The Impact of Cochlear Implantation on Sound Quality and Quality of Life in Postlingually Deaf Adults: A Prospective Study

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Original Article

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ABSTRACT

Background: There are few studies reporting on the perceptions of sound quality following cochlear implantation (CI) in everyday listening situations. The current study aimed to determine the subjective perception of sound quality by CI users and identify the relationship between sound quality and health-related quality of life (QoL) following implantation.
Method: During this prospective study, 60 postlingual adults (mean age: 53.13±15.19 years; 34 males) who underwent unilateral CI were enrolled. The Hearing Implant Sound Quality Index (HISQUI19) scale was utilized to determine a CI user's sound quality in everyday listening situations at "one month" and "six months" after implantation. The Nijmegen Cochlear Implant Questionnaire (NCIQ) scale was used to measure the effects of implantation on QoL across pre-CI and "six months" post-CI time intervals.
Result: We found a significant improvement in sound quality from pre-CI (mean: 43.56 ± 23.54) to post-CI (mean: 76.86 ± 21.17) phase (p<0.001). An improvement in sound quality was reported by 89% of CI recipients. A significant improvement in all NCIQ subscales after cochlear implantation was observed (p<0.001), greatest benefit was in the basic sound perception domain. There was a significant correlation between the total HISQUI19 score and NCIQ subscales.
Conclusion: Our results indicated a high-level improvement in sound quality and substantial change in QoL with the CI as a therapeutic option for postlingually deaf adults. A positive correlation between sound quality and QoL parameters suggests that the enhancement of sound quality in these patients can contribute to their improved QoL.

Key Words: Adult, cochlear implant, quality of life, sound quality.

Received: 28 June 2023, **Accepted:** 10 August 2023

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ISSN: 2090-0740, 2023

BACKGROUND

Cochlear implants (CIs) are successful sensory prosthetic devices providing significant improvements in sound detection, speech understanding, and music perception for patients who suffer from severe to profound degrees of sensorineural hearing loss (SNHL)[1-3]. Despite advances in cochlear implant technology, however, significant perceptual restrictions remain, especially for more complex sounds such as speech in noise, music, and voice emotion[4].

Sound quality could be defined as the perceived richness of an auditory stimulus. It has been suggested that sound quality is reduced in CI users compared to normal hearing listeners[5]. It seems that various aspects of sound may be affected by electrical stimulation, including temporal or spectral (frequency) cues. Frequency perception plays an important role in perceiving of complex forms of sound, including music and speech prosody. In implanted patients, pitch (a perceptual correlate of frequency) perception is profoundly impaired, evidenced by limited pitch change direction identification, pitch discrimination, recognition of pitch-driven musical emotion, harmony perception, and timbre identification[6-8].

Currently, CI candidacy and consequences are determined using free-field thresholds and speech

 DOI: 10.21608/ejentas.2023.220379.1651

perception scores[9]. However, these tools do not consider subjective aspects of the auditory input, such as sound quality or appraisal. It has been shown that CI users generally demonstrate degraded sound quality compared to those with normal hearing listeners[10-12] that may negatively affect their quality of life (QoL).

It has been demonstrated that significant hearing loss is associated with an increased likelihood of experiencing loneliness, isolation, depression, frustration, fear, anger, and hopelessness. Although several studies have reported an improvement in the social, psychological, and physical aspects of the user's life after implantation, the influence of CI on the QoL of these subjects is still a controversial issue[13,14]. Measuring health-related QoL is an essential method for determining treatment efficacy and is typically utilized in conjunction with medical assessment. It seems that the patient's perception of their emotional, physical, and mental health is a beneficial indicator of the success of modern medicine[15,16].

There are few studies reporting on the perceptions of sound quality following cochlear implantation in everyday listening situations, and even less is known about the possible relationship between CI users' self-perceived quality of sound and self-perceived QoL. The purpose of the present study was to determine the overall subjective perception of sound quality by CI users and identify the relationship between sound quality and QoL in postlingual implanted adults.

