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Audiology

Tinnitus suppression with electrical stimulation in adults: long-term follow-up

L'annullamento del tinnitus mediante stimolazione elettrica negli adulti: follow-up a lungo termine

Juan Carlos Falcón González[1], Silvia Borkoski Barreiro[1], Margarita Torres García de Celis[1], Ángel Ramos Macías[1,2]

[1] Department of Otolaryngology Head Neck Surgery, Complejo Hospitalario Universitario Insular Materno Infantil de Gran Canaria, Las Palmas, Spain; [2] Department of Otolaryngology, Faculty Medicine, University of Las Palmas de Gran Canaria, Spain

SUMMARY

Objectives. To investigate the long-term effects of cochlear implants as a treatment for patients with severe to profound neurosensory loss associated with severe tinnitus.

Methods. Prospective study in 17 adult patients with severe to profound sensorineural hearing loss associated with severe tinnitus, indicated with a Tinnitus Handicap Inventory (THI) score ≥ 58%, and hyperacusis. Measures were made on hearing, tinnitus, hyperacusis and quality of life up to 5 years after activation of the sound processor of the cochlear implant. It was evaluated by using the disyllabic test, THI, visual analogue scale and Glasgow Benefit Inventory questionnaire.

Results. 60 months after cochlear implantation, improvements in loudness and discomfort of tinnitus, speech discrimination and hyperacusis were observed. Subjects perceive an important subjective benefit upon receiving the cochlear implant.

Conclusions. Cochlear implants can be used as treatment for patients with severe to profound sensorineural hearing loss associated with severe tinnitus and hyperacusis with long-term benefits on quality of life and lasting relief of tinnitus.

KEY WORDS: cochlear implant, tinnitus, quality of life, hyperacusis, hearing loss

RIASSUNTO

Obiettivi. Mostrare gli effetti a lungo termine degli impianti cocleari nei pazienti con perdita neurosensoriale grave e profonda, associata ad acufene.

Metodi. Studio prospettico su 17 pazienti adulti con ipoacusia neurosensoriale da grave a profonda associata ad acufene grave, con un punteggio Tinnitus Handicap Inventory (THI) ≥ 58% e iperacusia. Abbiamo analizzato udito, tinnito, iperacusia e qualità della vita durante un follow-up di 5 anni dopo l'attivazione dell'elaboratore del suono dell'impianto cocleare. Mediante test disillabico, abbiam valutato il THI, la scala analogica visiva e il questionario Glasgow Benefit Inventory.

Risultati. 60 mesi dopo l'impianto cocleare, si osservano miglioramenti nell'intensità e grado di discomfort da acufene, nella discriminazione del linguaggio ed iperacusia. I soggetti percepiscono un importante beneficio soggettivo post impianto cocleare.

Conclusioni. gli impianti cocleari possono essere utilizzati come trattamento per i pazienti con ipoacusia neurosensoriale da grave a profonda associata ad acufene grave e iperacusia, poiché si osservano benefici a lungo termine sulla qualità della vita e un sollievo duraturo sull'acufene.

PAROLE CHIAVE: *impianto cocleare, tinnito, qualità della vita, iperacusia, perdita dell'udito*

Introduction

Tinnitus is defined as sound perception without any external sound source. The physiopathology of tinnitus is not completely understood [1]. The different theories assume that a peripheric lesion in the cochlear hair cells induce a cen-

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Correspondence
Silvia Borkoski Barreiro
Department of Otolaryngology Head Neck Surgery, Complejo Hospitalario Universitario Insular Materno Infantil de Gran Canaria, Av. Marítima del Sur s/n, 35016 Las Palmas de Gran Canaria, Spain
Tel. +34 928441801. Fax +34 928444068
E-mail: silviaborkoski@hotmail.com

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tral nervous system maladaptive or suboptimal plasticity, which in turn induces reorganisation and hyperactivity of non-auditory and central auditory structures [1,2].

Severe tinnitus can have debilitating psychosocial consequences and cause psychiatric disorders in 1-3% of the general population [3]. Disabling tinnitus in a patient with unilateral hearing loss can affect speech discrimination in noise, while a cochlear implant (that "activates" the deaf ear can improve tinnitus and speech discrimination in noise [4]. Tinnitus suppression occurs mainly during the active use of a cochlear implant and is stable over time [5-7]. Some cochlear implant holders experience a residual inhibition of tinnitus when the implant is switched off, and these periods can extend during the night; they thus experience complete relief of tinnitus [8]. The suppressive effects of concomitant tinnitus in cochlear implant holders can be explained by the effects of masking/blinding and the plastic changes in the hearing system by enhancement of peripheric hearing input [9].

