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Long-term outcome of cochlear implantation on speech perception and quality of life

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Abstract

Background Cochlear implantation (CI) is currently a well-established method for restoring hearing to people with profound hearing loss (Blamey and Artieres, Audiol Neurotol 18:36-47, 2013; Holden and Finley, Ear Hear 34:342-360, 2013).

Cochlear implantation not only affects hearing abilities, speech perception, and production, but also has an outstanding impact on the social life, activities, and self-esteem of each patient. The Nijmegen Cochlear Implant Questionnaire (NCIQ) and Parents' Views and Experiences with pediatric Cochlear Implant Questionnaire (PVECIQ) have been developed to assess the quality of life in such patients (Damen and Beynon, Otolaryngol Head Neck Surg 136:597-604, 2007; Hirschfelder and Gräbel, Otolaryngol Head Neck Surg 138:357-362, 2008).

The long-term outcome of cochlear implantation (CI) in Egypt and its influence on patients' lives have not been investigated. This study was designed to evaluate the long-term effect of CI on speech perception and to assess the quality of life (QoL) and get insight about major problems encountered by these patients over years.

Methods Forty adults and children CI users of least 5 years of CI experience were subjected to full history taking and CI outcome measures: CI questionnaires, aided sound field pure tone audiometry, and speech perception tests.

Results Through QoL questionnaires, the highest scores were obtained in the physical functioning domain than in the psychological and social domains in adults, while for children, the highest scores were obtained in the general domain than in the communication and self-reliance domains. No statistically significant correlation was found between QOL questionnaires and speech tests.

Conclusion Audiological evaluation including speech perception tests is not enough to reflect the true performance of CI subjects in everyday listening situations. The Arabic versions of QoL questionnaires were complementary to other outcome CI measures. Long-term evaluation for CI users is crucial.

Keywords Cochlear implant, Quality of life, Questionnaire, Speech perception tests, Long-term outcome

Background

Hearing impairment is the most prevalent disabling condition globally. Based on WHO 2018 estimates, there are 466 million persons in the world with disabling hearing loss. Projections show that the number could rise to 630 million by 2030 and may be over 900 million in 2050 [1].

Disabling hearing impairment impedes speech and language development and sets the affected children on a trajectory of limited educational and vocational

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attainment; such impairment has devastating consequences for interpersonal communication, psychosocial well-being, quality of life, and economic independence [2, 3].

In adulthood, disabling hearing impairment can lead to embarrassment, loneliness, social isolation and stigmatization, psychiatric disturbance, depression, difficulties in relationships with others, restricted career choices, occupational stress, and relatively low earnings [4].

Audiological rehabilitation is the process of minimizing the disability which an individual experiences as a result of hearing loss [5]. Cochlear implantation (CI) is currently a well-established method for restoring hearing in people with profound hearing loss [6]. There is no age limit for CI and even additional disabilities are no longer a contraindication for CI [7]. Cochlear implantation not only affects hearing abilities, speech perception, and speech production, but also has an outstanding impact on the social life, activities, and self-esteem of each patient. Various questionnaires have been developed to assess the quality of life in such patients [8].

Evaluation of implant outcome performance is gauged primarily using clinical measures of speech recognition. However, it is unclear how exactly speech recognition tests relate to actual functional improvement. Accordingly, two issues arise. First, the true benefits of CI may be underestimated because many patients do not exhibit large improvements in speech recognition. Second, clinical interventions focus on optimizing performance of speech recognition in quiet. Some patients may exhibit good speech recognition in the clinic, while still struggling in their daily lives. Thus, speech recognition tests alone are likely insufficient to fully examine the benefits or limitations of cochlear implantation [9].

One method to more broadly examine the outcome that has shown growing interest involves the use of quality of life (QoL) measures. For CI users, examining the functional impact of hearing loss and intervention captures more holistic evaluations of patient outcomes as speech production besides the impact on self-esteem, daily activities, and social functioning [10].

The Nijmegen Cochlear Implant Questionnaire (NCIQ) has become a standard sensitive and reliable questionnaire in assessing the quality of life (QoL) of patients with cochlear implants. In most of the reports, significant improvements in the NCIQ scores were observed in total scores as well as in all subdomains [11].

The Parents' Views and Experiences with pediatric Cochlear Implant Questionnaire (PVECIQ) can be used to describe how pediatric cochlear implants affect children's lives according to their parents' perceptions [12]. The parent can provide valuable information about the child's functioning, the process of implantation, the additional interventions needed, and the benefits and limitations experienced [13].

The long-term outcome of cochlear implantation in Egypt and its influence on patients' lives have not been yet investigated. This study was designed to explore how closely does cochlear implantation allow patients with severe to profound hearing losses to acquire communication skills commensurate with typical hearing individuals and to provide insight into the social development of those patients and the extent to which they feel part of the hearing community and to get insight about the major problems encountered over years.

Methods

Subjects

The study group is composed of 40 adult and children CI users.