METHODS

Study design

This prospective study of consecutive cochlear implant candidates was conducted during a period between March 2020 and October 2022. All participants were selected from our national database[17] and met the following inclusion criteria: (i) being post-lingually adults scheduled for their first CI, (ii) having bilateral severe to profound SNHL, (ii) being a native Persian speaker, (iii) keeping the full insertion of the CI electrode array, and (iv) having normal cochlear anatomy. Participants with a history of meningitis, neurological problems, or cognitive disorders were excluded. Adults with cochlear malformations or auditory nerve agenesis were also excluded from the study.

The local ethics committees approved the study procedures (Registration Number: IR.AJUMS.HGOLESTAN.REC.1401.025).

Audiological assessment

In the current study, audiometric measurements were carried out in an acoustic room using an AC40 audiometer (Intracoustics, Denmark) in accordance with ISO 8253-1. All subjects underwent air conduction (AC) pure-tone audiometry at 125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz, as well as the speech perception test before CI surgery. At the follow-up time, a free field (FF) audiometry was performed with the same frequencies with CI using acoustic stimuli delivered from a loudspeaker 100 cm in front of the patients. Speech perception was measured via a verbal perception test of Persian monosyllabic words in a free field. Subjects were asked to repeat the presented words without any visual help. The speech perception results were expressed as percentages (0-100%).

Functional cochlear implant benefit assessment

The subjective benefit of implant use was evaluated using the Hearing Implant Sound Quality Index (HISQUI19) and Nijmegen Cochlear Implant Questionnaire (NCIQ). These tests were performed for all patients and rated by two experienced audiologists as a routine evaluation.

The HISQUI19 is a 19-item hierarchical rating scale that evaluates sound quality in everyday communication environments (e.g., understanding speech on the telephone, TV or radio, listening to unfamiliar speakers, etc.). Each item is answered according to the frequency on a 7-point Likert scale, the endpoints of which are "never" (one point) and "always" (seven points). The total HISQUI19 score is the sum of the individual item scores. A total score of 110-133 indicates "very good"; 90-109 "good", 60-89 "moderate", 30-59 "poor," and <29 is "very poor" sound quality[5,18]. The HISQUI19 test was carried out at two time points:" one month" and "six months" after implantation.

The NCIQ is a five-point hierarchical rating scale utilized to assess health-related quality of life in CI recipients. The NCIQ has six sub-domains: speech production, basic sound perception, advanced sound perception, social interactions, and self-esteem. The questionnaire's total score ranges from 0 (very poor) to 100 (optimal). Each NCIQ sub-domain contains 10 items with five answers varying from ''no'' to ''good'' or ''never'' to ''always''[9,19]. The NCIQ score was determined at two time points: pre-CI and "six months" after CI surgery.

Data analysis

Descriptive statistics were used to report demographic and baseline data. Kolmogorov – Smirnov (KS) and Levene's tests were used to evaluate the normality of the data and the equality of variances, respectively. The scores of the sub-domains and total scores were compared between per-CI and post-CI conditions using paired sample t-test. A *p-value* <0.05 was considered significant.

RESULTS

Sixty postlingually CI users (Female/Male: 26/34) participated in the current study. The demographic and clinical data of participants are shown in (Table 1). All patients received a CI from Cochlear (Sydney, NSW, Australia) (n=35) or MED-EL (Innsbruck, Austria) (n=25).

Our results showed a significant HISQUI19 total score improvement after CI surgery (43.56 ± 23.54) compared to pre-CI (76.86 ± 21.17) condition (Paired sample t-test; $p<0.001$). The mean HISQUI19 total score at 6 months after CI surgery suggests patients had a 'moderate' self-perceived sound quality in their everyday listening situations. Our results also indicated that no patients reported "very poor" auditory benefit, 11 patients reported "poor" auditory benefit, 28 patients reported moderate auditory benefit, 16 patients reported good auditory benefit, and 5 subjects reported "very good" auditory benefit (Figure 1).

The Pearson correlation demonstrated a non-significant relationship between the HISQUI19 total score and age at implantation (r=0.27, $p=0.065$). Stratified analyses also demonstrated that patients younger than 60 years (n=24) at the time of implantation had slightly but not significantly (independent sample t-test, $p=0.267$) higher mean HISQUI19 values than those older than 60 years (n=36) at implantation.

