following cochlear implantation.

METHODS

The study was approved by the Ethics Committee of the Ali Yavar Jung National Institute of Speech and Hearing Disabilities, Mumbai, India and all procedures adhered to the approved protocol.

Participants

Study sample consisted of 12 children in the age range of 1 to 5 years with bilateral severe to profound hearing impairment who were candidates for cochlear implantation and were scheduled for cochlear implantation surgery. Children having additional disabilities and cochlear malformation or auditory nerve anomaly on radiological assessment were excluded from the study. Children living in Mumbai and its suburbs and attending regular post-implant habilitation were included. The data discussed in this article was acquired during January to March 2011 and the children are participating in a long-term follow-up study.

Tool

LiP developed by Sue Archbold was used to assess the progress in listening skills of the participants.[19] It is a profile devised to monitor changes in the early auditory performance of young implanted children. The profile covers a range of abilities from first response to environmental sounds, through discrimination of environmental sounds and discrimination of voice, to identification of own name. On this profile, responses are scored as follows: N (never observed) =0; S (sometimes observed) =1; A (always observed) =2. The total score is the sum of the above and if there is any uncertainty in their response, 'not known' is recorded and a score of zero given. There are 22 items and the maximum obtainable score is thus 44. The LiP is especially useful in children with minimal verbal language, or in children who are unable to report what they hear. Furthermore, the LiP has proven to identify malfunctions of the device, the need for mapping, monitoring limitations of the speech coding strategy and evaluating the appropriateness of the auditory learning environment.[19]

Procedure

Participants were recruited from different hospitals in Mumbai city. Informed consent was taken from the parents/caregivers, they were informed about the need for the study, procedure and the estimated time required for the testing. The detailed information on factors such as age of identification, age of intervention, benefit from amplification, type of amplification, duration of amplification use, and type and frequency of intervention was obtained using an intake proforma. The pre-implant listening skills were assessed one week before the implantation surgery. Subsequently, beginning with the day of switch on, listening skills were assessed every two weeks for a period of three months. Information about the cochlear implant assisted thresholds in the sound field was obtained for each child during the course of the study. In order to maintain uniformity in stimuli and testing conditions across the participants, sound stimuli were recorded using a digital voice recorder at a distance of 3 feet in a sound treated room (except for the environmental sounds). Assessment was done through indirect and/or direct observation using the LiP, either at the mapping or therapy centre when the child visited for follow-up appointments. A total score out of 44 was calculated at each testing interval. Confirmation was obtained by asking parents/caregivers about the child's responses observed at home and school. Information about the tool used and the specific items on the test was not disclosed to the parents and interventionists involved in the child's post-implant intervention, in order to control influence on the scores due to exposure to tasks specific to the tool. Parameters were assessed in random order, different each time, in order to control the influence of order of presentation of the stimuli.

Statistical analysis

Median scores were calculated for each testing interval. Wilcoxon signed ranks tests were then administered to find out if the median scores at the various testing intervals were significantly different from those at the pre-implant interval. The average scores of the two age groups were also compared using Wilcoxon signed ranks test. Significance level was set at 0.05.

RESULTS

The details of the 12 participants are shown in Table 1. Participants were further divided into two groups based on age at which they were implanted. Group 1 consisted of 6 children implanted between 1 and 3 years of age while Group 2 consisted of 6 children implanted between 3+ and 5 years of age. Group 1 had four female and two male participants, while Group 2 had three male and female participants each. The hearing aid benefit obtained by the participants during the pre-implant period was noted as follows: a) Poor benefit: no observable aided responses at any of the frequencies or some response at low frequencies but no observable response at mid and high frequencies. b) Partial benefit: aided responses below the speech spectrum at most frequencies. c) Considerable benefit: aided responses within speech spectrum for frequencies till 1000 Hz or 2000 Hz with no response or poor response at 2000 Hz and 4000 Hz.

