# The side of cochlear implantation and speech intelligibility in pediatric and adult cochlear implantees

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**Background**
A cochlear implant (CI) is an auditory prosthesis that stimulates the primary auditory nerve fibers electrically to elicit sound perception in individuals with severe-to-profound sensorineural hearing impairments. Speech intelligibility is a joint product of a speaker and a listener and can provide a close approximation of an individual's everyday communication status, and cochlear implants can facilitate the development of speech and language skills in prelingually deaf patients.

**Aim**
The aim of this work was to study whether there is an advantage of one ear in the improvement of speech intelligibility in pediatric and adult cochlear-implanted patients.

**Study design**
A cross-sectional study to assess the speech intelligibility of right and left cochlear-implanted patients.

**Patients and methods**
The study included 50 cochlear-implanted patients (24 male and 26 female): 25 of the patients were prelingual and 25 were postlingual. Twenty-six of the patients were implanted on the right ear and 24 were implanted on the left ear. Speech intelligibility assessment was conducted using the Arabic Speech Intelligibility test. This Arabic Speech Intelligibility test is meant to be an objective measure as the examiner does not have to evaluate how a word was said.

**Results**
The results revealed that there was no significant difference between the speech intelligibility percentage regarding the onset of deafness (prelingual or postlingual), the sex and the duration of therapy, but there was a significant difference between the speech intelligibility percentage in right-ear-implanted and left-ear-implanted patients, with marked advantage for the implanted right ear.

**Conclusion and recommendation**
Right-ear cochlear implantation has an advantage over left-ear implantation regarding the speech intelligibility. Hence, in case of bilateral profound deafness of the same degree with no anatomical complications in either of the ears, it is recommended to choose the right ear for cochlear implantation.

**Keywords:**
cochlear implant, right ear, speech intelligibility

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## Introduction

A cochlear implant (CI) is an auditory prosthesis that stimulates the primary auditory nerve fibers electrically to elicit sound perception in individuals with severe-to-profound sensorineural hearing impairments. A substantial number of studies have demonstrated that the use of CIs can facilitate the development of speech and language skills of children who are prelingually deaf (born deaf or become deaf before age 3) [1].

CIs are primarily aids to sound perception, but in both adults and children, they can also aid in the production of spoken language. Speech and spoken language of children with CIs have been examined at several structural levels, including the articulatory, the phonological, and the morphological levels. For communication, however, overall speech intelligibility is the gold standard for assessing the benefit of cochlear implantation for the production of speech, because it addresses directly the communicative function of language. Speech intelligibility involves the transmission and the reception of linguistic information and meaning [2].

The term 'speech intelligibility' refers to the degree to which a speaker's intended message can be recovered by other listeners [3]. Speech intelligibility is a joint product of a speaker and a listener and can provide a close approximation of an individual's everyday communication status with regard to how well the individual can be understood by other listeners [4].

Although children with normal hearing achieved adult-like or near-adult-like speech intelligibility by around 4 years of age or shortly thereafter, children with CIs were considerably less intelligible than their chronological-age peers with normal hearing at all ages; the speech intelligibility of children who use CIs dating from the early 1990s to ~1998 have been reviewed by Svirsky and Chin [5], and the main results from previous research are as follows: (a) children's speech intelligibility improves from before implantation to after implantation, and then further improves with increased use of a CI and (b) CIs support the development of speech production intelligibility at least as well as conventional hearing aids (depending on factors such as the length of the device used, the age at device fitting, and the amount of residual hearing). Changes of speech production in postlingually deafened adults after receiving a CI are more subtle than those observed in prelingually deaf children [5].

It is well accepted that a majority of individuals (>90%) demonstrate left-hemisphere dominance for language [6]. Most individuals show a right-ear advantage for speech stimuli on dichotic listening tasks [7]. This right-ear advantage for verbal input has been attributed to the right ear having privileged access to left hemisphere. Consistent with this notion, poorer speech recognition, poorer performance, greater academic difficulty, and lower performance on speech tasks have been noted with right-ear unilateral hearing loss compared with children with left-ear unilateral hearing loss [8]. Patients make multiple errors in the articulation of specific sounds and sound patterns and are often unintelligible because they produce few words accurately [9].

