Auditory Performance in Pediatrics Cochlear Implant Program of Cairo University

Original Article

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ABSTRACT

Background: Cochlear implantation (CI) became an effective procedure in restoring hearing in patients with severe to profound hearing loss (HL). It can help youngsters who do not benefit from hearing aids improve their auditory skills and speech perception. The outcome depends on several factors which affect it one at a time or in combination.

Aim: This study was designed to document factors that might affect the outcome of Cairo University's CI program.

Patients and Methods: This prospective study was conducted on fifty children with bilateral severe to profound sensorineural HL who underwent unilateral CI at the CI Unit, Kasr Al-Ainy Hospital, Cairo University. All patients were subjected to careful history taking, full medical examination, audiological and preoperative investigations, phoniatric and IQ assessment then subjected to audiological and language assessment after one year of using the device.

Results: After one year of CI, significant improvement in hearing was found with a significant association with the duration of using hearing aids. The language age and vocabulary size were significantly improved. Regarding vocabulary size, it was significantly improved and associated with the preoperative IQ level and preoperative vocabulary size. There was a statistically significant improvement in categories of auditory performance scores with a significant association with the postoperative vocabulary size.

Conclusion: CI is an effective and safe treatment in children with sensorineural HL. Its positive outcome could be affected by the preoperative use of hearing aids, preoperative language age, vocabulary size, and child's IQ.

Key Words: Cochlear Implantation, outcome, pediatric.

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INTRODUCTION

Cochlear implantation (CI) is a well-established surgical procedure for those who have bilateral severe to profound sensorineural hearing impairment. This procedure aims to provide those people with a sensation of sound which they can learn to interpret with meaning[1]. These electronic prosthetic devices are surgically implanted into the inner ear through the mastoid and middle ear, directly activating the sound's response of the auditory nerve[2].

Several factors must be examined when determining if a child is a good candidate for implantation; hence, patients' selection is a critical step for effective CI. A comprehensive assessment should involve a succession of tests, including audiological, medical and imaging studies, as well as speech and language evaluation. In addition, patient/family counseling is essential for explaining the potential advantages and setting appropriate expectations[3].

Children who do not benefit from hearing aids have their auditory skills and speech perception improved by CI; however, the outcomes of children who have been implanted is dependent on several variables. These variables can affect the outcome singly or in combination[4].

Thus, the current study aimed to evaluate the preoperative, operative, and postoperative variables that may affect the outcome of the CI of the children in the Cairo University program regarding the auditory and language performance after using the CI device one year.

PATIENTS AND METHODS:

This was a prospective study conducted on fifty children who underwent unilateral CI at the CI unit, Kasr Al-Ainy Hospital, Cairo University, from 2015 to 2018. At the time of implantation, included patients were children of both genders aged six years or less who had bilateral severe to profound sensorineural hearing impairment. All included patients had a pre- or peri-lingual onset of deafness with evidence of functioning auditory nerve, which had almost no benefit from hearing aids. Children above six years old, those with post-lingual onset of deafness, complete

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agenesis of the cochlea, cochlear nerve aplasia, and children with multi-handicaps were excluded.

Methods

Single-sided CI for treating severe to profound bilateral SNHL using a multichannel CI using either Med-El Sonata with 12 electrodes or Advanced Bionics (AB) device with 16 electrodes was performed, and outcomes were assessed after one year of the implant use.

All the patients were subjected to careful history taking, full otorhinolaryngological and medical examination, audiological, radiological, and preoperative investigations as well as preoperative phoniatric, psychiatric evaluation including intelligence quotient (IQ) score assessment by Stanford Binet Intelligence scale 4th edition. All patients were followed up throughout the year for programming and rehabilitation in the CI unit and subjected to audiological and language assessment at Kasr Al-Ainy Hospital of Cairo University.

Outcome assessment

Primary Outcome measure:

Auditory Performance-II CAP-II

The CAP-II, a standardized measure of a child's perceived functional hearing was used as the primary outcome measure. The CAP-II assesses the functional hearing on a Likert scale ranging from 0 (has no awareness of environmental sounds) to 9 (uses a phone with unknown speaker in unpredictable context)[5]. CAP-II scores ≥5 represents good communication scores[6]. It was assessed preoperative and after one year of using the CI device.

