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The Factors Influencing Decision Making to Perform Cochlear Implantation and its Outcomes: A Cluster Analysis

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Abstract

Background: The present study aimed to determine the factors affecting the decision of hearing-impaired adults to perform cochlear implantation (CI) and the impact of each factor on the results of hearing quality, speech understanding, spatial hearing, and quality of life (QoL) after implantation.

Methods: In this cross-sectional study, thirty-nine adults with CI completed the Speech, Spatial, and Hearing Quality Scale (SSQ), Quality of Life Standard (SF-12), and Tinnitus Handicap Index (THI) questionnaires. One-way ANOVA and two-step cluster analysis with Schwarz's Bayesian information criterion as clustering criterion were used to analyze the data.

Results: There was a significant difference between males and females in the total score of QoL, physical health, and age of hearing loss (HL) diagnosis, but not in the SSQ questionnaire. In the mental health of all participants, a significant difference was observed in two levels of THI. Age at implantation and income, age of HL diagnosis, duration of CI, degree of tinnitus, and level of education (literacy) play an important role in QoL, speech comprehension, spatial hearing, mental health, and SSQ, respectively. Some patients' decisions for CI surgery consisted of tinnitus before implantation, age, sex, income, and QoL.

Conclusion: Some demographic factors are effective in the process of a person's decision to perform implantation. Besides other implant factors in adult CI candidacy, considering the person's decision may lead to realistic expectations from the surgery and related results, which can be attended to in counseling before implantation.

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Introduction

A Cochlear implant (CI) is a suitable and standard therapeutic option in patients suffering from severe to profound sensory neural hearing loss.[1] According to studies, CI offers many advantages, including improved speech recognition in quiet environments and background noise, increased sound quality, music perception, hearing quality, spatial hearing, and quality of life (QoL).[2-9] In other words, CI directly contributes to improved communication and indirectly ameliorates other social and emotional aspects of the person's life.[10]

Generally, there is substantial variability in the results of CI usage due to the device-associated aspects and various audiological and demographic factors.[11-14] Since the identification of factors affecting the variability of CI outcome is dependent on the outcome domain, and each of these factors plays a diverse role in the different outcomes of the implant, including hearing and speech skills and QoL,[15] their

effect should be examined on each of these skills separately. In addition, given the existence of a weak or lack of correlation between the patient-related factors as well as the scores of speech recognition in most of the previous studies,[16] an investigation of the effects of these factors on the person's perception of hearing and speech abilities through self-assessment questionnaires is critical. In this regard, a recent study has emphasized the importance of using self-assessment questionnaires such as the Speech, Spatial, and Qualities of Hearing Scale (SSQ) as a comprehensive and practical assessment of CI candidacy for adults.[17]

Decision-making for cochlear implantation is affected by many barriers and facilitators.[18] They include fear of surgery, lack of personal motivation,[19] cost of operation,[20-22] patient-oriented factors such as age at CI and duration of hearing loss (HL),[16, 18, 19] having a different priority and importance in studies regarding decision-making for implantation. Accordingly, it seems that for decision-making on undergoing CI, consideration of a set of factors affecting the decision, including self-associated elements, is crucial. Cluster analysis can help determine the factors influencing patient decision-making in several clusters[23] and specify the extent of the importance of factors.[24-26] To the best of our knowledge, the decision criteria according to the patient's view using cluster analysis have not been given yet in adult CI studies.[27] The present study aimed to investigate the factors affecting the decision-making of adult hearing-impaired individuals to undergo cochlear implantation according to the patient characteristics through cluster analysis. The second aim of this study was to explore the effect of these factors on the outcomes of hearing quality, speech recognition, spatial hearing, and QoL of these people following CI using self-assessment questionnaires.