The objective of this study is to evaluate the long-term effects of cochlear implants as treatment for patients with severe to profound neurosensory loss associated with severe tinnitus.

Materials and methods

A repeated-measurements, intrasubject, prospective and 5-year follow-up study is presented. Patients to be included had to fulfil the following criteria: over 18 years of age, having an ear to be implanted fulfilling cochlear implantation criteria [10], presenting tinnitus with disability indicated by a Tinnitus Handicap Inventory (THI) [11] score ≥ 58%, showing normal hearing or mild/moderate hearing loss in the contralateral ear and failure of conventional treatments for tinnitus during ≥ 6 months. Tinnitus treatments were Tinnitus Retraining Therapy (TRT) and cognitive behavioural therapy.

Exclusion criteria included central-origin tinnitus, pulsatile tinnitus, paroxysmal tinnitus, somatosensorial tinnitus, headache/migraine-related tinnitus, vertigo-related tinnitus, posttraumatic tinnitus and psychological/psychiatric disorders associated with tinnitus verified by a psychologist/psychiatrist.

Before surgery, assessment of tinnitus, including medical history, of hearing and quality of life was performed. Tinnitus was assessed within the visit for cochlear implant activation. Tinnitus and hearing assessments were repeated in the scheduled visits of the study: 1, 6 and every 12 months until 5 years after the first activation.

The evaluation of disability provoked by tinnitus was performed using the Spanish version of THI; including disability categories for THI score: without handicap 0-16% (grade 1), mild disability 18-36% (grade 2), moderate disability 38-56% (grade 3) and severe disability 58-100% (grade 4) [12,13].

Tinnitus sonority/discomfort was assessed using a Visual Analogic Scale (VAS) ranging from 0 to 10 [14].

Hearing thresholds were evaluated by pure-tone audiometry; speech discrimination was evaluated by using the two-syllables words test in quiet (S0) and the Protocol for the Assessment of hearing in Spanish language, and hyperacusis was evaluated by using the Sound Hypersensitivity Questionnaire (SHQ), known in Spain as 'Test de Hipersensibilidad al Sonido" [15,16].

The effect of the intervention on the quality of life of the patient was assessed using the Glasgow Benefit Inventory Questionnaire (GBI), developed and validated by Robinson et al. in 1996 [17].

All surgeries were performed by the same surgical team/staff. The advanced combination encoders (ACE) codification strategy was applied to programme the speech processor using versions 5.0 and 6.0 of the Software Custom Sound, and frequency assignation by channel method was applied [18,19].

Statistical analysis

Exploratory and descriptive analysis was performed.

Distribution equality analysis was done by using analysis of variance (ANOVA) or the Kruskal-Wallis test, depending on the data characteristics.

Correlation analysis was performed among the indicators of communication difficulty level of the subscales and the quality of life.

The statistical package SPSS (Statistical Package for the Social Sciences), version 25.0 for Windows 10 Professional, was used. A p-value $\alpha < 0.05$ was considered to be statistically significant.

Results

A total of 17 patients, 10 men and 7 women, presenting severe to profound hearing loss in the ear to be implanted were included. With respect to the contralateral ear, 15 patients showed normal hearing and 2 showed mild hearing loss.

After 5-year follow-up of the contralateral ear, 11 patients still showed normal hearing, 5 patient showed mild hearing loss and 1 patient showed moderate hearing loss.

The aetiology of hearing loss was unknown in 58.82% of subjects (10 patients), otosclerosis in 29.42% of subjects (5 patients) and meningitis in 11.76% of subjects (2 patients).

The onset of the hearing loss was sudden in most patients (13/17 = 76.47%) and progressive in 4 patients (23.53%).

The time to hearing loss in the implanted ear was generally short (< 2 years in 13/17 = 76.47%), but was > 10 years in 4 patients (23.53%).

All patients received cochlear implants: Systems Nucleus® - Cochlear.

Figure 1 shows the THI evolution of patients with scores obtained in the presurgical visit, during activation of the speech processor, and at 1, 6, 12, 24, 36, 48 and 60 months after first activation of the speech processor. At 60 months post-activation, scores were significantly lower than those at pre-surgery ($p < 0.005$).

The SHQ pre-surgery scores were high, indicating ì important interference of tinnitus/hyperacusis on hearing; 'very severely incapacitating' (SHQ score: 26-45) in 9 patients, 'severely incapacitating' (SHQ score: 18-25) in 5 patients and 'moderately incapacitating' (SHQ score: 11-17) in 3 patients. Clinically, SHQ scores decreased from very severe to mild-moderate in all patients after 5 years.