Secondary outcome:

Language and Psychiatric Assessment

All the patients had language assessment preoperative and postoperative after a year of using their CI device. A standardized Arabic language test was used[7], with and without visual cues. Time of the test ranged from 30 to 60 minutes. The test assesses: semantic, receptive, expressive, and total language. This includes the vocabulary size, provisional language age and means of communication.

Statistical Analysis:

Data were analyzed using IBM SPSS for Windows (Version 24). Numerical data were summarized using means, standard deviations, and ranges. Data were explored for normality using the Kolmogorov-Smirnov test and Shapiro-Wilk test. Categorical data were summarized as percentages. Paired t-test was used to compare paired data (before and after). Chi-square (X^2) was used to compare categorical data. Univariate and Multivariate Analysis of Variance (MANOVA) was used to assess the association of different factors with the hearing thresholds, language age, vocabulary size and CAP scores. Significance level was set at *p value <0.05*.

RESULTS:

Table 1. Shows that the current study was performed on 23 females (46%) and 27 (54%) males who underwent unilateral CI. Implantation was conducted in the right ear for the majority of the cases (94%). The SNHL was hereditary in 16 patients (32%), post meningitis in one patient (2%), and of unknown etiology in 33 patients (66%). Only one patient was premature (2%) and the rest (98%) were born full term. Forty-six patients (92%) had no anomalies of their inner ears. Thirty-three patients (66%) used hearing aids ((HA) bilaterally preoperative while 16 patients (32%) used them unilaterally, and only one patient did not use hearing aids before the operation. Most patients (78%) received preoperative speech therapy sessions. The mean age of the SNHL diagnosis was 11 months, while the mean age of implantation was 4.2 years. The mean duration of hearing deprivation was 4.3 years and they preoperatively used powerful hearing aids for a mean duration of 15 months. The mean intelligence quotient (IQ) score was 90%.

Table 2. Demonstrates that there was a statistically significant difference between preoperative hearing levels when measured by free field (F-F) audiometry using hearing aids and after a year of using the implant device at frequencies 0.5 kHz, 1 kHz, 2 kHz, and 4 kHz (*p <0.001*). Statistically significant differences in the language age and vocabulary size of the children before and one year after the implantation were also reported (*p <0.001*).

Table 3. Shows a statistically significant difference between the levels of auditory performance of the children before and after one year of implantation (*p <0.001*).

Table 4. Reveals the association of different factors with the hearing thresholds after one year of using the device. There was a significant negative association between hearing threshold at 500, 1000 and 4000 Hz frequencies and the duration of hearing aid use as the more time the patient used hearing aids before implantation, the less threshold (better hearing) after the operation. There was also a negative association between the number of speech therapy sessions the child had per week and the hearing threshold at 4000Hz (a better hearing level was in those receiving more sessions).

Table 5. Shows that the language age of the patients in months after using the implant device for a year is directly associated with the preoperative and the one-year postoperative vocabulary size. The more words the patient

had, the more language age they could develop. There was a direct association with the preoperative language age as those with higher preoperative language age can reach higher ages after one year of using the implant. Meanwhile, there was a significant positive association between the postoperative vocabulary size and both the IQ score of children and the preoperative vocabulary size. The higher IQ score was associated with a better vocabulary size. Meanwhile, there was a statistically significant association between the CAP score and vocabulary size after one year; the more vocabulary size the patients had, the higher their auditory performance level.

