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How can the Success Post Cochlear Implant be Measured or Defined in Older Adults? Implications of the International Classification of Functioning Brief Core Set for Hearing Loss

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Abstract

Objectives: Hearing loss (HL) represents a broad category of normal age-related changes that lead to several diminished domains of functions including sensory, cognition, emotional, social, and overall quality of life which may increase loss of independence. Despite the enormous success of cochlear implantation (CI) to treat profound HL in older adults, the individual differences in outcome measures due to several functional deteriorations raise an important question: "How can the success post-CI be measured or defined in older adults?" In 2012, the International classification of functioning (ICF) brief core set of hearing loss was designed to provide clinicians an international standard of what to assess and report on persons with HL. The main objective of this pilot study is to demonstrate success post-CI in older adults using the ICF concepts and brief core set of HL and to discuss what is needed in order to meet the functional decline in older adult CI users.

Design: Case studies of nine older adult CI users were analyzed using single-subject analysis.

Results: Twenty of 27 ICF brief core set items were linked to from the study materials. The ICF analysis clearly demonstrated the individual differences in outcome measures. One case of nine met the criteria of the ICF.

Conclusions: The ICF is a valuable instrumental tool that can be used in CI clinics to optimize audiologic rehabilitation services provided to the aging population. Undoubtedly, there is a need to re-define success post CI in the elderly according to the ICF concept.

Keywords: World Health Organization's international classification of functioning; Disability and health; Brief core set for hearing loss; Hearing loss outcome measure; Cognitive outcome measure; Cochlear implant in older adults

Abbreviations:

WHO: World Health Organization; ICF: International Classification of Functioning, Disability and Health; AR: Audiologic Rehabilitation; HHIE-S: Hearing Handicap Inventory for Elderly-Screening version; WHODAS 2.0: WHO Disability Assessment version 2; MoCA: Montréal Cognition assessment; MCI: Mild Cognitive Impairment, AD: Alzheimer Disorder; HL: Hearing loss; CI: Cochlear Implant

Introduction

A cochlear implant (CI) is an electrical device that is placed in the inner ear to provide auditory information for individuals who cannot obtain sufficient benefit with regards to speech perception from hearing aids (HAs) to rely on listening for communication. CI is an accepted rehabilitative device used to manage hearing loss (HL) worldwide. Commonly, it is the most effective treatment method for individuals with severe to profound sensorineural HL in all ages. The literature shows that the ability to distinguish, hear, and follow conversations, use the telephone, and listen to the radio and television at acceptable levels, when compared to the individual's difficulty prior to obtaining the CI, was improved in older adult CI recipients [1]. However, little is known about the communication performance in real world [2]. Further, the CI can enhance the individual's quality of life, reduce limitations and enhance participation in community life [3-5]. However, poor speech perception in noise is the most common complaint among older adults even with the use cochlear implants [6,7] Studies found that memory and attention functions, neural processing, and life experience factors had the biggest contributions to hearing function (speech-in-noise performance) [8-10]. With the growing interest to discover the relationship between auditory and cognitive systems screening for cognitive function in individuals with HL was recommended. In 2015 Mosnier et al. evaluated 94 older adults with profound post-lingual HL pre- and 12 months post-CI. Results showed that the global cognitive function scores were improved [11], remained stable or declined after one year of cochlear implantation; however, it is still unclear why there is a variation in cognitive function scores post-CI. Indeed, this variation highlighted the role of individual differences in audiologic rehabilitation (AR) outcome measures and other hidden factors.

Aside from specific diseases, HL represents a broad category of normal age-related changes that lead to several diminished domains of function including sensory, cognition, emotional, social, and overall quality of life which may increase loss of independence [12]. A recent longitudinal study concerning aging, the auditory system, and

psychosocial health showed that hearing impairment increased at an average rate of 0.91 dB/year over an 11-year follow up. This rate accelerated with age, cognitive decline and hypertension [13]. Other longitudinal studies found depression to be present in older adults with HL after a three-year follow-up [14], emotional distress and social engagement restrictions after a five-year follow-up [15], dementia after a six-year follow-up [16] and personality changes during a six-year follow-up [17]. These findings raised an important question: "How can the success post-CI be measured or defined in older adults if hearing loss associated with undiagnosed cognitive decline, emotional distress, and social engagement restriction?" In addition, it emphasized the use of multidimensional approach in AR programs to uniquely investigate challenges of HL in geriatric population.