- Inclusion criteria: At least 5 years of CI experience with no additional physical disabilities
- After reviewing about 500 cochlear implanted patients' files at Audiology Unit, Ain Shams University Specialized Hospital, these 40 CI users could be reached through their phones

Consent was obtained from adults and children's parents prior to contribution in the study after clarifying the importance of the study.

All subjects in the study group were submitted to the following battery in the same order as shown in Fig. 1:

1. Complete history taking including the age of onset, duration and etiology of hearing loss, hearing aid use before implantation, age at CI surgery, duration of CI use, and revision of CI surgery (if present), as well as a history of rehabilitation and regularity of follow-up visits
2. Otological examination
3. Cochlear implant outcome

(a) CI questionnaires: Two questionnaires were used to assess the quality of life in CI users: *Nijmegen Cochlear Implant Questionnaire (NCIQ)*-Arabic version for adults and *Parents' Views and Experiences with pediatric Cochlear Implant Questionnaire (PVECIQ)-Arabic version* for children.

Both questionnaires were translated into Arabic language using forward-backward translation. The number of choices available for response questions in the Arabic questionnaire was reduced to limit the confusion and misunderstanding to suit the Egyptian culture.

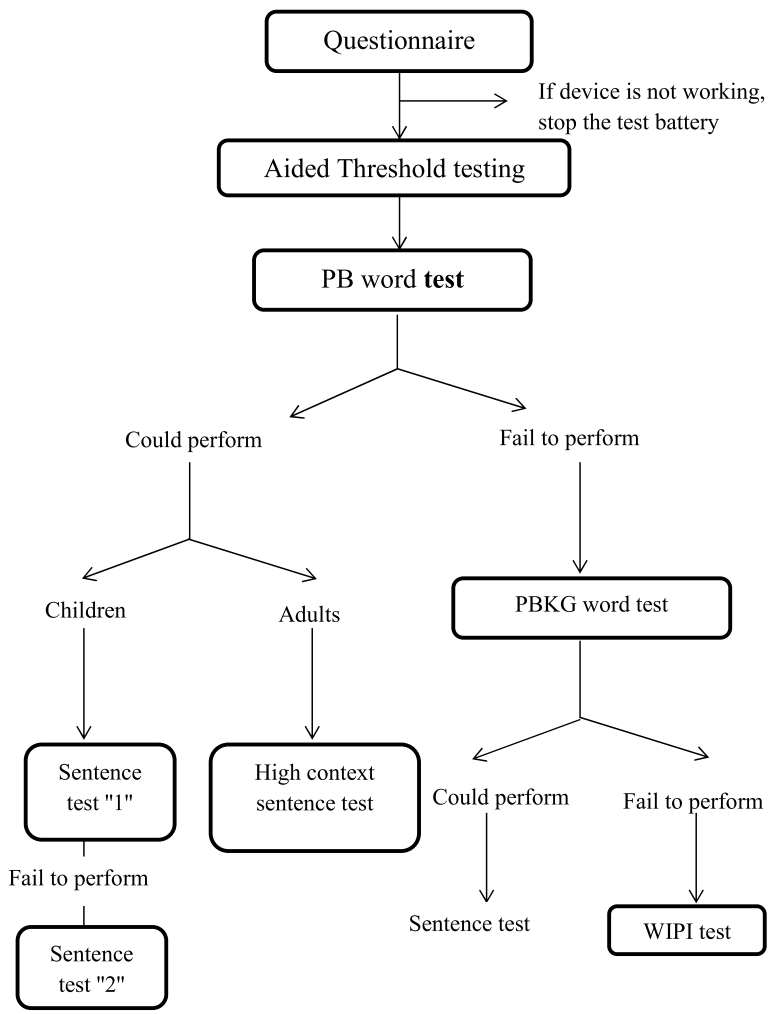

Fig. 1 Test battery flow chart in the study group. Speech perception tests were done with and without VC. Sentence tests were done in quiet and noise

In the NCIQ-Arabic version, choices were reduced from 6 choices (never, sometimes, regularly, usually, always, N/A "not applicable") in the original version to 4 choices (yes, sometimes, no, N/A) in the Arabic version, while PVECIQ-Arabic version choices were reduced from 5 choices (strongly agree, agree, neither agree nor disagree, disagree, strongly disagree) to 3 choices (agree, agree to some degree, disagree).

The reduction in the number of choices in both questionnaires was decided after a pilot study on CI users.

The questionnaires were presented to all adults and children's parents (even those with a nonfunctioning device) and they were instructed to answer all questions.

Scoring: As both questionnaires consist of affirmative and negative statements, the scoring was calculated as 2, 1, and 0 for yes, sometimes, and no answers in the NCIQ-Arabic version and for agree, agree to some degree, and disagree in the PVECIQ-Arabic version, respectively, in affirmative statements and the vice versa in negative statements.

The analysis of the answers was done in two ways:

1. Quantitative analysis: Mean and standard deviation of each domain were calculated.
2. Qualitative analysis: In order to categorize CI users into good, average, and poor performers in each domain, qualitative analysis was conducted. CI users who performed best in each item were given 2, those who could not achieve the expected outcome were given 0, and those who gave an inconsistent performance in some situations were given 1. A percent was calculated to show how many CI users could achieve the expected outcome in each item.

