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Original Article

A Predictive Model of Hearing Outcome for Cochlear Implantation in Children below 5 Years of Age

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ABSTRACT

Background: Cochlear Implantation (CI) has become an important modality of treatment for children with severe to profound pre-lingual sensorineural hearing loss who do not benefit from hearing aids (HAs). The final outcome is not totally predictable, as there are a large number of factors which either alone or in combination will play their roles in the final outcome of CI.

Aim of the Study: This study aims to evaluate prospectively the relative impact of multiple pre-, peri-, and post-operative factors on the final outcome of the CI in pre-lingual hearing impaired children aged 5 years under "Sruthitharangam" free cochlear implant program of Government of Kerala.

Materials and Methods: This study was conducted at Government Medical College, Kozhikode (GMC-KKD), Kerala, from January 2014 to January 2015. The study group consisted of 60 patients screened from the patients who have attended Auditory verbal habilitation (AVH) categories of Auditory Performance (CAP) test, Meaningful auditory integration scale (MAIS) and Speech intelligibility rating test (SIR) at GMC-KKD, Kerala. Counseling of parents was done regarding regular follow-ups and therapy/support to the child at home.

Observations and Results: Pearson correlation test and Spearman correlation test were done to check the correlation between age at which HA was first fitted and MAIS scores. Correlation between the age at which HA first fitted and MAIS was negative. As the age at which HAs were fitted increases, the MAIS score decreases. This indicates the significance of using the residual hearing and stimulation of auditory nerve as early as possible. Pearson correlation and Spearman correlation tests were applied to check the correlation between age of surgery and MAIS score and found that there was negative correlation existing between age of surgery and MAIS scores. This meant, as the age at which surgery was done increases, the MAIS score decreases. Pearson correlation test and Spearman correlation tests were applied to check the MAIS scores and duration of AVH with HAs.

Conclusions: A Cochlear implant was not a passive sensory aid or sensory substitution device that simply replaces a damaged or defective cochlea to restore normal hearing but requires prolonged period of aural rehabilitation that involves perceptual learning, adaptation, and readjustment of their attention. The various risk factors that affect the auditory gain and speech perception either acting singly or in combination and the statistical analysis of the present study showed are the age at implantation, duration of auditory deprivation, and the residual hearing which have a direct impact on the outcome over a period of 1 year.

Key words: Categories of auditory performance (CAP) test, Meaningful auditory integration scale (MAIS), Speech intelligibility Rating test (SIR)

INTRODUCTION

Speech perception has improved in children with pre-lingual sensorineural hearing loss (SNHL) after the cochlear implantation (CI) became the standard procedure for managing such cases. However, the post-CI rapidity of gain in hearing perception and speech development was varying in different groups of study and patients. Therefore, studies investigating the causes for slow in gain in auditory perception and speech development have become a necessity. Moreover, the development of approaches for doing so has become a principal focus in this field.[1] Among the various factors considered for gain in speech perception in children after CI, the important ones were demographic and hearing characteristics and the features of the implant

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device.[2] Identification of the factors contributing to poor speech perception after CI was necessary, and several studies have addressed this issue.[3,4] Pre-CI assessment of the responsible factors in each candidate will allow us to better predict outcomes after CI. Various retrospective multicenter studies are found in the literature that attempted to identify the prognostic factors using a three-stage model of auditory performance that assesses speech perception overtime.[5] However, these studies were based on models used for post-lingual deaf adults who underwent CI, hence, the age at the time of CI did not significantly affect post-CI outcomes,[6] whereas the studies conducted in children with pre-lingual SNHL showed that CI at earlier ages resulted in better speech perception than did CI at later ages.[7] In a study of children who underwent CI, pre- and post-implantation concerns were more evident in the poor speech perception group than the randomized good performance group.[8] Linguistic competence for complete speech perception was absent in most children with SNHL before and 1 year after CI.[9] As experience in listening using the cochlear implant increases, speech perception generally improves. Pediatric cochlear implant users in particular exhibit enhanced auditory performance for up to 10 years after CI.[8] Because improved speech perception overtime correlates with improved speech production and language, appropriate evaluation of speech perception in children after CI is important for optimal long-term post-CI performance.[10] A study done by Gupta[11] in 2007 found out that age at implantation, duration of auditory deprivation, and the pre-implant residual hearing affected the outcome of cochlear implantation in children below the age of 5 years. The children who had been fitted with HAs at a younger age and undergone longer duration of pre-implant therapy showed better outcome. Furthermore, children with good family support showed better results.

