Audiometric profile of cochlear implant recipients

Original Article

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Abstract

Objectives: Describe the population of cochlear implant (CI) recipients in one hospital across 9 years.
Study design: Retrospective
Material & methods: Hearing evaluation before and after cochlear implantation was obtained using tonal and vocal audiometry (each ear individually and sound field). Cases not suitable for conventional audiometry were tested using visual reinforcement audiometry or Brain Evoked Response Audiometry (BERA).
Results and Conclusions: 37 individuals (46 ears); mean age 35,1 years (min:1; max:74); 62,2% male. In terms of pre-CI hearing, in children there were 3 cases of absent waves on BERA, 6 cases of profound and 2 cases of severe hearing loss. In adults, pure tone average (PTA) pre-CI of the best ear was 91,9 dB (min:72,5; max:103,7). On post-IC audiometric evaluation, in children, PTA was 46,5 dB (min:26; max:71,3). Adults had a PTA of 39,9 dB (mín:22,8; máx:77,5). In terms of vocal audiometry, the maximum of intelligibility for disyllabic words went from 18,1% (min:0; max:80) without CI to 79,5% (min:30; max:100) with CI; p<0,001. Generally speaking, hearing performance of cochlear implant recipients improved.
Keywords: Hearing loss; Cochlear implant

Introduction

Cochlear implantation is a well-established form of auditory rehabilitation for certain cases of profound hearing loss[1,2]. Despite severe to profound bilateral deafness being the classic indication, in recent years, the criteria for cochlear implantation (CI) have been progressively broadened in some countries (e.g., unilateral deafness; bilateral implantation in adults)[1].

The auditory performance of the patient with a CI is one of the primary concerns of everyone involved in the rehabilitation process. There are multiple factors that can influence the success

of rehabilitation, including the age at which deafness was established, age at the time of implantation, duration, severity, and cause of deafness, viability and location of the spiral ganglion cells, openness of the *scala tympani*, motivation, mode of communication, duration and pattern of CI use, among others[4,5].

Over the years, centers specializing in CI surgery have sought to best define successful auditory rehabilitation. According to the literature, there are currently two complementary methods for assessing the auditory performance of patients with implants: 1) Audiometric tests; 2) Patient-reported measures. In the context of audiometric testing, not only are the basic pure-tone audiogram and speech audiogram with the speech recognition score significant, but the hearing in noise test has also gained considerable importance. This is because it more accurately reflects an individual's hearing challenges in the everyday environment. In the case of patient-reported measures, there is a range of questionnaires that can be administered, which reflect the patient's own perception of their hearing ability and quality of life (e.g.: *Nijmegen Cochlear Implant Questionnaire [NCIQ]; speech, spatial, and qualities of hearing scale [SSQ])*[6,7]. In certain populations that are more challenging to test, especially in children, electrophysiological tests (such as the Auditory Brainstem Response [ABR]) and age-adapted audiometry techniques (e.g., Visual Reinforcement Audiometry) are also important tools. This study aimed to characterize the population rehabilitated with CI at a single hospital.

Materials and Methods

During the first quarter of 2023, the medical records of all patients who underwent CI rehabilitation (either unilateral or bilateral) at the Otorhinolaryngology department of Professor Doctor Fernando Fonseca Hospital over a period of 9 years (2014–2022) were retrospectively analyzed. All patients being considered for CI were discussed in an auditory rehabilitation meeting (comprising otolaryngologists, audiology technicians, and speech therapists). The etiology of the hearing loss was investigated, and computed tomography (CT) of the ear as well as magnetic resonance imaging (MRI) of the ear and brain were performed. Anomalies/malformations that condition or contraindicate CI were excluded. Pre-implantation pneumococcal vaccination was administered. The sociodemographic data of the individuals, as well as the causes and risk factors for deafness, were recorded. The tonal thresholds at 250, 500, 1000, 2000, 4000, and 8000 Hz were recorded for both ears, together with the speech intelligibility percentages for both ears. Both the pure-tone and speech audiograms were also conducted in a sound field environment. All individuals underwent pre-CI and post-CI audiometric studies. The pre-CI audiometric assessment in patients who use hearing aids was conducted both with and without the hearing aid in place. For the purpose of comparing the pre- and post-CI hearing, the hearing test conducted under the best possible amplification condition was consistently taken into account. The average tonal threshold (ATT) was determined by calculating the mean of the tonal thresholds at 500, 1000, 2000, and 4000 Hz. Children who were not eligible for conventional audiometry underwent ABR testing and visual reinforcement audiometry (VRA) in a sound field. The post-CI follow-up duration and the daily usage hours of the CI for each individual were recorded. In cases of bilateral implantation with different usage hours in each ear, the ear with the higher number of usage hours was considered. As outlined in the clinical guidance standard "Screening and Treatment of Deafness with Cochlear Implants in Pediatric Age. Clinical Guidance Standard 018/2015"[2], CI was recommended only for individuals with profound bilateral deafness or severe bilateral hearing loss who do not derive functional benefit from hearing aids. The present study received approval from the hospital's ethics committee. The statistical analysis of the data was conducted using the

