

Using the International Classification of Functioning Model to Gain New Insight into the Impact of Cochlear Implants on Prelingually Deafened Recipients

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Abstract

Objective: Speech perceptions are a traditional measure typically used to diagnose and evaluate outcomes of cochlear implants (CI) in prelingually deafened recipients, but this limits the ability to evaluate all potential outcomes. This study used a new approach which may cover all potential outcomes.

Methods: A new measure based on the World Health Organization-International Classification of Functioning (WHO-ICF) model was used to diagnose and evaluate outcomes of a series of eight patients attended to our tertiary referral center. The patients were prelingual cochlear implant users. The outcomes were evaluated based on the scores in three WHO-ICF model based categories: 1) Quality of Participation Activities, 2) Quantity of Hearing Activities, and 3) Environmental Factors.

Results: Scores were inter-related among the categories. Environmental Factors increased the frequency of participation in hearing activities, but may not necessarily result in better quality or performance for those activities. The quality of life improved with CI for factors including one-on-one conversations, family relationships, enjoyment in music, safety, self-esteem, overall happiness, and level of independence.

Conclusions: Preliminary findings support the use of a WHO-ICF model in evaluating outcomes for the prelingually deafened adult CI users. Quality and frequency of hearing activities were improved in many aspects of the lives of prelingually deafened adults post-CI. This study also highlights the impact of support from family, health professionals and friends on the overall benefits received from the CI.

Keywords: Cochlear implants (CI); Prelingually deafened recipients; International classification of functioning (ICF); World Health Organization (WHO); Speech perceptions

Introduction

Currently, speech perception measures are considered the gold standard for evaluating cochlear implant (CI) outcomes. Evaluation using alternative measures may be needed for the prelingually deafened population as speech-related neural networks may not be well developed in this group. Alternative approaches have been mentioned in the past. For example, Schow & Nerbonne described a CORE assessment model, which incorporated the WHO-ICF specifically for aural habilitation/rehabilitation [1]. Rehabilitation is for all groups including different ages, different disorders, different therapies, and so on. As such, the pre-lingual CI group should be included in using alternative measures such as the WHO-ICF model. In fact, using the ICF model as it relates to hearing was reported in 2007 [2], which was earlier than 2013. Based on the investigators in the field such as Schow & Nerbonne and Hickson & Scarinci [1,2], the application of specific items related to the ICF to the prelingual CI population are still needed. The prelingual CI group contains prelingually deafened adults who have received their CI after the main

critical period in language development. They were either born with profound hearing loss or have acquired profound hearing loss before or during speech development (which can be considered between 1 and 4 years old). Margolis found that if people with profound hearing loss did not develop a concrete language base before 10 years of age, they were limited in the development of more abstract language as adults [3]. Banfai questioned whether or not prelingually deafened adults had mature enough auditory tracts and auditory centers to accommodate CIs. Ali & O'Connell reviewed the literature and found that prelingually deafened children benefited from CI at an earlier age [4,5]. The ICF was established by the World Health Organization (WHO) in 2001 [6]. It is a model whereby participation, activities, environmental factors and personal factors are used to quantitatively measure and determine the barriers and facilitators that go hand in hand with the disability [7]. The intention of this model was to provide a common language across health disciplines that allow data to be consistently compared between centers and even countries [8]. It is believed that the ICF may "likely become the generally accepted framework to describe functioning in rehabilitation" [9]. Given its application to rehabilitation, it may be a good fit for deafened individuals, particularly CI recipients. Five articles could be identified using the ICF model in some specific hearing impaired populations although not in prelingual CI users [9-12]. Two articles were

considered to be more relevant to our study. Smiley et al. [11] discussed two case studies and went into great detail separating each of the four components of the ICF model, as it relates to individuals who are deaf or hard of hearing including: 1) body functions, 2) body structures, 3) activities/participation, and 4) environmental factors. Kennedy et al. obtained the perspective of CI users' significant others and allocated the prospective factors into categories of activities, participation, and environmental factors [13]. They also found some important factors such as confidence, happiness, coping with loneliness, quality of the relationship, communication with the significant other, independence and participation in activities. To the best of our knowledge, our report appears to be the first study to apply the WHO-ICF model to prelingually deafened adults implanted with CIs, even there were recent report using ICF model in different hearing disorders [14,15]. Given multiple investigators have identified the need for an alternative assessment approach, and the ICF model appears to be a promising alternative approach both for hearing populations as well as other populations [1,10-13,16], the application of ICF model in prelingual CI users should be very worthwhile. This study is expected to contribute to the current knowledge-base of the broader effects that CIs can have on these recipients.