Table 1: Demographic characteristics and preoperative data of the study sample

Gender: N (%)	Female	23 (46%)
	Male	27 (54%)
Ear side of implantation: N (%)	Left	3 (6%)
	Right	47 (94%)
Etiology of hearing loss: N (%)	Heredofamilial	16 (32%)
	Postmeningitic	1 (2%)
	Unknown	33 (66%)
Use of hearing aid: N (%)	Bilateral	33 (66%)
	Non	1 (2%)
	Unilateral	16 (32%)
Prematurity: N (%)	No	49 (98%)
	Yes	1 (2%)
Parents' education: N (%)	High	4 (8%)
	Low	20 (40%)
	Moderate	26 (52%)
Inner ear malformations: N (%)	None	46 (92%)
	Bilateral semicircular canals dysplasia & hypoplastic stenotic internal auditory canals with hypoplastic both vestibulocochlear nerves	1 (2%)
	Enlarged vestibular aqueducts & endolymphatic sac	2 (4%)
	Labyrinthitis ossificans	1 (2%)
Preoperative speech therapy rehabilitation: N (%)	No	11 (22%)
	Yes	39 (78%)
Device used: N (%)	AB	11 (22%)
	Med-El	39 (78%)
Age At diagnosis (months)	Mean (SD)	11 (6)
Age at implantation (years)		4.2 (1)
IQ score		90 (16)
Duration of HA use (months)		15 (8)
Duration of HL (years)		4.3 (1.1)

N: Count, %: Percentage, SD: Standard Deviation, HA: Hearing Aid, HL: Hearing Loss

Table 2: Comparison between the hearing thresholds, language age in months, and vocabulary size before implantation and after one year after using the implant device

	Frequency	Preoperative Mean (SD)	1 year Mean (SD)	Mean Difference	95% CI MD	*P value*
Hearing thresholds (dB)	500Hz	68.4 (10.5)	38.9 (10.3)	29.5	25.8, 33.2	<0.001*
	1000Hz	73.4 (12.5)	39.2 (11.0)	34.2	29.6, 38.8	<0.001*
	2000Hz	76.2 (11.8)	36.5 (12.1)	39.7	35.2, 44.2	<0.001*
	4000Hz	72.9 (13.3)	37.5 (13.1)	35.4	30.2, 40.6	<0.001*
Language age in months		7 (2.0)	17 (8.0)	10.2	8.0, 12.4	<0.001*
Vocabulary size (words)		1 (3.0)	51 (59.0)	49.5	32.9, 66.1	<0.001*

SD: Standard Deviation, CI: Confidence Interval, MD: Mean Difference
*Statistically significant at *p value <0.05*

Table 3: Comparison between the preoperative and one-year postoperative CAP scores

		Preoperative		Postoperative		
		Count	%	Count	%	*P-value*
CAP categories	0	37	74.0%	0	0%	< 0.001*
	1	13	26.0%	0	0%	
	3	0	0%	3	6.0%	
	4	0	0%	1	2.0%	
	5	0	0%	18	36.0%	
	6	0	0%	14	28.0%	
	7	0	0%	14	28.0%	
Outcome	Good (≥5)	0	0%	46	92.0%	< 0.001*
	Bad (≤4)	50	100%	4	8.0%	

N: Count, %: Percentage
*Statistically significant difference at *p value <0.05*

Table 4: Associations between the different variables and the hearing thresholds at different frequencies after a year of device use

		500Hz	1000Hz	2000Hz	4000Hz
Age at diagnosis (months)	B (95% CI)	0.04 (0.87, -0.46, 0.55)	-0.03 (-0.60, 0.55)	0.15 (-0.47, 0.76)	0.18 (-0.48, 0.83)
	P value	0.87	0.93	0.64	0.59
Age at implantation (years)	B (95% CI)	-0.21 (-0.55, 0.14)	-0.18 (-0.56, 0.21)	-0.30 (-0.72, 0.11)	-0.13 (-0.57, 0.38)
	P value	0.23	0.36	0.15	0.55
Duration of HA use (months)	B (95% CI)	-19.19 (-34.68,-3.71)	-19.26 (-36.76, -1.75)	-18.79 (-37.60, 0.03)	-22.80 (-42.75, -2.85)
	P value	0.02*	0.03*	0.051	0.03*
Duration of HL (years)	B (95% CI)	17.90 (3.17, 32.63)	17.69 (1.04, 34.34)	17.59 (-0.31, 35.49)	21.51 (2.53, 40.49)
	P value	0.02*	0.04*	0.054	0.03*
Number of speech therapy sessions	B (95% CI)	-1.55 (-3.73, 0.63)	-1.93 (-4.39, 0.53)	-2.28 (-4.92, 0.37)	-3.70 (-6.50, -0.90)
	P value	0.16	0.12	0.09	0.01*
Preoperative vocabulary size	B (95% CI)	0.05 (-0.05, 0.14)	1.38 (-1.60, 4.36)	1.60 (-1.61, 4.80)	2.95 (-0.45, 6.34)
	P value	0.32	0.35	0.32	0.09
Preoperative language age	B (95% CI)	-0.03 (-0.15, 0.09)	0.03 (-0.34, 0.39)	-0.11 (-0.51, 0.29)	-0.18 (-0.60, 0.25)
	P value	0.57	0.89	0.58	0.40
1year postoperative vocabulary size	B (95% CI)	-0.10 (-0.43, 0.22)	0.04 (-0.09, 0.18)	-0.02 (-0.16, 0.13)	-0.04 (-0.16, 0.08)
	P value	0.53	0.53	0.79	0.55
1year postoperative language age	B (95% CI)	2.23 (-0.40, 4.87)	-0.01 (-0.12, 0.09)	0.02 (-0.09, 0.13)	0.04 (-0.11, 0.20)
	P value	0.09	0.81	0.72	0.57

