Early effects of very early cochlear implant activation on tinnitus

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Abstract

Background: Cochlear implantation (CI) has long been the standard of care for patients with severe-to-profound hearing impairment. Yet the benefits of CI extend far beyond speech understanding, with mounting recent literature supporting its role in tinnitus abatement. However, those studies have uniformly analyzed the effects of tinnitus after the traditional 3–4 weeks waiting period between CI surgery and device activation. As many clinics are shifting these waiting intervals to become shorter (in some cases within 24 hours, little is known about tinnitus abatement very early in the postoperative period. The aim of this study was to compare preoperative and postoperative tinnitus handicaps in this unique but growing population of very early-activated patients.

Methods: Twenty-seven adults with severe-to-profound hearing impairment with chronic tinnitus (>6 months) were included. Patients with concomitant psychiatric disorders were excluded. All patients were implanted with the same array and were switched on within 24 hours after the surgery. Tinnitus Handicap Inventory (THI) was recorded preoperatively, immediately after activation at 24 hours postoperatively, at 1 week, 2 weeks, and I month after activation. Wilcoxon signed-rank test was used to compare values between preoperative assessment and respective fitting sessions.

Results: Mean THI 24 hours after implantation increased in comparison to that assessed preoperatively (77.6 vs 72.5, $p = 0.001$). By 1 week after surgery, the THI had decreased to 54.9 ($p < 0.001$). This trend continued and was statistically significant at 2 weeks (36.0, $p < 0.001$) and 1 month (28.5, $p < 0.001$).

Conclusion: On average, most patients with tinnitus will note a significant improvement in their tinnitus handicap when activated within 24 hours of CI. However, tinnitus does increase between surgery and 24 hours, most likely reflecting not only intracochlear changes, but modulation of the entire auditory pathway. Following this early rise, the tinnitus continues to abate over the following month. Patients with tinnitus may benefit from early activation, although should be counseled that they may experience an exacerbation during the very early postoperative period.

Keywords: Cochlear implantation; Early activation; Fitting; Tinnitus; Tinnitus handicap inventory

1. INTRODUCTION

Tinnitus is commonly defined as "feeling of noise in the ear/brain without external sources of sound".[1] As a symptom with varying degrees of associated distress ranging from mild to catastrophic life impairment, tinnitus is frequently associated with major disorders of mood, including depression and anxiety.[2–4] Although the pathogenesis remains complex and incompletely understood, one of the main coexisting contributions is hearing impairment.[5,6] As such, any treatment based at addressing existing auditory deprivation has become the hallmark of treatment for patients with tinnitus, ranging from sound therapy and maskers to hearing aids, and more recently cochlear implantation (CI).

For nearly five decades, CI has been the treatment of choice for patients with severe-to-profound hearing loss.[7–9] Although lately, the effects of CI on tinnitus in users have gained attention among both researchers and clinicians.[10,11] Although variable, the degree of tinnitus suppression can, in some patients, be remarkable.[11–14] Yet the purported mechanism remains purely theoretical. Moreover, almost everything that is known about tinnitus suppression in CI users comes from patients who have their implants activated at the traditional interval following surgery—usually roughly 1-month postoperatively.

As more centers are moving towards early (<2 weeks postoperatively) and very early (<3 days postoperatively) activation of their patients, the opportunity arises to gain insight into what may be happening in the entire auditory system within hours of implantation.[7–9] Prior studies already suggest changes in auditory plasticity can occur within 20–30 minutes after the stimuli in human beings.[15] The aim of this study was to investigate

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changes in subjective measurements of tinnitus in patients undergoing CI and activation within 24 hours of surgery. Such information could yield important information regarding changes in auditory plasticity soon after implantation while also providing guidelines to clinics that are already doing or are considering very early activation in patients with tinnitus.