## Aim

The aim of this work was to study the advantage of right-ear cochlear implantation over left-ear cochlear implantation in the improvement of speech intelligibility in pediatric and adult cochlear-implanted patients.

## Patients and methods

A cross-sectional study assessing the speech intelligibility of right/left cochlear-implanted patients. The study included 50 cochlear-implanted patients (24 male and 26 female) from the Phoniatrics Unit, Ain Shams University Specialized Hospital. Twenty-five of the patients were prelingual and 25 were postlingual. Twenty-six of the patients were implanted on the right ear and 24 were implanted on the left ear (the mean age for prelingual children was 5.94 ± 1.44 years, and the mean age for postlingual patients was 26.12 ± 8.69 years). The patients had the following inclusion criteria:

(1) Bilateral profound sensorineural hearing loss before cochlear implantation.
(2) No medical history other than deafness.
(3) Implanted with either Nucleus 24 (Cochlear Corporation, Melbourne, Australia) or Med-El (Medical Electronics (Med El) corporation, Innsburck, Austria) device.
(4) The mean ± SD age at implantation was 4.62 ± 1.38 years in prelingual patients and 24.85 ± 9.21 years in postlingual patients.
(5) The mean ± SD duration of hearing loss was 4.35 ± 1.29 years in prelingual patients and 4.22 ± 2.12 years in postlingual patients.
(6) The mean ± SD duration for implant activation was 18.23 ± 4.11 months in prelingual patients and 17.92 ± 3.81 months in postlingual patients.
(7) The duration of phoniatric therapy received was minimum 12 months to maximum 18 months.
(8) Regular attendance of therapy sessions.
(9) Patients with irregular attendance were excluded.
(10) All patients received structured auditory and language therapy sessions with a mean of three sessions per week (40 min each).
(11) Each patient can utter at least three-word sentences for prelingual children and fully developed language in postlingual patients.

All patients were subjected to the following:

Personal history, language assessment by an Arabic language test [10], psychometric evaluation, and the speech intelligibility test [11].

The speech intelligibility of the patients was assessed using the Arabic Speech Intelligibility test. This Arabic Speech Intelligibility test is meant to be an objective measure. The test is composed of 100 cards carrying 50 pictures (each picture is repeated twice). The pictures are structurally organized into three sets as follows:

(1) Set A includes 20 pictures of monosyllabic words that start with bilabial, nasal, epicodental, and supra-alveolar consonants.
(2) Set B includes 20 pictures of monosyllabic words that start with dorsopalatal, uvular, velar, and pharyngeal consonants.
(3) Set C includes 10 pictures indicating simple action–verb sentences.

The pictures of each set are shuffled carefully and presented one by one to the patient who is asked to

name what is in the picture. Thereafter, the clinician will write down what he heard from the patient in the clinician response form. The Arabic Speech Intelligibility test is designed to provide an estimation of the overall speech intelligibility of patients by providing a total score in terms of percentage. The patient's task is to say the pictured word correctly enough so that the listener can decide which word, among the 20 or 10 possible choices, he/she was trying to say. Although the examiner knows the set of 20 (or 10 in sentences) possibilities, the examiner does not know which word the patient will try to say on any given test item. Therefore, the examiner does not have to evaluate how a word was said but only whether the quality of articulation was functionally good enough to make the word understandable. The assessment was performed by two expert phoniatricians and the results were obtained. The number of correct responses by the examiner is tabulated and a percent score is calculated. This score represents the patient's speech intelligibility.

#### Data management and analysis

The collected data were revised, coded, tabulated, and introduced into a PC using the statistical package for the social sciences (SPSS 15.0, 2001; SPSS Inc., Chicago, Illinois, USA) for Windows. Data were presented and suitable analysis was performed according to the type of data obtained for each parameter.

(1) Descriptive statistics:
   (a) Mean.
   (b) SD.
   (c) Minimum and maximum values (range) for numerical data.
   (d) Frequency and percentage of non-numerical data.
(2) Analytical statistics:
   (a) The independent samples *t*-test was used to assess the statistical significance of the difference between two study group means.
   (b) The $\chi^2$-test was used to examine the relationship between two qualitative variables.