The VAS results obtained during the pre-surgery visit, when the speech processor was activated and at 1, 6, 12, 24, 36, 48 and 60 months after the first activation are shown in Figure 2.

Two-syllable word recognition results per patient obtained at 12, 24, 36, 48 and 60 months after speech processor first activation are shown in Figure 3.

Table I shows the results of the THI and VAS for individual patients obtained during the pre-operative visit and over 5-year follow-up with the cochlear implant (CI) switched on and off.

Figures 4 and 5 show the overall score per patient in subscales of the quality questionnaire GBI.

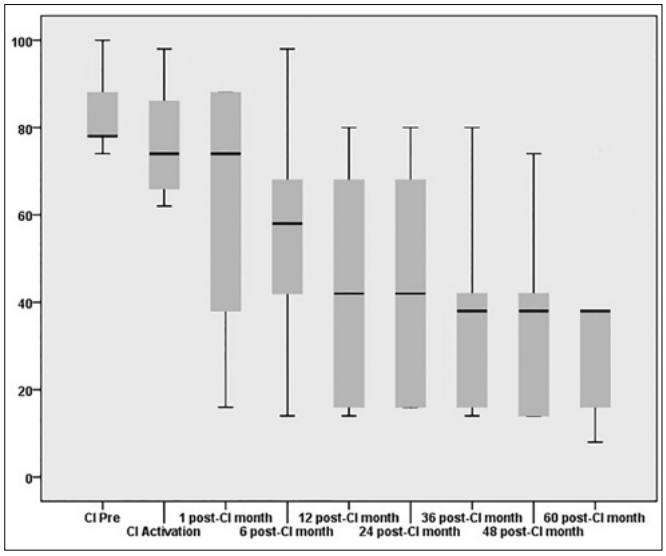

Figure 1. THI evolution since before speech processor activation up to the 60th month post implantation.

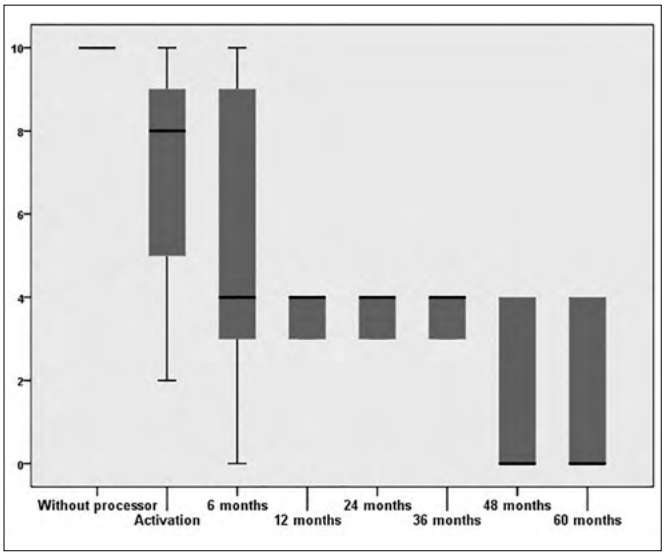

Figure 2. VAS changes in presurgical and processor tinnitus perception before its implantation and up to 60 months post-implantation.

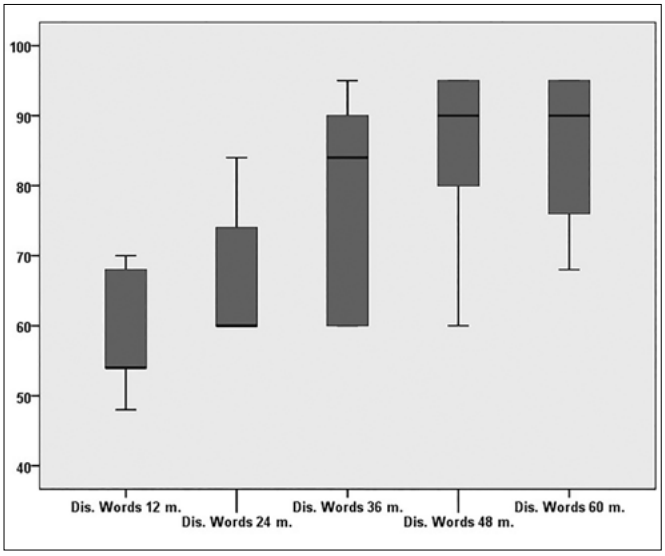

Figure 3. Percentage of disyllabic word recognition. Dis: disyllabic; m: months.