Aims and Objectives

The aims of the study were as follows:

- To assess the various pre-, peri-, and post-operative factors which are likely to affect the outcome of cochlear implant on a numerical scoring system and to evaluate the outcome using subjective criteria at predefined period after implantation.
- To statistically analyze the data using appropriate statistical tools to assess the predictive potential of the various factors alone or in combination.
- To develop a predictive model for outcome of CI in children aged 5 years and below.

MATERIALS AND METHODS

This study was conducted at Government Medical College, Kozhikode (GMC-KKD), from January 2014 to January 2015. The study group consisted of 60 patients screened from the patients who have attended auditory verbal habilitation (AVH) at GMC-KKD, Kozhikode, Kerala. An ethical committee clearance was obtained before commencement of the study. An ethical committee cleared consent form was use for the study. An ethical committee clearance was obtained.

Inclusion Criteria

1. Children with bilateral severe to profound sensorineural hearing loss were included in the study
2. Children aged <5 years were included in the study
3. Children with pre-lingual hearing impairment were included in the study
4. All the children who had undergone cochlear implantation from GMC-KKD, Kozhikode, under Sruthitharangam scheme, a government initiated free cochlear implant program in Kerala were included in the study.

Exclusion Criteria

1. Children above 5 years were not included in the study
2. Children who were not fitted with hearing aid (HA) and undergone auditory training before surgery were not included in the study
3. Children with associated mental retardation were not included in the study
4. Children with congenital cochlear abnormalities were not included in the study.

Evaluation Protocol

An ethical committee clearance certificate was obtained before the commencement of the study. An ethical committee cleared informed written consent was taken from the parents for the study. Speech perception was also assessed by Categories of Auditory Performance (CAP) test (Archbold, 1995) and Meaningful Auditory Integration Scale (MAIS) (Robbins *et al*., 1991). Speech Intelligibility Rating test (SIR) (Robyn M. Cox, 1989) was also done. Counseling of parents was done regarding regular follow-ups and therapy/support to the child at home.

Outcome Measures

Post-operative follow-up of the subjects was carried out for 12 months after CI. During these visits, the outcome measures were carried out under: CAP, MAIS, and SIR scales.

Evaluation of factors

Factors were grouped into subject-related and parental factors.

Subject factors

Factors such as age of onset, duration of auditory deprivation, duration of use of HAs, and age at implantation was elicited.

Parental factors

Factors like family support were observed and necessary counseling was done.

OBSERVATIONS AND RESULTS

This study was conducted at GMC-KKD, Kozhikode, Kerala, from January 2014 to January 2015. The study group consisted of 60 patients screened from the patients who have attended AVH at GMC-KKD, Kozhikode, Kerala. The family support was categorized into three grades: Good, average, and poor. Kruskal–Wallis test was also undertaken which is a non-parametric test for comparing two or more groups to check relation between different family support groups and MAIS score, CAP score, and SIR score.

The null hypothesis H_0: Three groups were identical
Grouping variable
1=Poor,
2=Average,
3=Good.

In this study, statistical significance was considered when $P < 0.05$ was obtained. Here, $P = 0.001$ was obtained, which is <0.05. Hence, we reject the null hypothesis, that is, the three groups were considered not identical.

The error bar diagram shows high scores for MAIS in good family support group children [Figure 1]. Pearson correlation test and Spearman correlation test were done to check the correlation between age at which HL detected and MAIS score. The study showed the correlation between age and MAIS as negative. As the age at which HL was detected increases, MAIS score decreases. This underlines the importance of early identification of hearing impairment and further intervention programs. Pearson correlation test and Spearman correlation test were done to check the correlation between age at which HA was first fitted and MAIS scores. Correlation between the age at which HA first fitted and MAIS was negative. As the age at which HAs were fitted increases, the MAIS score decreases. This indicates the significance of using the residual hearing and stimulation of auditory nerve as early as possible. Pearson correlation and Spearman correlation tests were applied to check the correlation between the age of surgery and MAIS score and found that there was negative correlation existing between age of surgery and MAIS scores. This meant, as the age at which surgery was done increases, the MAIS score decreases. Pearson correlation test and Spearman correlation tests were applied to check the MAIS scores and duration of audiovisual training (AVT) with HAs. The tests showed positive correlation. The longer the duration of AVT with HAs before cochlear implant (CI), the better was the outcome after CI. Pearson correlation test and Spearman correlation test were applied to check the correlation between age at which HL detected and CAP scores, which showed negative correlation. That meant earlier the detection of hearing impairment; the better was the CAP scores. Pearson correlation test and Spearman correlation test were applied to check the correlation between ages at which HA first fitted and CAP scores, which showed negative correlation. It confirms that earlier the stimulation of auditory nerve starts, better the CAP scores after CI. Pearson correlation test and Spearman correlation test were applied to check the correlation between age of surgery and CAP scores, which showed negative correlation. That meant children who had undergone CI at a younger age showed higher CAP scores [Figure 2].

