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Research Article

Language Development and Speech Intelligibility of Arabic Speaking Children Using Cochlear Implant

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Abstract

Cochlear implanted children are expected to take advantage of the young age at implantation giving best chances for developing optimal language and speech skills. In this study, two groups of prelingually deafened children were followed up over a period of 1 year after implantation to determine the effect of implantation on their language and speech skills as well as their auditory abilities. The first group [early implanted (GI)] consisted of 10 children who received their implantation at or before the age of 3 years, 8 months. The second group [late implanted (GII)] received their implants after the age of 3 years, 8 months. Both groups received the same habilitation program. The results showed that both groups produced highly significant improvement after 1 year in language skills, auditory abilities, and speech reading abilities. The results also showed that - 1 year after implantation - there were significant differences between both groups concerning auditory abilities, speech reading abilities and speech skills in favor of the early implant group. Language development, however, did not show a significant difference between both groups. Language improvement quotient (measured as the amount of language improvement in months divided by 12 months) showed non-significant difference between both groups 1 year after implantation. These results indicate that early implantation has a favorable effect on speech characteristics as well as the auditory abilities of cochlear implanted children. However, it is too early to judge the effect of the age at implantation on the language acquisition skills of these children.

Key words: Prelingual cochlear implantation, implantation age, language and speech skills

Introduction

Cochlear implants have become a popular option for children with profound hearing loss. Evidence supporting the benefits of early implantation is found in experimental [1], developmental [2], and clinical cochlear implant studies [3]. The general consensus is that children have the best opportunity to learn language during their first 5 years of life. According to [2], this critical period for language learning is particularly important in deaf and hearing-impaired children. Providing cochlear implants to deaf children at a young age may enable them to take advantage of this critical period for learning language and is likely to increase their chances for developing speech and language skills similar to those of normal-hearing children. Early implantation would also result in a decrease in the duration of auditory deprivation, a decrease considered to positively influence performance with a cochlear implant [4].

Aim of the Study

The purpose of this study is to investigate the effect of implantation on language and speech of cochlear implanted children treated with the same program of habilitation, in order to decide the optimal timing of implanting children. For this purpose, language and speech were evaluated at a fixed post-implantation interval (1 year) in children divided into 2 groups according to their age at implantation.

Subjects and Methods

This research was conducted between the months of February 2017 and March 2018. The study protocol was approved by the Otolaryngology Department Council of King Abd Al Aziz Specialized Hospital, Ministry of Health, Jouf, Saudi Arabia. Consent to participate in this research was obtained from the subjects' parents before commencement of the study.

This study was performed on 20 children, who received cochlear implantation at an age range of (2 years, 4 months) to (6 years, 3 months). For the purpose of the study, they were divided into group I **(GI)** and group II **(GII),** with a cut-off age of 3 years, 8 months. GI (number = 10) included children younger than 3y 8m while GII (number = 10) included children who are older. Both groups received the same habilitation program of language and speech therapy based on combined group and individual therapy sessions.

Language and speech scores were analyzed at a fixed post-implantation interval of 12 months. Language was analyzed before implantation and at 1 year, interval post-implantation. Speech scores were analyzed also and compared at the 1-year assessment. On the time interval (1 year) the language age deficit was calculated as the difference between the chronological age at time of evaluation and the corresponding language age score obtained at that time using the Standardized Arabic Language Test [5]. This test measures receptive and expressive language skills giving a total language age in years.

In this analysis, age at the time of test administration may be a confounding variable because children who underwent implantation at a younger age were also younger when the 12-month post-implantation interval testing was performed. Thus, one may hypothesize that children who receive implants at an older age may perform better on these tests because they are developmentally more advanced at the time of evaluation.

Thus a language improvement quotient was determined by calculating the difference between the languages ages in a period of time divided by the period of time. For example, language improvement quotient after 1 year = [Language age in months after 1 year of implant – language age at the time of implant] ÷ 12 months. In this way, the effect of language age as a confounding variable may be less likely to affect the results.

Speech analysis was performed using the assessment protocol which includes analysis of supra-segmental phonology (rate, stress and tonality), segmental phonology (consonants and vowels), nasal resonance and general intelligibility of speech, giving scores that ranged from 0 (normal) to 3 (denoting severe abnormality) [6]. Assessment of auditory perception skills was performed evaluating a hierarchy of listening skills ranging from detection, to discrimination, identification, recognition and comprehension. Assessment of speech reading abilities was done and expressed as percent change over time.