Methods

We describe the construction of the questionnaire, tasks of the participants, and the methods of data analysis.

Questionnaire

A number of factors influence the quality of life of pre-lingual deaf individuals following cochlear implantation. We planned to use WHO-ICF to assess the influence. However, no previous experience can be referred to because no articles had been identified in the literature with a questionnaire that was ready to use for this population. A number of articles are related to ICF but not to hearing, or not to the pre-lingual deafness CI users. Thus, we developed a one for our study. We based on the description from ICF, referred to general options from Schow & Nerbonne's article, selected items from the ICF, and modified them to be adapted to the specific group of pre-lingual deafness CI users. To base on the ICF, some basics needed to know. The ICF covers all domains (i.e., all health or health-related domains), all functioning aspects (i.e., body functions, activities or participation), all disabilities (i.e., impairments, activity limitations or participation restrictions), and all environmental factors. So, the ICF cannot be ready to use as a whole as it contains cardiovascular items that are not all appropriate for hearing studies. Therefore, Schow & Nerbonne discussed using ICF in the aural rehabilitation area in general, and provided general options of how to use the ICF so that readers can refer to in developing a specific one to match a specific patient group [1]. For example, the specific group in our study is of pre-lingual deafness CI users. Appropriate length of the questionnaire needed to be determined. If too lengthy, the patients may not be patient enough to complete the whole questionnaire. If too short, the data would be too scant, ended up with 63 items (Appendix A). The Appendix A was tested for the appropriateness of its length by our five authors and several others. It took 20-35 minutes to complete, which seemed appropriate. Of the 63 items, we selected from ICF as many as possible, and then added on them with some other appropriate items as described below. We also ensure that the selected items from ICF were appropriate to the group of prelingually deafened CI users. The 63 items seemed many but was filled up quickly. As a result, the majority of the 63 were from ICF,

which are labeled with a bullet "•" in the Appendix A. Several of the 63 were from literature, which are not labeled. To our knowledge, these items from literature are important for the cochlear implant area. A few of the 63 were from ourselves, which are labeled with an asterisk "*". They are important based on our clinical experience for prelingual deafness CI users. The 63 items are lined up with the ICF categories. Of the 63 questionnaire items (Appendix A), 30 are related to "Quality of Participation Activities" (A1-A30, pg. 2 in Appendix A), 7 are related to "Personal Factors" (A31-A37), 6 are related to "Quantity/frequency of (Hearing) Activities" (B1-B6, pg. 1), and 9 items are related to "Environment Factors" (C1-C9, pg. 3). The remaining 11 items are related to "Personal Information" (age, gender, marriage, and formal education) and effect of CI on their employment (pg. 1 in Appendix A). These categories are related to those in the ICF. We also added a conversation interview item (Appendix B) which was designed to obtain some extra information for explaining the data from the written questionnaire.

Participants and their tasks

This study was approved by the Institutional Review Board of the University of Alberta, and all participants were provided informed consent. Participants were asked to fill a 63-item questionnaire (Appendix A), and two of them agreed to be interviewed (Appendix B).