Scores of the General (health state) Subscale (Fig. 4) and Physical Health Subscale increases, and significant differences were observed when comparing pre-surgery scores and their evolution until the 60th post-CI month (P value < 0.001).

With respect to the Social Support Subscale (Fig. 5), the scores obtained before CI and throughout 60 months remained stable, and no significant differences were observed (P value > 0.05).

Table I. Results of THI and VAS during 5-year follow-up.

Subject	Test	Pre CI	Activation	1 m.	6 m.	12 m.	24 m.	36 m.	48 m.	60 m.
1	THI	78	62	38	58	68	68	38	42	38
	VAS processor off	8	8	8	9	10	10	8	8	8
	VAS processor on		5	4	4	8	8	4	4	4
2	THI	78	66	16	14	14	16	14	14	8
	VAS processor off	10	10	7	7	7	7	5	5	5
	VAS processor on		2	0	0	0	0	0	0	0
3	THI	100	98	74	98	80	80	80	74	74
	VAS processor off	10	10	10	10	10	10	10	10	10
	VAS processor on		10	8	10	4	4	4	4	4
4	THI	88	74	88	42	42	42	42	38	38
	VAS processor off	10	10	10	3	5	5	5	5	5
	VAS processor on		8	8	3	4	4	4	0	0
5	THI	74	86	88	68	16	16	16	14	16
	VAS processor off	10	10	10	10	8	8	8	5	5
	VAS processor on		9	9	9	3	3	3	0	0
6	THI	78	62	38	58	68	68	38	42	38
	VAS processor off	8	8	8	9	10	10	8	8	8
	VAS processor on		5	4	4	8	8	4	4	4
7	THI	78	66	16	14	14	16	14	14	8
	VAS processor off	10	10	7	7	7	7	5	5	5
	VAS processor on		2	0	0	0	0	0	0	0
8	THI	100	98	74	98	80	80	80	74	74
	VAS processor off	10	10	10	10	10	10	10	10	10
	VAS processor on		10	8	10	4	4	4	4	4
9	THI	88	74	88	42	42	42	42	38	38
	VAS processor off	10	10	10	3	5	5	5	5	5
	VAS processor on		8	8	3	4	4	4	0	0
10	THI	74	86	88	68	16	16	16	14	16
	VAS processor off	10	10	10	10	8	8	8	5	5
	VAS processor on		9	9	9	3	3	3	0	0
11	THI	78	62	38	58	68	68	38	42	38
	VAS processor off	8	8	8	9	10	10	8	8	8
	VAS processor on		5	4	4	8	8	4	4	4
12	THI	78	66	16	14	14	16	14	14	8
	VAS processor off	10	10	7	7	7	7	5	5	5
	VAS processor on		2	0	0	0	0	0	0	0
13	THI	100	98	74	98	80	80	80	74	74
	VAS processor off	10	10	10	10	10	10	10	10	10
	VAS processor on		10	8	10	4	4	4	4	4
14	THI	88	74	88	42	42	42	42	38	38
	VAS processor off	10	10	10	3	5	5	5	5	5
	VAS processor on		8	8	3	4	4	4	0	0
15	THI	74	86	88	68	16	16	16	14	16
	VAS processor off	10	10	10	10	8	8	8	5	5
	VAS processor on		9	9	9	3	3	3	0	0
16	THI	78	62	38	58	68	68	38	42	38
	VAS processor off	8	8	8	9	10	10	8	8	8
	VAS processor on		5	4	4	8	8	4	4	4
17	THI	78	66	16	14	14	16	14	14	8
	VAS processor off	10	10	7	7	7	7	5	5	5
	VAS processor on		2	0	0	0	0	0	0	0

CI: Cochlear Implantation; m: months.

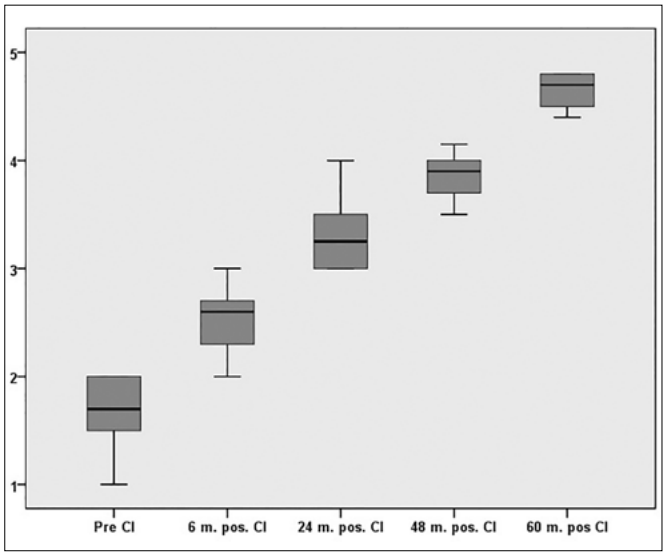

Figure 4. General Score of the GBI. m: months; pos: post; CI Cochlear Implantation.

