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HOLISTIC REHABILITATION OF COCHLEAR IMPLANT USERS: USING THE INTERNATIONAL CLASSIFICATION OF FUNCTIONING, DISABILITY, AND HEALTH

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

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Abstract

Background: The purpose of this article is to propose how the International Classification of Functioning, Disability and Health (ICF), particularly the ICF core sets for hearing loss, can be used to plan and evaluate the holistic (re)habilitation of cochlear implant recipients.

Methods and materials: The opinions of HearRing experts were gathered on what – based on their clinical experience – are the most relevant ICF categories and codes to describe audiological rehabilitation after cochlear implantation. For each ICF category, the most commonly used audiological assessment tools and methods were identified.

Results: The most relevant codes for *Body functions and structures*, *Activities and Participation* as well as *Environmental factors* were identified. These were the following. *Body structures*: structure of the inner ear (s260), auditory nerve (s260), brainstem (s1105), midbrain (s1101), diencephalon (s1102), and cortical lobe (s110). *Hearing functions*: sound detection (b2300), sound discrimination (b2301), localization of sound source (b2302), lateralization of sound (b2303), and speech discrimination (b2304). *Activities and participation*: listening (d115); communicating with (receiving) spoken messages (d310); handling stress and other psychological demands (d240); using communication devices and techniques (d360); conversation (d350); family relationships (d760); school education (d820); paid employment (d850); and community life (d910). *Environmental factors*: sounds (e250), products and technology for communication (e125), immediate family (e310), attitudes of immediate family members (e410), societal attitudes (e460), health professionals (e355), and health services, systems, and policies (e580).

Conclusions: Using the ICF can help target the holistic (re)habilitation of cochlear implant recipients. By providing a common language, it can enable clearer communication across disciplines, and closer comparison between different studies, which is essential for meta-analyses.

Key words: hearing loss • audiological rehabilitation • impairment • ICF • holistic approach to hearing loss

HOLISTYCZNY MODEL REHABILITACJI PO WSZCZEPIENIU IMPLANTU ŚLIMAKOWEGO Z WYKORZYSTANIEM MIĘDZYNARODOWEJ KLASYFIKACJI FUNKCJONOWANIA NIEPEŁNOSPRAWNOŚCI I ZDROWIA

Streszczenie

Wprowadzenie: Celem tego artykułu jest stworzenie propozycji wykorzystania Międzynarodowej Klasyfikacji Funkcjonowania, Niepełnosprawności i Zdrowia (ICF), a szczególnie list kluczowych ICF dla niedosłuchu, do planowania i oceny holistycznej (re)habilitacji pacjentów po wszczepieniu implantu ślimakowego.

Materiał i metody: Zebrano opinie specjalistów należących do grupy HearRing odnośnie tego, które kategorie i kody ICF zgodnie z ich doświadczeniem klinicznym są najistotniejsze do opisu rehabilitacji audiologicznej po wszczepieniu implantu ślimakowego. Dla odpowiednich kategorii ICF zidentyfikowano najczęściej stosowane narzędzia i metody oceny audiologicznej.

Wyniki: Zidentyfikowano najistotniejsze kody dla obszarów: *Funkcje i struktury ciała*, *Aktywności i uczestniczenie* oraz *Czynniki środowiskowe*. Należą do nich wymienione dalej kody. *Funkcje i struktury ciała*: struktury ucha wewnętrznego (s260), nerw słuchowy (s1106), struktury pnia mózgu (s1105), struktury śródmózgowia (s1101), struktury międzymózgowia (s1102), struktury płatów korowych (s1100). *Funkcje słyszenia*: wykrywanie dźwięków (b2300), rozróżnianie dźwięków (b2301), umiejscowienie źródła dźwięku (b2302), lateralizacja dźwięku (b2303), odróżnianie mowy (b2304). *Aktywności i uczestniczenie*: słuchanie (d115), porozumiewanie się – odbieranie – wiadomości ustne (d310), radzenie sobie ze stresem i innymi obciążeniami psychicznymi (d240), używanie urządzeń i technik służących do porozumiewania się (d360), rozmowa (d350), związki rodzinne (d760), kształcenie szkolne (d820), zatrudnienie za wynagrodzeniem (d850) oraz życie w społeczności lokalnej (d910). *Czynniki środowiskowe*: dźwięk (e250), produkty i technologie służące do porozumiewania się (e125), najbliższa rodzina (e310), postawy członków najbliższej rodziny (e410), postawy społeczne (e460), pracownicy fachowi ochrony zdrowia (e355), usługi, systemy i polityka w zakresie ochrony zdrowia (e580).

