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TINNITUS SEVERITY IN PATIENTS WITH COCHLEAR IMPLANTS

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

Introduction: Cochlear implantation is the most effective method of hearing rehabilitation in a group method in group of patients with severe and profound sensorineural hearing loss. Furthermore, tinnitus is a frequent symptom related to hearing impairment. The aim of this study was to assess severity of tinnitus before and after cochlear implantation.

Material and methods: This study included 70 patients (35 women and 35 men), who were implanted. Tinnitus severity was evaluated three times: preoperatively, at activation and one month after implantation. Tinnitus and Hearing Survey (THS), Tinnitus Handicap Inventory (THI) and Tinnitus Functional Index (TFI) were used to assess tinnitus severity. THS and THI adaptation were conducted in the World Hearing Center of the Institute of Physiology and Pathology of Hearing.

Results: The results showed that tinnitus was experienced in 65.7% of patients who were qualified to cochlear implantation. One-sided tinnitus (in the operated ear) was experienced in 54.4% cases and bilateral tinnitus in 45.6%. Hearing impairment was the primary complaint of 93.5% cases. Preoperatively, severity of tinnitus was assessed as moderate (THI *M*=39.9; *SD*=23.4; TFI *M*=38.4; *SD*=21). Results after one monthly observation suggested mild tinnitus severity (*M*=25.6; *SD*=21.9; TFI *M*=29.2; *SD*=20.6).

Conclusions: Monthly observation showed that severity of tinnitus after cochlear implantation decreased.

Keys words: adults • cochlear implant • tinnitus

TINNITUS EN PACIENTES CON IMPLANTES COCLEARES

Resumen

Introducción: A lo largo de varias décadas, los implantes cocleares llegaron a ser la prótesis más eficaz en caso de una pérdida de audición profunda y considerable. Un síntoma frecuente que coexiste en el grupo de pacientes con pérdida de audición profunda o considerable lo es el tinnitus. El objetivo del trabajo consistió en la evaluación de la molestia producida por el tinnitus antes y después de la implantación coclear.

Material y métodos: En la investigación participó un grupo de 70 pacientes (35 mujeres y 35 hombres), sometidos al procedimiento de implantación coclear. La evaluación de la presencia y la molestia causada por el tinnitus se realizó cuatro veces, o sea, durante: la consulta preoperatoria, la activación, como también un mes más tarde.

En la investigación se aplicó un conjunto de cuestionarios que evalúan la molestia provocada por el tinnitus: Tinnitus and Hearing Survey (THS), Tinnitus Handicap Inventory (THI) y Tinnitus Functional Index (TFI). La adaptación del THS y del THI se llevó a cabo en el Instituto de Fisiología y Patología Auditiva (IFPS).

Resultados: El análisis de los resultados demostró que el 65,7% de los pacientes calificados para la implantación coclear sintió tinnitus. El 54.4% de los pacientes notificaron tinnitus unilateral, sólo en el oído calificado para la operación, y el 45,6% de los pacientes comunicó notar ruidos en ambos oídos. Según la evaluación de los pacientes, la deficiencia auditiva era un problema más grave que el tinnitus (el 93,5%)

Antes de la operación, las molestias causadas por el tinnitus se evaluaron a un nivel moderado, THI *M*=39,9; *SD*=23,4; TFI *M*=38,4; *SD*=21. Después de la operación, durante la observación mensual, THI *M*=25,6; *SD*=21,9; TFI *M*=29,2; *SD*=20,6, se clasificaron como leves.

Conclusiones: En la observación mensual, la implantación coclear hace reducir la intensidad del tinnitus.

Palabras clave: adultos • implantes cocleares • tinnitus

НАЛИЧИЕ ШУМА В УШАХ У ПАЦИЕНТОВ С КОХЛЕАРНЫМИ ИМПЛАНТАТАМИ

Изложение

Введение: В течение нескольких последних десятилетий кохлеарные имплантаты стали самым эффективным способом протезирования тугоухости глубокой и значительной степени. Частым сопутствующим симптомом в группе пациентов со значительной или глубокой тугоухостью является шум в ушах. Целью работы была оценка обременительности шума в ушах до и после кохлеарной имплантации.

Материал и методы: Исследование проводилось на группе 70 пациентов (35 женщин, 35 мужчин), которым был вживлён кохлеарный имплантат. Оценка наличия и обременительности шума в ушах была проведена четыре раза: во время предоперационного приёма, активации, а также через месяц.

В исследовании использовался комплект опросников, определяющих обременительность шума в ушах: Tinnitus and Hearing Survey (THS), Tinnitus Handicap Inventory (THI) и Tinnitus Functional Index (TFI). Адаптация THS и THI была проведена в Институте физиологии и патологии слуха.

Результаты: Анализ результатов показал, что 65,7% пациентов, квалифицирующихся на установку кохлеарного имплантата, слышало шум в ушах. 54.4% пациентов говорило об одностороннем шуме в ушах, только в ухе, которое квалифицировалось на операцию, а 45.6% информировало о двустороннем шуме в ушах. По оценке пациентов, большей проблемой являлась тугоухость, нежели шум в ушах (93,5%).

