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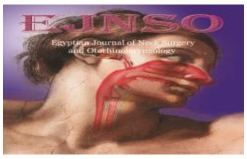

Predictors of language and auditory abilities in prelingual cochlear implanted children at Sohag university hospital

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Abstract:

Background: Cochlear implantation helps to decrease the consequences of hearing impairment.There are severalfactors that can predict language and auditory outcomes in prelingual cochlear implanted children. These factors can be divided into: patient factors,family and environment factors, operative factors and rehabilitation factors.

Objectives: To study the predictors that affect the cochlear implantation outcome in prelingual hearing impaired Egyptian children.

Patients and methods: The study was performed at the Phoniatrics Unit at Sohag University hospital on 141 prelingual children (85 boys and 57 girls) who had cochlear implantation.This study was a three-year cross-sectional study.Assessment of receptive, expressive language, auditory abilities performance and speech intelligibility were done using Sohag university hospital phoniatric protocol for cochlear implanted children, categories of auditory performance and speech intelligibility rating. Evaluationwas done preoperative and 18 months postoperative. The predictors were assessed and correlated with receptive, expressive and auditory abilities.

Results: Parent interaction at home, postoperative auditory threshold and number of sessions postoperative are the most important predictive factors of receptive, expressive and auditory scores in ourresearch.

Conclusion: Family counseling as regards parent interaction and compliance at rehabilitation sessions is considered a cornerstone that guide to positive outcomes in prelingual cochlear implanted children.

Keywords: Hearing impairment, cochlear implantation, predictors, parent participation.

Introduction

Cochlear implantation is a methodrather than cure, for reducing the consequences of hearing impairment. Managing this tool to make sure it works properly to take advantage of all the technological benefits it offers is the first step toward achieving the greatest outcome for each child. [1]

As the findings reported show complicated interactions between multiple factors, it is doubtful that a single factor can predict speech and language outcomes in all CI patients. These factors can be divided into:

1. Patient factors: intelligence quotient, age discovered, level of hearing impairment and duration of deafness.
2. The family and environment factors: Distance away from rehabilitation unit, Hours of parent participation in language stimulation preoperatively and postoperatively.
3. The operative factors: The age at which the cochlear implantation was done, auditory level in CI patients and

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shape of cochlea and number of stimulated electrodes.

4. The rehabilitation factors: age-fitting hearing aid, Period of using hearing aid, Aided response preoperatively as well as number and period of rehabilitation sessions postoperatively .

Early detection of hearing loss has an important effect on how quickly hearing-impaired infants acquire new abilities. [2] When HAs used very early in infants who have residual hearing, they can serve as a bridge to give them auditory access to language until they get an implant. [3] The children with HAs before implantation may benefit more from early auditory stimulation due to their prior familiarity with HAs. [4] Lower language scores and slower rates of language acquisition were also linked to higher before implant aided threshold (lower hearing sensitivity). [5]

When language and speech services introduced early it will have a positive influence on speech perception, intelligibility and language age, also it may have a later influence on the child's capability to make use of the auditory information provided by the cochlear implant to produce intelligible speech. [6]

De Meneses et al. 2014 [7] refer that long period of hearing impairment can negatively influence the speech perception tests and that the period of hearing impairment is directly proportional to the lowest performance in speech recognition.

Faesand Gillis 2017 [8] stated that infants who experience unaided hearing loss for a shorter period of time have a better chance of achieving speech and language levels that are comparable to those of their hearing age peers. **Abou-Elsaad et al. 2016** [9] reported that infants who receive implants early on (before the age of three) catch up rapidly because they are subjected to the period known as the sensitive period for language auditory development.

Saki et al. 2018 [2] stated that residence did not affect postoperative auditory, receptive, or expressive outcomes. Neither living in a city near a rehabilitation center nor living in a village far from one had a significant impact on the age of identification of hearing impairment that in turn affects the rate at which hearing impaired infants develop their developmental abilities.

According to **Smith et al. 2012** [10] parents are the primary influence on their children's language development, and a successful rehabilitation program needs to involve parents to ensure favorable results.