Methods

Participants

Based on the inclusion criteria (age range of 18-80 years), 60 subjects were selected using convenience sampling. Eight out of 60 patients died before the study, and 13 were unwilling to cooperate. Therefor, 39 post-lingually deaf adults with CIs at Fars Cochlear Implant Center, including 23 women and 16 men were surveyed. Inclusion criteria were having undergone unilateral implantation, passing at least one year from the operation, using the device constantly, and receiving rehabilitation services. 27 participants had tinnitus before implantation but only in the eight of them tinnitus was continued after implantation. For illiterate and low-literate individuals, the questionnaires were completed by their children. The informed consent form was signed by all patients. The research was approved by the Shiraz University of Medical Sciences (SUMS) ethics committee with the code number of IR.SUMS.REHAB.REC.1400.013.

Instruments and Data Collection Process

Given the conditions of the coronavirus-19 pandemic, online consent forms and questionnaires were sent, and the relevant explanations were given through phone contact. The Persian version of the SSQ, 12-Item Short Form Health Survey (SF-12), tinnitus handicap index (THI), and a form designed by the researcher for collecting demographic information were changed into online form through the www.avalform.com site.

The SSQ questionnaire evaluated speech recognition, spatial hearing, and hearing quality. Its score ranges from 0 to 100, with higher scores indicating greater ability. The speech hearing subset has 14 items about speech hearing in quiet, background noise, reverberation, and through the phone. The spatial hearing has 16 items about spatial hearing, which determine the direction of sounds and approximate distances. Qualities of hearing component has 17 items dealing with quality of hearing, four subscales of recognition, naturality of sounds and objects, segregation of sounds, and listening effort.[28, 29] This questionnaire has high validity and suitable reliability.[30]

SF12 questionnaire was used for assessing the QoL. This questionnaire is a valid and reliable scale[31] and has 12 items in eight domains with multiple Likert scale.[32, 33] The scores are calculated from 0 to 100, with 0 denoting the worst and 100 the best QoL.[32]

The THI questionnaire was used to determine perceived tinnitus handicap severity. This scale has 25 items in 3 subscales. The items have three answers yes (4 scores), sometimes (2 scores), and no (0 scores). Accordingly, the final score ranges from 0 (no tinnitus handicap) to 100 (the worst possible annoyance). Higher scores indicate more handicaps.[34] It has suitable validity and reliability.[35]

The effect of gender, income, tinnitus before CI, level of QoL, literacy (level of education), age, age at implantation, age of HL diagnosis, duration of HL before CI, hearing aid (HA) use before CI on the cochlear implant decision, and SSQ and QoL questionnaires were investigated.

Statistical Analysis

Data analysis was performed using SPSS software version 26 (IBM Co., Ann Arbore). Mean and standard deviation was used to describe the data. The independent sample t-test, chi-square non-parametric test and Fisher's exact tests were used to compare all variables on the sex variable. One-way ANOVA and 2-step cluster analysis (TSCA) with Schwarz's

Bayesian information criterion[36] as clustering criterion were used to analyze the data. The significance level in all tests was considered 0.05.

Results

Thirty-nine CI adults (41 and 59.5 percent male and female, respectively) with a mean age of 59.13 (SD=13.37) who were implanted in the Fars Cochlear Implant Center participated in this study. According to the results, the mean age at implantation was 46.64 (SD=13.22) years; hence, the mean age for men and women was 49.9 (SD=13.15) and 44.3 (SD=13.05) years, respectively. Among the participants, 64.1% were literate (high school graduation and above). Regarding income, 36.9% earned less than 240 US$ per month (belonging to the middle and low-income community), and 56.4% of the sample's QoL (n=22) was average. The demographic and clinical characteristics of the samples are shown in Table 1.

Regarding the main variables, the mean scores of speech comprehension, spatial hearing, hearing quality, THI, physical health, mental health, and the mean total score of QoL after operation were 53.3 (SD=32.12), 54.87 (SD=35.23), 77.36 (SD=40.45), 58.5 (SD=28.05), 14.36 (SD=3.22), 18.87 (SD=5.05), and 33.23 (SD=7.52), respectively. 30.7% complained about tinnitus after CI. The average age of HL diagnosis was 33 (SD=11.05) years; hence, the mean score for men and women were 37.23 (SD=12.38) and 30.01 (SD=9.15) years, respectively. The mean duration of HL before CI was 13.67 (SD=11.14) years.