Wnioski: Stosowanie ICF może pomóc ukierunkować holistyczną (re)habilitację pacjentów po wszczepieniu implantu ślimakowego. Ujednolicając język, może umożliwić jaśniejszą komunikację między specjalistami z różnych dziedzin i bliższe porównanie miedzy wynikami różnych badań, co jest niezbędne dla metaanaliz.

Słowa kluczowe: niedosłuch • rehabilitacja audiologiczna • niepełnosprawność • ICF • holistyczne podejście do niedosłuchu

Introduction

The year 2021 was the 20th anniversary of the World Health Organization's approval of the International Classification of Functioning, Disability, and Health (ICF). Over the years, the ICF has become a well-established framework for the integrated care of various illnesses and disabilities (e.g., [1,2]), including hearing health care (e.g., [3–8]).

A cochlear implant (CI) is an advanced technical device that allows many people with sensorineural hearing loss to understand speech and improves their quality of life. To the best of our knowledge, however, only two publications have specifically focused on CI users. Of these, Morettin et al. [9] is limited to children, and Psarros & Love [10] is limited to infants. While children and infants are important demographics of CI users, most CI recipients are adults and the estimated mean age of recipients seems to be increasing rather than decreasing [11,12]. Additionally, the more rehabilitation is viewed holistically, the clearer it is that solutions designed to benefit children and infants are of limited usefulness for adults, who have rather different life needs. Thus, if the aim of CI rehabilitation is improving someone's life and not just their speech perception and sound localization, there is need for an ICF-based framework that can be used for CI users in general. Such a framework, by using ICF terminology and language, would help facilitate communication across the different professions involved in CI provision and rehabilitation (e.g., medical doctors, audiologists, therapists, etc.).

Implementing an ICF framework would also benefit clinical research because it could generate more robust data across clinics, particularly across language, and compensate for a lack of standardization in design, measurement, and testing set-ups (e.g., [13]).

This paper's aim is to propose how the ICF framework could be applied to rehabilitation after CI provision. It could then be used to plan and structure rehabilitation and serve as an assessment tool.

Material and methods

ICF Core Sets for Hearing Loss (CSHL) were developed to make the ICF hearing-specific [5–7,14]. The CSHL are short-lists of the ICF categories that are pertinent to the holistic functioning or people with hearing loss. There is not, however, an agreement on how the CSHL can be operationalized so that they can be used in a real-world setting [4]. The specific aim was to operationalize the Brief CSHL into a tool that could be used as an assessment battery. As a first step, we identified outcome measures used for audiological rehabilitation after a CI. Next, all the outcome measures were connected to the ICF classification with help of the CSHL, to develop a process specifically for CI users. The key concepts here were to 1) interpret identified outcome measures, 2) translate them into the ICF nomenclature, and thus 3) enable results to be described from an ICF perspective.

The framework proposed here is the product of discussion between members of the HearRing group during annual meetings. The HearRing group is a network of world-leading centers and experts dealing with all aspects of hearing disorders. We examined the ICF core sets for hearing loss and, after consultation with Melissa Selb, a member of the ICF Research Branch, developed this proposal on how they can be specifically and holistically applied to intervention and rehabilitation with a CI.

Functional model of disability and the ICF

The basic model of disability used by rehabilitation science is a functional model in which the loss of auditory capacity is understood as composed of four sub-processes: 1) a pathological process occurring on a molecular level in the hair cells, 2) damage manifested as a sensory deficit, 3) functional disability (inability to perform a task, e.g., understanding spoken communication), and 4) difficulties encountered in his/her social life, e.g., difficulties in fulfilling social expectations [15,16].

Following the newest recommendations of audiological organizations, postsurgical care after CI provision should be based on the functional model of disability developed by the International Classification of Functioning, Disability and Health (ICF) (e.g., [17]). In this model, disability is a comprehensive term involving *impairment*, *activity limitations,* and *participation restrictions* [18]. Moreover, the ICF defines an individual's functioning (and their experienced disability) as the effect of a dynamic interaction between health condition(s) and the environment (i.e., contextual factors) [18]. Relations between components of the ICF are shown in **Figure 1**.

