Chapter 10

Bilateral Cochlear Implants, Minimizing Auditory Rehabilitation

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Additional information is available at the end of the chapter

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Abstract

Bilateral cochlear implant has increased in recent years due to benefits such as the location of the sign, decrease in head shadow effect, and binaural summation. The aim of this chapter is to discuss issues related to the bilateral cochlear implant costs and benefits and its reflections on auditory rehabilitation, allowing the reader to do a search and strengthen it scientifically with this issue, giving theoretical foundation to better guide and advise their patients.

Keywords: Bilateral cochlear implants, rehabilitation, social impact, individual impact, hearing aids

1. Introduction

Hearing loss has an important impact on people's lives, especially in cases of severe and profound hearing loss. In developed countries, approximately one to two children per 1,000 have moderate to profound bilateral sensorineural hearing loss. Sensorineural hearing loss can be classified as hereditary, acquired, or idiopathic, and acquired environmental etiology is present in approximately 35% [1].

Hearing is an important key to the oral language acquisition and to the world perception. Children who are not exposed to language stimulation in the first years of life will present a lag in their auditory and linguistic development. The first years of life are critical for the greatest neuronal plasticity in the auditory pathway as it is the period of the development of auditory and language skills. Depending on the auditory external stimulus, the central auditory nervous system can be changed positively or negatively. In addition, the period of receipt of hearing linguistic symbols is a prerequisite to form the oral communication [2].

Hearing loss restrict the entry of sounds that will change the auditory development and consequently the language.

In most cases of sensorineural hearing loss, the first site of lesion is inside the cochlea, with results in insufficient energy transduction of the acoustic mechanism of neural impulses to the auditory nerve. In some cases, conventional hearing aids are not enough to restore the hearing; cochlear implant could be indicated.

2. The role of bilateral cochlear implant and rehabilitation process

The cochlear implant is considered the only high-tech device capable of converting acoustic signals into electrical stimuli, causing auditory sensation through direct stimulation of the auditory nerve. It is considered the most effective sensory prosthesis in the history of medicine (Figure 1).

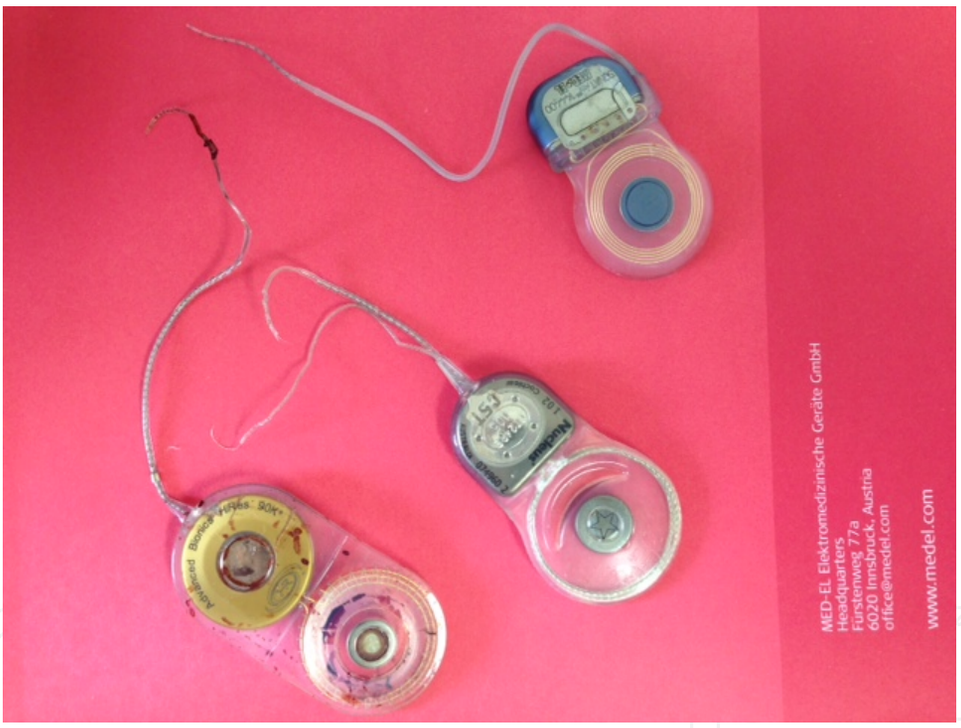

Figure 1. The cochlear implant system. Internal device implant of various manufacturers.

