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Effect of Different Variables on Auditory and Language Development in Prelingual Children Using Cochlear Implant in Zagazig University CI Program Experience

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Abstract

Background: For severe to profound deaf persons, cochlear implantation has been used as a successful procedure to regain partial hearing. The variability seen in language and speech development after cochlear implantation is due to contribution of multiple factors not only demographic and hearing history but also neurological and cognitive factors.

Objectives: The aim of this study was to explore the effect of different variables as age of implantation, duration of CI use and preoperative IQ score on auditory and language development of prelingual cochlear implanted children.

Methods: This study included 62 participants operated in zagazig university hospital and follow the candidacy criteria for cochlear implantation of Zagazig University CI program. All patients were subjected topostoperative audiological and phonological assessment including Warble tone response thresholds in sound field, aided speech discrimination, language test and speech analysis.

Results: The results of the study proved that the better outcomes of CI children are correlated with younger age at implantation, longer duration of CI use, preoperative improvement quotient.

Conclusion: Better speech and language development were significant correlated with earlier age at implantation, better IQ score, longer duration of CI use.

Key words: Cochlear implant, Children language, CI outcome.

1. Introduction

Cochlear implants are complex electronic devices surgically implanted behind the ear. These devices use electrodes placed in the inner ear (the cochlea) to stimulate the auditory nerve of individuals who have significant permanent hearing loss (1).

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Cochlear implantation is very successful in restoring partial hearing for the severe to profound deaf people. Many children with CIs are now able to communicate and understand speech without lip-reading, develop spoken-language skills and attend normal schools (2).

The FDA-approved guidelines for cochlear implantation in children: Bilateral severe to profound sensorineural hearing loss, age of 12-18 months or older, little or no benefit from hearing aids, placement in intensive auditory skill rehabilitation program, no radiological or medical contraindications to surgery, appropriate expectations from the family (3). Candidacy for cochlear implantation also extended to some children with some residual hearing (4).

widespread newborn hearing screening has led to an increase in early diagnosis and greater opportunities for early intervention, including children younger than 1 year. Cochlear implantation in children less than age 12 months has shown both short-term and long-term safety and efficacy (5).

American Academy of Pediatrics (6) recommended "1-3-6" benchmarks for the newborn hearing screening process: complete newborn hearing screening -by one month of age, diagnose hearing loss by three months of age, and enroll those identified with hearing loss into early intervention by six months of age(7).

There are strong predictors that are tied to:the patient (e.g., age, age at implantation, degree of hearing loss, duration of hearing loss, hearing aid use, residual hearing, previous phoniatric evaluation),the device (e.g., generation of implant, surgical technique, active channels, dynamic range). Although these predictors provide an initial foundation for predicting potential outcomes for the majority of cochlear implant users, a substantial amount of variance still remains unexplained (8).

2. Patients and Methods

This retrospective study was applied at the Audio-Vestibular medicine and Phoniatrics Units – Otolaryngology Head and Neck Surgery Department – Zagazig University Hospitals from 12/2018 to 6/2019 to assess the auditory and language skills in chidren patients performed CI surgery in ENT department of Zagazig University Hospitals since 2010 (the date of beginning of zagazig university cochlear implant program).

Up to June 2019, 162 children were operated in zagazig university CI program. Only 62 children were included in this study, some parents didn’t give consent to participate in research, some lost contact with them either changed their residence or phone number and some shifted to follow up in nearby other medical centers. These 62 participants follow the candidacy criteria for cochlear implantation followed in Zagazig University CI program.

Postoperative audiological assessment:

1) Warble tone response thresholds in sound field were assessed at frequency range 500 through 4000 Hz.

2) Arabic monosyllabic phonetically balanced kindergarten words (9): Done by life voice, the speech was introduced at intensity 65 dBHL (10). The child was seated in a sound treated booth facing the speaker from which speech was introduced at 1m with zero azimuths.

Postoperative phoniatric assessment:

1) Language test (11): Language was assessed using the Standardized Arabic Language Test. This test measures receptive and expressive language skills, giving the total language age in years. Language deficit was expressed as language quotient. It was calculated by dividing raw score of the children by the normal cut off point of the same chronological age. Language quotient was Patients and Methods - 60 - used to avoid biased results if language age was used, as children had different chronological ages at the time of assessment.