There was no statistically significant difference between male and female patients in these variables (t=2.087, P≥0.05). However, a significant difference was seen between male and female patients in the total score of QoL and physical health (males were better) (independent sample t-test=3.643 and 20.123, respectively, P≤0.05) and also in the age of HL diagnosis (independent sample t-test=2.097, P≤0.05). In addition, there was a significant difference in the mental health of participants in two levels (level 1 & 2: slight & mild) of THI (independent sample t-test=3.305, P≤0.05). As shown in Table 2, the fixed effect ANOVA results (7 extracted models) were obtained for the significant variables. The effect size values (Eta squared) demonstrate the effectiveness of seven factors, i.e. age at implantation, age of HL diagnosis, duration of CI use, Tinnitus before CI, literacy, and income on explaining the main variables related to the health status of patients (P≤0.05). The age at implantation has the most effect (F (1, 11)=2.866, Eta squared=0.786) on the level of quality of life (P≤0.05).

Table 1: Demographic and clinical characteristics of the samples (n=39)

Variables	Subdomains	Number of Sample		P value
		n	%	
Gender	Male	29	74.4	--
	Female	10	25.6	
Literacy	Illiterate	4	10.3	0.408[a]
	Elementary	8	20.5	
	Middle School	2	5.1	
	High School	16	41.0	
	Graduated	9	23.1	
Income in US $ per month	Less than 240	14	35.9	0.237[a]
	241-480	6	15.4	
	481-720	10	25.6	
	More than 721	9	23.1	
Level of QoL	Low	4	10.3	0.471[b]
	Middle	22	56.4	
	High	13	33.3	
HA use before CI	Yes	29	74.4	0.264[a]
	No	10	25.6	
HA use after CI	Yes	9	23.1	0.711[b]
	No	30	76.9	
Tinnitus before CI	Yes	27	69.2	0.291[a]
	No	12	30.8	
Tinnitus after CI	Yes	20	51.3	0.894[a]
	No	19	48.7	
Level of tinnitus severity	Slight	3	7.7	0.757[b]
	Mild	2	5.1	
	Moderate	3	7.7	
	Severe	7	17.9	
	Catastrophic	5	12.8	
	Nothing	19	48.7	

[a]Using chi-square to compare men and women. [b]Fisher's Exact Test, Sig. (1-sided); QoL: Quality of Life; CI: Cochlear implant; HA: Hearing Aid

Table 2: Fixed effect ANOVA results of 7 factors (n=39)

Dependent Variables	df	F	Effect Size[a]	Sig.
	7 Fixed Factors:			
	Age at implantation			
Level of QoL	11	2.866	0.876	0.005
	Age of HL Diagnosis			
Speech comprehension	26	2.701	0.739	0.037
	Duration of CI use			
Spatial hearing	27	2.016	0.451	0.050
	Level of tinnitus severity			
Mental health	19	1.544	0.292	0.004
	Tinnitus before CI			
Physical health	37	13.120	0.262	0.001
Total level of QoL	38	7.134	0.162	0.011
	Literacy			
Spatial hearing	34	2.590	0.234	0.050
Quality of hearing	34	2.773	0.246	0.043
Mental health	34	2.785	0.247	0.042
	Income			
Level of QoL	35	3.126	0.211	0.038

[a]Using Eta square (η2), P≤0.05. †P<0.05. QoL: Quality of Life; CI: Cochlear implant; HL: Hearing Loss

Table 3: Cluster quality analysis with Silhouette measure of cohesion and separation (n=39)

Nodes	Importance
Tinnitus before CI	1
Age	0.9372
Gender	0.9021
Income	0.8596
Level of QoL	0.8388
Age at implantation	0.7501
Age of HL Diagnosis	0.5838
HA use before CI	0.5689
Duration of HL before CI	0.5407
Literacy	0.4087
Silhouette measure of cohesion and separation	0.752
n in cluster 1	12
n in cluster 2	11
n in cluster 3	7
n in cluster 4	9
P	0.001

CI: Cochlear implant; QoL: Quality of Life; HL: Hearing Loss; HA: Hearing Aid

Based on the results, age at implantation plays an important role in patients' QoL (effect size=0.876, P≤0.05). The effectiveness of age of HL diagnosis on speech comprehension was 74% (Eta square=0.739, P≤0.05), and effect size of the duration of CI use on spatial hearing was Eta square=0.451, meaning that the measures were high (P≤0.05).