The purpose of the research was to look into the predictors of auditory, expressive, and receptive language skills in prelingual Egyptian children with hearing impairments following cochlear implantation to help improve auditory and language outcomes after cochlear implant.

Patients and methods:

A 3-year cross-sectional study that was performed on prelingual infants that underwent cochlear implantation atSohag university hospital. Mental retardation, postlingual and perilingual hearing impairments were excluded in the current study.

According to Sohag university hospital protocol for assessment of cochlear implant. [11] Scheduled clinic follow-up was done at 1.5 years after cochlear implantation, which includes: quasi-objective assessment of the infant's auditory skills (sound detection, sound localization and discrimination), passive vocabulary, semantics, and syntax .

Clinical diagnostic aids were done as follows :

1 Intelligent Quotient (I.Q): Using Stanford-Binet Intelligence Scale 5th edition. [12]

2 Full audiological evaluation including threshold level (T level).
3 Speech intelligibility rating (SIR) [13] to detect the intelligibility of speech
4 Categories of Auditory Performance (CAP) [14] to detect the auditory skills.

Ethical consideration: The study was carried out after being approved by Sohag Faculty of Medicine Research Ethics Committee before the beginning of research with registration number Soh-Med-23-06-09PD. The participants' parents or legal guardians provided informed written consent .

Predictors that were studied here include: distance away from our unit by kilometers was calculated using Google maps, Length of hearing impairment was assessed by months from time when hearing impairment discovered to age when first fitting of cochlear implant, intelligent quotient calculated by Stanford Binet test fifth edition, age discovered hearing loss by months subjectively according to mother/family, age fitting hearing aid by months, duration of using hearing aid by months, aided response preoperative by dB, age of implantation by months, number of sessions post-operative, auditory threshold with CI in dB and hours of weekly parent participation post-operative calculated subjectively by the caregiver.

Results

A total of 141 children with; 85 males and 57 females were implanted with multichannel cochlear implants. Distance away from our unit range from 1 km to 506 km with values of 395km and 506km considered as outliers with the mean of 118.2 km. Table 1 shows the demographic date of our studied CI children.

There is a significant improvement in receptive and expressive skills, auditory abilities, Speech intelligibility rating (SIR) and Categories of Auditory Performance (CAP) results. The negative value of the mean indicates that the posttest results are larger than the pretest results. The largest improvement was at the receptive, auditory and expressive scores respectively (Table 2).

There was a high significant correlation between auditory threshold, hours of parent participation, and number of sessions postoperatively with auditory and language abilities.

Significant correlation was found between the duration of auditory and language abilities only. There was significant correlation between IQ and SIR only.

Non-significant correlation was found between language and auditory abilities and the following predictors: distance away from our unit, age discovered HL, age fitting HA, duration using HA, aided response preoperatively, and age of operation.

Final model regression analysis of predictors showed the following (Table 4):

1) Highly significant predictors for language and auditory skills were auditory threshold and hours of parent participation.
2) IQ was a non-significant predictor for auditory and language skills.
3) Number of sessions was a significant predictor for receptive language abilities only
4) Duration of hearing loss was a significant predictor for receptive and expressive language abilities.

Table 1: Means of different predictors of language & auditory abilities in the study group (n=141)

Variable	Mean ± SD
Distance away from our unit (Km)	118.2±56.4

Duration of hearing loss (months)	37.2±15.1
Age discovered hearing loss (months)	15.6±9.6
Age fitting hearing aid (months)	23.9±10.8
Duration of using hearing aid (months)	13.6±9.4
Aided response preoperative (dB)	64.96±10.88
Age of implantation (months)	46.3±12.3
Total number of sessions post operative (session)	109.4±52.9
Auditory threshold postoperative (dB)	31.1±9.2
Hours of parent participation post operative (hour/week)	6.6±7.1
Intelligent Quotient	85.9±6.5

Table 2: Comparing Language and auditory results pre-implantation and after 18 months

Variables	**Paired sample T test**			
	mean	**std**	**t**	Sig. (2-tailed)
Auditory score (pre -post)	-15.60	7.92	-23.38	<.001*
Receptive score (pre -post)	-20.87	19.41	-12.76	<.001*
Expressive score (pre -post)	-15.11	16.42	-10.92	<.001*
CAP(pre -post)	-2.61	1.30	-23.76	<.001*
SIR(pre -post)	-2.16	1.23	-20.81	<.001*