Our criteria was adults with severe to profound hearing loss before age four who received their CI after age seven. Of the CI recipients served at Glenrose Rehabilitation Hospital, we were able to obtain consent from 8 participants. Their personal information was collected in the Questionnaire (pg. 1 in Appendix A), and are listed as follows:

Gender: males x3, Female x5

Marriage status: married x6, not x2

Employment: employed x3, self-employed x2, volunteer work x1, retired x1, and housewife x1

Age: average 45.5 years, range 21-70 years

Post-CI duration: average 8.2 years, range 4-13 years

Data analysis

Besides trying to apply the ICF in assessing prelingual CI users, we had two more hypotheses related to the ICF related categories in our study, e.g., 1. The CI can benefit some of prelingual subjects in Quality of Participation Activities, and 2. Better Environment Factors may lead to higher Quality of Participation Activities. If the first hypothesis is confirmed, a prelingually deafened subject may reasonably be a potential CI candidate. If the second hypothesis is confirmed, emphasizing improving environment may be an important factor to improve the outcome of CI in prelingual uses. To test the hypotheses, we divided subjects into two groups (4 subjects per group): one with high scores, and one with low scores. High score group can indicate that the CI benefits the CI users, which then can confirm the hypothesis 1 (or the first hypothesis). If the environment factors are better in the high score group than in the low score group, the second hypothesis may be supported. We use one criteria in dividing high or low score groups. Of 37 "A" items in Appendix A (A1-A37 on pg. 2), the participant could check (i.e., select) only one of 5 options (No response, Worse, Unchanged, Slightly better, or Better, much better). Selecting "much better" means a higher score.

Those participants who select the “much better” for two items, A27 ‘Self-esteem’ & A33 ‘Music enjoyment’ were placed in the high score group. So four subjects were placed in the high score group, and rest four in the low score group. The ‘Self-esteem’ is a high level factor in quality of life, and the ‘music enjoyment’ is high level of auditory function. With two groups determined, the number of checked options within whole groups was counted. For example, of 37 “A” items (i.e., category of “Quality of Participation Activities”), each subject can check 37 times, i.e., for each item, only one of 5 options (much better, better, etc.) can be checked. Total counts for one group (i.e., 4 subjects) would be 148 counts (i.e., 4 subjects x 37 items). In high score group, as shown on Table 1 (Column A), of 148 counts on “A” items, 71 counts were the checks on “much better”, and 77 counts were the checks on

the rest four options (i.e., No response, Worse, Unchanged, Slightly better, or Better). In low score group, of 148 counts, 14 were the checks on the “much better”, and 134 were the checks on the rest four options. For the quality or descriptive analysis, based on the counts listed above, the high score group was obviously benefited by CI more than the low score group. We have attempted conducting quantitative analysis as well by using Chi-square test. The total counts of “much better” for both groups was 85 (71 + 14). Of the total 85 counts, the rate for “much better” in high score group is 83.53% (i.e., 71/85). The Chi-square value was used to compare the two groups based on the rates of “much better” and of the rest four options, and p value was derived based on the Chi-square value. For the results of the Chi-square test, see the Results section for more details.

Table 1. Counts checked by participants & Comparison between high and low score groups.								
A. Participants’ responses on “Quality of Participation Activities”			B. Participants’ responses on “Quantity/ frequency of Hearing Activities”			C. Participant responses on “Environment Factors”		
Rating (Counts): “Much better” vs. Rest	High-Score Group	Low-Score Group	Rating (Counts): “Often” vs. Rest	High-Score Group	Low-Score Group	Rating (Counts): “Made it” vs. Rest	High-Score Group	Low-Score Group
Counts that the “Much better” was checked	71	14	Counts that the “Often” was checked	19	16	Counts that the “Made it much easier” was checked	29	12
Counts that the rest was checked “No response, Worse, Unchanged, Slightly better, or Better”	77	134	Counts that the rest was checked “Never, Rarely, or Sometimes”	5	8	Counts that the rest was checked “No effect, or Made it slightly easier”	7	24
Rate of the above 2 sets of counts	0.92 (71/77)	0.1 (14/134)	Rate of the above 2 sets of counts	3.8 (19/5)	2.0 (16/8)	Rate of the above 2 sets of counts	4.1 (29/7)	0.5 (12/24)

Table 1: Counts checked by participants & Comparison between high and low score groups.

In the same way, the counts for 6 “B” items (category of “Quantity/ frequency of Hearing Activities”) were obtained, so were the counts for the 9 “C” items (category of “Environment Factors”). The Chi-square test was run for these two categories as well. See the Results section for the results.