Our results indicated that "gender" did not affect self-perceived auditory benefit (independent sample t-test, $p=0.568$). Patients with a shorter duration of hearing loss (<10 years, n=25) revealed significantly higher (independent sample t-test, $p=0.015$) self-perceived sound quality than those with a longer duration of hearing loss (≥10 years, n=35). We also found that "type of CI prosthesis" (Cochlear or MED-EL) did not significantly affect CI sound quality scores (independent sample t-test; $p=0.653$).

The NCIQ evaluation showed a significant improvement in all subscales after cochlear implantation ($p<0.001$). The greatest benefit was observed in the "basic sound perception" aspect (Table 2).

Pearson correlation was conducted to test the relationship between sound quality and QoL scores following implantation. We found a significant correlation between the mean HISQUI19 total score and mean NCIQ subscales (Table 3).

The median best-aided WRS score in quiet was 19.92 % (±21.03) before implantation and significantly improved to 74.65% (±24.24) six months after implantation (paired sample t-test, $p<0.001$). There was no significant correlation between the mean overall NCIQ levels and WRS scores (in quiet conditions) in implanted patients (Pearson's correlation coefficient = 0.13; $p>0.05$) groups.

Table 1: Participant characteristics

Variable		No. (%)
Etiology of deafness (n) %	Male	34 (53.3%)
	Female	26 (46.7%)
	Congenital	2 (3.33%)
	Meningitis	2 (3.33%)
	Infection	4 (6.66%)
	Trauma	6 (10%)
	Ototoxicity	4 (6.66%)
	Cholesteatoma	6 (10%)
	Meniere	8 (13.33%)
	Otosclerosis	7 (11.66%)
	Unknown	21 (35%)
Side of implant	Right ear	40 (66.67%)
	Left ear	20 (33.33%)
		Mean ± SD
Age (years)		53.13 ± 15.19
Duration of hearing loss (years)		14.78 ± 18.55
PTA4 (dB) in the implanted ear (pre-CI)		95.74 ± 20.26
WRS (%) in the implanted ear (pre-CI)		19.92 ± 28.03

PTA4: Pure Tone Average (500, 1000, 2000, and 4000 Hz); WRS: Word Recognition Score; CI: Cochlear Implant; SD: Standard Deviation

Table 2: The mean (±SD) scores of the NCIQ subscales

NCIQ subscale	Before CI	After CI	*p-value*
Basic sound perception	23.31 ± 13.25	75.64 ± 19.35	<0.001
Advanced sound perception	48.24 ± 23.23	72.49 ± 18.01	<0.001
Speech production	32.15 ± 14.34	67.24 ± 23.18	<0.001
Self-esteem	43.55 ± 17.48	65.37 ± 20.79	<0.001
Activity	42.94 ± 22.33	73.36 ± 23.72	<0.001
Social interaction	40.83 ±17.465	68.94 ± 16.28	<0.001

CI: Cochlear Implantation; NCIQ: Nijmegen Cochlear Implant Questionnaire; SD: Standard Deviation

Table 3: Correlation between the mean total HISQUI19 and NCIQ subscale scores (6 months after cochlear implantation)

NCIQ subscale	r	*p-value*
Basic sound perception	0.31	<0.001
Advanced sound perception	48.24	<0.001
Speech production	32.15	<0.001
Self-esteem	43.55	<0.001
Activity	42.94	<0.001
Social interaction	40.83	<0.001

r= Pearson's correlation coefficient; NCIQ: Nijmegen Cochlear Implant Questionnaire; HISQUI19: Hearing Implant Sound Quality Index