*Statistically significant

Table 3: Correlation between predictor variables and language & auditory abilities
***Statistically significant, Audit: auditory score, Recep: receptive abilities, Expr: expressive abilities.**

Variables	**Pearson correlation**					**P-value**				
	Audit	**Recep**	**Expr**	**CAP**	**SIR**	**Audit**	**Recep**	**Expr**	**CAP**	**SIR**
Parent participation	.623	.707	.689	.571	.528	<.001*	<.001*	<.001*	<.001*	<.001*
Threshold in dB	-.557	-.560	-.502	-.472	-.376	<.001*	<.001*	<.001*	<.001*	<.001*
Number of sessions	.221	.272	.252	.243	.143	.010*	.001*	.003*	.004*	.096
Duration of HL	.090	.200	.198	.007	-.045	.289	.018*	.019*	.939	.597
Distance from our unit	.030	.007	.018	.048	-.008	.724	.938	.834	.570	.923
IQ	.098	.094	.114	.080	.189	.249	.267	.178	.346	.024*
Age discovered HL	.023	.140	.141	.031	.078	.785	.097	.095	.712	.359
Age fitting HA	.034	.099	.110	.057	.032	.708	.275	.226	.528	.726
Duration using HA	-.041	-.029	-.019	-.004	-.075	.627	.735	.821	.965	.375
Aided response preop.	-.019	-.109	-.085	.042	-.034	.825	.198	.317	.617	.688
Age of operation	-.018	.080	.097	-.039	-.069	.834	.346	.253	.648	.414

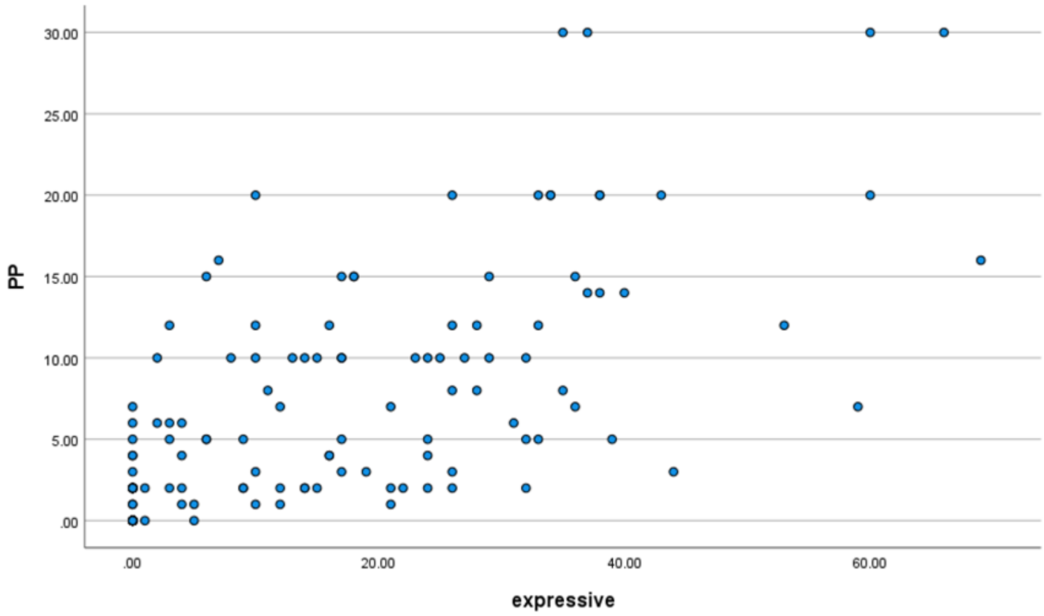

Diagram 1: Showing positive correlation between parent participation (PP) and expressive language abilities in our study

Discussion:

Many factors contributing together to the auditory and language outcomes of prelingual CI children, this study highlighted the most important predictors namely: the parent sharing in their child's habilitation, auditory threshold, number of sessions and duration of hearing loss.