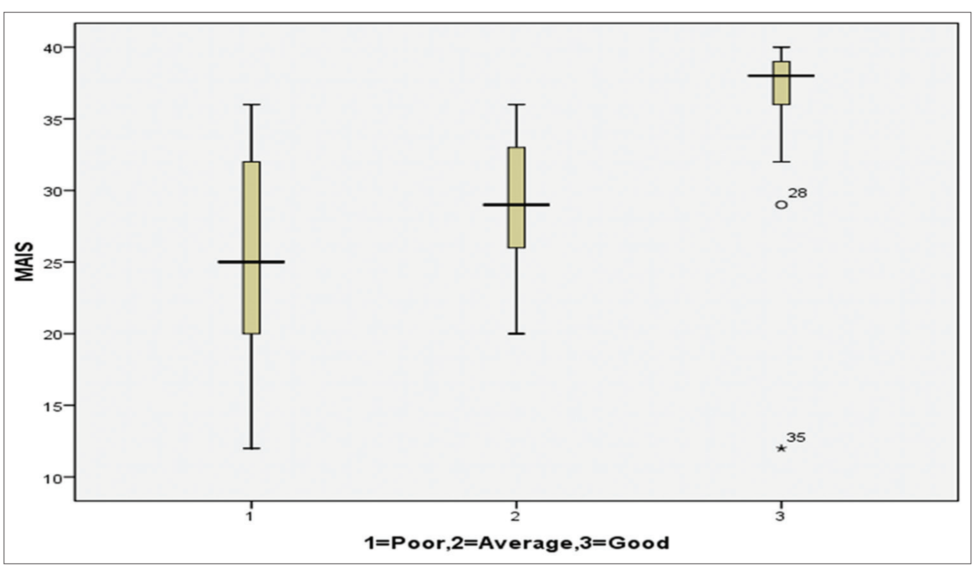

Figure 1: The error bar diagram of meaningful auditory integration scale score with family support groups

As the age at the time of surgery increases, the mean CAP score decreases. Positive correlation exists between the duration of AVT with HAs and CAP scores as per Pearson test and Spearman correlation test. Longer the duration of AVT with HAs, better the CAP scores after CI. Pearson correlation and Spearman correlation tests were applied to check the correlation between SIR scores and age at which HL detected which showed negative correlation. This means that as the age at which the hearing impairment detected increases, the SIR score decreases after CI surgery. Pearson correlation test and Spearman correlation tests were administered to check the correlation between SIR scores and age at which HA first fitted which again showed negative correlation. The children who were fitted with HA at younger age showed better SIR score after CI. Pearson correlation test and Spearman correlation tests were administered to check the correlation between SIR scores and age of surgery which again showed negative correlation. The children who had undergone CI at a younger age showed better SIR score after CI. After applying Pearson and Spearman correlation tests, it was found to have a positive correlation between SIR scores and duration of AVT with HA. Longer the duration of AVT with HA before CI, better the SIR score after CI. Multiple linear regressions were done to get a predictive model for predicting the scores of MAIS, CAP, and SIR [Table 1].

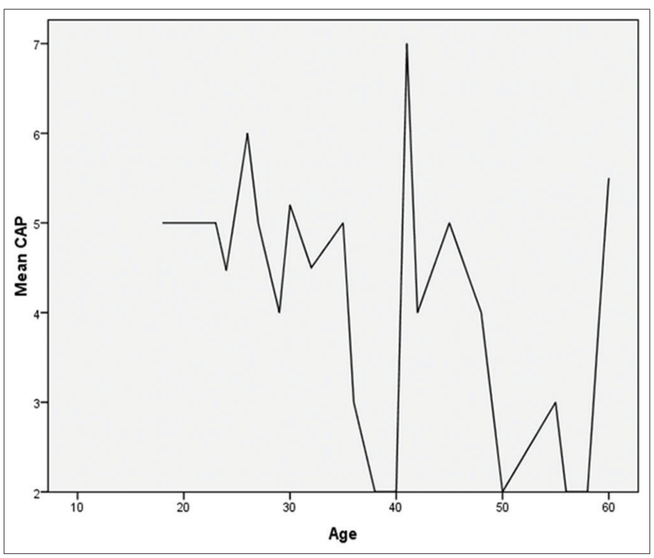

Figure 2: The correlation graph showing negative correlation between mean CAP scores and age at the time of surgery

Table 1: The different variables in the multiple linear regression model

Variable 1	Age at which HL detected (months)
Variable 2	Age of bilateral HA fitted (months)
Variable 3	Duration of AVT with HA (months)
Variable 4	Age of CI surgery (months)

Multiple linear regression models for MAIS.