Results

Quality of participation activities and comparison 1

This category “Quality of Participation Activities” is related to “A” items. As described in the Methods section, of 37 “A” items, each subject can check 37 times, and total counts for either group can be 148. In the high score group, of 148 counts on “A” items, 71 counts were the checks on the option “much better”, and 77 counts were the checks on the rest four options as shown on Table 1 (Column A). In the low score group, of 148 counts, 14 were the checks on the “much better”, and 134 were the checks on the rest four options. For these quality or descriptive analyses, the results obviously show that the CI

benefited the high score group substantially more than the low score group as the rate inside the group is around 92% (71/77) for the high score group, while only around 10% (14/134) for the low score group. For the quantitative analysis we attempted using Chi-square test. The total counts of the “much better” option for both two groups was 85 (71+14), the rate for the “much better” option in high score group is 83.53% (i.e., 71/85), the rate in low score group is 36.49% (14/85). The total counts for the rest four options was 211 (77+134), the rate for the rest four options in high score group is 36.49%, and in low score group is 63.51%. By comparing the two groups based on these four rates, the Chi-square value was calculated, which is much greater than 3.84. Based on degree of freedom $n' = 1$ and the Chi-square value, the p value is much smaller than 0.05 ($p < 0.05$). So, the difference between the two groups on the “A” items of category of “Quality of Participation Activities” is significant, indicating that the CI benefitted the high score group more than the low score group for this “A” category. The high-score group shows greater quality of participation activities, and so, the CI can benefit some of prelingual subjects in Quality of Participation Activities.

Quantity/frequency of hearing activities and comparison 2

This category is related to “B” items. Of 6 “B” items, each subject can check 6 times. Total counts for the either group can be 24 counts (4 subjects x 6 items). In the high score group, of 24 checks on “B” items, 19 counts were the checks on the option “often”, and 5 counts were the checks on the rest three options (Never, Rarely, or Sometimes), as shown on the Table 1 (Column B). In the low score group, of 24 counts, 16 were the checks on the “often”, and 8 were the checks on the rest three options. For the quality or descriptive analysis, the high score group tended to be benefited by CI more than the low score group as the rate inside the group is 380% (19/5) for the high score group, while only 200% (16/8) for the low score group, showing that 380% is almost two folds than 200%. For the quantitative analysis, the same Chi-square test was attempted. The Chi-square value comparing the two groups was much smaller than 3.84, and so, the p value is greater than 0.05 ($p > 0.05$). So, the difference between the two groups for the “B” items of category of “Quantity/frequency of Hearing Activities” is not significant.

Environmental factors and comparison 3

This category is related to “C” items. Of 9 “C” items, each subject can check 9 times. Total counts for either group were 36 (4 subjects x 9 items). In the high score group, 29 counts were the checks on “made it much easier”, and 7 counts were the checks on the rest two options (No effect, or Made it slightly easier), as shown on Table 1 (Column C). In the low score group, 12 were the checks on the “made it much easier”, and 24 were checks on the rest two options. For the quality or descriptive analysis, the score is obviously better in the high score group than the low score group, because the rate inside the group is 410% (29/7) for the high score group while only 50% (12/24) for the low score group. For the quantitative analysis, by comparing the two groups, the Chi-square value was much greater than 3.84, so the p value is much smaller than 0.05 ($p < 0.05$). So, the difference between the two groups on the “C” items of category of “Environment Factors” is significant. By consider the two categories together, both the differences between two groups are significant (i.e., < 0.05) in the results in both the “C” category “Environment Factors” and the “A” category “Quality of Participation Activities”. The two significances indicate that two scores in the “C” categories and in the “A” categories are correlated.

Job satisfaction

Of the 6 employed subjects, 83% stated that their job had improved since receiving their CI. Two out of 6 participants indicated that the CI resulted in a good change in their employment.