Cochlear implant results allow listening sensation and access to oral language. Its users can do speech acquisition and development of auditory and language skills. In humans, variability in the results is evident. An important detail and worthy of emphasis is the fact that the earlier the intervention occurs, the better the result reached with the use of the cochlear implant [3].

In the USA, cochlear implants were approved for adults with postlingual (hearing loss after 4 years old) severe to profound hearing loss in 1985 [4], and 10 years later, it was approved for adults with prelingual deafness (hearing loss before 4 years old) [5].

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Developments in the indication criteria suffer direct interference of the constant technological development along with the improvement of surgical techniques and training and qualification of interdisciplinary teams.

Children who receive the cochlear implant early, until 2 years old, often present an appropriate oral language development, which is similar to the child who does not present any deficiency in the hearing [6, 7].

Based on the current knowledge on patients who received unilateral cochlear implants with good results, which provide normal hearing to the implanted ear, the majority of these patients have some difficulties on sound location and sound discrimination abilities in noisy environments. When evaluated by the hearing in noise test (HINT), patients are required to use both ears together (binaural hearing) to repeat sentences. Unilateral cochlear implant users have greater effort to conversation in noise because binaural hearing ability is essential for communication in noisy settings and for other aspects of functional hearing, such as sound localization and recognition of environmental sounds [8].

The benefits of the unilateral cochlear implants are evidenced by several studies in the literature [9-13].

Studies have shown that children with bilateral cochlear implants have better sensitivity for the perception of sounds and improvement in the quality of speech [14-16].

Studies comparing the use of bilateral cochlear implants with unilateral cochlear implants associated with a hearing aid in the other ear on children had shown that the bilateral cochlear implant brings better educational benefits in terms of academic results. Children who were implanted before attending the school have a greater propensity to achieve better academic results and be in regular education than those deployed after reaching school age [15-17].

The studies in the systematic review present that the procedure of bilateral implantation is relatively recent and that little research on these results is available [18]. The existing studies on bilateral cochlear implant have approached diversified topics, such as language, communication, and quality-of-life measures. Important results pointed out the benefit of bilateral implantation in children, among them, father-and-son interaction and school performance [19-22].

The additional benefits provided by the second implant considering costs and additional risks, such as additional hardware expense, surgical risk, and programming time, need to be considered [23].

A study that examined the cost utility of postlingual children and adults concluded that quality of life is likely to be obtained per unit of expenditure deployment with unilateral than bilateral implantation [24].

For adults, there was no significant change in quality of life with the second CI than with the first CI. However, these results cannot be extrapolated to children due to the very different nature of auditory stimulation for prelingually deaf children when we consider the neuroplasticity of the central nervous system and synaptic neuronal remodeling with the binaural auditory stimulation, which will become important for speech acquisition and language

development around 5 years old, like normal hearing children reflecting on learning, especially in the school environment. These studies could be important in determining the benefits of the second implant to children in school, in the family, and in social environments.

With a unilateral cochlear implant, individuals have some limitations in the ability to perceive multiple sound entries with segregated independent sources, and this situation reflects a difficulty in understanding speech in the presence of competitive signals (noise) and to the location of the sound in the environment. To improve this condition to understand difficulties in the presence of noise and localization of sound source, thousands of patients have sought the bilateral cochlear implant [25].

Several studies have demonstrated better performance resulting from the use of the bilateral cochlear implant to identify sounds within a multispeaker environment [26-28].

