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Original Research Article

Association of Cochlear Implant Electrode Depth and Post Op Hearing and Speech Assessment in Deaf Children Aged Less than 6 Years

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Abstract:

Background: Cochlear implants are the first true bionic sense organs. Cochlear implants, like the human hair cell, receive mechanical sound energy and convert it into series of electrical impulses. Cochlear implants have proven to be a successful intervention for individuals with severe sensorineural hearing loss who do not see improvement with conventional hearing aids. There are many factors that may impact upon poorly performing recipient some of which include the depth of electrode insertion, duration of severe to profound deafness and age of implantation. This study examined the performance of patients in relation to the depth of insertion at a regional level.

Aim and Objectives: To study the correlation between angle of insertion of cochlear implant and hearing outcomes in terms of SIR and CAP Scores.

Materials and Method: A comparative interventional study done on 35 patients under the age of 6 years, who underwent Cochlear implantation at KKR institute, Chennai over a period of one year. They were evaluated post operatively for the hearing performance on the basis of SIP and CAP score and the same was co related with the angle of insertion of the electrode and the type of cochleostomy done.

Results: CAPS Improvement is statistically better in extended round window type than other types while SIRS Improvement was statistically better in round window type than extended round window type.

Conclusion: Auditory performance improves significantly in most children who undergo cochlear implantation at age less than 6 years. Cochlear implantation outcome depends on number of factors and depth of insertion might be one of them. The effect of angle of insertion on outcome is not independently statistically significant and depends upon many other factors.

Keywords: CAP; Cochlear implant; SIP.

Introduction

Cochlear implants are the first true bionic sense organs. Cochlear implants, like the human hair cell, receive mechanical sound energy and convert it into series of electrical impulses. Cochlear implantation in both children and adult has been established as a means of auditory rehabilitation over the late 15 years or more.

Although the result remains variable and unpredictable for a given individual, a substantial proportion of implant recipient's now recover high level of open –set speech understanding. [1] History of cochlear implantation in adults goes back well over 30 years but cochlear implantation in children is more recent. Implantation was initially limited to post lingual deafened children because it was widely believed that the device would have little utility for children with severe to profound congenital hearing loss but now it is well established that application of a cochlear implant in children affected by profound congenital hearing loss is of paramount importance for development of adequate performance and language skills by reducing the effect of speech deprivation. [2]

Cochlear implants have proven to be a successful intervention for individuals with severe sensorineural hearing impairment who do not see improvement with conventional hearing aids. Progress in surgical methodology and electrode engineering enables the conservation of remaining auditory capabilities. Although despite the advancements in cochlear implantation, results still exhibit substantial variation across individual users. The variability in performance might likely be attributed to the positioning technique of the

electrode within the cochlea. The extent to which the electrode is inserted into the cochlea in a cochlear implant has been proposed as a clinical factor that may be associated with the ability to recognise words utilising the implant. [3] A cochlear implant is a sophisticated electronic device that can partially restore auditory function in individuals who have been carefully chosen and diagnosed as deaf. The implant is implanted in the inner ear by surgery and is operated by a wearable device placed behind the ear. A cochlear implant differs from a conventional hearing aid by converting sound into electrical signals, which are subsequently transferred to the auditory nerve responsible for carrying the auditory information to the brain. The technology circumvents impaired outer hair cells and directly activates the auditory nerve. [4]

Since initial FDA approval in 1984, cochlear implant has been highly successful in providing sound perception to over 200,000 deaf individuals. [5] While the vast majority of recipients perform well and can hear effectively with their cochlear implant, a minority of patients struggle with performance despite repeated efforts at modifying programming parameters. There are many factors that may impact upon poorly performing recipient some of which include the depth of electrode insertion, duration of severe to profound deafness and age of implantation. The primary objective of this study was to assess the performance of patients in relation to the depth of insertion. There are many studies conducted in western countries to evaluate the range of performance across patient but there is no regional data to comment about the same. Taking the abovementioned points in consideration we decided to conduct a study entitled "Association of cochlear implant electrode depth and post op hearing and speech assessment in deaf children aged less than 6 years" in KKR ENT Hospital and Research Institute, Chennai.