The median and quartiles for LiP scores obtained by the participants at the various test intervals are shown in Table 2. As seen from Table 2, the median score for the 12 participants is seen to consistently increase during each of the test intervals. None of the 12 participants achieved the maximum possible score of 44 at the end of the three-month period. Wilcoxon Signed Rank Test shows a significant difference between the median LiP scores of the 12 participants before implantation and those obtained after 12 weeks ('z' =-3.062, p=0.002). There is also a significant difference in the median LiP scores at switch-on and those after 12 weeks ('z' =-3.086, p=0.002). Scores were also analysed to find out whether the difference between the pre-implant scores and the scores at each of the test intervals is significant. The corresponding z values are given in Table 3, which shows that there is a significant difference between the pre-implant LiP scores and the LiP scores obtained at each test interval, from the switch-on period till the end of three months post implantation.

Looking at the performance of the participants according to age, it is evident that the median LiP score for Group 1 was higher than that for Group 2 at the pre-implant interval, mainly due to one participant having considerable hearing aid benefit. The median LiP scores increased during each test interval for both the groups. It is also seen that till about 6 weeks post-switch-on, Group 2 was lagging behind that of Group 1; however, after the 6th week the median score for Group 2 was higher than

that of Group 1. At the end of the 12th week, in fact, the median score of Group 2 is marginally higher than that of Group 1. No significant difference was found between the mean LiP scores of the two age groups (z =-0.486, p=0.627). Thus, there is no significant effect of age at implantation on the development of listening skills during the first three months following implantation.

The participants were not equally distributed across groups based on gender. Even though gender was not considered as a variable in the study due to the limited sample size, the distribution of LiP scores in both the groups according to gender was recorded and analysed descriptively and is shown in Table 4.

Table 1: Details of participants.

Groups	Participant	Gender	Age (years)	Hearing aid benefit	Frequency of intervention	Rehabilitation professional
Group 1	1	M	1.5	Poor	Once a week	ASLP
	2	M	2.7	Considerable	Once a week	ASLP
	3	F	2.9	Partial	Once a week	ASLP
	4	F	2.3	Partial	Twice a week	Special educator
	5	F	2.8	Poor	Once a week	Special educator
	6	F	2.6	Poor	Twice a week	ASLP
Group 2	7	F	3.3	Partial	Once a week	Special educator
	8	F	3.2	Poor	Once a week	ASLP
	9	M	3.1	Partial	Twice a week	ASLP
	10	M	4	Partial	Once a week	Special educator
	11	M	3.7	Poor	Once a week	ASLP
	12	F	3.2	Poor	Once a week	ASLP

Table 2: Medians and quartiles for LiP Scores at various test intervals.

		Pre-CI	Switch on	2 weeks	4 Weeks	6 weeks	8 weeks	10 weeks	12 weeks
Group 1	Q1	3.5	10.5	14.5	17.5	21	24	27.25	28.5
	Median	5	11	16	19	22.5	25	28.5	30
	Q3	6.5	12.5	19.75	22.75	24.75	30.5	32	33.75
Group 2	Q1	1.75	6.75	12	15.25	18.5	26	28.25	30.5
	Median	4.5	9.5	12.5	16	20.5	26.5	29.5	32
	Q3	5.75	11.5	13	16	21.75	27.75	31.5	35
Total	Q1	2.5	9.5	12	15.5	20.5	24	27.5	29
	Median	5	10.5	13.5	16	21	26	29	31
	Q3	6.5	12	16	19	23.5	28.5	32.5	35.5

Table 3: z values on Wilcoxon signed rank test for LiP scores.

	Switch on	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks
z value	-3.086	-3.065	-3.066	-3.075	-3.064	-3.063	-3.062
Significance	0.002	0.002	0.002	0.002	0.002	0.002	0.002

Table 4: Distribution of median LiP scores in male and female participants in both the groups across three-month period post implantation.