The magnitude and the type of advantage of the cochlear implant are not universal. Comparing the performance of unilateral versus bilateral hearing conditions with cochlear implants, head shadow effect, squelch effect, and binaural summation are three situations that contribute significantly to improve speech understanding, especially in environments with noise and sound location, because the central auditory pathways on the brainstem can differentiate sound characteristics in seconds, which arrive in each ear as an auditory reflex.

The following three hearing conditions must be defined:

1. Head shadow effect. This is defined as a physical phenomenon and head blocks the arrival of sound in the hearing ear from different locations, which allows the listener to hear using the ear with better signal-to-noise ratio (SNR).

2. Binaural redundancy or binaural summation. This is a result of the central auditory processing of the sound entries on both ears at the same time and is analyzed in the central auditory pathways of the brainstem. This reflects the ability of the auditory nervous system to integrate and use bilateral auditory information for better performance than in a single ear.

3. Squelch effect. This reflects the ability of the auditory brainstem to use bilateral auditory information when words or speech in noise sources are spatially separated using the ear with worse signal-to-noise ratio [29].

Bilateral cochlear implant users easily locate sounds, and they are also able to understand speech in noise. These individuals have a good performance of speech intelligibility and location, and binaural hearing is being used in such a way to facilitate their performance [30].

There is a critical period for the binaural auditory development for early simultaneous deployment when the evidences of plasticity of central auditory pathways act as soon as early bilateral implantation and differences are observed in the electrophysiological studies in children implanted bilaterally in sequence, even when the second implant was performed in a time interval shorter than 1 year [31, 32].

Children who received simultaneous bilateral cochlear implant between 5 and 18 months of age and used cochlear implant for 9 to 12 months achieved a result of auditory and language

http://dx.doi.org/10.5772/61228

development equal to the listener children with the same chronological age. Therefore, children with prelingual deafness may develop oral expressive and receptive language within the normal range if they are implanted early [30].

In adults, both simultaneous and sequential bilateral cochlear implants improve comfort of listening with additional benefits besides the location of sound because two ears are getting auditory sensations [33].

For the best rehabilitation and greater opportunity for the development of speech and language, benefits minimizing the time of bilateral deafness are important, and the sequential cochlear implant in children will decrease as a result of the increase in the time interval between the first and the second contralateral implant. In this way, good benefits in word recognition and sound location begin in the first 12 months after cochlear implants and continue to occur over time [34].

Therefore, bilateral cochlear implant could be indicated to the following (Table 1):

- Children above 5 and 18 months of age with bilateral severe to profound sensorineural hearing loss less than 80 dB NA on the better ear, absence of cognitive impairment, and autism
- Individuals older than 5 years with severe to profound bilateral sensorineural postlingual hearing loss less than 80 dB NA on the better ear, with linguistic code established, first cochlear implant surgery performed up to 2 years of age, and interval between the first and the second implant not exceeding 5 years with no cognitive impairment and autism
- Individuals with severe to profound bilateral sensorineural postlingual hearing loss less than 80 dB NA on the better ear using cochlear implant in contralateral ear for at least 1 year, excepted in meningitis
- Individuals with severe to profound bilateral sensorineural hearing loss less than 80 dB NA in the better ear and blindness.

Age	Hearing loss level	Bilateral hearing losses	dB (better ear)	Cognitive impairment	Speech acquisition	CI intervals
5-18 months	Severe to profound	Present	<80	Negative	Prelingual	-
>5 years	Severe to profound	Present	<80	Negative	Postlingual	<5 years
>18 years	Severe to profound	Present	<80	Negative	Postlingual	>1 years
All ages	Severe to profound	Present	<80	Negative blindness*	Pre- or postlingual	-

* Two-sensory disability.

Table 1. Bilateral cochlear implant indications.

The best time and age for the CI surgery should be well discussed with the cochlear implant program team, which will have an early intervention for better hearing conditions in every way as its goal, providing individual hearing benefits and early social inclusion.