MAIS = 39.518–0.085 (VAR1)–0.078 (VAR2)+0.338 (VAR3)–0.301(VAR4)

CAP = 5.106–0.000 (VAR1)–0.008 (VAR2)+0.055 (VAR3)–0.038 (VAR4)

SIR = 3.440–0.022 (VAR1)–0.017 (VAR2)+0.051 (VAR3)–0.039 (VAR4)

DISCUSSION

The present study was conducted to not only to observe the efficacy of the CI but also to predict the post-implantation results by scrutinizing the different risk factors involved. Most of the literature of clinical research on CIs since 25–30 was concerned with device efficacy. They have worked to prove and designed to demonstrate that CIs work in individuals or samples of patients with severe-to-profound hearing loss. However, very little sustained longitudinal research was focused on the reasoning as to why they often work very well in some patients, sometimes work more poorly or not at all in other patients of the same age, gender, demographics, and medical hearing history.[12] Only recently, the "process" measures of performance were obtained from patients with CIs to study the underlying elementary information processing mechanisms used to perceive and produce spoken language in this clinical situations.[13] The children who were diagnosed with hearing impairment at a younger age also showed good family support. The same category also had undergone regular pre implant therapy. This shows the significance of newborn hearing program and counseling regarding the rehabilitation options. Community awareness programs regarding hearing impairment and different intervention programs should also be conducted more effectively. The present study was in concert with the study conducted by Tomblin *et a*l. (2005)[14] who concluded that cochlear implantation early in the 2nd year of life was likely results in an early burst of language growth. Tomblin reports that this rapid rate of initial language growth is a phenomenon that was not evident in the language scores of children implanted after the age of about 18 months, a finding confirmed by these data. Whereas Nicholas and Geers (2004)[15] reported from his study that only 43% of a nation-wide sample of 8–9-year-old deaf children who received a cochlear implant between 24 and 35 months of age achieved combined speech and language skills within the average range for hearing children of that chronological age.

Results of the current study indicate that children who receive a cochlear implant and oral education before 24 months developed speech and hearing much better than other children. In sum, the total amount of language produced, the breadth of vocabulary, complexity of sentences, and use of varied morphology seem to be directly affected by both the amount of hearing available to the child before the implant as well as the age at which the cochlear implant surgery was performed. We should also promote research work to look into the reasons for auditory deprivation even after diagnosis of hearing impairment. The children who had been fitted with HAs at a younger age and undergone longer duration of pre-implant therapy showed better outcome. Furthermore, children with good family support showed better results. This was supported by a study which revealed that three variables, namely, age at implantation, duration of auditory deprivation, and the residual hearing had a direct impact on the outcome over a period of 1 year (Gupta, 2007).[11] Patients performed significantly better as length of cochlear implant use increased and age at implantation decreased (Kileny *et al*., 2001).[13] In a previous work by Nicholas and Geers, 2006,[15] who have shown that the age at diagnosis of the hearing loss and the length of time that a HA was used were not significant predictors of later spoken language outcomes, unless the child received a cochlear implant within this training time period. These results favor early diagnosis of profound hearing loss, early initiation of a HA trial, and cochlear implantation by 18 months of age, especially for children with better ear aided pure tone average thresholds greater than 65 dB. We should also promote research work to look into the reasons for auditory deprivation even after diagnosis of hearing impairment. The children who had been fitted with HAs at a younger age and undergone longer duration of pre-implant therapy showed better outcome. Furthermore, children with good family support showed better results. This was supported by a study which revealed that three variables, namely, age at implantation, duration of auditory deprivation, and the residual hearing had a direct impact on the outcome over a period of 1 year (Gupta, 2007).[11] Patients performed significantly better as length of cochlear implant use increased and age at implantation decreased (Kileny *et al*., 2001).[13] We, as professionals, should implement newborn hearing screening effectively and should also take necessary steps for proper rehabilitation program soon after the detection of hearing impairment. Community awareness programs regarding hearing impairment and the intervention options should also be conducted periodically.

CONCLUSIONS

A cochlear implant was not a passive sensory aid or sensory substitution device that simply replaces a damaged or defective cochlea to restore normal hearing but requires prolonged period of aural rehabilitation that involves perceptual learning, adaptation, and readjustment of their attention. The various liability factors that determine the auditory gain and speech perception either acting singly or in combination and the statistical analysis of the present study showed are, the age at implantation, duration of auditory deprivation, and the residual hearing have a direct impact on the outcome over a period of 1 year. These results confirm previous findings indicating continued improvement of speech recognition with time in implanted children. Furthermore, the results support the concept of the advantage of a younger age at implantation.

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