		N	Pre-CI	Switch on	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks
Male	Group 1	2	5.5	15	22	24.5	27	32	33.5	37
	Group 2	3	6	10	13	16	22	27	32	36
	Total	5	6	12	13	16	23	28	33	36
Female	Group 1	4	5	10.5	15	18	21	24	27.5	29
	Group 2	3	4	9	12	16	18	26	28	30
	Total	7	5	10	14	16	21	24	28	30

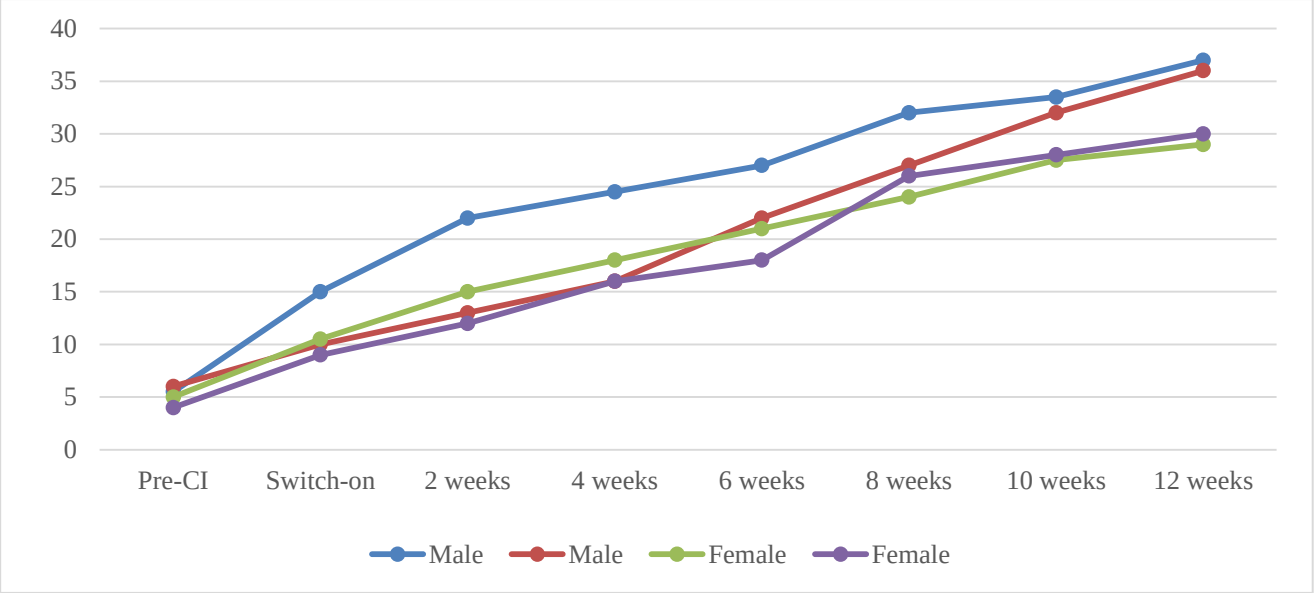

Figure 1: Median scores of male and female participants from the two age groups.

It is seen that male participants have higher median scores as compared to the female participants at each test interval except 2 weeks and 4 weeks. The trend of scores of the male and female participants for the two age groups is not exactly the same and is shown in Figure 1. It is evident that the male participants from the younger age group consistently performed the best. The male participants from the older age group started at a lower score but by the end of the 12th week, caught up with the younger males. The performance of the females from both age groups was similar and consistently below that of the male participants.

DISCUSSION

The response behaviour during the pre-implant period is influenced by the benefit obtained from the hearing aid, the type and frequency of intervention, exposure to various sounds in day to day life, age of the child, etc. It was observed that the responses which were commonly seen during the pre-implant period vary for both the groups; participants in Group 1 responded more towards the environmental sounds, drum beats and Ling sounds whereas Group 2 participants responded more towards the Ling sounds and identification of own name. This can be attributed to the age factor where younger children respond more towards environmental sounds as compared to older children who may have developed their skills to concentrate more on meaningful sounds rather than environmental sounds. Also, the better response to speech sounds by Group 2 participants could be due to the prolonged exposure to the acoustic stimuli as compared to Group 1 participants. Thus, the results obtained in this study show comparable findings with the outcome of studies done by Archbold and Nikolopoulos et al, where the LiP scores were found to be minimal while evaluating the listening skills of children prior to cochlear implantation.[13,19]