(a) Aided sound field pure tone audiometry

This test and the following tests were applied only to patients who are using their CI devices.

By using a two-channel audiometer, model GSI 61with sound field facilities in the sound-treated room IAC model 1602, subjects were tested wearing their auditory device (single CI or CI plus hearing aid), with no readjustment or reprogramming was done before testing. Aided voluntary behavioral pure tone audiometry was performed using warble tones in the frequencies 250–500–1000–2000–4000–6000–8000 Hz. The subject was seated 1 m from the loudspeaker at zero azimuth in the sound-treated room.

Scoring: No response at any tested frequency was considered at 95dB for statistical analysis.

(b)Speech perception tests

The following test materials were selected from an already developed and standardized different speech test material in Ain Shams University to assess auditory function. They included monosyllabic word tests and sentence tests.

1. Arabic speech test material for adults

(i) Phonetically balanced (PB) word test [14]
(ii) High-context sentence test [15]. Each sentence has high predictability where the context of the sentence can lead to the last word.

2 Arabic speech test material for children

(i) Phonetically balanced kindergarten (PBKG) word lists [16]
(ii) Word Intelligibility by Picture Identification (WIPI) test [17]
(iii) Sentence test "1": based on the Speech Intelligibility In noise (SPIN) test [18]
(iv) Sentence test "2": based on the Pediatric Speech Intelligibility (PSI) test [19]. It was used in an open-set format.

The subject was seated in the sound-treated room 1 m from the loudspeaker at zero azimuth from where speech material was delivered using monitored live voice at 55dB HL in quiet condition with an additional loudspeaker at180° azimuth to deliver babbling noise at different signal-to-noise (S/N) ratios.

Zero signal-to-noise (S/N) ratio was considered as the starting point in the test. It was either increased or decreased according to the subject's response within a range of +20 to −10. The target was to identify at which S/N ratio the subject could reach 50% discrimination. This was done with and without visual cues (VC) in both conditions.

The speech material used was based on the linguistic abilities of the patients and not on their chronological age. All speech tests were used as an open set except the WIPI test.

Monosyllabic PB word test was first conducted for both adults and children. In case of poor performance, PBKG were used instead. If the subject could not perform open-set tests, WIPI (closed set test) was then applied.

The high-context sentence test was then used for adults. The subject was instructed to express the whole meaning of the sentence and to repeat correctly the last word. For children, sentence test "1" which is based on the Speech Intelligibility In noise (SPIN) test was first tried. If they could not perform the test, sentence test "2" which is based on the Pediatric Speech Intelligibility (PSI) test was used.

Scoring: *Monosyllabic word tests*: Percent correct was calculated. Scoring was done by word correct and phoneme correct for every list. *Sentence tests*: Each sentence in the list (10 items) represented 10%. Scoring was done by counting the correct sentences for every list. For the high-context sentence test, scoring was done by counting the correct sentences (10%) and the correct last word (10%).

Statistics

Data were analyzed using the Statistical Package for Social Sciences, version 20.0 (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The following tests were done:

- Independent samples *t*-test of significance was used when comparing two means.
- Paired sample *t*-test of significance was used when comparing related samples.
- Spearman's rank correlation coefficient (rs) was used to assess the degree of association between two sets of variables if one or both of them was skewed.
- The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the *p*-value was considered significant as the following:
  - Probability (*p*-value)

Table 1 Summary of the age of onset, duration of HL, duration of CI use, and duration since the last visit to the CI center

	Adults (n=16)			Children (n=24)		
	Mean	**±SD**	**Range**	**Mean**	**±SD**	**Range**
Age	28.3	±16.1	16–65	10.9	±2.4	8–17
Onset of hearing loss	8.5	±12.2	0–44	0.7	±1.3	0–6
Duration of hearing loss	6.7	±6.2	1–24	3.9	±2.2	0.5–10
Duration of use of CI	14.1	±3.5	8–21	6.0	±2.0	5–13
Duration since the last visit to the CI center	5.5	±5.5	0.5–15	1.5	±1.6	0.5–6

- p-value ≤0.05 was considered significant.
- p-value ≤0.001 was considered as highly significant.
- p-value >0.05 was considered insignificant.

Results

The study group consisted of 40 subjects ranging in age from 8 to 65 years, with no other disabilities, all were unilateral cochlear implanters. Four subjects aged ≥16–18 years old who had comparable speech and language to adults and were evaluated using the same material used for adults. Accordingly, they were included in the adult subgroup making the children subgroup 24 children and the adult subgroup became 16 subjects.

The majority of adults (62.5%) had a prelingual onset of hearing loss. They were operated before 5 years of age and were grown using their CI devices. Their mean age was 18.6 years old, and the mean onset of hearing loss was 1.15 years. The remaining adults (6) had postlingual onset of hearing loss. Accordingly, subgrouping was according to language age and not according to the onset of HL and language development: pre- and postlingual HL.