2) Speech analysis (12): This test was performed using a speech assessment protocol, which included analysis of supra-segmental phonology (rate, stress, and tonality), segmental phonology (consonants and vowels), nasal resonance, and general intelligibility of speech, as well as voice (dysphonia). Every item was given a score that ranged from 0 (normal) to 4 (denoting severe abnormality) except for general intelligibility, for which score 4 indicated normal and 0 indicated severely unintelligible speech. This test could not be applied to all children because it needs language age > 2 years as it is difficult to assess the speech before this age.

3. Results

Table (1) shows personal data of the studied group (Age & sex) also shows age at implantation, duration of CI use and preoperative IQ test. Table (2) shows that there was +ve statistically significant correlation between age at implantation and aided at 500Hz, -ve statistically significant correlation between age at implantation and intelligibility of speech. There was +ve high statistically significant correlation between age at implantation and articulation of consonants and vowels and resonance, -ve high statistically significant correlation between age at implantation and aided speech discrimination and receptive & expressive and total language age. Table (2) shows that there were +ve statistically high significant correlations between duration of CI use and aided speech discrimination and receptive & expressive and total language age and there was +ve statistically significant correlation between duration of CI use and intelligibility of speech. Table (3) shows that there were +ve high statistically significant correlations between IQ and aided discrimination and receptive & expressive and total language age.

Table 1: Personal data.

Variable		(n=62)	
Age: (year)	Mean ± SD Median Range	7.74 ± 2.11 8 3y 7m - 13	
Variable		**No**	**%**
Sex:	Female Male	32 30	51.6 48.4
Variable		**(n=62)**	
Age at Implantation: (years)	Mean ± SD Median Range	4.10 ± 1.18 4 1y 5m – 7y	
Duration of CI use: (years)	Mean ± SD Median Range	3.63 ± 1.56 3y 9m 1y 3m – 8y 9m	
Preoperative IQ	Mean ± SD Range	93.68 ± 9.11 80 – 115	

SD:Standard deviation

Table (2): Correlation between age at implantation and different parameters among the studied cases:

Variable			Age at implantation (n=62)
Postoperative aided response	**500Hz**	**R**	**0.176*****
		P	**0.031**
	1000Hz	**R**	0.130
		P	0.111
	2000Hz	**R**	0.039
		P	0.630
	4000Hz	**R**	0.048
		P	0.559
	Aided discrimination	**R**	**-0.182****
		P	**0.030**
Language assessment	**Receptive Age**	**R**	**-0.257**
		P	**0.048****
	Expressive age	**R**	**-0.194**
		P	**0.049****
	Total age	**R**	**-0.341**

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		P	0.004**
Speech assessment	Articulation consonants	R	0.350**
		P	<0.001
	Vowels	R	0.315
		P	<0.001**
	Resonance	R	0.539
		P	<0.001**
	Intelligibility of speech	R	-0.275
		P	0.03*

r: Correlation coefficient NS: Non significant (P>0.05)

*: Significant (P<0.01) **: highly significant (P<0.01)

Table (3): Correlation between duration of CI use and different parameters among the studied cases:

Variable			Duration of CI use (n=62)
Postoperative aided response	500Hz	r	0.147
		P	0.071
	1000Hz	r	-0.119
		P	0.145
	2000Hz	r	-0.093
		P	0.207
	4000Hz	R	-0.035
		P	0.666
	Aided discrimination	R	**0.221****
		P	**0.006**
Language assessment	Receptive Age	R	**0.356****
		P	**<0.001**
	Expressive age	R	**0.397****
		P	**<0.001**
	Total age	R	**0.384****
		P	**<0.001**
Speech assessment	Articulation consonants	R	0.074
		P	0.382
	Vowels	R	-0.025
		P	0.767
	Resonance	R	0.046
		P	0.585

	Intelligibility of speech	**R**	**0.27**
		P	**0.02***

r: Correlation coefficient NS: Non significant (P>0.05)
*: Significant (P<0.01) **: highly significant (P<0.01)

