ORIGINAL ARTICLE

The Cochlear Implant as a Tinnitus Treatment

Héctor Vallés-Varela,* Juan Royo-López, Luis Carmen-Sampériz, José M. Sebastián-Cortés, Ignacio Alfonso-Collado

Servicio de Otorrinolaringología, Hospital Clínico Universitario Lozano Blesa, Zaragoza, Spain

Received 16 September 2012; accepted 30 November 2012

KEYWORDS
Tinnitus; Cochlear implants; Hearing loss

Abstract
Introduction and objectives: Tinnitus is a symptom of high prevalence in patients with cochlear pathology. We studied the evolution of tinnitus in patients undergoing unilateral cochlear implantation for treatment of profound hearing loss.

Methods: This was a longitudinal, retrospective study of patients that underwent unilateral cochlear implantation and who had bilateral tinnitus. Tinnitus was assessed quantitatively and qualitatively before surgery and at 6 and 12 months after surgery.

Results: We evaluated 20 patients that underwent unilateral cochlear implantation with a Nucleus® CI24RE Contour Advance™ electrode device. During the periods in which the device was in operation, improvement or disappearance of tinnitus was evidenced in the ipsilateral ear in 65% of patients, and in the contralateral ear, in 50%. In periods in which the device was disconnected, improvement or disappearance of tinnitus was found in the ipsilateral ear in 50% of patients, and in the ear contralateral to the implant in 45% of the patients. In 10% of the patients, a new tinnitus appeared in the ipsilateral ear.

Conclusions: The patients with profound hearing loss and bilateral tinnitus treated with unilateral cochlear implantation improved in a high percentage of cases, in the ipsilateral ear and in the contralateral ear.

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PALABRAS CLAVE
Acúfeno; Implante coclear; Hipoacusia

El implante coclear como tratamiento del acúfeno

Resumen
Introduction y objetivos: El acúfeno es un síntoma de elevada prevalencia en pacientes afectados de una cocleopatía. Estudiamos la evolución del acúfeno en pacientes sometidos a implantación coclear unilateral como tratamiento de la hipoacusia profunda.

Métodos: Estudio longitudinal y retrospectivo de pacientes intervenidos de implantación coclear unilateral que presentaban acúfenos bilaterales. Se ha realizado valoración cuantitativa y cualitativa de los acúfenos previo a la cirugía, y a los 6 y 12 meses de la intervención quirúrgica.

* Corresponding author.
E-mail address: hvalles@salud.aragon.es (H. Vallés-Varela).

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Introduction

The therapeutic effect of cochlear implantation on previously existing tinnitus in patients had already been noted in the initial moments of the history of the cochlear implant. In 1981 House and Brackmann reported that patients with cochlear implants indicated, after the surgery, an improvement in previously existing tinnitus. Given these results, these authors suggested the possibility of using cochlear implantation procedures for patients suffering severe tinnitus.

In fact, following the diffusion of cochlear implant techniques, numerous authors have pointed out this possibility. For that reason, we decided to study the influence of cochlear implantation on tinnitus and the possible application of this surgical technique to treat this symptom.

Methods

We studied the influence of unilateral cochlear implantation on bilateral tinnitus existing previously in patients treated with this technique. The assessment was carried out on 20 patients that received unilateral cochlear implantation using a Nucleus CI24RE implant with a Contour Advance™ electrode.

The aetiology of the hearing loss of the patients under study varied greatly and was unknown in many cases. Consequently, it was difficult to use this information statistically in this study.

The laterality of the surgical procedure (that is, the ear chosen for implantation) was generally independent of the characteristics of the tinnitus suffered by the patient, the decision being based on various anatomical and audiological criteria. Nevertheless, in several cases, the severity of hearing loss in 1 of the 2 sides, in ears having similar anatomical and auditory conditions, determined the ear to implant.

As criteria of inclusion, we used the following: patients of either gender, of an age greater than 15 years; with presence of stable bilateral tinnitus having existed over 2 years; and lacking response to any of the treatments used previously.