Table 2 Distribution of the study group according to etiology of hearing loss

	Adults (n=16)		Children (n=24)	
	N.	**%**	***N.***	**%**
Unknown	6	37.5%	14	58.3%
Heredofamilial	2	12.5%	3	12.5%
Postfebrile	2	12.5%	1	4.2%
Postmeningitic	2	12.5%	1	4.2%
Ototoxicity	1	6.25%	3	12.5%
Genetic	1	6.25%	0	0.0%
Far advanced otosclerosis	1	6.25%	0	0.0%
Hypoxia (perinatal)	1	6.25%	1	4.2%
CMV	0	0.0%	1	4.2%

On the other hand, all children had prelingual onset of hearing loss except one (who had a history of postmeningitic hearing loss at the age of 6.5 years) (Tables 1 and 2).

Table 3 shows the distribution of the study group according to rehabilitation history; the majority of subjects used hearing aids before implantation; also, most of them used their CI device regularly and the irregular users were due to the recurrent malfunction of the device. Internal device failure was encountered in 3 subjects.

All adults with the postlingual onset of hearing loss (n=6) did not receive any rehabilitation session. They had developed their language before the onset of hearing loss. They depended on general exposure to sounds and voices through daily activities such as watching television or movies, listening to the radio or familiar music, or talking on the telephone. On the other hand, all children received speech rehabilitation sessions. Ten of them (41.7%) were irregularly attending their sessions due to recurrent external device problems, due to the absence of nearby rehabilitation centers, or due to financial constraints. Unfortunately, this was reflected on the outcome.

CI outcome will be presented as follows: QoL questionnaires then the audiological and speech perception evaluations.

A. QoL questionnaires

Figure 2 shows the analysis of the NCIQ-Arabic version questionnaire for adults and revealed that the best achievement was found at physical functioning, while the least score was found in psychological functioning followed by social functioning domains. Figure 3 shows that the best score achieved in the PVECIQ-Arabic version questionnaire for children was found at the process of implantation and general function, while the least score was found at the effect of implantation and communication domains.

B. Audiological evaluation

Table 3 Distribution of the study group according to rehabilitation history

		Adults (*n*=16)		Children (*n*=24)	
		N.	**%**	***N.***	**%**
Use of hearing aid before implantation		15	93.8%	24	100%
Side of CI	Right	5	31.3%	10	41.7%
	Left	11	68.7%	14	58.3%
Type of CI	Cochlear	16	100%	20	83.3%
	Med-EL	0	0.0%	4	16.7%
Regularity of CI use		13	81.3%	19	79.2%
Bimodal stimulation		0	0.0%	1	4.2%
Failure of the internal part		1	6.3%	2	8.3%
Regularity of follow-up visits to the CI center	Regular	3	18.7%	4	16.7%
	Irregular	4	25.0%	4	16.7%
	On demand	9	56.3%	16	66.6%
Speech rehabilitation sessions	Regular	9	56.3%	14	58.3%
	Irregular	1	6.2%	10	41.7%
	Not received	6	37.5%	0	0.0%

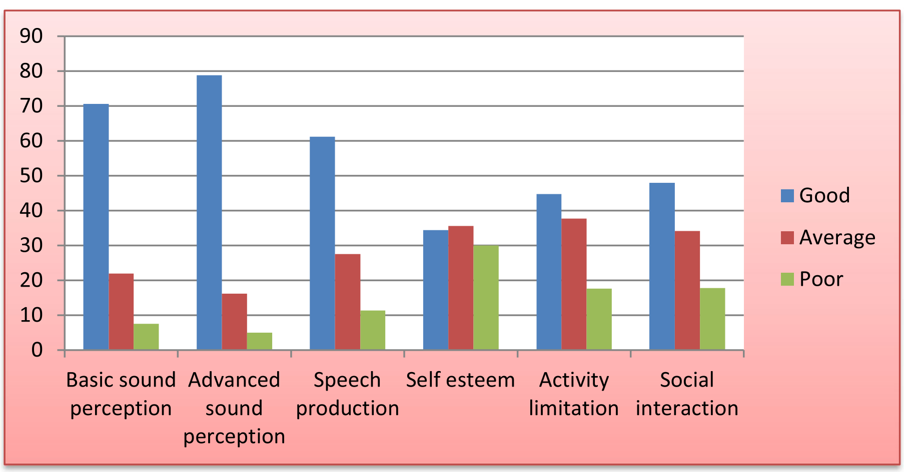

Fig. 2 Distribution of adults according to their performance in the NCIQ-Arabic version subdomains

Figures 4 and 5 show that the mean aided PTA thresholds for most of the CI subjects were 24.1 ± 6.4dB HL for adults and 26 ± 7.9 dB HL for children. One adult (subject no. 8) and two children (subject no. 24 and 36) had CI-aided thresholds worse than "LTASS." Subject no. 8 had a history of postmeningitic hearing loss and was implanted 24 years later at the age of 44 years and never used a hearing aid before implantation. He did not come for regular assessment in the CI center or asked for medical advice since 2005 (9 years after implantation) most probably because of limited benefit from CI. The parents of the other two children reported that they tried to do reprogramming of the CI device several times but they did not reach a satisfactory aided response with their devices with no obvious cause.