Results

Tables 1-3 demonstrate the progress of the language abilities, the auditory abilities and the speech reading abilities, in both groups respectively, from the time just prior to the cochlear implantation as compared to the evaluation done one year after implantation. It is clear that both groups showed highly significant improvement in language and auditory abilities. Speech reading abilities dropped in both groups one year after implantation in a highly significant manner.

Table 4 demonstrates the comparison between both groups concerning the language status at 2 different occasions, namely at time of implantation, and 1 year after. Group II had higher chronological age at the operation time and higher language age at operation time than group I, in a highly significant value.

Table 1: Results of collective language improvement using paired-T test.

	Language age at operation	Language age after 1 year	Paired-T value	Significance
G I	9 m ± 5 m	2y 9m ± 1y 8m	6.7	P < 0.01 HS
G II	1y 10 m ± 7 m	3y 2m ± 1y 7m	4.2	P < 0.01 HS

Table 2: Results of improvement in the auditory abilities of the 2 groups after 1 year using paired-T test.

	Before implantation	1 year after implantation	Paired-T value	Significance
G I	3 % ± 6 %	81 % ± 17 %	16.5	P < 0.01 HS
G II	2 % ± 4 %	56 % ± 21 %	7.9	P < 0.01 HS

Table 3: Results of progress in speech reading ability before and after rehabilitation in the 2 groups (using Paired-T Test).

	Before implantation	After implantation	Paired-T value	Significance
G I	100 % ± 0	19 % ±3 %	16.5	P < 0.01 HS
G II	100 % ± 0	58 % ± 21 %	7.9	P < 0.01 HS

The language age deficit was significantly higher in group II than group I at operation time.

Table 5 shows the difference in the auditory abilities between both groups immediately post-implantation, and along the follow up, as well as the difference in the speech reading abilities between both groups. There was non-significant difference between both groups in the immediate post-operative evaluation while in the follow up, group I showed significantly higher auditory skills than group II. The speech reading abilities of both groups showed a highly significant decrease in post-implantation follow up with more decrease in favor of group I.

AA = auditory abilities, SRA = speech reading ability NS = non-significant, S = significant, HS = highly significant.

The difference in the speech skills between both groups measured 1 year after implantation is demonstrated in (Table 6). There was a highly significant difference, in all parameters, in favor of group I.

Discussion

This study involved primarily an analysis of results of language and speech skills of cochlear implanted children at a fixed post-implantation interval (12 months). In this analysis,

Table 4: Difference in the chronological age of implantation, language status at implantation, and language performance (manifested by language age deficit, and language improvement quotient) at 1 year post-implantation, between the 2 groups by T-test.

	Group I	Group II	T-value	Significance
Chronological age at implant (mean, SD and range)	3y 6m ± 11m (2y 4m – 4y 8m)	7y 4m ± 1y 6m (4y 9m – 9y 3m)	5.6	P < 0.01 HS
LA at operation	9m ± 5m	1y 10 m ± 7m	4.9	P < 0.01 HS
LAD at implant	2y 6m ± 11m	4y 10m ± 1y 5m	3.8	P < 0.01 HS
LAD 1 year after implant	2y 2m ± 8m	3y 9m ± 1y 8m	2.7	P < 0.05 S
LIQ 1 year after implant	1.5 ± 0.8	1.6 ± 1	0.2	P > 0.05 NS

LA = Language age, LAD = Language age deficit, LIQ = Language improvement quotient, NS = non-significant, S = significant, HS = highly significant

Table 5 : Comparison between the 2 groups concerning the auditory abilities immediately post-implantation, and 1 year post-implantation, as well as the speech reading abilities 1 year post-implantation, using T-Test.

	Group I	Group II	T-value	Significance
AA immediately post-implantation	3 % ± 7 %	2 % ± 4 %	0.31	P > 0.05 NS
AA 1 year after implantation	49 % ± 11%	41 % ± 8 %	1.70	P > 0.05 NS
SRA 1 year after implantation	19 % ± 3 %	58 % ± 21 %	5.5	P < 0.01 HS

AA = auditory abilities, SRA = speech reading ability NS = non-significant, S = significant, HS = highly significant.

Table 6: Difference in the speech ratings between the 2 groups after 1 year of rehabilitation (using Mann-Whitney test).