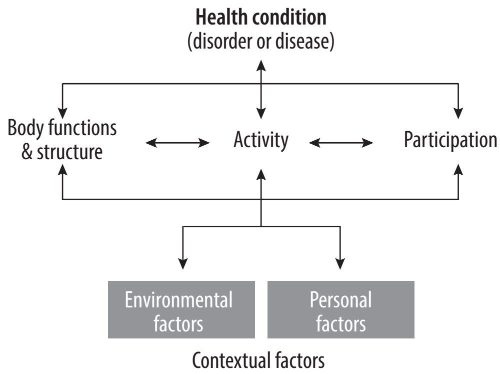

Figure 1. Relationship between the components of the ICF [1]

Several studies have been performed to facilitate the use of the ICF in caring for people with hearing loss (e.g., [3–8]). The results of these studies have led to the creation of *core sets for hearing loss*, which are lists of particular body functions and body structures, forms of activity and participation, and environmental factors related to hearing impairment [6,14].

Audiological management after cochlear implantation

One of the consequences of sensorineural hearing loss is a period of sensory deprivation before cochlear implantation. This period may lead to changes in the organization of structures in the central nervous system (CNS) that are involved in processing auditory information. These changes could involve structures located in cortical structures (s110, particularly the temporal lobe, s11001), midbrain (s1101), diencephalon (s1102), brainstem (s1105), or vestibulocochlear nerve (s1106) [19]. While the extent of these changes is difficult to predict, as neuroplastic mechanisms are unique in each person, the essential point is that they may decrease a person's ability to process auditory information [20]. Thus, even in an ideal case of complete restoration of the biological function of hair cells via a CI, problems with sensory information processing at higher levels in the CNS might significantly limit a CI user's hearing ability.

Evaluation of structures of an implanted inner ear (s260)

Imaging (e.g., Stenver's X-ray, CT-scan, MRI, or impedance telemetry) can be performed to ascertain the position of the electrode array in the cochlea and the integrity of cochlear structures (s260). With CT images, it is possible to check if the position of the array relative to the auditory nerve structures allows for effective electrical stimulation. Impedance telemetry can be used to identify short circuits between the electrode contacts (low impedance) or damaged electrode–implant connections (high impedance) [21]. Analysis of impedance changes over time in the brain may provide information about pathologies which could significantly limit the ability to hear [22].

Assessment of auditory nerve (s260), brainstem (s1105), midbrain (s1101), diencephalon (s1102), cortical lobe (s110)

Functional diagnostics of the auditory nerve are done based on the assessment of the electrically evoked compound action potential (EECAP) [23]. The EECAP arises as a neuronal response to an electrical impulse sent to the auditory nerve endings through the implant's array.

Electrically evoked auditory potentials can monitor auditory information processing higher up in the brain. Potentials arising approximately 10 ms after electrical stimulation carry information about the function of brainstem and midbrain structures; potentials arising later than 10 ms carry information about the activity of the diencephalon and cortex [24]. In the auditory system, information is processed sequentially from lower to higher levels, and so an abnormal finding may indicate pathology within that source structure, or point to a deficit in auditory processing preceding it [25].

Knowledge of these features helps in fitting an audio processor. Because the audio processor is digital, fitting of electrostimulation parameters involves appropriate programming [15]. Using a computer with specialist software and a user interface, electrical stimulation parameters are programmed into its internal memory [21]. The parameters include current levels that correspond to the hearing threshold and comfort levels, the number of active electrodes, the speed of stimulation, the coding strategy, and the shape of the compression function. The combination of these parameters is termed a 'programme' [15,21], and is used to fit audio processors. Recently, flat-based fitting methods, i.e. those which enable the audiologist to fit each channel simultaneously, have been developed (e.g., [26]). These may prove useful in fitting children.

Audiological management after cochlear implantation: helping hearing function

According to the ICF, hearing functions involve sound detection (b2300), sound discrimination (b2301), localization of the sound source (b2302), lateralization of sound (b2303), and speech discrimination relating to determining spoken language and distinguishing it from other sounds (b2304) [18].

Sound detection (b2300)

To confirm a CI recipient's ability to correctly detect sounds, free-field pure tone audiometry is performed [15,21]. Auditory reactions of children younger than about 5 months may be evaluated using behavioural observation audiometry [25]. Visual reinforcement audiometry is performed for children aged 5 m to 2 years. Older children are capable (in most cases) to be assessed with conditioned play audiometry [25].

Sound discrimination (b2301)

To assess sound detection ability, a Ling sound discrimination test as well as environmental sound discrimination tests can be used, but these are uncommon [27].