All adults except two could perform the PB word test with a mean score of 73.9% and the high-context sentence test with a mean of 70.8% without visual cues. One CI adult (subject no. 8) could perform PB only with visual cues, while subject no. 12 could not perform the PB test neither with nor without visual cues, so an easier test PBKG was used although it was not planned to be used in the adult group.

All adults needed a positive S/N ratio to reach 50% discrimination without visual cues. With visual cues, almost half of the cases could perform the test with an S/N ratio

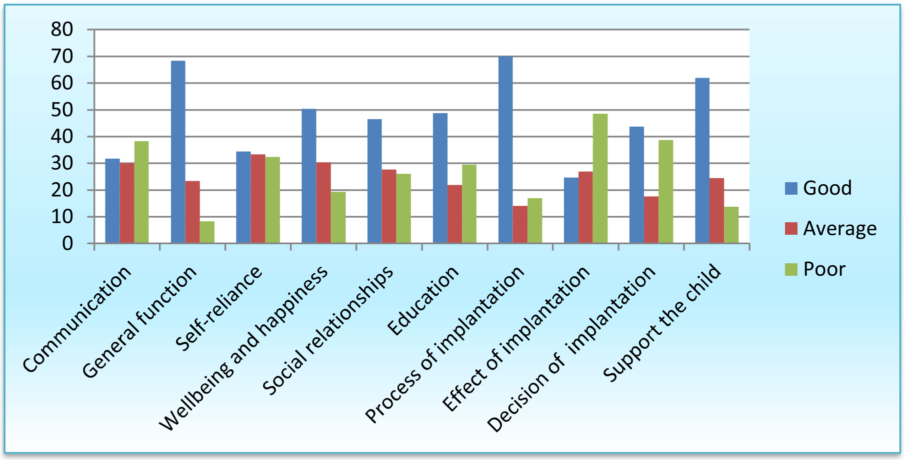

Fig. 3 Distribution of children according to their answers of the PVECIQ-Arabic version domains

of 0, while normal adults could reach 100% discrimination at an S/N ratio −10.

In contrast to the adult subgroup, there was a wide range of variability of performance among CI children as shown in Fig. 6. It ranged from good performers who could reach high scores in speech tests and had discriminative abilities comparable to normal children to poor performers who did not acquire any spoken language and unfortunately used sign language. The good performers could do the PB word test and sentence test "1" in quiet, and this was the most difficult task (11 subjects "50 %"). CI children who could perform properly PBKG and sentence test "2" in quiet were considered average performers (six subjects "27.8 %"). CI children who could only perform PBKG are considered fair performers (three subjects "3.6 %"). The last group of CI children who could only perform WIPI with visual cues represents the poor performers (two subjects "9.1 %").

Among the 24 implanted children who participated in this study, 13 subjects only could perform the sentence test in noise; 11 subjects (84.6%) could perform test "1" and two subjects (15.4%) could perform test "2." When compared to the control group, most of the subjects needed a higher S/N ratio. They could reach 50% discrimination at an S/N ratio +10 without visual cues and at an S/N ratio +5 with visual cues while the majority of normal subjects could reach 50% discrimination at an S/N ratio −10.

Discussion

Studying the long-term effect of CI represents a way to guide professionals and families regarding the therapeutic process and expectations. It also helps in better understanding the factors involved in the development processes needed for communicative, educational, and occupational skills of the CI children [20]. From these points, the current study evaluates the long-term effect of cochlear implantation on speech perception together with the quality of life and communication status in