Speech Skills	Group I	Group II	Z-value	Significance
Rate	0.6 ± 0.5	1.6 ± 0.7	2.7	P < 0.01 HS
Stress	0.6 ± 0.4	2.0 ± 0.5	3.8	P < 0.01 HS
Tonality	0.4 ± 0.5	1.7 ± 1.0	2.7	P < 0.01 HS
Consonants	1.0 ± 0	2.1 ± 0.6	3.7	P < 0.01 HS
Vowels	0.9 ± 0.3	2.0 ± 0.7	3.3	P < 0.01 HS
Resonance	0	1.0 ± 0.9	3.0	P < 0.01 HS
General intelligibility	0.8 ± 0.4	2.2 ± 0.4	3.9	P < 0.01 HS

HS = highly significant

three factors co-varied: age at implantation, language age at implantation, and chronological age at 12 months' evaluation. Thus, children who underwent implantation at a younger age were also younger at the time of the 12-month evaluation. In theory, this places the younger children at a maturational and developmental disadvantage in comparison with their older peers. Thus analyzing the results in terms of language age scores might put the younger group at a disadvantage. At the same time, analyzing the results in terms of language age deficits, although more reasonable, but still, in theory, puts the older group at a disadvantage because of the impact of their ages giving higher values for the deficit from the scored language age. That's why the hypotheses of using a language improvement quotient may be more realistic and less biased by the chronological age differences at the time of evaluation. However, language improvement quotient, although the most optimum at this stage, but may not be quite perfect to depend on while drawing final conclusions as will be discussed in short.

On the whole, and as shown in (Table 1), both groups showed highly significant improvement in the language skills. They also showed highly significant improvement in the auditory abilities (Table 2) and highly significant decrease in the speech reading abilities (Table 3). All these effects are expected due to the access gained by the cochlear implanted children into the acoustic environment.

To date, only a few systematic studies have involved large numbers of children who received implants at various ages and have investigated both the effects of age at implantation and the amount of experience with an implant. The majority of such studies were concerned with the speech perception skills after cochlear implantation with a clear evidence of the effect of early implantation on rate of acquisition of such perception skills when they are implanted at 2 – 4 years of age [7]. [3] Also recorded speech perception tests for 38 children after a fixed period of cochlear implantation (36 months). They divided the children into 4 groups age-wise; 2 - 4 years, 5 - 6 years, 7-10 yrs. and 11 – 15 years. Their results showed a general trend for the younger groups to have higher scores than the older groups on most tests. However, a significant group effect was found in only one out of 6 tests of their speech perception tests in favor of the youngest age group [8]. Also studied the outcome of cochlear implantation at ages from 0 to 6 years examining categories of auditory (CAP) scores. They concluded that implantation beyond the age of 4 years hardly ever resulted in normal CAP scores while implantation between the age of 2 and 4 years always resulted in normal CAP scores after 3 years. Moreover, implantation before the age of 2 years always resulted in immediate normalization of the CAP scores.

The results of the present study point to the fact that the early implanted group demonstrated significantly better speech production skills 1 year after implantation than the older group (Table 6). Intelligibility of speech of children after cochlear implantation in general has been proved to show great improvement [9]. In this study, the significant difference between speech intelligibility statuses in both groups after 1 year of implantation indicates the favorable effect of young age of implantation on such ability (i.e. speech intelligibility) that marks the overall speech characteristics of a hearing impaired individual. These differences in the speech skills and speech intelligibility between both groups may be explained by the fact that the older children were more habituated to their faulty speech habits so that, even after improvement of their auditory skills, they may require a longer period and training to improve such habits. The early implanted group also produced significantly less speech reading abilities than the older group (Table 5) which is explained by their success to depend on their auditory inputs more than the older implanted group. A study of 133 children by [10] found that among those reaching the 6-year interval, the percentage able to understand conversation without lip-reading rose from 0% to 82%. Concerning the auditory abilities, the progress imposed by the effect of cochlear implantation was equally effective to the 2 groups in the evaluation after 1 year (Table 5). This may be explained by the fact that the older group were also more rigid to their habits of relying on their visual cues making the children less efficient in acquiring the training proficiency provided to them during therapy sessions. In an explanation of this, [11] described recruitment of the auditory cortex by the visual and somato-sensory systems in congenitally deaf humans. They reported that the extent of cross-modal recruitment of the auditory cortex increases as the duration of deafness increases, deterring the restoration of auditory processing in the auditory cortex of long-term deafened individuals after cochlear implantation. They also suggested that the age beyond which the effects of cross-modal plasticity in the auditory cortex are more difficult to reverse is about 6.5 years. It has also been documented that there is a change in the cochlear place code during development [1]. This may be necessary for the formation of normal and effective connections between auditory centers and for the proper development of elements within the central auditory pathways. Early cochlear implantation may contribute to the maintenance of these important developmental milestones.