До операции обременительность шума в ушах оценивалась на умеренном уровне, THI *M*=39,9; *SD*=23,4; TFI *M*=38,4; *SD*=21. После операции, по результатам месяца наблюдения THI *M*=25,6; *SD*=21,9; TFI *M*=29,2; *SD*=20,6 обременительность шума классифицировалась на низком уровне.

Выводы: Результаты месяца наблюдения показали, что кохлеарная имплантация уменьшает интенсивность шума в ушах.

Ключевые слова: взрослые • кохлеарные имплантаты • шум в ушах

WYSTĘPOWANIE SZUMÓW USZNYCH U PACJENTÓW Z IMPLANTAMI ŚLIMAKOWYMI

Streszczenie

Wprowadzenie: Na przestrzeni kilku dekad implanty ślimakowe stały się najskuteczniejszym sposobem protezowania ubytku słuchu w stopniu głębokim i znacznym. Częstym objawem współwystępującym w grupie pacjentów z znacznym lub głębokim niedosłuchem są szumy uszne. Celem pracy była ocena uciążliwości szumów usznych przed i po implantacji ślimakowej.

Materiał i metody: Badaniami objęto grupę 70 pacjentów (35 kobiet, 35 mężczyzn), poddanych procedurze wszczepienia implantu ślimakowego. Oceny występowania i uciążliwości szumów usznych dokonano trzykrotnie, podczas: wizyty przedoperacyjnej, aktywacji, a także miesiąc po aktywacji. W badaniu zastosowano zestaw kwestionariuszy określających uciążliwość szumów usznych: Tinnitus and Hearing Survey (THS), Tinnitus Handicap Inventory (THI) and Tinnitus Functional Index (TFI). Adaptacja THS oraz THI została przeprowadzona w IFPS.

Wyniki: Analiza wyników wykazała, że 65,7% pacjentów kwalifikowanych do wszczepienia implantu ślimakowego odczuwało szumy uszne. 54,4% pacjentów zgłaszało jednostronne szumy uszne tylko w uchu kwalifikowanym do operacji a 45,6% pacjentów zgłaszało obustronne szumy uszne. W ocenie większości pacjentów (93,5%) większy problem stanowił niedosłuch niż szumy uszne. Przedoperacyjna dokuczliwość szumów usznych oceniana była na poziomie umiarkowanym (THI *M*=39,9; *SD*=23.4; TFI *M*=38,4; *SD*=21). Pooperacyjnie w miesięcznej obserwacji (THI *M*=25,6; *SD*=21,9; TFI *M*=29,2; *SD*=20,6), klasyfikowane w stopniu łagodnym.

Wnioski: W obserwacji miesięcznej implantacja ślimakowa zmniejsza nasilenie szumów usznych.

Słowa kluczowe: dorośli • implanty ślimakowe • szumy uszne

Introduction

Tinnitus (Latin *tinnire*, ring) is defined as a phantom auditory sensation without any external acoustic input [1–3]. In the majority of cases, patients describe it as "ringing", but sometimes squeaking, knocking, rustling, whizzing, buzzing, whistling, rumbling, or other sounds are reported. Mechanisms responsible for tinnitus are unknown. One of many hypotheses suggests it is caused by decreased or increased cochlear electrical activity [4]. Another theory assumes that tinnitus results from changes in neural activity caused by reduced or lost auditory input (hearing loss) [5]. To discover what neural discharge patterns could be responsible for a sensation of sound when there is no acoustic input to the ear, we first need to examine discharge patterns that occur in response to known sounds. There is considerable evidence that it is not as simple as an increased discharge rate of individual nerve cells; rather it is the temporal coherence of neural activity in many nerve cells which signals the presence of a sound. It has been hypothesized that neural synchrony in one form or another may play an important role, and this has been supported in an experimental study [6]. Functional magnetic resonance imaging of people who can voluntarily alter

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their tinnitus [7] supports the hypothesis that the neural activity responsible for the sensation of tinnitus is not generated in the ear. Other studies (using the same technique) have shown evidence that the neural activity in the cerebral cortex originating from tinnitus is not generated in the same way as sound-evoked activity and is not generated in the ear [8]. In contrast, tinnitus activates the auditory cortex on both sides. These findings are in strong agreement with the results of studies on the auditory nervous system which may relate to tinnitus sensation in some people.

Hoffman and colleagues [9] estimated that tinnitus affects about 50 million Americans and 70 million European Union citizens. According to Punte et al. [10], the disorder affects 10–16% of the world's adult population.