The Cluster Analysis of the Factors Influencing Decision to Cochlear Implantation

Cluster analysis was conducted to understand the decision of patients leading to cochlear implantation surgery based on gender, income, tinnitus before CI, level of QoL, literacy (level of education), age, age at implantation, age of HL diagnosis, duration of HL before CI, and hearing aid (HA) use before CI. The TSCA, with a manual increase of cluster sizes, was chosen. According to Bennassi et al. (2020), TSCA suits a dataset with variables measured on different scale levels.[36] Using this method, clusters of the nodes were identified by first making a pre-clustering, and then using hierarchical methods. The method suits the data set well (Silhouette criterion ≥0.60) as the cluster quality (silhouette measure of cohesion and separation) was calculated for each step as the number of clusters was incremented manually. The main and demographic variables were entered into the model using the TSCA. As shown in Table 3, the importance criterion indicates that tinnitus before CI has the highest measure (100%) and literacy has the lowest score (41%). Additionally, the model below is obtained with a high score in cohesion and separation, 0.752 (P≤0.05).

The silhouette measure of cohesion (closeness) and separation (detachment) is a measure of the overall goodness-of-fit for the clustering solution.[36]

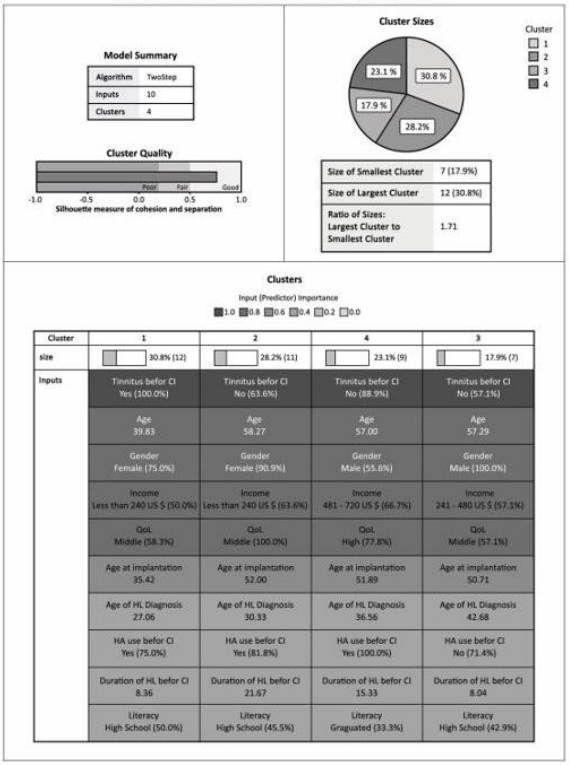

Figure 1: Cluster analysis of factors influencing decision. CI: Cochlear implant; QoL: Quality of Life; HL: Hearing Loss; HA: Hearing Aid

This measure is based on the average distances between the nodes and can vary between -1 and +1; the silhouette measure below 0.20 is a poor solution quality, between 0.20 and 0.50 is a fair solution, and a measure above 0.50 indicates a good solution.[36] The results of this analysis are displayed in Figure 1.

As seen in Figure 1, a solution with 4 clusters resulted in the best cluster quality. The largest cluster (cluster 1) featured 12 patients (30.8% of the data set), and the smallest cluster (cluster 3) consisted of 7 patients (17.9% of the data set) in Figure 1. The size distribution in the clusters was good since no clusters featured the majority of the samples while analyzing with two clusters ($P \leq 0.05$).