Expectations for the CI treatment: Seven participants have responded to this item. Of these responses, 71% stated that they had high expectations, and 29% stated they had moderate expectations. Even if the expectation is high in 71% of them, all participants (100%) said that their expectation was met or surpassed. One of them with expectations surpassed described “expected the CI to be only a little better than the hearing aid, but it is a lot better”. One with expectations fully met described “It is a big difference in my life. I can hear very well with my CI.” One with expectations partially met described “It only matched my expectation to a certain degree, I was hoping not to have to rely as much on lip-reading.”

Discussion

Rationale for using the ICF questionnaire: We see the need to collect alternative forms of information regarding prelingual CI usage and effectiveness beyond just speech perception tasks based on the nature of this special population or group, the difference in approach of questionnaire from speech perception, the benefits of using ICF model, and the view from many other investigators in the field [17,18]. Previous research has found that adults with prelingual deafness often have limited speech perception or recognition gains from CI [19]. An objective study using positron emission tomography (PET) suggested that prelingually deafened individuals may not have completely developed speech-related neural networks, even after implantation, because the speech acquisition period has passed [20]. Therefore, obviously, the prelingual population is different from other types of groups such as postlingual group. Therefore, using speech recognition as a primary outcome measure may not be a full representation of the positive impact that a CI can have on this population including their enhanced ability to participate effectively in society [21]. These findings suggest that using a more holistic approach to evaluate the effectiveness of CIs in the prelingual population may help shed light on the discrepancy between objective and subjective benefits. One approach alternative to speech perception is to assess quality of life as it is an important factor. Studies have explored quality of life issues in the prelingual cochlear implant population, although not yet adopted the ICF model. Banfai, Karczag & Luers showed there were improvements in social activities and understanding of language in adult prelingually deafened CI users [22]. Although speech perception in postlingually deafened recipients remained better, the improvement of the quality of life in prelingually deafened recipients is obvious [23]. In addition, despite a lack of objective auditory gains, prelingually deafened CI recipients perceived significant improvement in their quality of life besides auditory skills [24,25]. Using a broader outcome measure, such as the sense of security and participation in hearing society to assess the effects, a fuller picture of the benefits that CIs can provide to recipients’ lives may be able to be painted [19,26]. Chee et al. conducted a survey to evaluate many factors including employment, confidence in communication, telephone ability, one-on-one conversation, dependence, safety, and social life. Positive results regarding employment changes, telephone ability, confidence, communication, level of dependency and personal safety were reported.

So, using quality of life approach is one step further as it can assess factors outside the speech perception scope. Yet, for assessing the prelingual CI users, another approach (or framework) can be considered as another step further than the quality of life approach, which is the International Classification of Functioning (ICF). The ICF contains items of quality of life but much more standardized as the ICF is recommended by WHO and also popularly and ever-increasingly used in variety of fields. Specifically, by using the WHO-ICF model, in addition to previous studies on quality of life, our questionnaire is a modifications from the ICF Checklist and so contains items related to the ICF categories such as activities, participation, personal factors, hearing activities, and environmental factors. By doing so, we expected to show that the cochlear implantation would improve the adults with prelingual deafness in the areas related to these ICF categories, which may be overlapping with and better than the quality of life approach. Again, the speech perception approach is unable to assess the areas related to these categories. While popularly adopted in many other areas long ago, the ICF had not been popularly in hearing clinics as an alternative approach to speech perception. Now, although not many,