Tinnitus coincides most often with the following phenomena: profound sensorineural hearing loss [2,3,11]; ototoxic drug treatment; and metabolic and neurological psychogenic disorders [12]. Only 8–10% of patients with tinnitus have normal hearing [13], while 85 to 96% have some degree of hearing loss [14]. Tinnitus prevalence may also vary when we analyze particular age groups. Such studies are particularly important, because in schoolchildren tinnitus is related to worse reports, more aggressive behavior, or even not being promoted to a higher class. In some countries, tinnitus could be present in 6–14% of children aged 6 to 12 years [15–19].

Currently, many tinnitus treatment methods focus on cognitive behavioral therapy [20]. The aim is to improve habituation based on Jastreboff's neuropsychological model [21]. Basic treatment involves standard hearing aids, sound enrichment therapy, and tinnitus maskers [5]. However, sound therapy is not always effective in patients suffering from profound hearing loss.

Research has shown that a large percentage of patients with a cochlear implant experienced tinnitus before the surgery. This problem affects 51% to 100% of CI candidates [20–24]. Cochlear implantation has become common practice in treating patients with severe or profound hearing loss who cannot benefit from hearing aids [22]. Some decades ago, specialists were satisfied when a cochlear implantation was surgically successful and it was possible to obtain a modicum of electrical stimulation [23–25]. However, recent recipients expect much more than 20 or 30 years ago when the goal was just basic speech understanding [25,26]. One aspect which is increasingly important, especially in aging populations, is tinnitus. There are always questions about suitable indications for cochlear implantation, and now one of them is how will implantation affect tinnitus [27–29].

In 1981, House and Brackmann [30] described the impact of cochlear implants on the suppression of tinnitus. Not only was the therapy completely successful in 8–61% of patients, but tinnitus was also reduced in 64–100% of them. Additionally, research by Baugley and Atlas in 2007 [31] and Pan et al. in 2009 [32] showed that implantation significantly reduced or completely eliminated tinnitus in 46–95% of patients. However, other sources describe several cases where, post-implantation, tinnitus distress increased. For instance, Quaranta et al. [33] observed such an increase, which occurred in 4–26% of their cases.

Although the literature generally reports tinnitus improvement after CI, there is still no consensus on how much benefit is obtained and what is the chance of exacerbating existing tinnitus. This article is a summary of the results of ongoing research conducted on patients experiencing tinnitus who have been implanted in the World Hearing Center in Kajetany.

Material and methods

Participants

The study included patients undergoing cochlear implantation between August 2016 and April 2017 at the Institute of Physiology and Pathology of Hearing (Kajetany, Poland), who completed a battery of tinnitus questionnaires. The material comprised 70 adults (35 female and 35 male) with severe to profound sensorineural hearing loss. All of them were scheduled for first-time cochlear implantation. The mean age at the time of the operation was 50.3±14.1 years (range 18–85). We excluded all patients under 18 years old.

Some 65.7% of the study group (n=46) had been suffering tinnitus; 45.6% (n=21) experienced bilateral tinnitus and 54.4% (n=25) experienced unilateral tinnitus. In this study, contralateral tinnitus was not considered.

Questionnaires

All patients were asked to complete three tinnitus questionnaires in the following time frames: before implantation (1st), before CI activation (2nd), and 1 month after activation (3rd). We used two questionnaires standardized and adapted into the Polish language in our Institute: the Tinnitus and Hearing Survey (THS-POL, data presently unpublished) and the Tinnitus Handicap Inventory (THI-POL) [34]. The third questionnaire – the Tinnitus Functional Index (TFI) – was used in our study under license from Oregon Health and Science, and was obtained from the authors of the original tool.

The Tinnitus and Hearing Survey (THS), published by Henry et al. 2015 [35], is a screening tool. Its aim is to quickly and efficiently separate hearing problems from tinnitus problems, which, in turn, allows the clinician to choose the best available intervention. THS consists of three parts: four items in the A subscale (Tinnitus) describe common problems with tinnitus that are unrelated to hearing problems; four items in the B subscale (Hearing) describe common hearing problems not caused by tinnitus; and two items in the C subscale (Sound Tolerance) are additional, currently non-standardized questions which cover possible experience of hyperacusis.

The Tinnitus Handicap Inventory (THI), developed by Newman et al. in 1996 [36], assesses the impact of tinnitus on everyday functioning. THI consists of 25 items and, in our adaptation, has an unidimensional structure [34]. The total score on THI can range from 0 to 100 points (the maximum possible handicap), and its classification is

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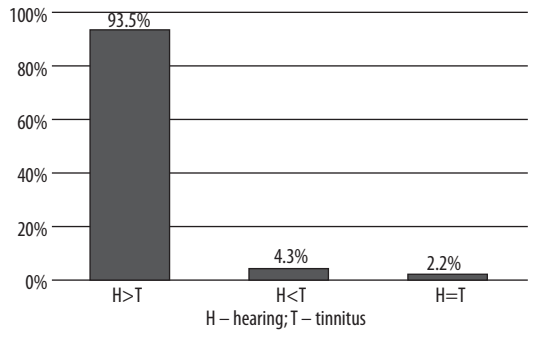

Figure 1. Comparison of THS results from part A (Tinnitus) with part B (Hearing)

based on five handicap categories proposed by McCombe et al. in 2001 [37].