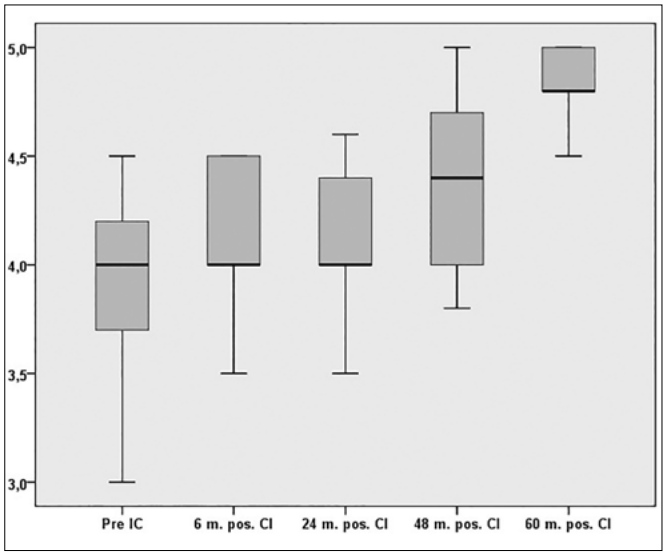

Figure 5. Social support score of the GBI. m: months; pos: post; CI Cochlear Implantation

Discussion

The study by Van de Heyning et al. was the first to demonstrate a significant and consistent decrease in tinnitus volume after cochlear implantation and, consequently, suggested the use of cochlear implant as a new treatment for tinnitus [20].

The physio-pathological mechanisms of tinnitus suppression after cochlear implantation are not yet completely understood. It is surmised that electrical stimulation through the CI induces cortex reorganisation by neuroplasticity, which affects the perception of tinnitus. Some patients experience a significant decrease in tinnitus just after first activation of their CI, which suggests an effect of tinnitus masking/blinding due to the increase in auditory information.

Currently, many studies have established the impact of cochlear implantation on the decrease of tinnitus [6,8,21-24]. The results in our patients show a significant and clinical decrease in tinnitus disability and perception in the long-term, similar to those described in other studies [23,25,26].

As described by Mertens et al., a significant decrease in tinnitus sonority score was seen in the long-term with the implant switched off, although this effect was lower than that observed when the implant was switched on [23].

Patients with hyperacusis show a lower capacity to ignore tinnitus, and the impact of associated depression and quality of life is higher than that observed in patients with tinnitus without hyperacusis. These patients have a significant need for treatment of their incapacitating tinnitus when it is accompanied by hyperacusis. As described by Mertens et al. [23], a significant decrease from very severe to mild-moderate in all patients in the long term in the SHQ test scores was observed. In our patients, CI surgery resulted in a positive effect on sound intolerance.

The results of this study show, in subscales General Score and Physical Health Score of the quality questionnaire GBI, a significant subjective benefit when comparing pre-surgery scores and their changes up to the 60th post-CI month; similar results are seen in other published series, in which a significant benefit in quality of life is observed in patients with tinnitus treated with a CI [24-26].

All patients in our study presented complete insertion of the electrodes, and we believe this is necessary to achieve good CI performance and suppression of tinnitus.

In view of the above, cochlear implants should be considered as a valid treatment option for this population, although careful selection of the patient must be performed.

Conclusions

Cochlear implant can be successfully used as treatment for patients with severe to profound sensorineural hearing loss associated with disabling tinnitus and hyperacusis with lasting relief of tinnitus and hyperacusis, and benefits in hearing and quality of life in the long-term.

Conflict of interest statement

The authors declare no conflict of interest.

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Authors' contributions

FGJC: data acquisition, cochlear implant fitting programming, and statistics study. BBS: data acquisition and manuscript writing. TGdCM: literature review and audiological assessments. ARM: literature review and writing of the manuscript. All authors contributed to the article and approved the submitted version.

Ethical consideration

This study was approved by the Institutional Ethics Committee of the Complejo Hospitalario Universitario Insular Materno Infantil de Gran Canaria (approval number/protocol number 54 CE certificate).

Researchers informed patients about the risks and benefits of participating in this study, who gave their informed consent prior to study initiation.

The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki.

Written informed consent was obtained from each participant/patient for study participation and data publication.

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