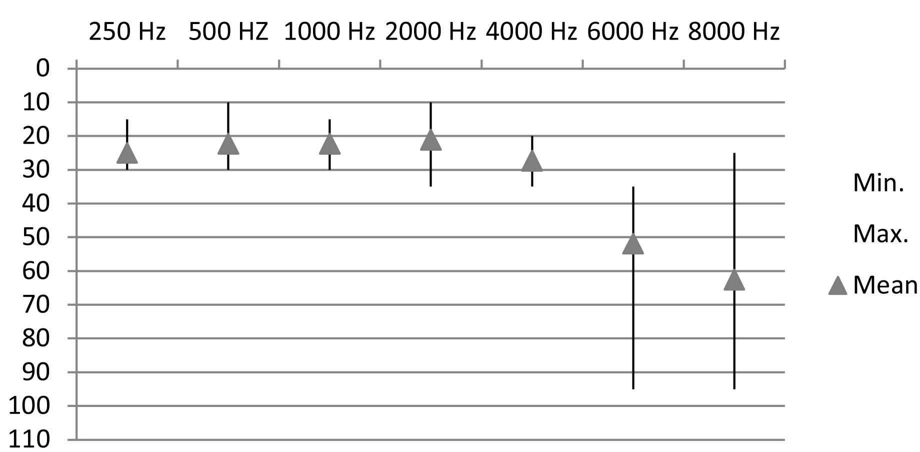

Fig. 4 The mean and range of CI-aided thresholds in adults

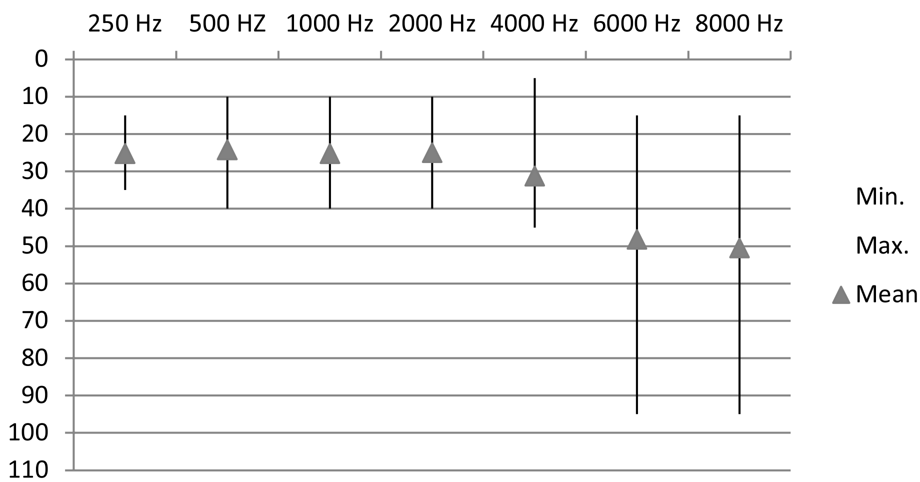

Fig. 5 The mean and range of CI-aided thresholds in children

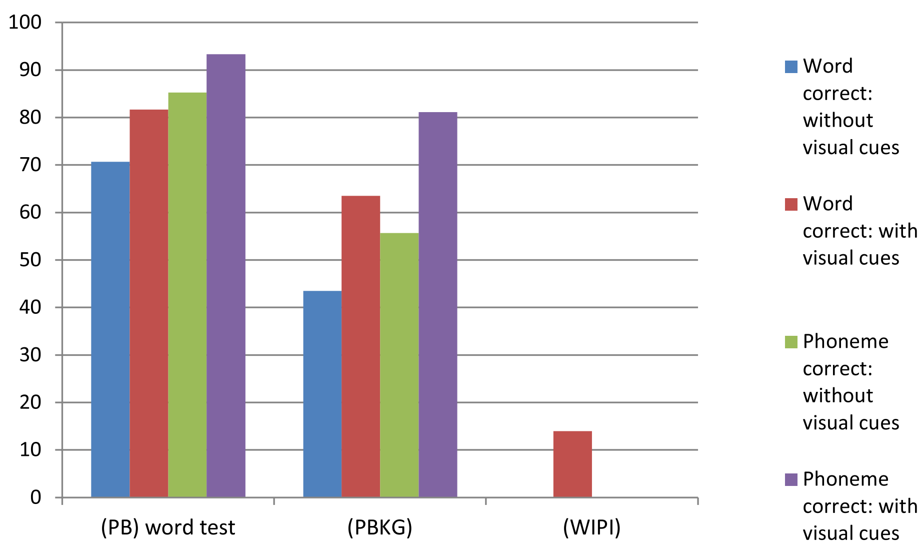

Fig. 6 Mean of different monosyllabic word tests in children subgroup

cochlear implant users (adults and children) who had used their implants for at least 5 years.

Table 1 shows the age, onset and duration of hearing loss, duration of use of CI, and also duration since the last visit to the CI center in the study group in years where most of the subjects (adults and children) in this study used to visit the CI center only on demand after completing the first 2 years of programming. This was attributed to the stability in their performance, distance from CI centers, or lack of the knowledge of the importance of follow-up.

In our study, most of the subjects (81.3% adults and 79.2% children) used their device regularly as shown in Fig. 3. This agrees with Contrera et al. [21] who estimated that between 63 and 96% of pediatric CI users continue to regularly use their implants over periods of 5 to 14 years. The most common reasons for nonuse were poor hearing benefit, social pressure, and recurrent displacement of the transmitter coil. In the present study, irregular use of CI was due to recurrent malfunction of the device.

Regarding the distribution of the etiology of Hl among the study group, it was noticed that the majority of patients had HL of unknown etiology followed by heredofamilial HL as shown in Table 2. However, finding the etiology is crucial as it would affect CI procedure, programming, and outcome.

Among CI users who participated in this study, one adult subject (6.3%) experienced internal device failure after 4 years of primary CI and reimplantation was done with no obvious deterioration of his performance (Table 3). Moreover, two children (8.3%) reported failure of their internal devices after 7 years and reimplantation was done for both of them but they had delayed language development (Table 3). The exact cause of their internal device failure was unknown.