Parent participation in language stimulation postoperative:

There was strong positive correlation between auditory, language skills, CAP and SIR and hours of parent participation (P-value = <0.001).This is consistent with the findings of **Abdel Hamid et al. 2015**[15], who realized that mother participation in treatment is a strong predictor because language exposure and caregivers' mentoring provide the environment for language acquisition. According to **Ganek et al. 2012** [16] parents have the greatest impact on their child's development. Some healthcare professionals lack the necessary training to work with infants or deliver services in a family-centered intervention style. The parents and the family as a whole are the main concern of such intervention. In order to meet the rehabilitation needs of individuals with communication difficulties, the phoniatrician/logopedist team collaborates with other relevant disciplines. [17] Also, parent involvement in therapy as in auditory verbal therapy has positive influence on language outcome.

Auditory Threshold in CI patients:

Following implantation, there was significant negative correlation (P value = <0.001) between language, auditory skills, CAP and SIR, and auditory threshold in dB. Better T levels have been shown to enhance monosyllable and phrase perception in both quiet and noisy environments, according to **Nunn et al. 2019** [18]. Improved T levels during CI programming increase equivalent electrical current stimulation, which enhances mild intensity sound audibility.

Peixoto et al. 2013[19] selected 132 children from the pediatric population who underwent cochlear implantation and had a minimum follow-up period of 10 years, based on a retrospective case study. Speech and pure-tone audiometry were done just after implantation and after 10 years. There were no statistically significant variations between the auditory threshold tests conducted early and late. Apart from 2000 Hz, where the results were even better after ten years, both speech and pure-tone audiometry appears to stabilize. This can be explained by good programming and good electrode placement that can affect auditory threshold and also affect results of auditory and language outcomes.

Number of sessions after CI:

In this study, Strong positive correlations were seen between language, auditory skills, CAP, and the number of postoperative sessions (P value = 0.10, .001, .003, .004, .096 for auditory, receptive, expressive, CAP, SIR respectively).Also, it was found to be an important predictor of receptive score only this can be explained by the short period of evaluation that couldn’t affect much the expressive language. This was in line with the findings of **AbouElsaad et al.** 2016 [9], who reported a strong relationship between the length of postoperative language treatment and the developmental stage, auditory ability and language age of post-implant language users. On the other hand, **Geers 2002**[20] realized that the main rehabilitative component linked to performance outcome was educational emphasis on oral-aural communication, and that the quantity of therapy had little effect on auditory and spoken language outcomes.

A systematic study by **Binos et al. 2021**[21] provides insight into the outcomes of auditory-verbal therapy (AVT) and its efficacy for children with CIs. Based on research findings over the past ten years, the outcome that is being given. The findings showed that kids receiving AV therapy could develop language abilities on par with their peers who are hearing. Voice quality appeared to be positively impacted, putting young children with CIs in the typical range for the development of receptive vocabulary. Reading comprehension, however, appeared to gain less. It appears that AV therapy aids with reintegration into the community.

Chu et al. 2019 [22] study revealed the complicated relationship between the frequency and dose (measured in hours) of early intervention and the development of expressive language in the young CI user group. Regardless of the frequency and dosage of early intervention, they showed that language delays and impairments can be minimized by early access to CIs as an intervention. These results add credence to growing evidence that babies and toddlers who have CIs can start learning language in a way that is comparable to that of children who have normal hearing. Weekly, fortnightly, or monthly attendance at early intervention sessions is still crucial for guiding and coaching families; however, early childhood interventions (CIs) allow children everyday access to meaningful interactions with their caregivers during their waking hours.

Duration of hearing loss:

Within our study, the mean length of hearing impairment is 37.2 months. There was weak positive correlation between receptive and expressive language skills and duration of hearing impairment (P value = 0.018, 0.019) for receptive and expressive scores respectively this can be explained by the short period of the study only 18 months. However, most of literature noted negative correlation between duration of language outcomes and hearing impairment. Also, duration of hearing impairment was an important predictor of receptive and expressive scores in our study. **Derinsu et al., 2019**[23] was inconsistent with our study and noted that shorter auditory deprivation may result in better CI outcomes. According to **Zohdi et al. 2014** [24], there is a significant positive link between the age at implantation, the length of hearing loss on one side, and the postoperative auditory ability, receptive and expressive language age at one year after implantation on the other side. These findings run counter to the majority of the research, which suggests that higher language age outcomes are related to earlier implantation ages and shorter hearing loss durations. They explained this by the limited period (1year) after which language assessment had been conducted after cochlear implant in their study.