International Classification of Functioning, Disability and Health (ICF)

In 2001, World Health Organization (WHO) merged a biomedical paradigm with a social paradigm to better understand human functioning and proposed the International Classification of Functioning, Disability and Health (ICF) (Figure 1). The general concept of ICF is the interaction between health condition and the environmental factors that produce the impairments and disability. Health condition and disability are the counterparts of the functioning continuum.

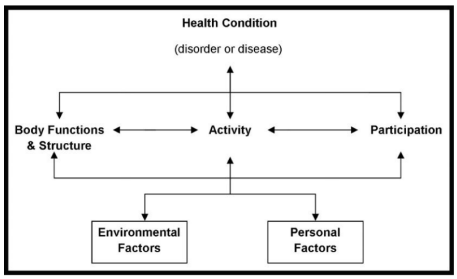

Figure 1: Illustration of WHO-ICF (World Health Organization, 2001) domains.

The ICF was designed to optimize rehabilitation serveries that looking to improve performance of well-being health. The ICF has been established to complement the diagnostic information provided by the International Statistical Classification of Diseases and Related Health Problems (ICD-10). While the ICD-10 classifies etiological framework, the ICF classifies functioning and disability associated with health conditions, and is recommended to be used as a common language among health professionals. The ICF components have multiple domains (b: Body Functions, s: Body Structures, d: Activities and Participation, e: Environmental Factors) and over 1400 categories that serve as the units of the classification used to describe the individuals health. The ICF categories can be measured by the ICF scale or ICF qualifiers (ICF Manual, 2001). Recording ICF qualifiers is based on the presence and severity of problems in functioning at the body, individual, and societal levels.

The development of ICF Core Sets for hearing loss

To facilitate the use of ICF the WHO proposed the "core sets projects". The objectives of the core sets projects were to identify categories that are related to specific health conditions. AR, like any rehabilitation program, can benefit from both the comprehensive and brief core sets provided by the ICF. The ICF core sets project for HL was introduced in 2010 and followed by the development of the comprehensive core set, consists of 117 ICF categories, and the brief core set, consists of 27 categories of the 117 [18]. The two core sets are now recommend to be validated through the use in research and clinical settings. In 2015, Alfakir et al. applied the ICF brief core set for HL to examine the dimensions of hearing performance measures used in a standard care university clinic specializing in amplification [19]. This was done to explore if those dimensions support the structure provided by the core set. Results support the ICF brief core set structure and concepts, and highlighted the complexity of interaction between the ICF domains. Furthermore, results showed that the use of the ICF may help clinicians to modify the audiologic test battery.

The main objective of this pilot study is to demonstrate success post-CI in older adults using the ICF concepts and ICF brief core set of HL as part of the validation process. In addition, to highlight what is needed meet the functional decline in older adult CI users will be discussed.

Methods

Participants

Nine older adult cochlear implant recipients who were post-lingually hearing impaired, (Mage=74.33 years, SD=6.57) were recruited from the out-patient population at the University of Florida cochlear implant clinic. Nine subjects implanted in one ear and continued to use their hearing aids in the other ear (bio-modal). Prior to being seen for the clinic appointments, patients consented to participating in the study by signing an informed consent document approved by the UF Institutional Review Board on the use of human subjects which conforms to the Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects. HL duration was more than 20 years in six participants. More detailed participant characteristics are provided in (Table 1).

Characteristics	Number=9
Age	Mean (74.33) SD (6.57)
Gender	
Male	4
Female	5
Education levels	
High school (12 years)	3
B.S (14 - 16 years)	2
professional degree (>16 years)	4
Work status	
Employed	3
Retired	6
Hearing loss duration	
Less than 10 years	1
Between 10-20 years	2
More than 20 years	6

CI Experience	
Less than 6 months	5
Between 6-12 months	1
Between 1 year and 5 years	2
More than 5 years	1
MOCA	
Normal cognition>26	5
Possible MCI<26	1
Possible severe cognitive decline<20	3

Table 1: Demographic characteristics of participants.