Aims and Objectives:

To study the correlation between angle of insertion of cochlear implant and hearing outcomes in terms of SIR and CAP Scores

Materials and Methods:

Study Design: A Comparative Interventional Study

Study Period: One Year

Study Area: The study was done at KKR ENT Hospital & Research Institute

Sample Size Estimation: Kameshwaran M [6] et al reported that the Mean (±SD) CAP score among a group of children (1 to 10 years of age) who had undergone cochlear implantation was found to be 5.172 (±1.795). The sample size was estimated using the method as shown:

Sample Size (n) = (4 x σ) / L2 where,4 = constant; σ = Standard Deviation = 1.795; L = Allowable error = 10% of Mean Substituting the values in the formula, n = (4 x 1.795) / (0.5172)2 = 7.18 / 0.27 = 27.Adding 20% (to account for non-response and attrition) to the estimated sample size estimated, the final sample size came up to 33 that were rounded off to 35.Hence, the final sample size for this study was 35.

Study Population:

The study population comprised of a total of 35 patients in the age group of 6 months to 6 years that were eligible to undergo the cochlear implantation surgery and fulfilling the inclusion and exclusion criteria formed the study population. The following inclusion and exclusion criteria will be used to select the study subjects

Inclusion Criteria:

1. Bilateral severe to profound sensory-neural hearing loss.
2. Documentation of very less or no improvement with the help of hearing aids.
3. Having functional auditory nerve.
4. No medical or surgical contraindication to surgery.

Exclusion Criteria:

1. Patients with retro cochlear lesion or higher centre lesion.
2. Absence of cochlea.
3. Absence of 8th nerve development.
4. Active middle ear infection.
5. Conductive hearing loss.
6. Medically or surgically unfit.
7. Mentally retarded patient

The Study is approved by the institutional ethical and scientific committee

Methodology:

1. Parents / guardians of the all patients fulfilling the inclusion and exclusion criteria at

KKR ENT hospital will first be administered an informed consent form.

2. Every patient underwent auditory and speech evaluation prior to the cochlear implantation surgery. CAPS score was generated for each kid before the surgery.

3. A case record form was filled for the child with all the relevant details. The child then had cochlear implantation surgery.

4. After the surgery, Modified stenver's view xray was taken for all the patients to measure of angular insertion depth.

5. The child's auditory and speech development status was assessed at the time of

"switch-on" and at 3 months and 6 months and 9 months using the CAP (Category of Auditory Performance Scale) ad SIR scores.

Categories of auditory performance scale:

0. No awareness of environmental sound
1. Awareness of environmental sounds
2. Response to speech sound
3. Recognition of environmental sound
4. Discrimination at least to speech sounds
5. Understand common phrase without lip reading
6. Understand conversation without lip reading and a familiar talker
7. Can use telephone with familiar talker

CAP scale was applied to all the patients before and after surgery, in follow up visits at 0, 3, 6 & 9 months interval.

The extent of auditory perception in terms of utility of auditory mechanisms to pursue day to day tasks from awareness of environmental sound to making telephonic conversation was assessed and result of CAP score was compared with location of electrode.

Category Criteria:

5. Connected speech is intelligible to all listeners; child is understood easily in everyday contexts.
4. Connected speech is intelligible to all listeners who have a little experience of a deaf person's speech.
3. Connected speech is intelligible to all listeners who concentrate and lip reads
2. Connected speech is unintelligible. Intelligible speech is developing in single words when context and lip reading cues are available.
1. Connected speech is unintelligible. Pre-recognizable words in spoken language. Primary mode of communication may be manual.

SIR was applied to all the subjects before and after surgery, in follow up visits at 0, 3, 6 and 9 months interval. The results were assessed and categorized accordingly and scores were given taking into account the number of months taken to achieve and the results of SIR scores will be compared with location of electrode.