*P*-value was used to determine level of significance; *P*-value more than 0.05 was considered nonsignificant (NS), *P*-value less than 0.05 was considered significant (S), *P*-value less than 0.01 was considered highly significant (HS).

## Results

Comparing the speech intelligibility percentage and severity regarding the onset of deafness (prelingual or postlingual), the sex and the laterality (the side of cochlear implantation: right ear or left ear) revealed that there was no significant difference between the mean of the speech intelligibility percentage in prelingual and postlingual patients, and there was also no significant difference between the mean of the speech intelligibility percentage in male and female patients, but there was a highly significant difference between the mean of the speech intelligibility percentage in right-ear-implanted and left-ear-implanted patients, with marked advantage in patients with the implanted right ear (Table 1).

Comparing the results of the mean of the speech intelligibility percentage regarding the laterality (the side of ear implantation: right or left) in prelingual and postlingual cochlear-implant patients revealed that there was a highly significant difference between the mean of the speech intelligibility percentage in right-sided and left-sided prelingual cochlear-implant patients, with an advantage to the right ear. There was also a highly significant difference between the mean of the speech intelligibility percentage in right-sided and left-sided postlingual cochlear-implant patients, with advantage to the right ear. The highest mean of the speech intelligibility percentage was recorded in right-ear postlingual cochlear-implant patients and the lowest mean of the speech intelligibility percentage was recorded in the left-ear prelingual cochlear-implant patients (Table 2 and Fig. 1).

Correlation of the percentage of speech intelligibility with the duration of therapy among prelingual and postlingual CI showed that the speech intelligibility

**Table 1 Comparison of the percentage of the speech intelligibility regarding the cochlear-implant site, the sex and the laterality using the independent samples *t*-test**

| Percentage of the speech intelligibility test | *N* | Mean | SD | *t* | *P* |
|---|---|---|---|---|---|
| Cochlear implant | | | | | |
| Prelingual | 25 | 45.12 | 22.430 | −1.367 | 0.178 |
| Postlingual | 25 | 54.48 | 25.854 | | |
| Sex | | | | | |
| Males | 24 | 54.38 | 24.491 | 1.281 | 0.206 |
| Females | 26 | 45.58 | 24.042 | | |
| Laterality | | | | | |
| Right | 26 | 67.12 | 19.660 | 7.752 | 0.000 |
| Left | 24 | 31.04 | 11.994 | | |

**Table 2 Comparison of the percentage of the speech intelligibility regarding the laterality among prelingual and postlingual cochlear implant using the independent samples *t*-test**

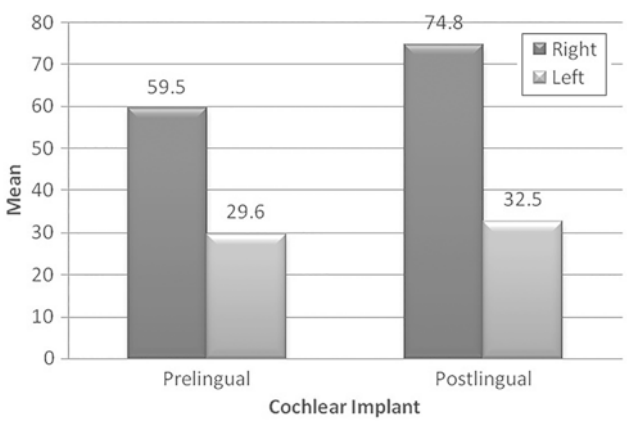
| Laterality | Cochlear implant | | | | | |
|---|---|---|---|---|---|---|
| | Prelingual | | | Postlingual | | |
| | Mean | SD | *P* | Mean | SD | *P* |
| Right | 59.46 | 20.484 | 0.000 | 74.77 | 16.084 | 0.000 |
| Left | 29.58 | 11.556 | | 32.50 | 12.753 | |

percentage increases as long as the duration of therapy increases in prelingual cochlear-implant patients, but there was no significant difference between the right or the left ear. Among the postlingual cochlear-implant patients, there was no significant difference between the percentages of speech intelligibility in patients with the implant in the right or the left ear regarding the duration of therapy (Table 3).