2. METHODS

This was a prospective cohort study set in a large tertiary referral CI center. Patients were included if they satisfied traditional implantation candidacy criteria with severe-to-profound sensorineural hearing loss and had tinnitus (unilateral or bilateral) lasting for more than 6 months before implantation. Patients were screened by the Mini-International Neuropsychiatric Interview, version 7.0.2, questionnaire to exclude psychiatric disorders on recruitment.[16] All patients were administered the Tinnitus Handicap Inventory (THI) at five different time points: preoperatively, immediately following activation (24 hours postoperatively), 1 week postoperatively, 2 weeks postoperatively, and 1-month postoperatively. The THI was administered by a single, experienced CI audiologist. All patients underwent standard transmastoid posterior tympanotomy/facial recess approach using soft technique and intraoperative eletrophysiologic auditory testing and x-ray confirmation of electrode positioning by a single surgeon.[17] To avoid an additional confounding variable, only patients who underwent a single manufacturer array (HiFocus, Advanced Bionics, Stäfa, Switzerland) were included. Patients with long-term noise exposure, major comorbidities, or medications with side effects likely to cause tinnitus were excluded. In addition, patients with neurological or neurodegenerative diagnoses or those with a history of trauma were excluded.

All statistical analyses were performed using SPSS, version 18.0.0 (SPSS, Inc., Chicago, IL, USA). Wilcoxon signed-rank test was used to compare values between preoperative assessment and respective fitting sessions. Statistical significance was set at $p < 0.05$. The study conformed to the Declaration of Helsinki and the guidelines of the institutional ethics and research committee of the Cheng Hsin General Hospital (CHGH), which approved the study.

3. RESULTS

Twenty-seven patients met inclusion criteria (Table 1). All underwent surgery without complication or untoward postoperative side effects. The average age of patients was 43.4 years (SD ± 16.2) of whom 13 (48.1%) were male. Just over half (51.9% [n = 14]) noted bilateral tinnitus, 33.3% (n = 9) left tinnitus, and 14.8% (n = 4) right tinnitus. All but one patient were implanted in an ear affected by tinnitus.

Mean preoperative THI was 72.5. This elevated significantly to 77.6 at 24-hour activation ($p = 0.001$). By 1 week after surgery, the THI had decreased to 54.9 ($p < 0.001$). This trend continued and was statistically significant at 2 weeks (36.0, $p < 0.001$) and 1 month (28.5, $p < 0.001$) (Fig. 1).

4. DISCUSSION

These data add to the growing body of literature that finds substantial mitigation of tinnitus in CI users.[10,11] A recent systematic review noted statistically significant tinnitus reduction at multiple follow-up points across seven studies.[18] Tinnitus evaluations across various studies have generally been conducted at 1, 3, 6, or 12 months postactivation intervals demonstrating relatively early and sustained benefit, with most patients experiencing marked improvement in THI over even the first month of use.[18,19] Three studies demonstrated a statistically significant decrease between preimplant and postimplant THI scores 1-month postactivation, ranging from 37.0 to 54.9 points.[20–22] Of all studies, only two measured tinnitus upon activation with only one demonstrating statistical significance decrease.[20,23] Additionally, neither study elaborated on the interval between surgery and implant activation. Although not explicitly stated, it is presumed that activation was at the standard 3–4 weeks postoperative interval.

Yet unlike other studies that examined the effect of CI on tinnitus with standard intervals before activation, the current study examined patients activated within 24 hours of surgery, yielding some novel and interesting results. Such very early activation may allow some insight into cochlear physiology and exactly how CI may modulate tinnitus perception. Counterintuitively, the average patient in this study experienced an increase in tinnitus during those first day(s). The reasons for this are unclear but have several potential explanations. First, most patients had measurable hearing, with only few with true bilateral anacusis. Although a soft surgical technique was utilized, a drop in residual hearing would cause acute relative auditory deprivation. This is analogous to the new/different/worsened tinnitus experienced by patients who experience sudden sensorineural hearing loss. Second, presurgical pain, stress, and anxiety are all known risk factors associated with tinnitus exacerbation. Despite exhaustive literature search, no studies could be found that reported tinnitus immediately following CI surgery (irrespective of activation timing), although anecdotal evidence supports its frequent occurrence.