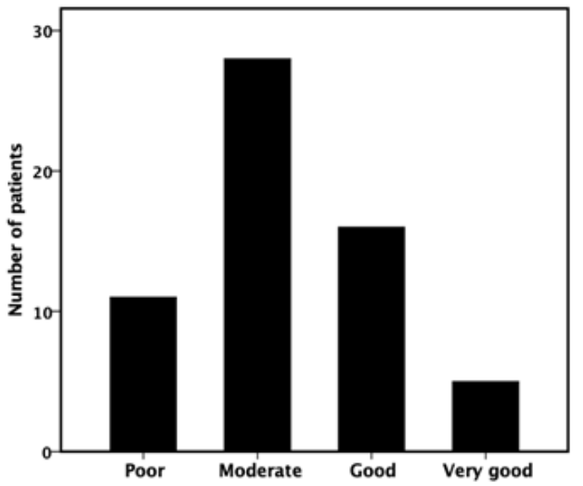

Fig. 1: Frequency of cochlear implant users according to their self-perceived sound quality (HISQUI19 results)

DISCUSSION

In recent years, there has been considerable interest in cochlear implant efficacy, and extensive assessments have been carried out to measure CI users' auditory benefit in everyday listening situations. In this study, we evaluated the functional outcome of the implantation using HISQUI19 and NCIQ scales. As all our included patients had a bilateral severe to profound SNHL, we could assume that the advantages described herein were predominantly due to CI provision, not to the contralateral ear's influence. The HISQUI19 is a convenient scale for clinicians because it is quick, easy to complete, and easy to score. The mean total scores 6 months post-CI (76.86 ± 21.17 points) indicated they had a "moderate" self-perceived sound quality.

Our findings indicated that patients younger than 60 years at the time of implantation had slightly but not significantly greater auditory benefit in everyday communication situations than subjects older than 60 years at implantation. Vermeire *et al*.[20] also found no significant difference in CI benefit outcomes between the postlingually deafened patients older than 70 years and younger than 70 years at the time of implantation regarding the Hearing Handicap Inventory for Adults and the Glasgow Benefit Inventory (GBI). However, Cohen *et al*.[21] also found a significant inverse relationship between self-perceived benefit score and age at implantation for CI users.

In the current study, duration of hearing loss, side of implantation, and gender factors did not affect self-perceived sound quality in CI users. These findings are in agreement with Mertens *et al*.[22] and Amann and Anderson[18] studies

It has been demonstrated that patients with severe to profound hearing loss usually experience fewer relationships, reduced social activities, and increased feelings of isolation. They may also suffer from irritability and depression. CI can improve the adverse impacts of hearing impairment in these groups of patients. Then, the influence of CI use on health-related QoL is important to give CI users realistic expectations of the alternations that they can expect[23].

The NCIQ is a reliable self-assessment health-related QoL instrument specific for CI users to assess physical, psychological, and social aspects of implantation before and after surgery[20,24]. According to the NCIQ, our candidates reported a positive QoL after surgery. In the current study, a substantial increase in QoL following implantation was reported by the great majority of participants. A significant improvement in QoL was observed following CI in all the NCIQ sub-domains, particularly in the "basic sound perception" domain. This finding is similar to Sanchez-Cuadrado *et al*. results who also reported the greatest improvement in the "basic sound perception" domain after implantation[9].

In this study, CI surgery had a tremendous effect on speech perception. However, no correlation was observed between health-related QoL and monosyllabic speech perception ability. This result is similar to Vermeire *et al*.[19], Völter *et al*.[25], and Sanchez-Cuadrado *et al*.[9] studies which also reported no significant correlation between speech perception and QoL scores in implanted patients.

In our study, significant correlations were found between the sound quality (HISQUI19 total score) and psychological, social as well as physical aspects of QoL assessment. This finding suggests that improvement of sound quality in daily situations has a positive impact on different domains of life in implanted patients.

AUTHORS' CONTRIBUTIONS

AB and NS developed the trial design. AB, SN, HB and NS were responsible for data collection. GM and SS were responsible for data analysis. All members of the study team contributed to the management or administration of the research project. All authors read and approved the final manuscript.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

DECLARATIONS

Ethics approval and consent to participate

The study was approved by the ethical research committee of Ahvaz Jundishapur University of Medical Sciences, Iran (approval code: IR.AJUMS.HGOLESTAN.REC.1401.025). Every participant provided their informed permission.

CONFLICT OF INTERESTS

There are no conflicts of interest.

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