As criteria of exclusion, we established the following: the existence of possible organic causes for tinnitus—except for the cochlear pathology itself—; presence of vascular loops, situations of cochlear nerve aplasia or dysplasia; retrococlear regrowth at any stage of evolution; existence of dysfunction in the temporomandibular joint; and cases of cochlear implantation in which there had been difficulties in inserting the electrode-bearing bundle.

The surgical technique was identical in all cases, inserting the implant to the same depth in all the patients. This intervention was performed by the same surgeons.

To assess our results, we used 2 interviews in addition to the initial medical history. The first interview was carried out 6 months after the surgical procedure and the second, 1 year following the cochlear implantation.

In the initial medical history and the later interviews, tinnitus existing in both ears of the patient was assessed. Likewise, we assessed tinnitus by asking the patient about it with the implant both functioning and disconnected.

To assess the tinnitus qualitatively and quantitatively, we used the modification of the Tinnitus Handicap Inventory (THI) scale proposed by McCombe et al. and visual analogue scale (VAS) respectively.

In the case of qualitative assessment, given that what was involved was bilateral tinnitus for which it was hard for the patient to give a precise estimate, we decided to use the McCombe test. In this test, the patients were asked to include themselves within 1 of the 5 groups proposed by the author, based on their overall sensation.

Quantitative assessment was carried out by surveying the patients about each ear separately. We used a 10-point VAS (basically, a numerical scale between 1 and 10) with which the patients could quantify their tinnitus, in one ear and the other, by simply assigning it a number.

Results

The pre-surgical assessment of the tinnitus existing in the target population, using the THI scale as modified by McCombe et al., showed that in 5% of the cases (1 patient) the tinnitus was considered severe (Grade 4), while in 10% of the cases (2 patients) it was considered moderate (Grade
3), in 50% of the cases (10 patients) it was assessed as mild (Grade 2) and in 35% of the cases (7 patients) the tinnitus was considered not bothersome (Grade 1).

In the prior quantitative assessment, in 80% of our cases (16 cases) the tinnitus was assessed as dominant in 1 of the 2 ears; in the rest of the cases (4 patients) the tinnitus was considered of equal intensity in both ears or difficult to differentiate. In 10 cases of the 16 in which the tinnitus was considered dominant, it was located in the right ear, representing 62.5% of the cases.

With respect to quantitative assessment, the mean analogue assessment from the patients, including all of the cases, was 5.15±1.9 in the ear with tinnitus considered as dominant, and 2.85±1.07 in the other ear.

Fig. 1: The graph shows the qualitative improvement of pre-existing tinnitus following surgery, according to the McCombe modification of the THI scale. The bar graph represents the different groups of qualitative assessment, the solid bars indicating the tinnitus perceived by the patients before the intervention, while the cross-hatched bars indicate residual tinnitus following the surgical intervention.

Referring to the implanted ears, the pre-surgical patient assessment of the tinnitus, using the VAS, was 4.6±2.4. In the non-implanted ear, the initial assessment yielded a pre-surgical tinnitus of 3.3±1.2.

After the surgical intervention, we found an improvement in the existing tinnitus. Of the 20 cases, in 5% of the cases (1 patient) tinnitus was assessed as moderate (Grade 3), in 20% of the cases (4 patients) it was assessed as mild (Grade 2), in 60% of the cases (12 patients) it was considered as non-bothersome (Grade 1) and in 3 cases (15%) the tinnitus disappeared (Fig. 1).

The overall quantitative post-surgical assessment using an analogue scale showed an improvement in tinnitus intensity. Its score decreased from 5.1±1.9 to 3.3±1.6 in the ear with more intense tinnitus, and from 2.8±1 to 1.9±1 in the ear considered the better one (Fig. 2).

Referring to the implanted ears, after the surgical intervention the tinnitus assessed by the patient using the VAS dropped from 4.6±2.4 to 2.8±1.6. In the non-implanted ear, after the surgery the tinnitus improved from 3.3±1.2 to 2.4±1.1 (Fig. 3).