Outcome measures: The angular insertion depth of cochlear implant electrode was ascertained using Post-operative x-rays performed in a Modified Stenver's view or cochlear view. [7] The audio logical performances were measured using the categories of auditory performance score (CAPS) and SIRS Score.

Statistical Analysis: Data was collected using case record forms and entered on Microsoft excel spread sheet. Statistical analysis was done using Statistic software SPSS Version 21.0 Descriptive statistics such as Frequency, mean, percentages and standard error was used and Inferential Statistics such as Kruskal Wallis test, Mann Whitney test proportions are used to describe the data.

Results: Out of 35 patients implanted 13 underwent implant insertion through round window, 17 patients had extended round window insertion and remaining 5 had a separate anteroinferior cochleostomy for electrode insertion.

CAPS Improvement is statistically better in extended round window type than other types. **[Table 1]**

Table 1: Comparison of Mean CAPS following implant surgery based on Type of Cochleostomy

Type of Cochleostomy	Switch on Day 0	3 months	6 months	9 months	Friedman test	P value
Round window (n=13)	1.00 ± 0.00	2.62 ± 0.14	3.85 ± 0.19	4.77 ± 0.17	38.414	0.0001
Extended round window	0.94 ± 0.06	2.06 ± 0.14	3.24 ± 0.18	4.24 ± 0.28	49.952	0.0001
Antero-inferior Cochleostomy (n=5)	1.00 ± 0.00	2.00 ± 0.00	3.00 ± 0.00	4.25 ± 0.25	12.000	0.007

SIRS Improvement was statistically better in round window type than extended round window type. There was no statistically significant improvement in antero-inferior cochleostomy, probably due to less sample in that group (n=5) **[Table 2]**

Table 2: Comparison of Mean SIRS following implant surgery based on Type of Cochleostomy

Type of Cochleostomy	Switch on Day 0	3 months	6 months	9 months	Friedman test	P value
Round window (n=13)	1.00 ± 0.00	1.15 ± 0.10	1.46 ± 0.24	1.92 ± 0.31	18.474	0.0001
Extended round window	1.00 ± 0.00	1.06 ± 0.06	1.18 ± 0.10	1.41 ± 0.15	14.163	0.003
Antero-inferior Cochleostomy (n=5)	1.00 ± 0.00	1.00 ± 0.00	1.25 ± 0.25	4.71 ± 0.19	4.714	0.194

Out of 35 patients 19 patients received Advanced Bionics 1J implant and 16 patients received Cochlear nucleus implant. Both are lateral wall electrodes. Advanced Bionics 1J implant gave a statistically better outcome following surgery in terms of CAPS and SIRS compared to Cochlear nucleus in our study (Figure 1 and 2). There is no statistically significant correlation between the angle of insertion and hearing outcome in terms of CAP & SIRS scores at any point in our study among the patients who received Advance bionics1J implants or cochlear nucleus. **[Table 3]**

Table 3: Correlation between Angle of insertion and hearing outcome in terms of CAP & SIR Scores

Parameters	**Angle of insertion**	
Scores at intervals	Spearman correlation rho	P value
CAP at 3 months	-0.222	0.206
CAP at 6 months	-0.186	0.293
CAP at 9 months	-0.217	0.217
SIR at 3 months	-0.090	0.613
SIR at 6 months	-0.254	0.146
SIR at 9 months	0.098	0.582

The 19 patients who received the Advance bionics 1J implant had an average angular insertion depth of 471.74°, with a standard error of 10.99°. The 16 patients who received the Cochlear nucleus implant had an average angular insertion depth of 376.49 degrees with a standard error of 12.29 degrees. The depth of angular insertion of between the two groups is statistically significant difference with Advance bionics IJ Population patients having deeper insertion as compared to cochlear nucleus. **[Table 4]**

Table 4: Correlation between Angle of insertion and type of chocleostomy

Type of Cochleostomy	**Angle of insertion**		**Kruskal Wallis test**	**P value**
	Mean	SE		
Round window (n=13)	448.41	22.14		
Extended round window (n=17)	423.32	13.54	2.769	0.251
Antero-inferior Cochleostomy (n=5)	396.15	32.91		

Out of 35 patients for 13 patients round window surgical approach was used and 17 patients underwent extended round window approach and remaining 5 patients underwent antero-inferior cochleostomy. The Surgical approach, with either pure or extended round window or antero-inferior cochleostomy did not influence the angular insertion depth as per our study.