In addition, although virtually all published literature on the matter notes improvement in tinnitus for most patients with CI, there are individual patients who did note worsening of tinnitus over time.[24–26] This occurred in only two patients in the current study, and although uncommon it is worth mentioning that all patients should be counseled to the risks, albeit small, of worsening tinnitus with CI.[24] Finally, and a curious phenomenon in its own right, the somatosensory system itself might play an important role in the modulation of loudness feeling for tinnitus.[27,28] Variation in the subjective annoyance of tinnitus has long been observed to be accompanied by manipulation of muscle/gesture around regions over head and neck for some patients in clinics.[29] This phenomenon hints at the existence of a physiologic relationship between structures residing in the sensory modalities, sensorimotor systems, and even neurocognitive/neuroemotional networks associated with pathophysiology of tinnitus.[27] Since muscle repair is part of surgical wound healing, activation of the somatosensory system may contribute to the temporary rise in tinnitus perception.

Interestingly, all but one patient was implanted in an ear affected by tinnitus. This one patient, a woman 25 years old, experienced the typically observed elevation of THI immediately following surgery, but still experienced substantial abatement of tinnitus in her nonimplanted ear. This is consistent with prior findings, including Quaranta et al.[30] who noted over half of patients had contralateral tinnitus suppression when the device was off, and nearly 70% when the device was on (which was equal to the rate of ipsilateral tinnitus suppression). The exact mechanisms underlying the tinnitus reduction after CI remains unclear. The simplest explanation is that CI restores the input to central auditory pathways and induces neuroplasticity, which in turn may affect tinnitus perception.[31,32] Knipper and colleagues posited the most plausible detailed explanation. Tinnitus is believed to be a failure of the inhibitory network that normally works to enable enhanced stimulus resolution, attention-driven contrast improvement, and augmentation of auditory responses in central auditory pathways (neural gain) after damage of slow

Table 1

THI scoring before as well as after cochlear implantation and demographic characteristics for all subjects

					THI				
					Preoperative	Postoperative			
No.	Gender	Age (yr)	Side of implantation	Tinnitus laterality		24 hr	1 wk	2 wk	1 mo
1	Male	42	Right	Bilateral	96	94	56	20	8
2	Male	31	Right	Bilateral	82	90	66	24	12
3	Female	62	Right	Bilateral	42	40	30	16	10
4	Male	64	Left	Bilateral	48	48	46	48	44
5	Male	29	Left	Bilateral	34	52	50	28	20
6	Male	40	Right	Bilateral	68	80	52	78	80
7	Female	26	Right	Bilateral	74	90	68	62	46
8	Female	35	Right	Bilateral	100	100	88	98	100
9	Male	38	Right	Right	4	6	4	4	0
10	Female	53	Left	Bilateral	98	90	92	80	80
11	Female	33	Left	Bilateral	100	100	82	68	66
12	Female	20	Left	Bilateral	90	98	64	28	18
13	Female	20	Right	Right	6	8	2	4	2
14	Female	34	Left	Right	8	12	2	0	0
15	Male	25	Left	Right	82	100	68	44	24
16	Female	38	Right	Bilateral	60	72	56	44	66
17	Female	49	Left	Bilateral	96	98	56	32	24
18	Male	60	Left	Left	94	98	88	84	86
19	Female	55	Left	Left	100	100	78	62	50
20	Male	76	Left	Left	80	88	78	82	76
21	Male	32	Left	Left	64	74	38	16	12
22	Male	65	Left	Bilateral	44	50	36	36	6
23	Female	32	Left	Left	100	100	56	30	22
24	Male	71	Left	Left	96	100	62	28	12
25	Male	57	Left	Left	94	98	48	22	18
26	Female	55	Left	Left	100	100	64	26	24
27	Female	29	Left	Left	98	100	58	20	8
m		43.4			72.5	77.6	54.9	36	28.5
SD		16.2			31.4	30.9	24.4	24.9	28.1
p						0.001	<0.001	<0.001	<0.001

Threshold for statistical significance using Wilcoxon signed-rank test was set at $p < 0.05$.