Sound source localization and lateralization (b2302, b2303)

The auditory system takes advantage of small differences in intensity or time of sound reception in each ear to locate a sound source. Thus, in persons with profound hearing loss, it is necessary to implant them bilaterally in order to provide good sound localization and sound lateralization [28]. Because CIs transmit only a fraction of the information relating to the intensity and temporal structure of a signal, sound localisation and lateralisation may only be partially delivered by a CI [29]. However, in the case of adults with congenital *unilateral* deafness and who lost hearing in adulthood, bilateral cochlear implants will still not restore sound localization or sound lateralization. This is due to the initial unilateral sensory deprivation, which meant that irreversible changes took place in the organization of the CNS during the critical period for its development [30].

Speech discrimination (b2304)

(Re)habilitation focuses on a CI user's ability to detect spoken language and understand its meaning. Assessment generally involves monosyllabic word tests, disyllabic word tests, and sentence tests. The tests are done in quiet or in the presence of background noise, with an open- or closed-set of answers, and with or without the use of a contralateral hearing aid (if a user wears one). The choice is based on the individual's experience with a CI and ability, the targeted skill (e.g., understanding speech in noise), and clinical preference. Many validated tools exist to this end, e.g., the Hearing in Noise Test or the Freiburg monosyllabic word test.

A variety of tests exist for young children who cannot be assessed in the same way as adults, e.g., the Common Objects Token (COT) test or the LittlEARS Auditory Questionnaire (LEAQ).

Regarding "other sounds", CI users report that being able to hear and identify non-speech noises around them is a major benefit [31]. However, correctly recognizing environmental sounds is difficult for CI users [32] and may not significantly improve even after months of use [33], although some CI users may benefit from targeted practice.

Audiological management after cochlear implantation: eliminating activity and participation limitations

The ICF defines an 'activity' as the execution of a task or the undertaking of an action by an individual [20]. Based on the core sets for hearing loss [34], the activity limitations caused by a hearing impairment most often concern listening-related activities (d115) and the reception of spoken messages (d310). Handling stress and other psychological demands (d240) and using communication devices and techniques (d360) are crucial to counteract the negative effects of hearing impairment. The possibility of eliminating these activity limitations by using a CI, and undergoing auditory (re)habilitation, depends on the degree of compensation for hearing functions and on contextual factors. These contextual factors will be discussed in the following sections.

Listening (d115)

Directly after the activation of a CI system, many CI users find listening difficult, particularly in complex auditory environments. Therefore, perceptual training directed at discriminating and identifying environmental and speech sounds is recommended. In CI users with partial deafness who were able to detect low-frequency tones before implantation, restoring the detection of high-frequency tones may initially cause even larger listening difficulties [35]. This happens most often in the presence of external factors such as high-frequency interfering sounds (such as the clinking of cutlery or dishes). Auditory experiences which were restricted only to low frequencies before cochlear implantation may cause pathological changes of the auditory processing in the CNS. After provision of a CI, such pathologies can give rise to excessive auditory effort in situations where processing of high-frequency sounds is necessary [36]. Prolonged mental effort may lead to a sense of exhaustion in everyday situations.

Therefore, when selecting the stimulation parameters during fitting, the audiologist must consider both compensation of hearing and the necessity to prevent excessive auditory effort [22]. It is possible to reduce auditory effort through proper training aimed at improving the processing of auditory information in the CNS [37]. To prevent auditory effort from restricting hearing activities, psychological counselling can also be used to direct CI users towards the appropriate use of other body functions besides hearing, e.g., temperament and personality functions (b126), attention functions (b140), and emotional functions (b152) [34]. To maximise the benefits from each CI user's fitting, auditory training, and counselling, it is necessary to monitor how the user's listening limitations change over time. These changes can be determined using validated questionnaires for measuring listening limitations. Suitable questionnaires include the Abbreviated Profile of Hearing Aid Benefit (APBAB) for adults and LittlEARS for children [38].

Receiving spoken messages (understanding) (d310)

For CI users, understanding spoken messages is one of the most difficult cognitive tasks. To accomplish it, psychological functions other than hearing need to be activated: intellectual (b117), attention (b140), higher-level cognition (b164), mental functions of language (b167), semantic memory of language (b1441), and short-term memory (1440) [39]. Because hearing functions are only partially compensated with a CI, adapting to them should take advantage of these supplementary functions to optimise speech understanding [40]. The simultaneous involvement of all these functions sometimes borders on overload, and can lead to an excessive mental effort [41]. A new CI user should be instructed to increase their awareness of why communication problems continue to persist and that it is impossible to eliminate all limitations in receiving spoken messages; rehabilitation will then become more informed and effective [42]. Counselling should also be provided so as to develop strategies for lowering mental effort when receiving a spoken message [43]. Training higher-level cognition and short-term memory is recommended for quickening and strengthening adaptation, the aim being to utilise supplementary non-auditory functions to increase speech understanding [44].