Some papers report that financial issues are not a problem to bilateral cochlear implant. Although it would benefit all children with deep bilateral sensorineural deafness, children will not be subject to additional risks with simultaneous CI. Moreover, if the benefit of the second implant is small, it is not worth the cost, and health systems and doctors will consider the cost-effectiveness issue [34]. The coverage by insurance providers is growing for bilateral implants.

Some points in the rehabilitation of individuals with bilateral cochlear implant should be considered in aiming to understand the speech and functional integration of each implant, resulting in a balanced binaural hearing that requires an effective hearing rehabilitation work. To all rehabilitation process, it is important to consider that each is an individual user and there are factors that affect the end result. Creating positive auditory experiences and selecting appropriate activities for every hearing age and skill are important to each individual. Adults, parents, and teachers should always have extra batteries available, and the speech therapist should show the importance of hearing practice through interactions of structured natural speech and hearing therapy.

The reeducational process involves relearning to listen, interpret, and process the sound information and speech. This way, the speech therapist should check separately each ear using the Ling Sounds or auditory discrimination until the user is able to identify when one of the implants is not working or when the batteries fail, establish specific goals for each ear separately or for binaural hearing based on speech acoustics and auditory development, check if parents or users understood the goals and reasons for this rehabilitation process, monitor all the progress and inform the user and the parents of the improvements in auditory skills and pay special attention to the practice to recommended individual therapy. The expectations in the following progress are the recognition in closed to open set, the recognition from predictable to unpredictable information, the recognition of familiar to unfamiliar words, the use of repetition to nonrepetition, the recognition of close to more distant sounds, and the recognition in quiet to noisy environments.

With the simultaneous CI implantation, users use two implants all the time. However, if a great discrepancy between the two ears is present, the worse ear is trained at a specific time.

To sequential CI implantation, the last ear implanted should get the maximum benefit from the bilateral cochlear implant to balance the second hearing competence with the first implant. The integration of the two ears is important to rehabilitation because together they contribute to daily hearing [14]. The rehabilitation process in the second implanted ear must be continued until the score of speech perception of the second implant is next to the first one or achieved good open set scores on speech recognition in a quiet environment. In some situations, the second implant will never reach the first [14].

For the guidance of the individual and his or her family as well as the rehabilitation in sequential CI, it is important that parents and users understand that the initial hearing

http://dx.doi.org/10.5772/61228

perception of the implanted ear must be on the basic level and not on advanced skills as the first implant. Moreover, current research indicates that progress is faster with the second than the first implant, and both implants must be used every day in all environments and with news and complex information. The therapist must create some situations to demonstrate the benefit of two implants as in location, noise, or speech tests in different environments. If the child is under 3 years of age, it is recommended to use both implants all the time. If no perception or auditory discrimination is observed, hearing practice training with the newer implant or with the worst result implant is recommended.

Cochlear implant studies have shown that the bilateral cochlear implant indicated at an early age in children with profound bilateral prelingual deafness, considering the clinical conditions, etiologies, and surgical conditions of the deployment, has important benefits in overcoming and legitimating the costs and expenses of children under the same rehabilitation process. It is expected that these children acquire the same skills as 5-year-old children without deafness. The early bilateral cochlear implantation is important to the central auditory system plasticity response to the new electrical stimulation. The input of new auditory information on both ears is important in understanding speech and specific environmental situations like music, and several studies have shown the benefits of "head shadow effect" and binaural summation on bilateral cochlear implant users. Bilateral cochlear implanted individuals have better speech recognition in noise and sound localization with bilateral cochlear implant compared to a single implant. The roles of the multidisciplinary team in minimizing risks and optimizing the benefits of bilateral cochlear implant are important to be involved in indication and rehabilitation for better speech results with no significant risks. Therefore, bilaterally implanted patients generally report greater satisfaction with their bilateral implants compared with the unilateral situation. They describe better clarity, greater ease of listening, and better hearing overall.

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