The Tinnitus Functional Index (TFI) was published by Meikle et al. in New Zealand [38]. TFI has eight domains that address the intrusiveness of tinnitus, the degree of control the patient has over the disease, cognitive interference, sleep disturbance, auditory issues, relaxation issues, quality of life, and emotional distress. The questionnaire can be used to gauge the change that treatment brings about. TFI has a documented validity for gauging both the severity and negative impact of tinnitus on daily functioning, and provides comprehensive coverage of multiple tinnitus domains. TFI consists of 25 items, with each item scored on an 11-point scale set by descriptors at either end. The procedure for scoring TFI in our study followed the instructions provided by Meikle et al. [38].

Descriptive statistics (SPSS v. 24) were used to characterize the study group and the questionnaire scores. Student *t*-tests were used to assess changes in scores at different follow-ups.

Results

Tinnitus and Hearing Survey (THS-POL)

Before implantation, a problem with hearing ability was the main concern of the study group (Figure 1). For only two patients was tinnitus a bigger problem than hearing impairment. There was one patient who rated tinnitus and hearing impairment as equal problems. The results from the second and third follow-ups were the same as before the operation.

The results of sound tolerance are shown in Table 1. Before implantation, hyperacusis was a moderate to very big problem for over 56% of the study group. In addition, after their CI two patients started suffering from hyperacusis and rated it as a moderate problem. However, most patients reported a reduction in problems associated with auditory sensitivity.

Statistical analysis revealed that the scores obtained in part A (Tinnitus) did not differ significantly between the period before the operation and CI activation ($t(45)=1.108$; $p=0.3$). However, significant changes were observed after 1 month of CI use ($t(45)=3.943$; $p<0.001$).

Tinnitus Handicap Inventory (THI-POL)

The analysis included 46 patients experiencing tinnitus. Patients who had never experienced tinnitus ($n=24$) according to the THS questionnaire (and confirmed at an interview) were excluded.

Preoperatively, the mean THI score of the tinnitus patients was 46.4 (SD=21.7), and almost half the patients were classified as being more than moderately handicapped (Figure 2). After the operation, but before CI activation, tinnitus somewhat decreased in 45.6% of patients ($n=21$). The handicap degree was unchanged in 17/46 (37%) of patients and worsened in 8/46 (17.4%). However, immediately after the CI operation, 5 patients began to experience tinnitus (2 slightly, 1 mildly, 2 severely); but after one month, in 3 of them the tinnitus disappeared completely and in the other 2 it decreased slightly.

One month after CI activation, 58.7% ($n=27$) of patients had a reduction in the level of their handicap score (compared with the preoperative score), and tinnitus subsided completely in 17.4% ($n=8$) of them. Thirty-seven percent ($n=17$) of patients had no change in their tinnitus handicap. Increase in tinnitus occurred in two patients: one of them had a slight severity score beforehand, and this increased to mild tinnitus after implantation; the second patient had a severe score before the CI, and this increased to catastrophic.

As a group, the mean preoperative THI score (before activation) was 39.9 (SD=23.4), classified as moderately severe; one month later the score was 25.6 (SD=21.9), classified as a mild severity. We observed a statistically significant change between the preoperative and CI activation periods ($t(45)= 2.490$; $p=0.02$), as well as at 1 month follow-up ($t(45)= 5.428$; $p<0.001$).

Table 1. Results of Tinnitus Handicap Survey (THS) part C (Sound Tolerance) at various stages of follow-up ($n=20$)

	Sound Tolerance				
Follow-up stage	**Not a problem**	**Small problem**	**Moderate problem**	**Big problem**	**Very big problem**
Preoperative	34.8% (n=16)	13.0% (n=6)	21.7% (n=10)	21.7% (n=10)	13.0% (n=6)
At activation	34.8% (n=16)	15.2% (n=7)	30.4% (n=14)	10.9% (n=5)	13.0% (n=6)
1 month	30.4% (n=14)	21.7% (n=10)	32.6% (n=15)	13.0% (n=6)	4.3% (n=2)