"IBM SPSS Statistics 25.0®" software. A p-value of <0.05 was used to determine statistical significance.

Results

Sample Characterization

Between 2014 and 2022, 37 individuals (46 ears) were fitted with CI devices; the average age was 35.1 years (min: 1; max: 74); 62.2% were male. Of the 37 individuals who received implants, 26 were adults and 11 were children. Nine cases of bilateral CI were documented (eight children; one adult), with six being simultaneous implantations and three being sequential implantations. The average post-implantation follow-up period was 3.6 years (minimum: 1 year; maximum: 9 years). There are no cases of unilateral deafness in the sample.

Etiology of Deafness

In children, the primary identifiable etiology was congenital cytomegalovirus infection (three out of 11 cases), whereas in adults, the main reason for CI was progressive idiopathic sensorineural hearing loss with insufficient gain from hearing amplification (10 out of 26 cases). Table 1 shows the etiologies identified in the implanted patients.

Cochlear Implant Surgery – Technical Specificities and Complications

The surgical technique used in most cases involved the insertion of the electrode array through the round window following a closed mastoidectomy with posterior tympanotomy. The exceptions were: two cases of anteroinferior cochleostomy relative to the round window, and one case of CI placement in a patient with a radical mastoidectomy cavity; a subtotal petrosectomy was performed at the time of implantation. Among the intraoperative complications, it is important to highlight two cases of chorda tympani sacrifice, with no sequelae observed at the 3-month follow-up.

In terms of the postoperative complications, there was one case of retroauricular hematoma and two cases of vertigo lasting 2 to 3 weeks.

Table 1
Etiology of deafness

CHILDREN (n=11)*	
Congenital CMV	3/11
GJB2 mutation	2/11
Prematurity	2/11
Neonatal sepsis	2/11
Meningitis	1/11
Peripartum asphyxia (low Apgar)	1/11
Aicardi 's disease	1/11
Idiopathic	1/11
ADULTS (n=26)	
Idiopathic progressive sensorineural hearing loss	10/26
Progressive congenital sensorineural hearing loss	3/26
Otosclerosis	3/26
Sudden deafness	3/26
Systemic lupus erythematosus	2/26
Ototoxicity	2/26
Chronic otitis media	2/26
Meniere 's disease	1/26

*There were two children with >1 etiological factor for deafness. CMV, cytomegalovirus

No major complications and/or need for explantation were documented.
In all patients, at the conclusion of the surgery, neural response telemetry (NRT) was performed, along with a modified Stenvers projection radiograph, to confirm the correct placement of the electrode array.

Pre-Cochlear Implant Audiometric Profile

Children

Eleven children were implanted (average age: 3.7 years; min: 1 year; max: 9 years). Eight children received bilateral implants (simultaneously in seven cases), and three children received a unilateral implant.
Only one child was capable of undergoing conventional audiometry. All others underwent transient evoked otoacoustic emissions (TEOAE) and VRA in a sound field.
The findings were as follows:
- Three children with no detectable waves on ABR and no response in VRA with bilateral hearing amplification
- The remaining eight children exhibited an ATT of 92.7dB in the best amplification condition (min: 63.3 dB; max: 105.1 dB)*
*Accounting for the best-hearing ear (one child was capable of undergoing conventional pure-tone audiometry) and/or the outcome of VRA in a free field (seven children)
It is worth noting that since only one of the implanted children was post-lingual, the results of the speech audiometry for this group have not been described.