Language skills, however, did not show a significant difference in improvement, between the 2 groups the evaluation after implantation, though the younger group showed a general tendency for a better language improvement quotient , while the older group produced a slightly higher improvement quotient after 1 year of implantation. The fact that language age deficits were always significantly higher in the older group than the younger group may be attributed to the difference in the chronological ages of the 2 groups, producing wider deficits in the older group. That's why language age deficits could not be relied upon as a parameter for such a comparative study. However, the older group, being the wiser group, demonstrated a more rapid improvement in the language skills in the first year. On the contrary, the younger group continued to have more or less continuing improvement in the language skills over the evaluation.

In a study by [12] over 33 children implanted before 5 years of age, rapid improvement was noted in speech production and language acquisition after improved speech perception for children. They noted non-significant differences between children from their group implanted before 3 years of age and those after 3 years. Although they emphasized the effect of early implantation on language and speech skills, but their conclusion was based on comparison between levels reported in literature for older children. According to [12], children younger than 5 years of age enter the implant process with limited language, allowing them to integrate the auditory information into a functional spoken language system. Children older than 5 years have to incorporate sound into their highly visual communication system and to learn to monitor their own speech via auditory rather than kinesthetic feedback. Although the choice of the language improvement quotient to compare the language skills progress of both groups may be the most appropriate, yet it still has the disadvantage of not bearing into consideration the fact that language does not improve at the same pace in all chronological ages. That is to say, a considerable progress occurring between the ages of 2 to 3 years may be accounted for as slight progress if it occurs to another child aging 6 to 7 years. Thus, if we want to examine the effect of the age of implantation on language skills, it is recommended that an evaluation of language is to be done after language plateaus totally in the child at any age. Thus, at the moment, it is too early to conclude facts about the effect of age of implantation on the language skills or the rate at which language skills are acquired. However, the present study demonstrates clearly the favorable effect of early cochlear implantation on the auditory abilities and the speech skills of children. Our results point to that implantation before the age of 3.8 years definitely yields better results in such abilities. This is most crucial while counseling parents about the proper timing for implantation of their children and expectations regarding the outcome at different ages. [13] stressed that factors, such as motivation and participation of the parents, regularity of attendance of therapy sessions, long-term implant experience with consistent use of the device and an aural–oral educational placement, all contribute to successful development of both language and speech skills of prelingually deafened children who received cochlear implants. In a study also by [14], they found that significant predictors of language skills of 181 children evaluated 4-7 years post-implantation included greater nonverbal intelligence, smaller family size, higher socio-economic status and female gender. Age at receiving an implant did not affect language outcome.

The issue of the most favorable age for cochlear implantation varied in literature. As a clinical study design, the group study design may not be successful to depend upon for deriving conclusions concerning this issue due to the factors previously discussed [15]. Tried to detect the maturity of central auditory pathways by measuring the latency of the P1 cortical auditory evoked potential. Because P1 latencies vary as a function of chronological age, they can be used to infer the maturational status of auditory pathways in congenitally deafened children who regain hearing after being fit with a cochlear implant. Their data suggested that in the absence of normal stimulation there was a sensitive period of about 3.5 year during which the human central auditory system remained maximally plastic. Plasticity remained in some, but not all children until approximately the age of 7 years. After age 7, plasticity was greatly reduced [16]. Also using P1 latency studies on children suggested that children with cochlear implants who experience a sufficiently long period of deafness before the age of 6 to 8 years never develop a fully functional set of axons in superficial layers of the auditory cortex.

Conclusion and Recommendations

The early implanted group demonstrated significantly better auditory abilities, better speech production skills, and better speech intelligibility 1 year after implantation - than the older implanted group. The early implanted group also ended with significantly less speech reading abilities than the older group 1 year after implantation. These results indicate the favorable effect of young age at implantation over the previous parameters. Language skills, however, did not show a significant difference in the magnitude of improvement, between the 2 groups at the evaluation 1 year after implantation. Judging the age at implantation as a prognostic factor for language improvement may require a period of follow up, longer than 1 year, allowing language either to reach its ceiling or to plateau.

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