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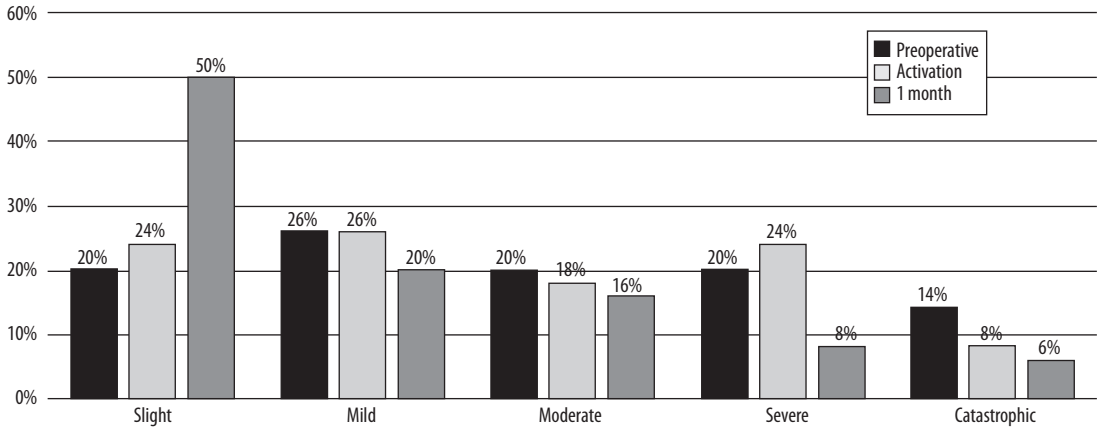

Figure 2. Comparison of THI tinnitus severity between preimplantation, activation, and postimplantation

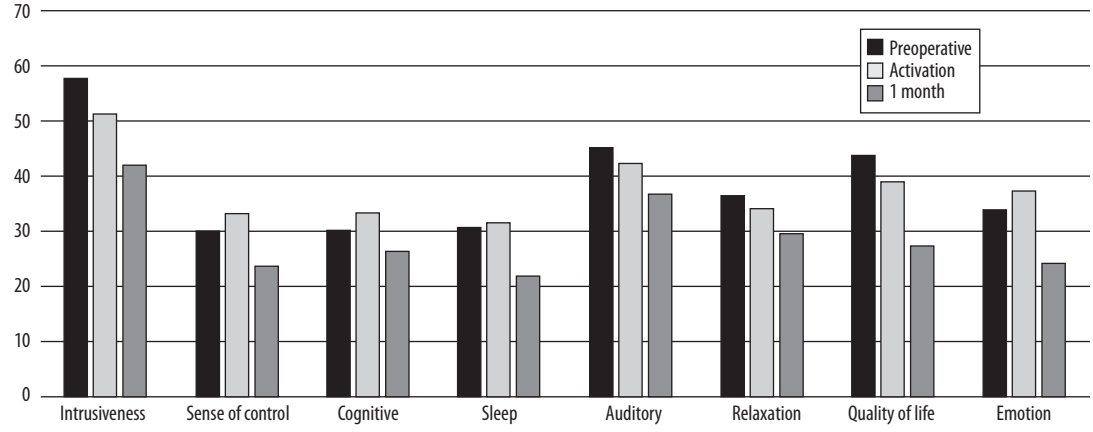

Figure 3. Comparison of TFI domain 'tinnitus influence' between preimplantation, activation, and postimplantation

Tinnitus Functional Index (TFI-PL)

Before implantation the biggest problem for patients with tinnitus was its intrusiveness (for around 60% of them). Moreover, tinnitus significantly impaired quality of life and hearing (Figure 3).

After surgery, the score was similar to the preimplantation score, although there was a decrease in intrusiveness; however an increase in the emotional, sense of control, and cognitive domains was observed. One month after CI activation, the score for all domains decreased.

Using guidelines created by Meikle et al. (2012) for group TFI scoring, the mean preoperative TFI score was 38.4 (SD=21.0), classified as a moderate problem; at the next follow-up, the score was similar 38.0 (SD=21.9), and one month later the score reduced to 29.2 (SD=20.6), classified as a mild problem.

Total preoperative TFI score indicates that 80% of the patients had a mild to very large problem with tinnitus. However, one month after CI activation 45.5% of the study sample had no problem with tinnitus (Figure 4). Similar to THS part A, and based on statistical analysis, we did not observe a statistically significant change between the preoperative and activation periods ($t(45)= 0.338$; $p=0.74$). After 1 month of CI use, this difference was, however, statistically significant ($t(45)=3.311$; $p=0.002$).

Discussion

A number of centers in Europe and America have shown that cochlear implantation not only improves hearing ability but also reduces the burden of tinnitus [39–42]. This is an important finding from a quality of life point of view. Tinnitus severity is quite often considered by insurance organizations, e.g. in the United States, when assessing potential benefits from treatment.

In this study of adult CI candidates, the prevalence of tinnitus was 65.7% (46/70). The literature reports tinnitus incidence in candidates for cochlear implantation ranging from 67% to 100% (mean 80%) [31]. Amoodi et al. [42] reported an incidence of 78%, and our data seems to confirm this previous series.