Handling stress and other psychological demands (d240)

CI users will benefit from learning strategies to manage stress, especially in the first year of CI use. To achieve the aims of rehabilitation, it is necessary to introduce changes into the CI user's life, particularly in terms of hearing activity and participation in verbal communication. It may be psychologically burdensome to use a CI if old habits and communication strategies are not adequate for the new hearing situation. Another source of psychological demand, most evident in the initial period after activation, is excessive listening effort. It is therefore necessary to apply different forms of psychological rehabilitation which focus on the psychological functions and problems a person with a disability has [45].

Using communication devices and techniques (d360)

Rehabilitation includes training in developing the ability to converse on the telephone while using an audio processor [22]. It can also include training to appreciate music [46], singing [47], dancing [48], recognising environmental sounds [32], and listening to audiobooks [49].

Eliminating participation limitations

The ICF defines 'participation' as involvement in everyday life situations [18]. The ICF core sets for hearing loss include five life situations in which a person with a hearing impairment may encounter participation problems: conversation (d350), family relationships (d760), school education (d820), paid employment (d850), and community life (d910). In these situations hearing impairment is the most often mentioned cause of participation restriction [14]. Thus, in addition to physical (medical) rehabilitation, CI users should receive psychological and social rehabilitation to help them overcome participation restrictions.

Contextual factors

Contextual factors represent the complete background of an individual's life and living. They include two components: environmental factors and personal factors.

Environmental factors refer to the physical, social, and attitudinal environments in which people live [18]. Following the ICF core sets for hearing loss, the external contextual factors that most affect the activity and participation of an individual with hearing impairment are sounds (e250), products and technology for communication (e125), immediate family (e310), individual attitudes of immediate family members (e410), societal attitudes (e460), health professionals (e355), and health services, systems, and policies (e580) [34].

Modelling an environment and working to eliminate activity limitations and participation restrictions encountered by CI users are necessary, although they are complex and difficult tasks [50]. Firstly, audiological rehabilitation aims to model the external environment on an individual level, i.e., the environment directly surrounding a CI user [18]. Sounds are a physical characteristic of the environment which may both facilitate or inhibit activity (e250). Sound perception largely depends on how the audio processor is fitted. Fitting effectively models the environment by modifying the physical impact on the implant user. Other basic ways of modifying environmental factors is instruction and expert counselling. According to the principles of evidence-based medicine, understanding the effectiveness of a CI should be grounded in documented scientific findings, particularly those concerning the degree to which hearing functions can be compensated and the deficits remaining after a CI [22]. If we understand the limitations of compensation (e.g., problems understanding speech in noise), this will help in modelling environments such as home, school, or work, and perhaps help modify the attitudes of immediate family members (e410) and societal attitudes (e460), making activity and participation easier for an implant user.

In audiological rehabilitation, the social-level environment also needs to be considered. This involves elements such as health services, systems, and policies (e580), as well as health professionals (e355). At each stage of working with a CI user, it is necessary to exchange information, coordinate activities, and take full advantage of all available resources. Audiological rehabilitation should involve shaping the relations and attitudes of all the people engaged in the process. The relationships between the CI user, their immediate environment, and the members of the multidisciplinary rehabilitation team should be in line with the principles of patient-oriented care. Following the definition developed by the Institute of Medicine, this model of care involves close cooperation between the therapist and the CI user (and their family) at all stages of auditory rehabilitation [51]. An important element of this model is that the CI user is knowledgeable about their device and is kept involved in the entire process.

Personal factors that affect a CI user's ability to overcome activity and participation limitations include age, the presence of additional health conditions, physical fitness, lifestyle, habits, coping styles, current life experience, overall behavioural patterns, character, and psychological characteristics, as well as other individual factors which, together or separately, may play a role in hearing-related activities. Personal factors are not classified in ICF [18].

Conclusions

The paper proposes a framework for how the four basic ICF core sets can be used to support the holistic rehabilitation of CI recipients, which is useful if they are regarded as people and not merely the owners of malfunctioning ears. The clinical benefit of such a framework is that it provides a common language for the various clinicians involved in rehabilitation. Notably, for future rehabilitation, this framework might enable closer comparison between different studies, which is essential for meta-analyses.

The next steps in our project are to determine the necessary components of ICF for cochlear implantation and then validate the tools we use in the ICF to ensure they are clinically applicable and usable in daily clinical practice.

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Conflict of interest

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