Adults

A t otal of 26 adults were implanted (average age: 48.3 years; min: 21 years; max: 74 years). Only one individual was implanted bilaterally (placement of CI initially on the right; however, after five years the gain proved to be insufficient and the CI ended up in the left ear).
All adults underwent a tonal and vocal audiogram.
-ATT– sample average was 91.9 dB (min: 72.5 db; max: 103.7 dB) **
- Maximum intelligibility (vocal audiometry) - sample average was 18.1% (min: 0%; max: 80%) **
**Results are from the best-hearing ear under the best amplification conditions.

Audiometric profile after cochlear implantation

The audiometric evaluation after CI was carried out in a similar way to that carried out pre-CI. The first audiometric evaluation after CI occurred 6 months after implantation. The most recent results for each individual are presented below.

Children

At the time of writing this article, three of the 11 children had not yet undergone a reevaluation audiogram.
- Children who underwent a post-CI audiogram had an ATT in the best amplification condition: average 46.5 dB (min: 26 dB; max: 71.3 dB)*
*The best- hearing ear or result of VRA in free field was counted
Graph 1 shows the ATTs of children pre- and post-CI.

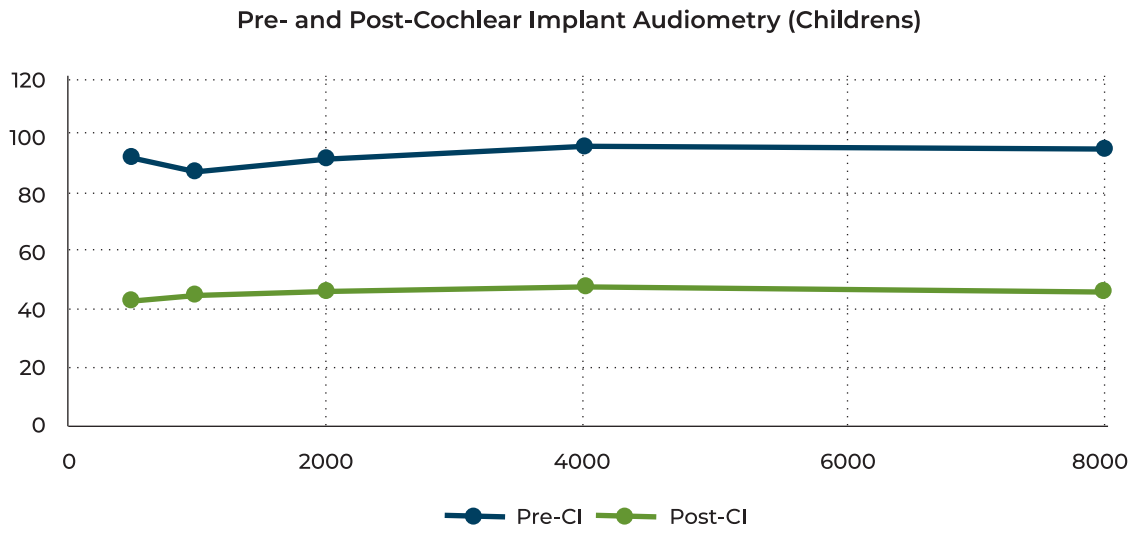
Adults

As the time of writing this article, among the 26 adults, five had not undergone reevaluation with either tonal or vocal audiometry.
-ATT– sample average was 39.9 dB (min: 22.8 db; max: 77.5 dB) **
- Maximum intelligibility (vocal audiometry) - sample average was 79.5% (min: 30%; max: 100%) **
**Outcomes from the better ear under optimal amplification conditions.
Graph 2 depicts the average tonal thresholds of adults pre- and post-CI.