Materials

The main data was collected using participants' clinical records including case histories, audiologic records, amplification histories, and follow-up reports, if applicable. In addition, nine participants filled out two paper-pencil screening questionnaires: Hearing Handicap Inventory for Elderly (HHIE-S) and World Health Organization Disability Assessment version 2 (WHO-DAS 2.0). Next, the Montréal Cognition Assessment (MoCA) was administered in a quiet office space in a normal face-to-face manner.

The HHIE-S outcome measure was used to evaluate the emotional and social behavioral effects of hearing impairment [20]. However, in order to gain a more comprehensive understanding of activity limitation and participation restriction, the HHIE-S was expanded to include open-ended responses. This format allowed participants to express their coping strategies and the reactions of others to each HHIE-S item. For example, for the item "Does a hearing problem cause you to feel embarrassed when you meet new people"? The researchers added "If yes, what do you do? What are the reactions of others to your coping strategy?"

The screening version of the WHO-DAS 2.0 outcome measure was also used to evaluate general quality of life, including cognition, mobility, self-care, getting along, life activities and participation domains [21].

The MoCA is a cognitive screening tool designed to assist health professionals in the detection of mild cognitive impairment (MCI) [22]. It assesses different cognitive domains including: visuo-constructional skills/executive functions, attention and concentration, memory, language, abstract, and orientation. The total possible score is 30 points; the suggested cutoff score for normal cognitive function was >26, <26 for cognitive impairment or possible Alzheimer's disorder (AD). The distinction between AD and MCI is mostly dependent on the presence of associated functional impartment and not on a specific score on the MoCA test. The administration of the MoCA was selected first to screen the global cognitive functions. Additionally, the memory and attention scores were used to classify the severity of the memory and attention impairment in ICF brief core set.

Procedure

The linking methodology was used to validate and translate health and health related information to the ICF. The procedure started by identifying the meaning concepts from the study materials and linking the identified concepts with the ICF brief core set items. Standardized linking methods were used according to the general rules developed by Cieze et al. and the specific rules recommended for audiology by Granberg et al. Examples provided in Table 2 [23,24].

Variables	ICF Domain	ICF category
File records		
Speech perception in noise test	Body function	b. 230 Hearing function
Pure-tone audiometry	Body structure	s.260 Structure of internal Ear
AR treatment (Hearing aids, CI, and Assistive devices)	Environmental and Contextual factors	e.125 Products and technology for communication
HHIE-S Variables		
Emotional		
Does a hearing problem cause you to feel embarrassed when you meet new people?	Body function	b.152 Emotional function
Does a hearing problem cause you to feel frustrated when talking to a member of your family?	Activities and participation	d.310 Communication with receiving -spoken message
Social		
Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?	Activities and participation	d.910 Community life
Does a hearing problem cause you to have arguments with family members?	Activities ad participation	d.760 Family relationship
Does a hearing problem cause you difficulty when listening to television or Radio?	Activities and participation	d.115 Listening
WHODAS Variables		
Cognition		
Concentrating on doing something for ten minutes?	Body function	b.140 Attention function
Life activities		
Taking care of his or her household responsibilities?	Activities and participation	d.910 Community life
Participation		
Joining in community activities (e.g., festivities, religious or other activities)	Activities and participation	d.910 Community life
How much has your relative been emotionally affected by his or her health condition?	Body unction	b.152 Emotional function
Examples for qualitative data analysis scheme from modified HHIE-S		

Coping strategy statement		
Smile and ask for repetition	Activities and participation	d.350 Conversation
Others reaction statement		
Family-understand and support Friends frustrated	Environmental and Contextual factors	e.310 support from immediate family
Coping strategy statement		
Told them to look at me so lip read what they are saying	Activities and participation	d.360 Using communication devices and techniques
Others reaction statement		
Apologize	Environmental and Contextual factors	e.410 Individual attitudes of immediate family

Table 2: Examples of linking variables to ICF items from: 1) case history, objective battery tests, amplification history and follow-up information from subjects file record, 2) Hearing Handicap Inventories HHIE-S, 3) World Health Organization Disability Assessment version 2.0 (12-item self-administered version- WHODAS2.0), and 4) qualitative data of modified HHIE-S.