A quantitative improvement was appreciated in the ear that received the cochlear implant (homolateral) in 65% of the patients (13 cases). In the ear opposite the cochlear implant (contralateral), the improvement was reported by 50% of the patients (10 cases). These figures all refer to periods in which the implant was working.

In addition, in the periods in which the cochlear implant was disconnected, improvement or disappearance of the tinnitus in the implanted ear was found in 50% of the patients (10 cases), along with improvement or disappearance of the tinnitus in the contralateral ear in 40% of the patients (8 cases).

In 10% of the cases (2 patients), a new tinnitus or an increase in the existing tinnitus occurred in the implanted ear, while no new tinnitus appeared in the non-implanted ear. These cases of new tinnitus were included in the overall assessment of the results obtained.

These results were found at 6 months after the surgery and remained stable without appreciable changes 1 year after the surgical intervention.

Discussion

We define tinnitus as a spontaneous, disagreeable auditory sensation, of varied origin and multiple causes. At one time or another, 35% of the general population has suffered it. In 5% of the population, tinnitus is responsible for difficulties in falling asleep or represents a moderate to intense problem.
From 0.5% to 1% of the population experiences tinnitus that severely affects their lives.\cite{Holliday}

The exact physiopathology of tinnitus is unknown. Consequently, the conclusion is that it must be produced by various events, at different levels of the hearing mechanism, that the brain interprets as sound.

Its topographic origin is conceived as extremely variable. However, the high percentages of tinnitus appearing in the course of well-known cochlear pathologies makes it possible to suggest that it originates, at least partially and in a great many cases, at the cochlear level. This explains why the prevalence of the tinnitus in patients having a cochlear implant (that is, affected by cochlear pathology) is 66%–86%.

These tinnitus problems in patients that received cochlear implantation are considered by the patients as severe in 20%–30% of the cases, depending on the authors consulted.

Assessing the various aspects and parameters of hearing loss is difficult. Comparison techniques with external sounds or the contralateral ear are often used. However, these possibilities are unusable in the specific case of patients with profound hearing loss. Among the many scales used to measure the amount and characteristics of hearing loss, such as the Tinnitus Grading System,\cite{Hollenhauer} Tinnitus Effect Questionnaire,\cite{Boch} Tinnitus Severi-

ity Questionnaire,\cite{Braun} Tinnitus Handicap Questionnaire,\cite{Nardone} Benefit-Problem Questionnaire,\cite{Horn} Subjective Tinnitus Severity Scale,\cite{Lindley} Tinnitus Reaction Questionnaire\cite{Groves} and the Tinnitus Handicap-Support Questionnaire,\cite{Lindley} we chose the modification of the Tinnitus Handicap Inventory\cite{Combs} done by McCombe in 1999.\cite{McCombe} This one was selected because it assesses aspects related to quality of life better, while the THI test evaluates the incapacity produced by the hearing loss; consequently, in the case of our cochlear implant patients, the THI is not applicable in many of the questions asked, given that the incapacity of the patient is explained more by the profound hearing loss than by the accompanying tinnitus.

Although many authors have pointed out improvement in tinnitus that ranges between 40%\cite{Heyning} and 93%\cite{Lindley} of implanted patients as a fact occurring after cochlear implantation, the first to carry out a specific study on this matter were Van de Heyning\cite{Heyning} and Vermeire.\cite{Vermeire} These authors studied the treatment of severe, untreated homolateral tinnitus, by means of cochlear implantation, in 21 patients with unilateral hearing loss and homolateral tinnitus; they found significant improvement in a high percentage of the patients, with the tinnitus dropping from 8.5 to 2.4 in the VAS scores.

More recently, in our environment, Ramos et al.\cite{Ramos} carried out a study on tinnitus occurring as a consequence of sudden hearing loss and treated by cochlear implantation, obtaining good results.

Our figures indicate that the proportion of tinnitus problems considered as severe in the implanted patients was lower (5% of the cases) than that published in the literature consulted (20%–30% of the cases). This difference might be due to the limited size of our sample.