there have been some reports showing practicing the ICF in hearing area but still not yet been in the prelingual CI area. As discussed earlier, using the ICF in the area of hearing has been supported by five investigators [2,10,11,13,16], as well as in aural habilitation and rehabilitation area by Schow & Nerbonne [1]. Therefore, using ICF questionnaire with the prelingual CI population is lined up with these endeavors of these investigators. In addition, while considering the limitation of the speech perception, using ICF model can provide a possibility that the outcome between prelingual and postlingual CI users and between different CI centers can be compared because the ICF questionnaire does not have the limitations that the speech perception approach has. The speech perception cannot allow us to achieve our purpose. Our purpose was to identify as well as gain insight into the broad scope of the benefits of CIs in prelingually deafened recipients. Specifically, we looked into change in activity and participation following cochlear implantation as well as, the involvement and limitations in life situations, the facilitators and barriers in their social environment, and any personal factors that may influence outcomes. Moreover, the results from our study per se may further speak for the rationale as using speech perception approach would not show these interesting and positive results. This case series report with multiple subjects is superior in number than a case report with one subject. For two categories of A and C items (Table 1, columns A and C), our quantitative analysis shows the significance in difference between two groups (i.e., $p < 0.05$), and our qualitative analysis shows that the effect is much better in high score group than the low score group, i.e., 92% (71/77) versus 10% (14/134). Besides the two categories (A and C items) mentioned in the two hypotheses in Methods section, the third one is of the B items, i.e., the category "Quantity of Hearing Activities" (Table 1, column B). For this category, although the difference between two groups is not significant for the quantitative analysis, the qualitative analysis shows a large difference in effect (i.e., almost two fold difference: 380% vs. 200%), indicating a strong trend in favor for the high score group against the low score group. The ICF approach is needed in addition to the speech perception because this study by adopting the ICF model can contribute to the current knowledge-base of the broader effects that CI can have on recipients. The need is further supported by our questionnaire because it is well-suited for this population and valid due to its construction through a blending of the WHO-ICF checklist, relevant research papers, and clinical expertise.

No previous experience can be referred as no such articles had been identified in the literature. As this was a first attempt to use the WHO-ICF in this area, the study is unique to apply the ICF model to this prelingual CI population to our knowledge. Being the first attempt, it can be further refined through future research and application in multiple CI centers. This article should facilitate the development of a more mature tool using the ICF model. Based on the multiple factors described above, the rationale is strong to use the ICF model for collecting alternative forms of information regarding prelingual CI usage and effectiveness beyond just speech perception tasks.

Key new findings from this study

Our research shows that CIs can be beneficial to some prelingual CI users as the Quality of Participation Activities can be significantly improved. It suggests that prelingual deafness should not be precluded from the consideration for cochlear implantation. The results of the questionnaire indicated the highest level of participation was in conversations and music-related activities. The lowest level of participation was telephone use. Participants may use the telephone

less often because other means such as text messaging and email are readily available. The significant difference ($p < 0.05$) exists between the high and low score groups in "C" item category "Environment Factors" and in "A" item category "Quality of Participation Activities". This indicates that correlation exists between these two categories, which further suggest that the environment may facilitate the participation. Specifically, family support was the highest rated environmental factor that had a positive impact on the CI experience. In this study, job satisfaction showed an improvement for most of the participants. Overall, expectations regarding participants' CI were unanimously met in this study. This finding indicates that most participants had realistic expectations about their CIs and likely received accurate information from health care professionals about the potential benefits.

Comparison with other studies

Applying this model can be regarded as valuable in general because our results are consistent with previous findings including an increase in participation activities, improved communication, social skills, relationships and work performance after receiving CIs. However, to the best of our knowledge, our report appears to be the first study to apply the WHO-ICF model to prelingually deafened adults implanted with CIs, even if the recent studies are considered. So, our study contributes to the current knowledge-base of the broader effects that CIs can have on these recipients. Although most of the results in our study were consistent with previous studies, there are some differences. For example, in our study, 50% or more of the participants rated "family relationships and self-esteem/confidence" as "much better" following CI. Most et al. did not report improvement in these areas while the post-CI duration in our study being average 8.2 years longer than that in their study [24-27].

Clinical applicability of the study

This study offers a more uniform approach to assess the CI outcome by promoting the use of an ICF based model. This would allow results to be comparable among multiple CI centers. The study may promote comparison among different types of interventions. As the ICF already has been applied in many other disciplines, the results obtained for CI research could be compared with other research treatments such as kidney implantation and knee replacement.

Conclusions

Using the ICF model to assess CI outcomes in prelingually deafened recipients is unique. The quality and frequency of hearing activities were improved in many aspects of the lives of this population. Environmental Factors (support) may positively impact such improvement. The impact can be from support from family, health professionals and friends on the overall benefits received from the CI. Preliminary findings support the use of an ICF based questionnaire in evaluating outcomes for the prelingually deafened adult CI users.

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