The listening abilities which were generally observed during the switch on period included response to environmental sounds, which was obtained by all the children in both the groups; response towards elicited voice was also observed sometimes though not always. Also, response to all the Ling sounds was observed sometimes during switch on, along with response to own name. The results also showed a difference in LiP scores during the switch on period and at the end of the 12th week post implantation which indicates that there is a continuous and steady improvement in listening abilities during the immediate post-implant period. The listening abilities which were seen to develop commonly by the end of two weeks post implantation include response towards spontaneous voice and the discrimination between two names of family members with different number of syllables. The response towards the elicited sounds of musical instruments was observed sometimes by the end of the fourth week, while the development of discrimination abilities between two musical instruments (drum and bell) was found to start by the end of six weeks post implantation. The development of identification abilities for most of the environmental sounds as well as the discrimination between at least two Ling sounds were observed by the end of eight weeks post implantation. By the end of 10 weeks post implantation, ability for discriminating single and repeated speech sounds as well as discrimination between loud and quiet drum beats started developing. The listening skills well developed by the end of 12 weeks post implantation included consistent response towards environmental sounds, elicited sounds of drum, musical instruments and spontaneous voice. Consistent responses were also observed in recognition and identification of all the Ling sounds, as well as for discrimination between names of family members with different number of syllables and identification of own names. The listening skills which started to emerge by the end of 12 weeks

after implantation included the discrimination abilities between single and repeated drum beats as well as single and repeated speech sounds. Also, the discrimination between loud and soft speech sounds as well as loud and soft drum beats was seen sometimes at 12th week post implantation. Even though the participants could not achieve or develop all the listening skills listed in LiP, most of the skills had started to emerge by the end of 12 weeks; the development was not seen uniformly across the participants in both age groups due to various factors that affect individual performances.

Bakshaee et al undertook a prospective study on 47 children in a pediatric tertiary referral center for CI.[20] All children were deaf prelingually and were younger than 8 years of age. They were followed up until 5 years after implantation. Auditory performance was assessed by using the categories of auditory performance (CAP) scale before and at frequent intervals for five years after implantation. Results showed that the pre-lingually deaf children showed significant improvement in auditory performance after implantation. Six months after implantation 91% of children had the ability to respond to speech sounds. At the end of year one, 96% of children could discriminate speech sounds and 84% of children who reached the three-year interval could understand common phrases without lip-reading. The findings of the present study endorse these results.

Robbins et al aimed to investigate the effect of age at cochlear implantation on the auditory development of children younger than 3 years and to compare these children's auditory development with that of peers having normal hearing.[21] They evaluated auditory skill development in 107 children who received cochlear implants (age range 12-36 months) before and 3, 6, and 12 months after implantation using the IT-MAIS and compared the data with previously published data from cohorts with normal hearing.[22] They concluded that infants and toddlers who receive implants show rapid improvement in auditory skills during the first year of device use regardless of age at implantation, although younger children achieve higher scores. They also reported children who undergo implantation at a younger age to acquire auditory skills nearer to those of their normal hearing peers at a younger age. The mean rate of acquisition of auditory skills was similar to that of infants and toddlers with normal hearing regardless of age at implantation. The present results are in agreement with this study.

LiP has not been used very often in the Indian scenario as compared to other tests. One of the major reasons for this could be the inherent difficulties regarding the parameters for assessment, like the use of various musical instruments for evaluating the detection, discrimination and identification skills of children. Less exposure to musical instruments during the early childhood days makes the task of discrimination and identification difficult which results in poor score in those particular categories.

CONCLUSION

Auditory skills in children with limited benefit from hearing aids are minimal just before cochlear implantation and are influenced by various factors including primarily the hearing aid benefit and duration of hearing aid use. The listening skills assessed in the same children during the first three months following cochlear implantation indicate a significant improvement in all children. Thus, it can be concluded that young children, below the age of five years without any other associated problems show a significant improvement in listening skills after cochlear implantation during the immediate three-month period post implantation. No significant difference was found between children implanted below three years of age and those implanted between 3 and 5 years of age in terms of the short-term listening skill development. Though the LiP appears to be a useful tool for use in the Indian context, it is seen that certain items on the LiP may not be appropriate for children in the Indian context. Information on listening skill development that takes place in the immediate period following cochlear implantation will prove useful in pre-CI counselling of families to develop realistic expectations and also during the post-implant period to keep a track of the responses to various stimuli achieved by the child. The study included limited subjects over a limited age range. Participants were not equally distributed according to gender and pre-implant hearing aid benefit.

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