Discussion

The benefits obtained with cochlear implant vary greatly across individual. The recommended clinical variable that may have a correlation with word recognition utilising a multichannel cochlear implant is the depth of electrode placement. The current examination of 35 participants did not demonstrate any correlation between the depth at which the electrode is inserted at an angle and the performance measured by CAP and SIRS scores.

The 19 patients who received the Advance Bionics 1J implant had an average angular insertion depth of 471.74°, with a standard error of 10.99°. The 15 patients who had the Cochlear nucleus implant had an average angular insertion depth of 376.49 with a standard error of 12.29°. The 95.25° shallower angular insertion of cochlear nucleus and 1.3° SE of cochlear nucleus represents significant difference compared with Advance bionics IJ Population but there was no statistically significant correlation between the angle of insertion and hearing outcome in terms of CAP & SIRS scores at any point in our study among the patients who received Advance bionics1J implants or cochlear nucleus as per above tables. The angular insertion depth was not affected by the Surgical method, whether it was pure or expanded round window or antero-inferior cochlestomy. The current findings are in opposition to the study done by Skinner et al. in 2002, which is the only study that reported a significant impact of the depth at which the electrode was inserted at an angle. [8] In 2009, Joonhan Lee et colleagues conducted a histological study on the depth of electrode implantation and postoperative performance in humans with cochlear implants. They found a rather weak connection between the depths of electrode insertion with speech reception. [9]

In this study, M. Annerie van der Jagt et colleagues examined the relationship between angular insertion depths and speech perception outcomes in patients who were implanted with either the HiFocus Mid-Scala or HiFocus 1J Electrode Array. The researchers found that the speech perception outcome was not influenced by the angular insertion depth or frequency mismatch. [10] In 2011, Paul J. Boyd conducted an evaluation of the impact of electrodes that were implanted deeply on performance. Imaging tests have shown that the electrode arrays now available only reach a maximum depth of two turns into the cochlea.

The average insertion angle for complete insertions of the MED-EL electrodes is around 630 degrees. Based on anatomical factors and other modelling studies, it is doubtful that creating any longer electrodes will yield any extra spectrum information. The question about the possible advantage of the topmost electrodes is if they may specifically activate distinct and tonotopically organised neuronal populations in the uppermost part of the spiral ganglion, where the ganglion cells are densely clustered. Studies on pitch scaling, utilising the MED-EL and experimental long arrays, have indicated that this is accomplished in numerous instances. However, a notable proportion of individuals exhibit indications of pitch confusions or reversals among the most apical electrodes. This is likely to diminish potential performance advantages and pose difficulties for processor programming. Consequently, the benefits in terms of speech recognition and other performance measures are not definitively established. [11]

Recommendations

1. The children with profound deafness are benefited with cochlear implantation.
2. Early intervention with cochlear implants in children less than 3 years is beneficial and is associated with better outcome.
3. Whether there is association between electrode insertion depth and auditory performance in terms of CAP and SIR scores should be further investigated.

Conclusion

Cochlear implantation is a major event in the life of a deaf child. Auditory performance improves significantly in most children who undergo cochlear implantation at age less than 6 years. Whether or not deeply inserted electrodes can offer performance benefits is still a dilemma. The factors possibly influencing performance outcomes suggested by various authors are (i) deep insertions resulted in absence of electrodes in the basal region of the cochlea and (ii) deep insertion was considered to carry a risk of apical trauma. These variables make it difficult to draw conclusions about the influence of electrode insertion depth in isolation.

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