Table (4): Correlation between IQ and different parameters among the studied cases:

Variable			**I.Q (n=62)**
Postoperative aided response	**500Hz**	**R**	-0.110
		P	0.176
	1000Hz	**R**	-0.090
		P	0.268
	2000Hz	**R**	-0.139
		P	0.089
	4000Hz	**R**	-0.059
		P	0.471
	Aided discrimination	**R**	**0.417****
		P	**<0.001**
Language assessment	**Receptive Age**	**R**	**0.391****
		P	**<0.001**
	Expressive age	**R**	**0.361****
		P	**<0.001**
	Total age	**R**	**0.377****
		P	**<0.001**
Speech assessment	**Articulation consonants**	**R**	-0.013
		P	0.882
	Vowels	**R**	0.004
		P	0.960
	Resonance	**R**	0.066
		P	0.433
	Intelligibility of speech	**R**	0.152
		P	0.070

r: Correlation coefficient NS: Non significant (P>0.05)
*: Significant (P<0.01) **: highly significant (P<0.01)

4. Discussion

This retrospective study was carried out to to explore the effect of different variableson auditory and language development of cochlear implant users in Zagazig University Hospitals and explore

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the effects of different factors on the postimplant outcome of prelingual CI children, to highlight both predictive and prognostic values of these factors on the progress of such children.

The study was performed on a group of children who performed cochlear implantation in zagazig university hospital 48.4% were male and 51.6% were female, the age of the studied group ranged from 3 yrs 7 ms to 13 yrs at the time of testing.

The age at implantation among the studied group ranged from 1 y 5m to 7y (one patient had implantation at age of 7 y) with mean 4.10 years while duration of CI use ranged from 1y 3m to 8y 9 m with mean 3.63 years, as regard IQ: it ranged from 80 to 115 with mean scores 93.68.

As regard aided hearing threshold, it was found that there was significant correlation between post- implant aided threshold at 500Hz and age at implantation. These results are in agreement with El Kayalwho examined a group of 25 implanted children and found statistically significant difference between the age at implantation and post-operative aided threshold (13).

However, Zohdistudied a group of 62 children implanted at an average age of 4.7 years and found no significant correlation between the age at implantation and post- operative average auditory threshold (14).

As regard aided speech discrimination, it was found that there was statistically significant increase in word discrimination scores with the decrease age at implantation and increase duration of CI use.

These results are in agreement withGuptawho studied children implanted below the age of 5 years and found that longer period of hearing loss was associated with a reduced rate of language development (15).

As regard language assessment it was found that there was significant correlation between age at implantation and language development. These results are in agreement with Lynessa who found that Children with early implants (before 3 years of age) quickly catch up(16), also Holt and Svirsky reported that children who are implanted by the age of 24 months make better linguistic progress than the children who are implanted later (17) as they are exposed to what is called the sensitive period for language auditory development(18).

Tomblinsuggested that early implantation can benefit long term development in two ways; firstly, it shortens the duration of deafness with its association with poorer rate of language acquisition and development, secondly it can provide language development by altering the rate after initial stimulation (19). In accordance with our findings several researchers found similar findings (20).

There is also significant correlation between duration of implant use and language development, this is in agreement with Yoshinaga-Itano who found that the longer the use of the implant, the greater the acquired vocabulary (21).

Also, Bevilaqua and Formigonni found that the lower the child's age at the time of implantation, associated with a longer use of CI and a better family participation, the better the child's development of oral language will be (22).

In conclusion there are many reasons why children demonstrate great heterogenicity in learning a spoken language of course, the quantity and quality of parental input as well as access to sound are enormous particularly for children with hearing loss. But other influential factors must be considered; cultural differences, psychosocial contexts, the child's learning capacities and environmental stressors such as poverty and low birth weight (23).

As regard consonants development It was found that there was statistically significant correlation between age at implantation and consonants development. This is in agreement with Dettman who have shown that relatively young CI recipients at the time of implantation also increased consonant inventories, consonant accuracy, and intelligibility following implantation but continued to lag behind TD children, especially when matched for chronological age (24).