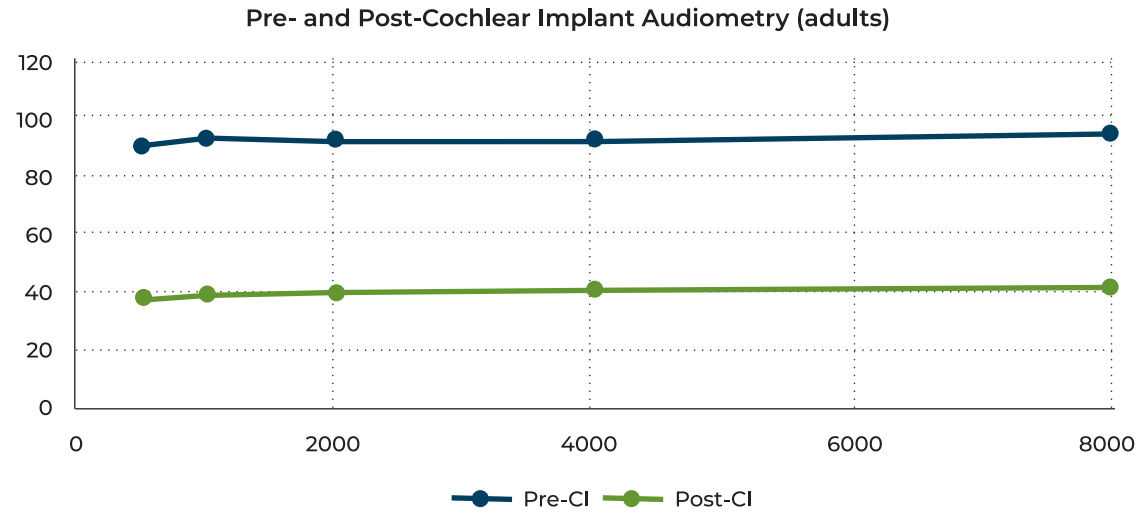
Use of Cochlear Implant – Daily Hours

Implanted individuals utilized their CI for an average of 10.84 hours per day (min: 1 h; max: 16 h)

Graph 1
Tonal threshold (children) pre and post cochlear implant (yy: dB HL; xx: Hz)



Graph 2
Tonal threshold (adults) pre and post-cochlear implant (yy: dB HL; xx: Hz)



Discussion

The sample of individuals with CI analyzed in this study is quite heterogeneous, not only in terms of the age and etiology of deafness but also in terms of the social context. Thus, a detailed description of the implanted population is essential for assessing the success of auditory rehabilitation and for validating the study results. As mentioned in the introduction, the success of CI rehabilitation can be assessed through various methods. However, it is invariably linked to a certain degree of subjectivity. Although this study primarily focused on audiometric thresholds and discrimination ability for evaluating the CI outcomes, we acknowledge that other tools such as the use of questionnaires, reviewing speech therapist records, or even feedback from family members are perfectly valid methods for assessing the success of auditory rehabilitation. It is now known that in addition to improving the auditory thresholds and speech perception, CI can also enhance spatial hearing, suppress tinnitus, improve the quality of life, and consequently, reduce the comorbidities associated with deafness[8].

When analyzing the results of this study, it is crucial to consider certain limitations regarding auditory assessment, especially in children. In three children, pre-CI auditory assessment was conducted solely through electrophysiological tests since it was impossible to obtain consistent responses in behavioral tests. Since the auditory assessment following CI was conducted through audiometry, the comparison of pre- and post-CI thresholds, although feasible, is subject to a certain degree of bias.

Despite the aforementioned limitations, it is possible to assess the differences in individuals' hearing before and after CI. In the case of children, the pre-CI ATT with optimized hearing amplification was 92.7 dB (average value; including three children with no waves in ABR), and improved to 46.5 dB (average value) after CI implantation. In adults, the pre-CI ATT with optimized hearing amplification was 91.9 dB (average value) and decreased to 39.9 dB (average value) after CI. Furthermore, in adults, in speech audiometry, the maximum intelligibility for disyllabic words increased from 18.1% (min: 0; max: 80) without an implant to 79.5% (min: 30; max: 100) with a CI; Wilcoxon test: $p<0.001$. The outcomes, although, as initially mentioned, not the sole measure of success of auditory rehabilitation, demonstrate a clear improvement in both the tonal thresholds and speech comprehension.

Conclusion

The studied population experienced a global improvement in their auditory performance following CI.

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Conflicts of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

Data Confidentiality

The authors declare having followed the protocols in use at their working center regarding patients' data publication.

Protection of humans and animals

The authors declare that the procedures were followed according to the regulations established by the Clinical Research and Ethics Committee and to the 2013 Helsinki Declaration of the World Medical Association.

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Availability of scientific data

There are no datasets available, publicly related to this work.

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