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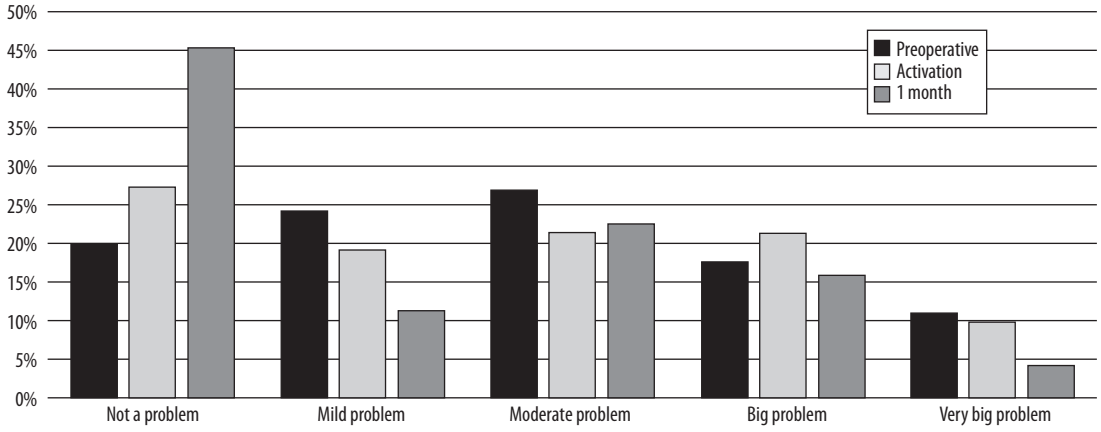

Figure 4. Severity of tinnitus as measured on the TFI subscale

Development of postoperative tinnitus was perceived in 5 of 24 patients who had not experienced tinnitus before. In our study, new symptoms of tinnitus appeared immediately after the operation in 5 patients, although one month later total suppression occurred in 3 of them. This is similar to reports of Kompis et al. [43]. Such changes might happen due to position of the body, and sometimes it is also associated with minor vestibular disorders [44–47].

The research of di Nardo et al. [48] showed a decrease of THI scores in 13 cases (65%), unchanged in 6 (30%), and increased in 1 (5%). In the present study, a high rate of patients reported an improvement in tinnitus one month after CI activation: there was total suppression of tinnitus in 8 patients, THI and TFI scores were reduced in 59% (n=27), and increased in 4% (n=2).

In our study the THI score after the operation, but before CI activation, showed a significant increase in the severity of tinnitus. In the same follow-up, the total TFI score was similar to the preoperative result, but there was an increase in the emotional, sense of control, and cognitive domains.

The mean THI severity score was 46.4±21.7 preoperatively, and almost 54% of this group had a tinnitus severity greater than mild. A similar result was reported by Bovo et al. [49], where almost 60% of patients were classified as more than mildly handicapped by tinnitus. In the study by Kim et al. [50], more than half the patients suffered from more than mild tinnitus.

There is no study using TFI for patients with impaired hearing. In the literature, we can only find research on people with normal hearing threshold. One is the study by Fackrell et al. [51] in which the mean TFI score was 38.4 (SD=21); however one month after CI activation it was 29.2 (SD=20.6). In addition, the intrusiveness of tinnitus can cause problems with cognition, sense of control, and emotion. In the present study, preimplantation scores showed that tinnitus had a negative effect on intrusiveness, hearing, and quality of life.

Conclusions

Our results show that the prevalence of tinnitus in CI patients is relatively high. Although an increase in tinnitus questionnaire scores can be recorded in CI patients at activation, this change is not statistically significant. Furthermore, after 1 month of CI use, the patients reported significantly lower tinnitus distress compared to the preoperative period.

References:

1. Akdogan O, Ozcan I, Ozbek C, Dere H. Tinnitus after cochlear implantation. Auris Nasus Larynx, 2009; 36: 210–12.
2. Arts RAGJ, George ELJ, Stokroos RJ, Vermeire K. Review: Cochlear implants as a treatment of tinnitus in single-sided deafness. Curr Opin Otolaryngol Head Neck Surg, 2012; 20: 398–403.
3. van Zon A, Smulders YE, Ramakers GG, Stegeman I, Smit AL, Van Zanten GA et al. Effect of unilateral and simultaneous bilateral cochlear implantation on tinnitus: A prospective study. Laryngoscope, 2016; 126: 956–61.
4. Greenberg D, Meerton L, Graham J, Vickers D. Developing an assessment approach for perceptual changes to tinnitus sound characteristics for adult cochlear implant recipients. Int J Audiol, 2015; 55: 392–404.
5. Arts RAGJ, George ELJ, Janssen M, Griessner A, Zierhofer C, Stokroos RJ. Tinnitus suppression by intracochlear electrical stimulation in single sided deafness – a prospective clinical trial: follow-up. PLoS One, 2016; 11: e0153131.
6. Møller AR. Hearing: Anatomy, physiology, and disorders of the auditory system, Third Edition. Plural Publishing; 2012; 331–32.
7. Pinchoff RJ, Burkard RF, Salvi RJ, Coad ML, Lockwood AH. Modulation of tinnitus by voluntary jaw movements. Am J Otol, 1998; 19: 785–89.
8. Lockwood AH, Salvi RJ, Coad ML, Towsley ML, Wack DS, Murphy BW. The functional neuroanatomy of tinnitus: Evidence for limbic system links and neural plasticity. Neurology, 1998; 50: 114–20.