It was reported that 3 to 8% of all cochlear implantation surgeries require revision for a range of indications spanning device failure, electrode array or receiver-stimulator migration/extrusion, and infection/wound complication. It is usually needed 5–13 years postimplantation [22]. Amaral et al. [23] found that 4.3% of the pediatric CI users required revision surgery.

Not only does hearing loss impact speech and language development, which are traditionally assessed at a clinical level, but also hearing loss has influences on self-esteem and emotional, social, and psychosocial development outcomes, hence the value of QoL measures [24].

In the present study, the NCIQ-Arabic version was used for adults to assess the different aspects of QoL. The highest scores were obtained for the physical functioning domain, while psychological and social domains scored the least (Fig. 2). This agrees with Hinderink et al. [10] who reported that the largest improvement was recorded for the basic and advanced sound perception subdomains (physical functioning domain). Some explanations of these low scores appeared through an open interview with CI adult subjects as they pointed to some issues that they face, such as lack of community awareness about CI users where they became part of the normal hearing community and they no longer belong to the deaf community. They also mentioned that they cannot join jobs easily as most governmental agencies refuse to employ them. They are also rejected in clubs and treated as disabled persons. In addition, they are suffering with strange peoples especially in noisy situations so they usually prefer to stay at home, hence the importance of awareness of the community to the problems of hearing-impaired adults and their needs.

The PVECIQ-Arabic version questionnaire was applied for children with CI (Fig. 3). The questionnaire took about 30 min to be filled out. Parents were more satisfied with general function than communication and self-reliance domains. This is in contrast to Stefanini et al. [25] who stated that the social relation and communication domains presented the highest median than the general function domain. Huttunen et al. [13] found that the CI improved the QoL of the children and their parents too. The parents reported being satisfied with the quality of life of their children after 2 to 3 years of CI use.

It is worth mentioning that during the interview with the parents some of their concerns and thoughts appeared as "the high possibility of malfunctioning of the CI device, affordability and availability of spare parts and devices." Moreover, the presence of a single agent for the company all over Egypt with limited branches implies traveling for long distances which is not always an easy task. All the previously mentioned difficulties lead to wasting a lot of time that would be needed for rehabilitation therapy and school.

The previous results of the questionnaire suggest that the percentage scores of QoL domains can be dynamic and changing as therapeutic goals are achieved and new challenges are faced; Almeida et al. [26] emphasized that achievements earned within a certain time after CI activation do not minimize parents' doubts and insecurities regarding the next steps of development.

Regarding audiological evaluation (Figs. 4 and 5), in the present study, thresholds at 6 and 8 kHz were higher than lower frequencies. It is recommended to evaluate routinely these frequencies in the follow-up of CI users in clinics and not to stop at 4 kHz because of their importance in speech discrimination and quality of sound.

As previously mentioned, one CI adult (subject no. 8) could perform PB only with visual cues, while subject no. 12 could perform PBKG only. This could be attributed to the lack of regular rehabilitation sessions and follow-up, hence the importance of an informative counseling before CI surgery to clarify that implanted adults exhibit different needs for rehabilitation and support postoperatively, besides there is urgency to increase the number of qualified centers for post-CI rehabilitation all over Egypt for easy accessibility. Online rehabilitation gives a new hope to reach CI users in remote residences and should be started as soon as possible. Centers applying online rehabilitation should be established all over Egypt to overcome the lack of technology in rural areas.

Results of speech perception evaluation of the CI adults point to the difficulty experienced by CI users in daily life. It was observed that results of monosyllabic word tests were better than the sentence test (whole meaning). Also, they all needed a positive S/N ratio to reach 50% discrimination compared to normal adults. This result is in agreement with the studies conducted by Capretta et al. [9] and Moberly et al. [27]. In spite of the advances in the technology of speech processors, there is still reduced signal redundancy and processing of noise reduction. Accordingly, bimodal stimulation and the use of FM systems should be encouraged together with central auditory training programs to improve speech in noise discriminative abilities.

Through evaluation of CI children, there were 2 subjects (9.1%) who could only perform WIPI with visual cues only. It is worth mentioning that they use sign language for communication. They had a history of unknown etiology of hearing loss with irregular speech rehabilitation therapy: one of them shifted to sign language by the decision of her parents 2 years postimplantation, and the other shifted upon the advice of his

Table 4 Pearson correlation coefficient correlation between aided PTA threshold and NCIQ-Arabic version subdomains, showing no statistically significant correlation

	r	*p*
Basic sound perception	−0.32	0.26
Advanced sound perception	0.10	0.72
Speech production	−0.05	0.86
Self-esteem	0.34	0.22
Activity limitation	0.14	0.62
Social interaction	0.33	0.24
Total	0.14	0.62

audiologist 3 years postimplantation. They were unable to communicate verbally or by speech reading and therefore had to join the school for the deaf.

Similarly, Barnard et al. [28] found that 6.5% of children had not achieved open-set speech recognition performance after 5 years of implant experience. Factors that may lead to such performance include poorer aided access to sound in the better ear, complicated perinatal history, and low socioeconomic status. These factors were all associated with the inability to develop open-set speech recognition after 5 years of cochlear implant use [28].