Discussion

Gender and SSQ

The results of this study indicate no significant relationship between women and men on the SSQ scale in adult CI users. The effect of gender on the results of this questionnaire has not yet been specifically examined. However, in some of its subsets, including speech hearing, the study of Bodmer et al. (2007) revealed a lack of significant relationship between the two genders.[37] Another study in line with our research showed both genders had a similar performance in monosyllabic and speech tracking tests. However, men scored higher in more complex hearing situations, such as speech in noise tests.[38] In Bergman et al.'s study (2020), women obtained greater speech recognition scores than men.[39]

Gender and QoL

In terms of QoL and physical health, men had higher scores than women, similar to the study of Tokat et al. (2021), which showed higher scores of QoL (not significantly) in men.[40] In the study by Bergman et al. (2020), no significant difference was found between the two genders in the QoL before, one, and three years after CI. However, the notable point was that after one year, men and after three years women obtained higher scores.[39] It generally seems that the men's score in QoL has been higher than women. Studies on hearing-impaired adults[41, 42] and the hearing population[41] showed lower QoL[41, 42] with higher mental distress scores[41] in women compared to men. On the contrary, Nijmegen Cochlear Implant Questionnaire-Portuguese (NCIQ-P) and abbreviated World Health Organization Quality of Life (WHOQOL-BREF) QoL questionnaires found no differences in genders.[43] Possible reasons for differences in outcomes are attributed to the post-operation time of acquisition of the results. In this regard, score changes in the Health Utilities Index Mark 3 (HUI3) QoL questionnaire were observed within the first-year post-cochlear implantation, not in the subsequent years.[44] The types of questionnaires used and the number of participants in different research can be the reason for the existing alterations.

Gender and Age of HL Diagnosis

In the present study, the age of HL diagnosis in women was significantly lower than in men. Although the prevalence of age-dependent HL is higher in men than in

women,[45] it seems that some differences between the two genders would cause younger age of diagnosis in women. Women with severe to profound HL are more likely to receive auditory rehabilitation services (like HA) than men. It may be attributed to the fact that HL has a more considerable negative effect on the daily life of women than men, which can induce greater motivation for them to seek solutions,[45] and therefore, lead to early diagnosis in women. In a recent study, women showed higher anxiety and worries than men in persons with tinnitus.[46] Since one of the causes of tinnitus is HL, higher anxiety and worries may be the reason for earlier diagnoses in women. It is essential to study gender as a biological variable.[47] It seems that the importance of gender in future studies should be investigated because, so far, few studies have addressed it. In most studies, surveys have been conducted on a particular gender, the gender has been noted as demographic information without statistical analysis, or analyses have been done only by adjustment for gender.

Mental Health and Level of Severity of Tinnitus

CI recipients with slight tinnitus had significantly greater mental health than those with mild tinnitus. The level of severity of tinnitus had a direct effect on mental health. The prevalence of tinnitus in CI users is about 10-15%.[48] Those suffering from tinnitus indicated considerable anxiety, depression, and insomnia.[49] In other words, a correlation was found between tinnitus and mental health (symptoms of anxiety and depression) in adults following CI.[50]

Effect of Age at Implantation on the QoL

The results of this study showed that age at implantation had a large direct effect on the QoL. According to previous studies, younger age at surgery predicts a better QoL.[1, 51, 52] Since speech recognition performance decreases as age increases at CI,[53] which can lead to QoL improvement,[54-56] it can be expected that age at implantation would significantly affect the QoL. Unlike this finding, some studies have mentioned no relationship between age at implantation and QoL.[56, 57] The contradiction between the results can be attributed to different tools investigating QoL. In these studies, NCIQ specifically designed for people with CI evaluates the effect of CI on physical, psychological, and social domains. The person's viewpoint about his/her sound recognition and speech production is investigated in the physical domain. This domain is similar to speech hearing and hearing quality domains in SSQ. Similarly, in the present study, age at implantation did not have a direct effect on these variables, which is in line with previous findings.[58-60] The Persian version of NCIQ was not available in the present study.