DOI: 10.17430/904529

9. Snow JB. Tinnitus: Theory and management. PMPH-USA; 2004.
10. Punte AK, Vermeire K, Hofkens A, De Bodt M, De Ridder D, Van de Heyning P. Cochlear implantation as a durable tinnitus treatment in single-sided deafness. Cochlear Implants Int, 2011; 12 (Suppl. 1): S26–29.
11. Kim DK1, Moon IS, Lim HJ, Yoo SY, Heo KW, Bae SC et al. Prospective, multicenter study on tinnitus changes after cochlear implantation. Audiol Neurotol, 2016; 21: 165–71.
12. Crummer RW, Hassan GA. Diagnostic approach to tinnitus. Am Fam Physician, 2004; 69: 120–26.
13. Barnea G, Attias J, Gold S, Shahar A. Tinnitus with normal hearing sensitivity: Extended high-frequency audiometry and auditory-nerve brain-stem-evoked responses. Audiology, 1990; 29: 36–45.
14. Sanchez TG, Medeiros IRT, Dias Levy CP, Ramalho JROR, Bento RF. Tinnitus in normally hearing patients: clinical aspects and repercussions. Rev Bras Otorrinolaringol, 2005; 71: 427–31.
15. Skarzynski PH, Kochanek K, Skarzynski H, Senderski A, Wysocki J, Szkielkowska A et al. Hearing screening program in school-age children in western Poland. J Int Adv Otol, 2015; 7(2): 94–200.
16. Skarzynski P, Pilka A, Ludwikowski M, Skarzyńska MB. Comparison of the frequency of positive hearing screening outcomes in school children from Poland and other countries of Europe, Central Asia, and Africa. J Hear Sci, 2015; 4: 51–58.
17. Skarzynski PH, Wlodarczyk AW, Kochanek K, Pilka A, Jedrzejczak WW, Olszewski L et al. Central auditory processing disorder (CAPD) tests in a school-age hearing screening programme: analysis of 76,429 children. Ann Agric Environ Med, 2015; 22: 90–95.
18. Skarzyński PH, Świerniak W, Piłka A, Skarżynska MB, Włodarczyk AW et al. A hearing screening program for children in primary schools in Tajikistan: A telemedicine model. Med Sci Monit, 2016; 22: 2424–30.
19. Raj-Koziak D. Występowanie szumów usznych u dzieci: przegląd piśmiennictwa. Now Audiofonol, 2016; 5: 9–14.
20. Parazzini M, Bo LD, Jastreboff M, Tognola G, Ravazzani P. Open ear hearing aids in tinnitus therapy: An efficacy comparison with sound generators. Int J Audiol, 2011; 50: 548–53.
21. Jastreboff PJ, Brennan JF, Sasaki CT. An animal model for tinnitus. Laryngoscope, 1988; 98: 280–86.
22. van Schoonhoven J, Sparreboom M, van Zanten BG, Scholten RJ, Mylanus EA, Dreschler WA et al. The effectiveness of bilateral cochlear implants for severe-to-profound deafness in adults: A systematic review. Otol Neurotol, 2013; 34: 190–98.
23. Chouard CH, MacLeod P. Implantation of multiple intracochlear electrodes for rehabilitation of total deafness: Preliminary report. Laryngoscope, 1976; 86: 1743–51.
24. House WF, Urban J. Long term results of electrode implantation and electronic stimulation of the cochlea in man. Ann Otol Rhinol Laryngol, 1973; 82: 504–17.
25. Burian K, Hochmair E, Hochmair-Desoyer I, Lessel MR. Designing of and experience with multichannel cochlear implants. Acta Otolaryngol (Stockh), 1979; 87: 190–95.
26. Clark GM, Tong YC, Black R, Forster IC, Patrick JF, Dewhurst DJ. A multiple electrode cochlear implant. J Laryngol Otol, 1977; 91: 935–45.
27. Sampaio AL, Araújo MF, Oliveira CA. New criteria of indication and selection of patients to cochlear implant. Int J Otolaryngol, 2011; 2011: 573968.
28. Olze H, Szczepek AJ, Haupt H, Förster U, Zirke N, Gräbel S et al. Cochlear implantation has a positive influence on quality of life, tinnitus, and psychological comorbidity. Laryngoscope, 2011; 121: 2220–27.
29. Plontke SK, Heider C, Koesling S, Hess S, Bieseke L, Goetze G et al. Cochlear implantation in a child with posttraumatic single-sided deafness. Eur Arch Oto-Rhino-Laryngol, 2013; 270: 1757–61.
30. House JW, Brackmann DE. Tinnitus: surgical treatment. Ciba Found Symp, 1981; 85: 204–16.
31. Baguley DM, Atlas MD. Cochlear implants and tinnitus. Prog Brain Res, 2007; 166: 347–55.
32. Pan T, Tyler RS, Ji H, Coelho C, Gehringer AK, Gogel SA. Changes in the Tinnitus Handicap Questionnaire after cochlear implantation. Am J Audiol, 2009; 18: 144–51.
33. Quaranta N, Wagstaff S, Baguley DM. Tinnitus and cochlear implantation. Int J Audiol, 2004; 43: 245–51.
34. Skarzynski PH, Raj-Koziak D, Rajchel JJ, Pilka A, Wlodarczyk AW, Skarzynski H. Adaptation of the Tinnitus Handicap Inventory into Polish and its testing on a clinical population of tinnitus sufferers. Int J Audiol; 2017; 56(10): 711–15
35. Henry JA, Griest S, Zaugg TL, Thielman E, Kaelin C, Galvez G et al. Tinnitus and hearing survey: A screening tool to differentiate bothersome tinnitus from hearing difficulties. Am J Audiol, 2015; 24: 66–77.
36. Newman CW, Jacobson GP, Spitzer JB. Development of the Tinnitus Handicap Inventory. Arch Otolaryngol Head Neck Surg, 1996; 122: 143–48.
37. McCombe A, Baguley D, Coles R, McKenna L, McKinney C, Windle-Taylor P et al. Guidelines for the grading of tinnitus severity: the results of a working group commissioned by the British Association of Otolaryngologists, Head and Neck Surgeons, 1999. Clin Otolaryngol Allied Sci, 2001; 26: 388–93.
38. Meikle MB, Henry JA, Griest SE, Stewart BJ, Abrams HB, McArdle R et al. The Tinnitus Functional Index: Development of a new clinical measure for chronic, intrusive tinnitus. Ear Hear, 2012; 33: 153–76.
39. Carlyon RP, Macherey O, Frijns JH, Axon PR, Kalkman RK, Boyle P et al. Pitch comparisons between electrical stimulation of a cochlear implant and acoustic stimuli presented to a normal-hearing contralateral ear. J Assoc Res Otolaryngol, 2010; 11: 625–40.
40. Ramos Macías A, Falcón González JC, Manrique M, Morera C, García-Ibáñez L, Cenjor C et al. Cochlear implants as a treatment option for unilateral hearing loss, severe tinnitus and hyperacusis. Audiol Neurootol, 2015; 20(Suppl. 1): 60–66.
41. Gartrell BC, Jones HG, Kan A, Buhr-Lawler M, Gubbels SP, Litovsky RY. Investigating long-term effects of cochlear implantation in single-sided deafness: A best practice model for longitudinal assessment of spatial hearing abilities and tinnitus handicap. Otol Neurotol, 2014; 35: 1525–32.
42. Amoodi HA, Mick PT, Shipp DB, Friesen LM, Nedzelski JM, Chen JM et al. The effects of unilateral cochlear implantation on the tinnitus handicap inventory and the influence on quality of life. Laryngoscope, 2011; 121: 1536–40.
43. Kompis M, Pelizzone M, Dillier N, Allum J, DeMin N, Senn P. Tinnitus before and 6 months after cochlear implantation. Audiol Neurotol, 2012; 17: 161–68.
44. Mick P, Amoodi H, Arnoldner C, Shipp D, Friesen L, Lin V et al. Cochlear implantation in patients with advanced Ménière's disease. Otol Neurotol, 2014; 35: 1172–78.
45. Frodlund J, Harder H, Mäki-Torkko E, Ledin T. Vestibular function after cochlear implantation: a comparison of three types of electrodes. Otol Neurotol, 2016; 37: 1535–40.