Next, the ICF qualifier coding procedure was completed following the ICF Manual [25] as shown in Table 3:

The qualifiers of body structure and body function domains, which indicates the degree of impairment, was recorded on a five-point scale (0=no impairment, 1=mild, 2=moderate, 3=severe, and 4=complete). For example, the code for hearing function is b.230. Therefore a participant with a severe hearing loss was coded as b.230.3.

The qualifiers of activity limitation and participation restriction domain were recorded based on performance and capacity. The first qualifier is performance, which describes the individual's functioning in their current environment with assistance or amplification. The second qualifier is capacity, which describes the individual's ability to complete tasks in a standardized environment without assistance or amplification. The degree of difficulty is also rated on a five-point scale (0=no difficulty, 1=mild, 2=moderate, 3=severe, and 4=complete). For the purpose of this study only the performance was recoded. For example, the code for the listening difficulty is d.115. Therefore participant with a severe difficulty was coded as d.115.3_.

The qualifiers of environmental domain were recorded based on the distinction between 'barriers' and 'facilitators'. The qualifier with a negative scale indicates the extent of barriers; while a qualifier with positive scale indicates the extent of facilitators. Therefor a participant who received a high support from his/her immediate family was coded as e.310.3+.

Finally, two additional qualifiers are used when no information was available for a specific item: 8=no specified information and 9=not applicable.

ICF chart									
ICF items	**Qualifiers per participant**								
	1	2	3	4	5	6	7	8	9
Body functions and structures									
Temperament and personality	8	8	8	8	8	8	8	8	8
Attention function	1	2	1	0	0	0	0	1	0
Memory function	3	3	0	2	0	3	0	3	1
Emotional function	3	0	0	1	1	3	1	3	1
Seeing function	8	8	8	8	8	8	8	8	8
Hearing function	2	1	0	2	3	2	2	3	1
Auditory sensation and vestibular function	0	0	0	0	0	0	0	0	0
Structure of brain	1	0	0	0	1	0	8	1	1
Structure of external Ear	0	0	0	0	0	0	0	0	0
Structure of middle Ear	0	0	0	0	0	0	0	0	0
Structure of internal Ear	3	3	3	4	4	4	4	4	4
Activates and participations									
Listening	4	0	3	4	0	3	3	2	2
Handling stress	8	8	8	8	8	8	8	8	8
Communication-receiving-spoken message	4	0	2	3	2	3	1	2	2
Conversation	4	0	2	3	1	2	2	8	2
Using communication devices and techniques	2	0	0	3	0	0	1	8	0
Family relationship	3	0	8	0	0	0	0	2	2
Community life	3	0	2	3	1	3	0	3	3
School education	9	9	9	9	9	9	9	9	9
Remunerative employment	8	8	8	8	8	8	8	8	8
Environmental factors									
Products and technology for communication	+2	+2	+2	+3	+2	+3	+3	+2	+2
Sound	0	0	0	0	0	0	0	0	0
Support from Immediate family	0	8	0	0	0	0	0	-2	-2
Support from health professional	8	8	8	8	8	8	8	8	8
Individual attitudes of immediate family	1	8	8	0	0	8	0	-2	-2
Societal attitudes	8	8	8	8	8	8	8	8	8

Health service system and policies	0	0	0	0	0	0	0	0	0
MoCA Scores									
CI experience	20	18	26	26	24	26	28	19	26
Hearing loss	10 m	10 m	2 m	3 m	2 m	3 m	10 m	2 m	2 m
duration	7 Y	>20 Y	13 Y	15 Y	>20 Y	>20 Y	>20 Y	>20 Y	>20 Y
Age	84	70	72	73	82	63	73	80	72
Gender	M	M	F	F	M	F	F	F	M

Table 3: Variability between subjects according to ICF qualifiers of impairment and perceived disabilities.

Investigators agreement procedure: Identification of concepts and linking to the ICF procedures were completed by two experienced audiologists. The two researchers independently classified the severity of impairment, difficulties of HL and environmental barriers or facilitators according to the ICF qualifier coding. A structured discussion was conducted to solve any disagreements by consensus. Generally the classification between the two audiologists was in agreement [26].