MANOVA was used, B: Regression coefficient, CI: Confidence Interval, HA: Hearing Aid, HL: Hearing Loss
*Statistically significant at *p value <0.05*

Table 5: Associations between the different variables and the language age, vocabulary size and CAP scores after a year of device use

		Language Age	Vocabulary Size	CAP Score
Age at diagnosis (months)	B (95% CI)	0.09 (-1.66, 1.83)	-0.17 (-1.43, 1.10)	0.02 (-0.03, 0.07)
	P value	0.92	0.79	0.37
Age at implantation (years)	B (95% CI)	15.96 (-37.08, 69.00)	0.51 (-38.28, 39.30)	-0.07 (-1.55, 1.42)
	P value	0.55	0.98	0.93
IQ score	B (95% CI)	-0.63 (-1.44, 0.19)	0.78 (0.22, 1.33)	-0.001 (-0.02, 0.02
	P value	0.13	0.007*	0.95
Duration of HA (months)	B (95% CI)	-0.30 (-1.48, 0.88)	0.16 (-0.70, 1.02)	0.003 (-0.03, 0.04)
	P value	0.61	0.71	0.87
Duration of HL (years)	B (95% CI)	-13.16 (-63.76, 37.44)	-2.05 (-39.01, 34.90)	-0.12 (-1.53, 1.30)
	P value	0.60	0.91	0.87
Number of speech therapy sessions	B (95% CI)	1.62 (-6.33, 8.66)	1.69 (-4.28, 6.62)	-0.12 (-0.33, 0.09)
	P value	0.76	0.67	0.24
Preoperative vocabulary size (words)	B (95% CI)	6.33 (2.50, 15.16)	3.85 (2.63, 10.33)	0.25 (0.0008, 0.51)
	P value	0.02*	0.03*	0.049*
Preoperative language age (months)	B (95% CI)	0.51 (-1.62, 0.61)	0.33 (-0.48, 1.14)	0.03 (-0.004, 0.06)
	P value	0.36	0.42	0.09
1year postoperative vocabulary size (words)	B (95% CI)	1.22 (1.01, 1.43)	-	0.01 (0.001, 0.02)
	P value	<0.001*	-	0.03*
1year postoperative language age (months)	B (95% CI)	-	0.65 (0.54, 0.76)	-0.001 (-0.01, 0.01)
	P value	-	<0.001*	0.93

B: Regression coefficient, CI: Confidence Interval, HA: Hearing Aid, HL: Hearing Loss
*Statistically significant at *p value <0.05*

DISCUSSION

CI is a viable technique for helping children with severe to profound SNHL learn to hear and gain age-appropriate communication skills. Nevertheless, patients' selection is of extreme significance to achieve optimal outcome[4]. For this reason, this study was designed to assess various factors that can affect the outcome of the implantation owing to getting better results in the future.

Findings of the current study state that after implantation, a significant improvement in the hearing level, language age, vocabulary size, and CAP scores were detected. These findings were supported by Stacey *et al*., who documented the improvement in spoken communication skills, educational achievements, and quality of life in implanted children compared to non-implanted children provided that they receive implants before the age of five[8]. In addition, for children who receive little or no benefit from amplification, CI is usually a practical alternative with positive outcome in listening, spoken language, literacy, and social/emotional well-being[9].