## Discussion

The results of this study indicated that prelingual and postlingual cochlear-implanted patients with the implant on their right ear showed better speech intelligibility than those implanted on their left ear. This could be explained by the right-ear advantage for verbal stimuli in normal-hearing individuals. The auditory region in each cerebral hemisphere receives sensorial stimuli from both ears, but it is more activated by the stimulation from the contralateral ear [12]. The language and speech centers are located in the left cerebral hemisphere, and so implantation of the right ear would provide the best auditory results. However, it must be taken into account when selecting the side of cochlear implantation that both ears are similar in their residual hearing and there are no anatomical restrictions in any of them. The right-ear advantage has been shown in other studies [13,14]. The performance of children with unilateral right-ear deafness was significantly poorer than that of children with left unilateral deafness in linguistic subtests of the Wechsler Intelligence Scale. Another study showed that prelingually deafened children with right cochlear implantation outperformed children with left cochlear implantation in speech perception [15]. A study conducted on adults with postlingual deafness to a severe to profound degree showed that the patients implanted on their right ear presented answers in the tests of speech perception significantly better than the patients implanted on the left ear [16]. Morris *et al.* [17] found no significant differences in speech perception abilities in large matched groups of adults with right compared with left cochlear implantation. Another study on a combined group of prelingual children and postlingual adults using cochlear implantation showed no significant differences between patients who were implanted on their dominant ear (based on handedness) and patients implanted on the nondominant side [18].

**Figure 1**




Percentage of the speech intelligibility regarding the laterality among prelingual and postlingual cochlear implant

**Table 3 Correlation of the percentage of speech intelligibility with the duration of therapy among prelingual and postlingual cochlear implant using the Pearson correlation test (*r*)**

| | Correlation test | % of the test | | | | | |
|---|---|---|---|---|---|---|---|
| | | Prelingual | | | Postlingual | | |
| | | Overall | Right | Left | Overall | Right | Left |
| Duration of training in months | Pearson's correlation (*r*) | 0.199 | 0.446 | 0.062 | −0.265 | 0.054 | 0.141 |
| | *P* | 0.340 | 0.123 | 0.848 | 0.200 | 0.861 | 0.663 |

In the present study, it was found that the speech intelligibility improved with increased duration of therapy in prelingual cochlear-implanted patients. The improvement with increased duration was also proved in other studies such as that of Allen *et al.* [19], where the speech intelligibility was evaluated yearly for 5 years, showing continuous improvement; the same finding was found by Calmels *et al.* [20]. However, in the present study, no improvement with increased therapy duration was found in the postlingual implanted patients. A study conducted by Lenarz *et al.* [21] on postlingual cochlear-implanted adults showed improved performance in the first 6 months after implantation, and afterwards, the performance entered a plateau phase in which no statistically significant improvement or deterioration were observed for more than 20 years of follow-up. As the present study was conducted after 12 months of therapy or more, so the postlingual implanted patients were in the plateau phase, showing no improvement with increased duration of therapy. In contrast, another study found improved performance in postlingual implanted patients with increased duration of implant use [22].

It was also found in this study that the speech intelligibility was independent of the sex of implanted patients. This was also seen in other studies [23,24].

In this study, despite the mean percentage of the speech intelligibility of the postlingual implanted patients being higher than that of the prelingual implanted patients, which may be due to the presence of previous auditory experience of the postlingual deafened

patients with spoken language, there was no significant difference between them. The nonsignificant difference may be due to the presence of left-ear implantation in both prelingual and postlingual implanted patients who have a lower percentage of the speech intelligibility or it may be due to the presence of early-implanted and late-implanted patients, which needs further investigation on a larger group of implanted patients.

## Conclusion and recommendation

Right-ear cochlear implantation has an advantage over left-ear implantation regarding the speech intelligibility. Hence, in case of bilateral profound deafness of the same degree with no anatomical complications in either of the ears, it is recommended to choose the right ear for cochlear implantation.

## Acknowledgements

### Conflicts of interest

None declared.

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