The improvement assessed using the analogue scale was lower than that reported by Van de Heyning\cite{Heyning} and Vermeire,\cite{Vermeire} possibly because of the different nature of the patients considered.

The improvement achieved in both ears, with respect to the implanted side and to the fact that the device was working or disconnected, coincided in general terms with already published results.

All of this confirms the possibility of treating tinnitus by cochlear implantation in specific situations.

Perhaps the most notable aspect of the influence of the cochlear implant on tinnitus is the discussion about the physiopathology of tinnitus itself. In this sense, the experiences of House and Brackmann\cite{House} make for a revealing starting point. These authors found that auditory nerve section or labyrinthine destruction produced an improvement in this symptom in 40% of the cases, while the tinnitus remained stable or even got worse in the rest of the patients. That indicates that the tinnitus improvement obtained from cochlear implantation cannot be attributed to destroying the labyrinth and has to be caused by other mechanisms.

With respect to treatment of tinnitus through electrical stimulation, Grapengiesser\cite{Grapengiesser} performed the first experiments in 1802, obtaining good results, although they were temporary and short-lived. After that, many authors have worked in this field. In this respect, we can cite Di Nardo et al.,\cite{DiNardo} who reported that tinnitus improved in 45.5% of the patients treated, after 1 month of electrical stimulation.

In this context, the continued electrical stimulation involved in cochlear implantation itself has to be considered. Chang and Zeng\cite{Chang} recently studied this aspect, varying the conditions of the electrical stimulation of the cochlea using the cochlear implant; they assessed the results obtained in the persistence of the tinnitus, without reaching conclusive results.

Despite the fact that both the destruction of the cochlea and its electrical stimulation can be considered as arguments for the improvement in tinnitus following cochlear implantation, other hypotheses can be advanced. To explain these phenomena, the following have been considered:

- Tonotopic reorganisation of the cochlea, auditory pathway and the cortex itself following implant programming and the consequent adaptation of the auditory infrastructure to the new situation of frequencies, as Vermeire et al.\cite{Vermeire} suggest.
- The masking effect that the sound perceived after cochlear implantation might produce on the existing tinnitus.
- The direct neural stimulation involved in the strategy of cochlear implantation itself, which avoids the participation of the cochlear sensory cells. This would prevent the Zener\cite{Zener} types II and III tinnitus.
- Modification of the activity of the efferent system that would readapt to the new afferent activity of the auditory pathway produced by the direct neural stimulation, which would prevent the type i tinnitus described by Zener and Ernst.\cite{Zener}
- Another aspect that should be considered is the fact that tinnitus improvement is produced in both the implanted ear and in the contralateral ear, and that this improvement exists with the cochlear implant working as well as with the implant disconnected; this has also been indicated in earlier studies.
- One has to think that the results obtained by cochlear implantation on the contralateral ear are explained by the decussation of the auditory pathway, and that these results are also perceptible with the implant.
disconnected as a consequence of the stable, permanent reorganisation of the central and peripheral nervous system, faced with the device implanted.

- With respect to tinnitus secondary to the cochlear implantation itself, none of the patients in our series or in any others have assessed them as severe.
- Another interesting aspect of this discussion is the cure or improvement of tinnitus after periods of over 2 years, which reduces the validity of the alleged irreversibility of the tinnitus labelled chronic.

It must be mentioned that, even though all the researchers indicated the benefits of the cochlear implant in the face of tinnitus, cost/benefit studies should be performed to make it possible to establish tinnitus as another indication for the cochlear implant and, at any rate, to determine the characteristics for selecting candidates for this procedure.

Conclusions

The unilateral cochlear implant improved tinnitus, in both homolateral and contralateral sides, previously suffered by the patient in a considerable percentage of the cases.

Cochlear implantation caused the appearance of homolateral tinnitus in a small percentage of the cases.

None of the cases of tinnitus that appeared following cochlear implantation were considered severe by the patient.

Cost/benefit studies should be carried out to assess tinnitus as another indication for the cochlear implant.

Conflict of Interests

The authors have no conflict of interests to declare.

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