Our findings show a significant improvement in the hearing thresholds by free field audiometry at frequencies 0.5, 1, 2, and 4 kHz after one year of CI compared to the preoperative thresholds using the hearing aids. This also comes in accordance with Swami *et al*., who reported that CI enhances the auditory skills and the speech perception of the children not responding to hearing aids[4]. Meanwhile, the hearing thresholds at 0.5, 1, and 2 kHz were significantly and negatively associated with the duration of HA use before implantation. The longest time the children used the HA, the fewer thresholds of F-F audiometry post-implantation, i.e., the better hearing level. This was similar to the finding of Zheng *et al*., who detected a significant positive outcome of the duration of pre-implant hearing aid use on both categories of outcome measures (Mandarin Infant-Toddler Meaningful Auditory Integration Scale and the Mandarin Early Speech Perception test)[10].

In terms of language age, significantly higher levels were found after implantation with a significant positive association with that of pre-implantation. Besides, there was a significant direct association with vocabulary sizes before and after the operation. This result agrees with that of Waltzman *et al*., who indicated significant gains in speech perception, use of oral language, and capability to function in a mainstream environment in children with implants after 5 and 13 years of follow-up without a decrease in performance or a significant incidence of device migration, extrusion, or failure[11]. Moreover, Davidson *et al*. indicated that early exposure to the language regardless of modality can improve the later language results[12].

The language age in our study also had a direct association with both preoperative and postoperative vocabulary size. The more words the patient got, the more language age he could develop. This is because the size and scope of vocabulary in early childhood are important indicators of overall language competence and are predictive of later reading comprehension. A further consequence of this sensory deficit is a gap that appears between chronologic age and language-performance age in deaf children[13].

Regarding the vocabulary size, the levels were significantly higher after one year of implantation. James *et al*. and El-Hakim *et al*. reported improvement in the vocabulary size as a positive outcome of CI[14,15]. Similarly, multiple studies indicated that children with CIs had attained an average level of vocabulary knowledge compared to their peers[16-19]. On the other hand, there was no association between vocabulary size and the age at implantation as none of the children was implanted neither below two years nor above six years. Also, most of the patients were close to each other at the age of implantation; the mean was 4.2 years (i.e., above three years and below five years).

Meanwhile, there was a statistically significant difference between the CAP scores before and one year after implantation, indicating that CAP improvement is one of the positive outcomes of CI. This result is inconsistent with Singh *et al*., who found that CAP II score increased from '0' to '3' at six months and to '5' at 12 months for children aged 0-3 years. Although this trend was not statistically significant, it was statistically significant for the age groups 3-6 year and 6-10. In addition, there was a substantial improvement in the quality of life and a significant overall shift to the auditory-oral mode from total communications[20,21]. Our results also agree with Bakhshaee *et al*. also reported a significant improvement in auditory performance after implantation in pre-lingually deaf children[22]. Moreover, Stacey *et al*. reported that auditory performance and spoken communication skills were consistently associated with CI[6].

Besides the significant improvement in CAP scores, there was a significant direct association with the postoperative vocabulary size. Given that, the more vocabulary they gained, the higher auditory performance they could achieve. Park *et al*. examined the relationship between nonverbal IQ and postoperative CI outcomes in CI users and found a strong correlation between performance IQ and the postoperative CAP scale[23]. In our study, although the association between the CAP scores and the IQ levels was not significant, the CAP scores were significantly associated with the postoperative vocabulary size, which was significantly associated with the IQ scores i.e., the higher IQ scores, the more vocabulary size and in turn the higher CAP scores.

CONCLUSION

CI can improve the hearing performance, language age and vocabulary size without serious complications. The positive outcome of CI could be affected by the duration of preoperative hearing aid use, preoperative language age, vocabulary size and child's IQ. Postoperative speech rehabilitation programs could also affect the outcome of CI. Further studies should be done in a broader age group including children below two years and assessment of the outcome through a longer duration of the device's usage will be very beneficial.

CONFLICT OF INTEREST

There are no conflicts of interest.

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