Results

First, through the linking methodology the researchers were able to link 20 of 27 ICF brief core set items from the study materials:

Review of each participant's file records were linked with two items from body functions (b.230 hearing function, b.240 auditory sensation and vestibular function), three items from body structure (s.240 Structure of external Ear, s.250 Structure of middle Ear, and s.260 Structure of internal Ear) and two environmental factors (e.125 Products and technology for communication and e. 250 sound).

HHIE-S was linked with one item from body functions (b.152 Emotional function) and four items from activities and participation (d.115 Listening, d.310 Communication with receiving-spoken message, d.760 Family relationship, and d.910 Community life).

In addition, the qualitative data analysis from the modified HHIE-S was linked with one item from activities and participation (d.350 Conversation) and five environmental factors (e.250 Sound, d.360 Using communication devices and techniques, e.410 Individual attitudes of immediate family, e.310 Support from immediate family, and Health service system and policies e.580).

WHO-DAS 2.0 was linked with two ICF body function items (b.140 Attention function and b.152 Emotional function) and one activities and participation items (d.910 Community life).

Second, through the ICF coding and qualifiers procedure of the 20 linked items the researchers were able to demonstrate the following problems experienced by older adult post-CI participants.

- Four of the nine subjects had a mild to moderate attention problem.
- Four had a severe memory problem.
- Three had a severe emotional problem.
- Six had a moderate to severe hearing problem (speech-in-noise).
- Seven had a moderate to severe listening difficulties.
- Six to Seven had a moderate to severe daily interaction difficulties (communication and conversation).
- Six had moderate to severe social participation (community life) difficulties.

Third, screening for the global cognitive function assessment (MoCA) showed that five participants scored 26 or higher indicating normal cognitive function, one scored below 26 indicating possible mild cognitive decline, and three participants scored 20 or lower suggesting significant cognitive impairment or suspected AD.

Finally, analysis according to the ICF concept and brief core set for HL showed that subject (7) was the most successful CI user among the cases, while the other subjects may still be reaching their full potential with CI.

Cases and Discussion

The main objective of this pilot study was to identify who had successful aging post-CI using the ICF concepts and brief core set of HL. Older adult CI users presented large individual differences in activities limitations post-CI (hearing disability) including listening, communication, and conversation. The individual differences in hearing disability post-CI may have resulted from the contribution of auditory, cognitive, and emotional impairments and/or it is interaction with personal and environmental factors. Undoubtedly, "social interactions refer to the complex forms of behavior, in which the attitude and support of two or more individuals affect an individual's preferences. Communication is a critical tool for social interaction of people with and without hearing loss that requires active listening and conversational skills. Communication difficulty is the one of most cognitive struggles experienced by older people creating not only a communication barrier, but also continuous stressful effort over the inability to react and respond appropriately. Continuous stressful effort may lead to feeling of frustration and loneliness and social isolation" [27].

Further, analysis showed that how defining success post-CI may vary between different health aspects. For example, according to the traditional AR outcome measures (speech in noise test), subjects (2, 3, and 9) may be considered to be successful CI recipients as they had the highest hearing function performance post-CI when compared to the other cases. According to mental health status, subjects (3, 4, 6, and 9) may reflect success post-CI as they passed the screening cognitive assessment (MoCA>26). According to the ICF concept, subjects (2 and 7) may be considered the most successful CI users in this series because they showed no social participation restriction as compared to other cases. Definitely, variation raised a need for a certain method or a standard parameter(s) to define success in older adults CI recipients.

In 2013, Dillon et al. found that the performance of hearing in noise test sentence scores significantly improved between the 1-year and 5-year follow-up intervals, with stability in performance between the 6-month to 1-year and 5-year to 10-year follow-up intervals [28]. However, Tyler, et al. found that the high performance in speech perception in noise post-CI intervention, which can be observed over 4-5 years, has a significant cognitive component. Blamey, et al. demonstrated that long-term CI experience is a more important predictor than duration of hearing loss in adult CI users because it is associated with a steeper learning curve as illustrated in the study [29]. However, further longitudinal clinical research is needed to investigate the effect of the long-term CI experience on cognition functions [30]. Re-connecting people with profound HL is one of the most critical CI advantages; hence, psychosocial, audition, and cognition issues all matter.