Age = age at implantation, y/o; m = mean; tinnitus laterality, tinnitus referral; THI = score for Tinnitus Handicap Inventory; *p* = significance of difference for THI at 24 hr, 1 wk, 2 wk, and 1 mo vs that assessed preoperatively, respectively.

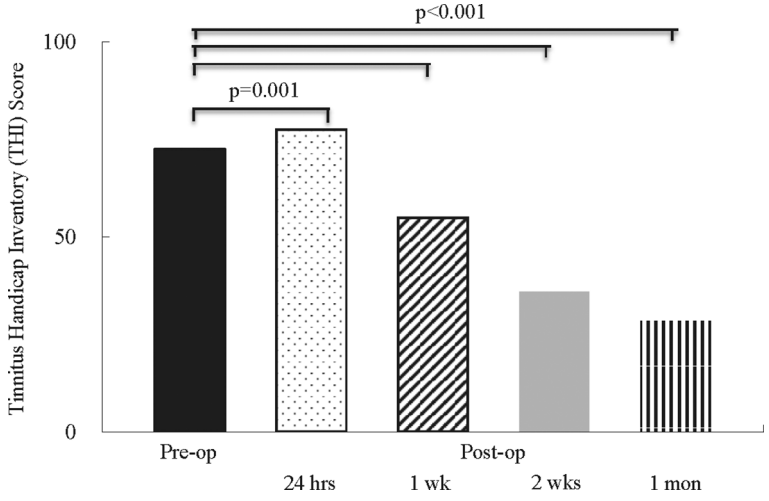

Fig. 1 Scenario of changes in THI scoring from consecutive fitting sessions. THI assessed preoperatively revealed a score of 72.5 (grade 4; severe). This score was significantly increased to 77.6 (grades 4–5; severe to catastrophic) when assessed 24 hr after the implantation on initial switch-on. One week after the implantation, the THI significantly decreased to a score of 54.9 (grade 3; moderate). The trend continued such that the THI score was 36 (grade 2; mild) assessed 2 wk after the implantation, and finally went to a level of 28.5 (grade 2; mild) assessed 1 mo after the implantation. THI = Tinnitus Handicap Inventory.

auditory fibers.[33] Electrical stimulation through CI, the authors suggest, may have the potential to reestablish these very tonic inhibitory networks.

The study is not without limitations. The sample size is relatively small, although it is consistent with or even greater than many of the articles published on the subject of CI and tinnitus. Nonetheless, no statistically valid conclusions were made regarding the contributions of gender or age to tinnitus changes. Likewise, this study was performed on a relatively genetically homogenous patient population and may not necessarily be applicable to other populations. This study did not record tinnitus data past 1-month postoperatively, and improvement or worsening of tinnitus is possible longer term. To reduce covariables, only one type of electrode array was used. Although unlikely, these findings may not necessarily be applicable to CI recipients with other arrays or stimulating paradigms.

In conclusion, very early activation provides a new window of insight into the changes that may be occurring within the auditory pathways following CI. These changes begin shortly after activation and continue to improve up to 1 month after activation. However, these patients also experience a transient rise in tinnitus as measured at first activation. These findings support prior literature that auditory plasticity in tinnitus can occur within hours to days of cochlear implant activation, and can continue thereafter. Whereas patients should be counseled as to the beneficial effects of CI on tinnitus for most patients, clinicians and researchers should be aware of temporary tinnitus exacerbation that does not improve in all cases. This is especially relevant as more centers are moving to early and very early postoperative activation of their patients.

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