Dawson found that implant users may exceed their preoperative performance for both intelligibility and articulation, after experience with a device for from 1 to 4.5 years. These improvements occur for front, middle and back consonants, for stops, fricatives and glides and for voiceless and voiced consonants (25).

Dininofound that voiced consonants were more difficult to perceive than unvoiced consonants, and there was a devoicing bias for the stops. A bias toward unvoiced stops was found. This may be related to two main issues: (1) implants convey the F0 in voiced sounds poorly due to missing temporal information in the electrical signal for most implant models and to the electrode's insertion depth being too shallow to cover the whole cochleaand (2) the VOT makes the unvoiced stops much easier to perceive than the voiced stops due to the aspirated pause between the stop and the following vowel (26).

Also, nasality adds a new obstacle to consonant recognition. This may be due to the prominence of low frequencies around 250 Hz in the nasals' spectrum; also called the nasal formant (F1). The CIs render low frequencies rather poorly compared to high frequencies (27).

However, Tobey found that age at implantation did not contribute to eventual outcomes. Overall, these studies of CI recipients, implanted at various ages, paint a guardedly optimistic picture of consonant development (28).

The speech of the Egyptian cochlear implanted children shows many developmental phonological patterns as well as non-developmental ones. The phonemic development sequence revealed that anterior sounds precede posterior ones, oral sounds precede nasal ones and stops precede fricatives. Glides and laterals showed very late acquisition. All segmental and supra-segmental disturbances improved gradually with regular use of CI and attending speech therapy sessions (29)

As regard vowels development: The vowels were the easiest task to master as vowels are known to be more easily perceived than consonants, due to their combination of high energy and long duration compared with consonants (30).

There was statistically significant correlation between age at implantation and vowels development. This is in agreement with Välimaa who found that all vowels should be possible to recognize and vowel discrimination reaching 100% in 8 months in certain circumstances as vowels are characterized mainly by F1 and F2, the first two formants, which can be found in the frequency range between 200 Hz and 2500 Hz. Thus, provided the input frequency range of the implant includes frequencies as low as 200 Hz (31).

As regard speech intelligibility: The ultimate goal of utilizing cochlear implantation is to enable intelligible speech, because this demonstrates the communication function of language (32).

It was found that there was significant correlation between age at implantation and intelligibility of speech. These results are in agreement with Dettman the majority of profoundly deaf children implanted in their sensitive period (before age 3.5–4.0 years) will develop intelligible speech and functional hearing for oral language (24).

There is also significant correlation between duration of implant usage and intelligibility of speech, these results in agreement with Tobey reported that pediatric CI recipients' speech intelligibility, although widely ranging, increased as the length of device experience accumulated over time (33).

Similarly, Huang proved that there was a positive correlation between the duration of implant usage and speech intelligibility (34). Ching found that speech intelligibility in pediatric CI recipients with 6 years of device experience did not reach a plateau (35).

However, Ruffin found that although later implantation may put a child at higher risk for poorer language outcomes and so intelligibility of speech, it does not guarantee it (36).

Also, Blamey showed that no correlation between age and speech intelligibility. Because access to auditory information via CIs is an important factor for sound repertoires and speech intelligibility and all of these children had the same period of hearing and auditory feedback (37).

As regard IQ test a significant correlation was found between postimplant language age of CI children and preoperative IQ. This is in agreement with the findings of Shrestha and Mahajan, who found children with high initial IQ scores performed better than children with low scores who had a poor outcome (38).

Also, Geers found that implanted children with higher intelligence quotients, smaller family sizes, and higher socioeconomic status had greater language competence (39).

Cognitive function tests consist of verbal and non-verbal (performance) tests. Since the feasibility of verbal testing is limited in deaf children, a performance test that presents tasks visually is important when evaluating the cognitive function of deaf subjects (47). a study of Mandarin-speaking children using cochlear implants reported that the verbal intelligence quotient (IQ) might not represent the true intelligence of CI users so we must rely on performance IQ (40).

5. Conclusion

Better speech and language development were significant correlated with earlier age at implantation, better IQ score, longer duration of CI use.

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