A recent longitudinal study highlighted the significant association between high scores in social participation restriction (loneliness and social isolation) and poorer speech-in-noise recognition after three years follow-up [31]. As a result, Pronk proposed that monitoring hearing of older persons may serve as a starting point to target loneliness-prevention efforts. It is well documented that socio-emotional isolation is a high risk for cognitive decline and dementia. In contrast, Havens et al. also found that cognitive decline is a psychological barrier that leads to social isolation [32]. This controversial issue led working group researchers [33] to indicate that when the cognitive decline is sufficiently great and negatively interact with daily and social function, the patient is diagnosed with AD dementia. Fortunately, the working group outlined the core clinical criteria that must be used to differentiate between normal cognition and MCI and between dementia: 1. Concern regarding a change in cognition. 2. Impairment in one or more cognitive domain. 3. Preservation of independence in functional abilities. 4. No evidence of a significant impairment in social functioning. The working group suggested that this clinical criteria can be applied broadly in any setting, without the need of highly specialized tests or and procedure. Accordingly, not only audition can define success post-CI, but also cognitive function and active social participation are the other measures that play a role in defining successful aging post-CI.

Cognitive function and active social participation as a measure of successful aging post-CI:

Subject (2) is a 70 years old male who had 10 months CI experience. Subject (2) had mild impairment in understanding speech in noise, lowest score in cognitive assessment (MoCA=18) that indicating a severe cognitive decline or possible AD, severe impairment in other cognitive domains (memory and attention), and reported neither daily interaction limitations nor social participation restrictions. Undeniably, one of the cognitive characteristics of MCI due to AD in older adults is that self-report may be less reliable than those with normal cognitive functions [34]. Therefore, it is important to determine whether the information reported by subject (2) is reliable by involving the significant others, family members, caregivers or psychologist clinician in evaluation process. Accordingly, subject (2) may or may not be considered a successful CI user until the opposite is proven.

Subject (5) is an 82 year old male, who had two months CI experience. Subject (5) had a severe hearing impairment, possible MCI (MoCA=24), normal performance in other cognitive domains (memory and attention). Subject (5) reported mild to moderate limitation in daily interactions (conversation and communication respectively) and mild social participation restrictions. Accordingly, subject (5) may be considered at the borderline level of successful CI performance. For this subject, it is unknown whether the mild social participation restriction is due to mild cognitive decline, effect of age, long period of deafness, less CI experience, combined sensory losses (hearing and vision), executive dysfunction (visuospatial domain) and/or social participation restrictions. Based on the National Research Council Committee on aging (2000) "cognitive decline is not a certain consequence of growing older, but it is mitigated by decline in functions and health disorders." Remarkably studies showed that: 1. Effect of age was observed only in difficult noisy conditions at SNR 0dB. 2. Lip-reading ability was negatively correlated with speech perception in quiet and noise. 3. Better speech perception scores correlated with shorter duration of hearing deprivation, residual hearing for the low frequencies, and the use of a hearing aid before implantation [35]. Long term auditory deprivation, history of depression, hearing assistive technology use, residential status, education and lacks of long-term speech perception monitoring post CI are the factors that influence psychosocial health and engagement in AR services [36]. Other studies presented that combined sensory losses may impact visual spatial information processing and executive function [37,38]. Executive functioning was found to be highly influenced by social support and family relationship [39]. Conversely, Cacioppo, et al. found that loneliness impairs executive functioning and produces higher depressive symptomatology [40]. In this regards, it is important to verify if the participants have memory, attention, executive dysfunctions, and probably vision, by using one of the tests recommend by the American Academy of Audiology (2006) in order to tailor what are needed to enhance cognitive and social outcomes beside the CI programing [41].