Most of the children needed a positive S/N ratio. As a consequence, children with CIs may have difficulty during general classroom discussions or in interacting with classmates during lunchtime. As children with CIs advance through their educational programs, demands on communication skills may become more of a barrier to academic achievement due to varying levels of background noise. Eisenberg et al. [29] highlighted the importance of developments in technology, noise reduction algorithms, assistive technology, and improvements in classroom acoustics to facilitate communication skill development for pediatric CI recipients.

In an attempt to find out whether the assessment conducted in the clinical setting could solely reflect the level of performance of CI users in everyday life, a correlation was held between aided PTA threshold and speech perception tests in the one hand and the questionnaires reflecting QoL on the other hand. Tables 4, 5, and 6 reveal no statistically significant correlation was found between NCIQ or PVECIQ and the clinical tests used. The lack of correlation strengthens the fact

Table 5 Correlation between NCIQ-Arabic version subdomains and speech perception tests in adults, showing no statistically significant correlation

		Basic sound perception	Advanced sound perception	Speech production	Self-esteem	Activity limitation	Social interaction	Total
Phonetically balanced (PB)								
Word correct								
Without visual cues	*R*	0.43	0.03	0.45	0.05	0.06	0.08	0.23
	p-value	0.14	0.91	0.12	0.84	0.83	0.77	0.45
With visual cues	*R*	0.29	0.02	0.30	−0.15	−0.21	−0.14	0.01
	p-value	0.34	0.93	0.30	0.61	0.48	0.63	0.97
Phoneme correct								
Without visual cues	*R*	0.37	−0.08	0.36	−0.08	−0.05	−0.05	0.09
	p-value	0.20	0.77	0.21	0.79	0.86	0.86	0.76
With visual cues	*R*	0.28	−0.03	0.28	−0.20	−0.27	−0.20	−0.04
	p-value	0.34	0.91	0.35	0.51	0.35	0.49	0.88
High-context sentence								
Whole meaning								
Without visual cues	*R*	−0.25	0.17	−0.19	0.12	−0.00	0.06	−0.03
	p-value	0.41	0.59	0.54	0.70	0.99	0.84	0.93
With visual cues	*R*	−0.44	0.24	−0.40	0.00	−0.23	−0.08	−0.20
	p-value	0.15	0.44	0.19	0.98	0.46	0.79	0.53
Last word								
Without visual cues	*R*	−0.34	−0.13	−0.28	−0.21	−0.07	−0.15	−0.24
	p-value	0.26	0.67	0.37	0.50	0.82	0.64	0.46
With visual cues	*R*	−0.55	0.18	−0.53	−0.14	−0.41	−0.22	−0.36
	p-value	0.06	0.57	0.07	0.66	0.17	0.48	0.25

Table 6 Pearson correlation coefficient correlation between aided PTA threshold and PVECIQ-Arabic version domains, showing no statistically significant correlation

	r	*p*
Communication	−0.25	0.25
General function	−0.25	0.25
Self-reliance	−0.23	0.28
Well-being and happiness	−0.10	0.64
Social relationships	−0.34	0.11
Education	−0.34	0.11
Total	−0.35	0.10

that QoL measures should be taken into consideration besides hearing tests to get a full view on the effect of CI on patients' real life. The QoL questionnaires represent an important outcome instrument in the CI process to provide information about the technical improvements, different treatments, and rehab strategies in the future. This was also recommended in many studies [25].

Conclusions

Measurement of outcomes from CI is crucial. It directs the treatment process and allows the planning and execution of rehabilitation strategies focused on the needs of CI users. Counseling of CI users and their families is essential before and after implantation to develop realistic expectation and clarify the variability in performance. Therefore, annual follow-up visits to CI rehabilitation centers are recommended to evaluate and redirect the rehabilitation strategies, if needed.

Formal audiological assessments in the form of aided threshold and speech perception tests are essential in programming and qualitatively assess the progress in performance. However, it must be complemented by QoL questionnaires which give information about the different aspects (self-esteem, daily activities, and social functioning) not explored through formal speech perception tests and capture a broader view on the patients' daily life. Hence, the use of QoL questionnaires is recommended in CI rehabilitation centers and clinics to evaluate the consequences of implantation surgery and refines the rehabilitation process.

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Authors' contributions
Conceptualization, ISE, DMH; methodology, AEE and EMG; software, AEE and EMG; formal analysis, EMG and AEE; investigation, ISE, DMH, AEE, and EMG; resources, ISE, DMH, AEE, and EMG; data analysis, ISE, DMH, AEE, and EMG; writing original draft preparation, AEE and EMG; writing—review and editing, ISE, DMH, AEE, and EMG; supervision, ISE, DMH, and EMG; project administration, EMG and AEE; all authors have read and agreed to the published version of the manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request

Declarations

Ethics approval and consent to participate
This study was approved by the research ethical committee (REC), Ain Shams University. Written consent was obtained from adults and children's parents prior to contribution in the study after clarifying the importance of the study.

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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