DOI: 10.17430/904529

46. Derks LSM, Wegner I, Smit AL, Thomeer HGXM, Topsakal V, Grolman W. Effect of day-case unilateral cochlear implantation in adults on general and disease-specific quality of life, post-operative complications and hearing results, tinnitus, vertigo and cost-effectiveness: Protocol for a randomised controlled trial. BMJ Open, 2016; 6: e012219.
47. Nordfalk KF, Rasmussen K, Hopp E, Bunne M, Silvola JT, Jablonski GE. Insertion depth in cochlear implantation and outcome in residual hearing and vestibular function. Ear Hear, 2016; 37: e129–37.
48. Di Nardo W, Cianfrone F, Scorpecci A, Cantore I, Giannantonio S, Paludetti G. Transtympanic electrical stimulation for immediate and long-term tinnitus suppression. Int Tinnitus J, 2009; 15: 100–6.
49. Bovo R, Ciorba A, Martini A. Tinnitus and cochlear implants. Auris Nasus Larynx, 2011; 38: 14–20.
50. Kim DK, Bae SC, Park KH, Jun BC, Lee DH, Yeo SW et al. Tinnitus in patients with profound hearing loss and the effect of cochlear implantation. Eur Arch Otorhinolaryngol, 2013; 270: 1803–8.
51. Fackrell K, Hall DA, Barry JG, Hoare DJ. Psychometric properties of the Tinnitus Functional Index (TFI): Assessment in a UK research volunteer population. Hear Res, 2016; 335: 220–35.

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