Effect of Age of HL Diagnosis on the SSQ

According to the present study, age of HL diagnosis had a moderate significant direct effect on the speech recognition subscale of SSQ. The higher SSQ scores for the younger age group compared to older ones have been noted in earlier studies.[38, 61] Nevertheless, in the studies using objective speech tests, age of HL onset did not predict post-implantation speech recognition.[60, 62] Accordingly, age of HL diagnosis can affect the person's attitude about speech recognition performance, but it may not affect the results of objective assessments.

Effect of Duration of CI Use on the SSQ

The duration of CI use had a direct effect of 45.1% on the spatial hearing ability in the present study. Adults with unilateral CI have shown that they can learn normal sound localization provided at least six years of CI use.[8] It suggests that the longer the duration of CI usage, the better the spatial hearing ability.

Effect of History of Tinnitus Before CI on the QoL

Results of the present study showed that the QoL (especially the physical health index) was affected by any history of tinnitus before CI. In agreement with this study, Le Roux et al. (2017) noted tinnitus as a predictor of the QoL in adult CI recipients (lower QoL due to tinnitus before implantation).[63]

Effect of Non-auditory Variables on the QoL

Economic status had a direct effect on the QoL of CI users. The psychological health index was under the influence of the level of education. Previous studies showed that the better the socioeconomic status and the higher levels of education, the greater QoL scores.[9, 10, 14, 43, 63, 64] The level of education affected the results of spatial hearing and hearing quality scores. It suggests that different educational degrees may induce a different understanding of hearing skills, because of discrepancies in the comprehension of questionnaire items. The effect of non-auditory variables, including the level of education, on SSQ scores was shown in previous studies.[65-67]

Cluster Analysis

Based on cluster analysis, the factors affecting the decision-making of adults with HL for undergoing CI operation in order of importance were pre-implantation tinnitus, age, gender, income, QoL, the age at implantation, age of HL diagnosis, history of using HA, duration of HL, and literacy. In CI candidates, the prevalence of tinnitus is 66-86%.[68] Pre-implant tinnitus, which is often reported as permanent and a disabling symptom, is rarely noted in pre-operation assessment.[69] Cochlear implantation can cause reduced tinnitus perception,[70] improvement, and even disappearance.[69] Tinnitus can be influential in accepting CI surgery in adults.[18] In addition to the history of tinnitus, cluster analysis showed that age and gender are other important decision-making

factors; younger women compared to men and older individuals showed a greater tendency to implantation. Similar to this finding, age and gender were different between the two groups with and without CI uptake (the older the[19, 71] men,[19] the lesser the acceptance of surgery). Another effective factor was the person's income. Previous studies have also noted the importance of CI cost in the patient's decision-making.[20-22]

Research suggests that, despite the increase in the number of CI surgeries, the duration of life in adults with severe HL (before CI) is increasing,[72] meaning that the rate of CI uptake has decreased in the US[73] and UK.[73-75] Knowing the person's decision and the pre-operation factors obtained through the cluster can help to increase the appropriate referral and the satisfaction of implantation and, therefore, have a considerable impact on the QoL. Although few studies have used cluster analysis in adults with CI, no one has addressed this analysis in decision-making for cochlear implantation surgery. The clusters obtained in this study can be examined via other statistical analyses in the future. This analysis can also be done in parents with a child who is a candidate for cochlear implantation. It is suggested that the Persian version of the NCIQ (NCIQ-P) questionnaire should be prepared, specifically designed for those with CI. The small sample size and the online completion of questionnaires were the limitations of this study.

Conclusion

Demographic factors can affect the outcomes of CI. These are among the influential factors in the process of decision-making in a person who is going to undergo CI surgery. The person's decision, alongside other factors considered today, may be necessary for CI candidacy, leading to realistic expectations, better acceptance of its outcomes, and reduced anxiety.

Authors' Contribution

A.D., Z.J., and S.O. conceived the presented idea, investigated and supervised the findings of this work. SB.H. conceived the presented idea. A.A. developed the theoretical formalism, and performed the analytic calculations. All authors discussed the results and contributed to the final manuscript.

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