Prior studies have demonstrated the benefits of cochlear implantation in kids whose single-sided deafness (SSD) has not lasted for a long time.

Six children who received cochlear implants for SSD had their records retrospectively reviewed by **Colasacco et al.** in 2024[25]. Prior to cochlear implantation, the average length of hearing loss was 10.8 years, while the mean age at the time of cochlear implantation was 14.7 years. Analysis was done on the audiometric data collected before and after surgery for aided speech perception tests, word recognition scores, and sentence recognition in noisy and calm environments. At 12 months after surgery, there was an increase of 24% in the median word score and 64% in the median sentence recognition score in quiet when compared to preoperative hearing aid scores. For children whose SSD has lasted longer, cochlear implantation may improve speech recognition. Within 12 months of getting a cochlear implant, this retrospective case study of kids with protracted single-sided deafness showed improvements in word and phrase recognition.

Intelligence Quotient (IQ):

There was weak positive correlation between SIR and intelligence quotient (IQ), However it was realized to be a non-significant predictor of CI results. This can be explained by the sample was used with no big variations of IQ (mean + SD = 85.9+6.5). These findings contradict the findings of Knutson et al. (2000) (26), who found that IQ before to implantation did not predict implant use or benefit; however, sociability and preimplant compliance did strongly predict use and benefit three years following implantation. According to **Geers et al., 2003** [27], who agreed with our findings, a child's high natural intelligence as shown by a nonverbal test is the most crucial requirement for them to benefit from a cochlear implant.

Park et al., 2015 [28] found that performance intelligence, especially social cognition, was significantly connected to the CI results (after operation) of CI handlers. Therefore, auditory rehabilitation, involving social rehabilitation, should improve the CI results after the operation.

Distance away from our unit:

Distance away from our unit was a non-significant predictor of language, auditory abilities, CAP and SIR. Distance is not a significant predictor as our SUH university hospital cochlear implant center is the only center that provides the service of cochlear implantation for all governorates from Cairo north to Aswan south. Cairo has been the nearest center which was at a distance of 500 km at Kasr elAini hospital.

Saki et al., 2018 [2] noted that residential status either living in the city or living in the village far from the rehabilitation center had a non-significant effect on age of identification of hearing impairment which in turn affects the ratio of developmental abilities in hearing impaired patients, but also residence didn’t affect postoperative auditory, language and speech outcomes.

Age discovered hearing loss:

In our study, the mean age discovered hearing loss was 15.6 months. Although age of discovery of HL was relatively early, the average age of the HA fitting was 23.9 months. This may be explained due to ignorance of the significance of early rehabilitation as well as the possible benefits of early cochlear implantation. It was found that mean age of discovery of HL was not a predictor for language, auditory abilities, CAP and SIR. This may be explained due to delayed HA fitting and prolonged duration of hearing loss (mean= 37.2 months). The findings agree with those of **Miyamoto et al., 1993** [29], who discovered that prelingual hearing-impaired children did not exhibit a significant correlation between age at beginning of hearing loss and other factors.

Numerous studies have shown that children who experience hearing deprivation prior to implantation and who develop deafness later in life have superior speech perception abilities compared to those who develop deafness earlier. [27]

Age at time of implantation:

There were non-significant correlations between language, auditory abilities, CAP and SIR and age at time of implantation. Also, it was realized to be an unreliable predictor of CI results. The average age of implantation was 46.3 months, which is older than the majority of research and studies' recommendations for getting the best results in prelingual patients. This is in agreement with **Abdel Hamid et al. 2015**[15] who found that age at time of cochlear implant is a non-significant predictor of CI results the age ranged between 2 and 6 years. Our findings disagreed with those of **Liu et al. 2019** [30], who discovered that the benefits of a cochlear implant were greater for younger implantation ages. Patients who have early implantation benefit from earlier speech therapy and hearing restoration. Considering how many research have demonstrated the benefits of early implantation, it is especially unexpected that age at implantation did not significantly affect results. It's likely that 3.9 years old is too young to demonstrate the extra benefit of really early language exposure. For children with normal hearing, the first two years of life are critical for auditory development, and missing these crucial years of auditory input may not be recovered. For children with CI, early implantation during the sensitive period up to 3.5 years (ideally by age 1 year) allows for the best results. Good neurocognitive results and neural cortical connections are made possible by early cochlear implant and therapy.

According **to Lee et al. 2024** [31], when CI is performed before the child reaches the age of two years old, all improvements are more noticeable in receptive language than in expressive language. Compared to later CI, CI administered prior to nine months of age greatly enhanced the development of receptive language, and the benefits persisted at least until the age of two.

In 2024, **Franchellaet al** [32], evaluated the immediate results of fifty-six kids who received bilateral implants. Outcomes of the analyzed follow-up data confirm the hypothesis that infants implanted at before 24 months are anticipated to have superior hearing performances. The length of the auditory deprivation period should be taken into account.

Age fitting HA:

The mean age fitting HA was 23.9 months. There were non-significant relations between language, auditory abilities, CAP and SIR and age fitting HA due to late fitting of HA. In children with residual hearing, very early use of HAs may serve as a bridge to give auditory access to language until the child has an implant. Consequently, they may benefit from early auditory stimulation from their prior experience with HAs compared to those who are more profoundly deaf. [3]

The age at which a child's hearing loss is discovered and hearing aids are given to him or her may be a key sign that family education and attention to the hearing loss are about to begin. This shows that, regardless of the severity of hearing loss, early detection and care are critical to the language development of young children with congenital hearing loss before the age of six months. Hence, it stands to reason that kids whose hearing loss was discovered early on could react to cochlear implants more favorably. [27]

Duration of hearing aid use:

The mean duration of HA usage was 13.6 months. Duration of hearing aid usage was a non-significant predictor of language and auditory results in our study. The prolonged duration of HA use has led to prolonged auditory stimulation. However, it didn't affect the outcome of CI. This contradicted the findings of **Geier et al. 1999** [33], who hypothesized that ears receiving more regular auditory stimulation over an extended period of time could benefit from cochlear implants more than ears receiving none at all and might be the preferable option for the implantation ear. Also, prolonged duration of HA use has led to delay in the age of implantation. However, it didn't affect the outcome of CI. In our study, hearing thresholds before operation were below 90 dB HL, the mean of aided response was 64 dB. Our results were inconsistent with **Jang et al. 2018** [34] who found that the length of time using hearing aids was inversely correlated with the results of CI. This was clarified by pointing out that their study's hearing thresholds before operation were greater than 90 dB HL, indicating severe hearing impairment. Consequently, early CI may be better for their condition than continuing to wear hearing aids.

Fitzpatrick et al. 2006 [35] found that after receiving cochlear implantation, infants who had been using conventional amplification for some years showed quick improvements in their auditory skills. These results imply that cochlear implantation might be a suitable option for certain kids who don't meet the existing eligibility requirements and/or have significant hearing impairments.

Aided response:

Patients who are prelingually hearing impaired and who gets light to no value from usual amplification are candidates for cochlear implant since the mean of their aided response was 64 dB. [36] In our study aided response preoperatively is not correlated with CI outcomes in any of the studies parameters. Better speech perception can sometimes be correlated with greater hearing sensitivity prior to implantation. [37]

Conclusion:

Although, surprisingly, the IQ of children did not affect the CI outcome, postoperative language stimulation of parent’s postoperative auditory threshold are the most important predictors for improving CI outcomes in all parameters. The frequency of rehabilitation sessions greatly predicted the receptive language abilities, while the duration of hearing loss predicted both receptive and expressive language abilities.

Distance away from service center wasn’t an obstacle for compliance of highly motivated parents to rehabilitation sessions. Early CI has better auditory, receptive and expressive skills. More researches are required for detection of predictors among early implanted children.

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