In comparison, subjects (1, 3, 4, 6, 8 and 9) reported moderate to severe social participation restriction. Subjects (3, 4, 6 and 9) had normal global cognitive function scores (MoCA>26); whereas, subjects (1 and 8) had a significant cognitive decline or possible AD (MoCA<20). All subjects in this group except subject (3) had mild to moderate hearing dysfunction with their CIs. It is unknown whether the restriction is due to hearing dysfunction, difficulties in listening and social interactions, global cognitive decline, attentional and or memory impairments. The severe social participation restriction could be explained by the negative synergistic effect of impairments [42]. For instance, the cognitive effect of negative synergy can be realized as secondary to common presentations of age-related dementia leading to social struggle. Cognitive decline is a gradual progressive disorder that may result from the accumulation of AD pathology. AD is also a slow progressive disorder which has no fixed events that define its onset. Negative symptoms and poor cognition are both associated with poor functional outcomes. Accordingly, poor social outcome for subjects (3, 4, 6 and 9) may be attributed to poor auditory functioning and poor memory. Poor social outcomes also are attributed to attention functions and high perceived disabilities of daily interaction. These subjects may be consider in a pre-dementia phase or asymptomatic phase and should be referred for further testing. While poor social outcome for subjects (1 and 8) may be attributed to poor cognition function rather than any independent contribution of other functional abilities. Subjects (1 and 8) may be considered to be at symptomatic pre-dementia phase. Indeed, these subjects emphasized the bi-directional path of the relationship between auditory, cognition and social participation restriction. The author believes that it is important to identify the cognitive mechanisms that predict community and social function and the moderators that enhance the negative synergistic effect. This will allow for the development of cognitive remediation programs that are successful in improving functional outcome.

Finally, subject (7) is a 73 year old female who had more than 5 years of CI experience. Regardless of the moderate performance of speech in noise tests and daily interaction, Subject (7) had normal global cognitive function (MoCA=28) and normal performance in other cognitive domains (memory and attention). Subject (7) reported severe listening limitations and mild daily interaction difficulties; however, the auditory dysfunction and activities limitations did not impact her involvement and participation in community life. It should be noted that this subject has no audition without the use of the CI. Among the all elements of defining successful aging post-CI, subject (7) was the most successful CI user in this participant sample, while the other subjects may still be reaching their full potential with CI as she had the higher level of cognitive function and active social participation. Indeed, subject (7) raised important questions that required further investigation "Does long term CI use enhance

cognitive functions?" and "Does the social participation maintain and improve cognitive function?"

Obviously, defining success post-CI in older adults is not easy as it seems. It requires an "ecological, interactive process that facilitates one's ability to minimize or prevent the limitations and restrictions that auditory dysfunctions can impose on well-being and communication including interpersonal, psychosocial, educational, and vocational functioning" (American Speech-Language-Hearing Association, 2001). The main goal of the ecological approach is to incorporating a client-centered approach to care in audiology practice. Therefore, it would be meaningful to add further information and assessments to determine what mitigates the cognitive decline or social isolation. Additional assessments may help preventing further decline in cognitive and social functions. The author suggested that modifying the traditional AR test battery according to the ICF brief core set standard may significantly optimize social participation, maximize cognitive and mental health, minimize emotional distress, involve the significant other in goal setting, and modify the environment. For example, to optimize social participation and enhance cognitive functions for subjects (3, 4, 6, and 9) the active communication education program and social training programs are highly recommended [43]. To optimize social participation and enhance cognitive function for subjects (1, 2, 5 and 8) applying the Progressive Audiologic Rehabilitation (PAR) model which was proposed by Abrams and Chisolm in 2013 is highly recommended [44]. However, the application of the PAR model should be based on the ten principles of experience-dependent neural plasticity: 1) Use It or Lose It, 2) Use It and Improve It, 3) Specificity, 4) Repetition Matters, 5) Intensity Matters, 6) Time Matters, 7) Salience Matters, 8) Age Matters, 9) Transference, and 10) Interference [45-50]. Further experimental studies are needed based on assessment of functional performance post-CI according to the ICF brief core set and the ten principles.

Conclusion

Without functional status information and the failure to address functioning and health in assessments, the researchers, clinicians and policymakers, may have at best a rough idea of how CI users are functioning and at worst they are making erroneous assumptions and decisions. Further research is needed to investigate the relationship between auditory, cognitive and social participation restriction in elderly CI users. Defining success post-CI in older adults is a multi-dimensional construct that not only includes hearing function but also their ability to communicate in real world and their cognitive functions and social participation status.

Applying the ICF brief core set in both clinical settings and research will significantly maximize the clinical outcome measures within AR programs. The author believe that it is time to shift clinical practice, research design, and AR goals to a multi-componential approach asses hearing loss in relation to other functional performance and environmental factors. This might not necessarily involve extra time or additional measures with every patient, but will significantly increase awareness when extra measures and extra levels of interventions are important and necessary to help with diagnosis and treatment.

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