Effect of Direct Stimulation of the Cochleovestibular Nerve on Tinnitus: A Long-Term Follow-Up Study

Minke J.C. van den Berge[1,3], J. Marc C. van Dijk[2], Rolien H. Free[1], Janke Stienstra[1], Pim van Dijk[1,3], Bernard F.A.M. van der Laan[1]

■ OBJECTIVE: **Tinnitus is a common entity that may lead to severe impairment in quality of life. An adequate treatment modality for severe tinnitus is currently lacking. Neurostimulation of the auditory tract may serve as a promising adjunct in tinnitus treatment. The aim is to investigate the effect of direct stimulation on the cochleovestibular nerve for intractable tinnitus.**

■ METHODS: **This study was conducted at the University Medical Center Groningen, The Netherlands. We studied 10 patients with severe, unilateral, intractable tinnitus, who were implanted with a cuff electrode around the cochleovestibular nerve between 2001 and 2013. All patients had preoperative ipsilateral hearing loss. Tinnitus Handicap Inventory (THI) scores and audiometric values were collected. Treatment success was determined based on the self-assessment of satisfactory usage by each patient.**

■ RESULTS: **The mean preoperative tinnitus duration was 8.0 ± 5.9 years. The preoperative THI score was 71 ± 18 points. During mean follow-up of 49 months, the mean THI reduction was 24 ± 26 points ($P = 0.02$). Treatment was regarded successful in 6 patients (60%). In these patients, tinnitus did not disappear, but transformed into a more bearable sound. In 4 patients, transient complications occurred, and 1 patient experienced permanent vertigo postoperatively. Furthermore, hearing deterioration was a result of implantation in 86% of the patients.**

■ CONCLUSIONS: **Direct neurostimulation resulted in treatment success in a small majority of the patients, with a significant decrease in THI score. However, because of a high risk of additional hearing damage, this technique seems not viable for patients with moderate hearing loss.**

INTRODUCTION

Tinnitus is the perception of sound or noise in the ear or head in the absence of an external physical sound source. With a prevalence of 5%–18%, it is a common disorder.[1] It can lead to a substantial impairment in quality of life, and additional symptoms, such as anxiety, depression, insomnia, and irritability, are often reported.[2] Conventional treatment methods for tinnitus include sound therapy and/or cognitive behavioral therapy. Unfortunately, not all patients benefit from these measures, and for those patients an adequate treatment modality is currently lacking.

Although tinnitus is still not completely understood, it is generally accepted that tinnitus is caused by an imbalance between excitatory and inhibitory input to auditory neurons.[3,4] This imbalance may occur at multiple levels of the auditory system and can be elicited by deprivation of auditory stimuli, such as the absence of normal auditory stimuli in patients with hearing loss. The loss of input can evoke plastic readjustments in the central auditory system and even in the nonauditory system, which include hyperactivity, bursting discharges, and increases in neural synchrony, leading to the percept of tinnitus.[3] For several years, electrical stimulation of the auditory system has been investigated as a treatment option for intractable tinnitus. This is based on the idea that restoration of peripheral sensory input may result in reorganization of the central auditory system and subsequently in a reduction of tinnitus.[5] Also, a masking effect on tinnitus may be achieved by electrical stimulation.[6] Several

Key words
- Neurostimulation
- Tinnitus
- Vestibulocochlear nerve

Abbreviations and Acronyms
CI: Cochlear implant
CVN: Cochleovestibular nerve
PTA: Pure tone audiometry
THI: Tinnitus Handicap Inventory
VAS: Visual analog scale

From the Departments of [1]Otorhinolaryngology/Head and Neck Surgery and [2]Neurosurgery, University of Groningen, University Medical Center Groningen, Groningen; and [3]Graduate School of Medical Sciences (Research School of Behavioral and Cognitive Neurosciences), University of Groningen, Groningen, The Netherlands

To whom correspondence should be addressed: Minke J.C. van den Berge, M.D. [E-mail: m.j.c.van.den.berge@umcg.nl]

Citation: World Neurosurg. (2017) 98:571-577.
http://dx.doi.org/10.1016/j.wneu.2016.11.036

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

techniques of permanent invasive stimulation of the auditory tract have been investigated, such as auditory and frontal cortex stimulation, round window stimulation,[7] promontory stimulation,[8] and cochlear implants (CIs).[9] Additionally, previously our center developed a cuff electrode for direct stimulation of the cochleovestibular nerve (CVN) for patients with intractable tinnitus.[10] This technique had not been explored before in tinnitus treatment. It was based on an existing treatment of direct stimulation of the nerve system for intractable neuropathic pain because it has been demonstrated that direct stimulation on the spinal cord can successfully treat neuropathic pain syndroms.[11,12] Neuropathic pain in fact shows similarities in pathophysiology with other hyperexcitability disorders, such as tinnitus.[13] Previously, we have treated 6 tinnitus patients with such a cuff electrode, proving safety and showing promising results in terms of tinnitus reduction.[10,14] To further investigate this supposedly beneficial effect, a larger study population is warranted. The aim of the present study is to investigate the long-term effects of direct stimulation of the CVN on therapeutically intractable tinnitus.

MATERIALS AND METHODS

Inclusion Criteria

In this case series, 11 adult patients with severe, intractable, and unilateral tinnitus were included. Patients were recruited from our tertiary referral outpatient clinic. An additional inclusion criterion was sensorineural hearing loss at the side of the tinnitus (defined as mean ≥80 dB over 1, 2, 3, 4, and 8 kHz for the latter 5 patients in a protocol amendment). Patients were excluded if there was a treatable cause of tinnitus (e.g., glomus tumor, otosclerosis, vestibular schwannoma) and/or if tinnitus was lateralized to the better hearing ear. Other exclusion criteria were previous cerebellopontine angle pathology and/or surgery or the presence of another electronic implant. All patients were screened for psychiatric pathology and were excluded in case of depression, for example. This study has been performed according to the Declaration of Helsinki, and approval was obtained by the ethical committee of the University Medical Center Groningen. All patients gave written informed consent.

Cuff Electrode and Surgical Technique

A custom-made cuff electrode designed for placement around the CVN was manufactured by Medtronic (Maastricht, The Netherlands). The full configuration of the implanted system is depicted in Figure 1A. The quadripolar cuff electrode has a circular distal housing with a slit, 2 opening levers, and 4 radial positioned electrodes for placement around the CVN as close to the brainstem as possible (Figures 1B and C). The cuff electrode was connected via an extension cable (model 37083 [Medtronic]) to the pulse generating device (model 37702 [Medtronic]) that was placed subcutaneously in the subclavicular or paraumbilical region. Programming of the system was performed using the MyStim-programmer (model 37742 [Medtronic]), which communicates

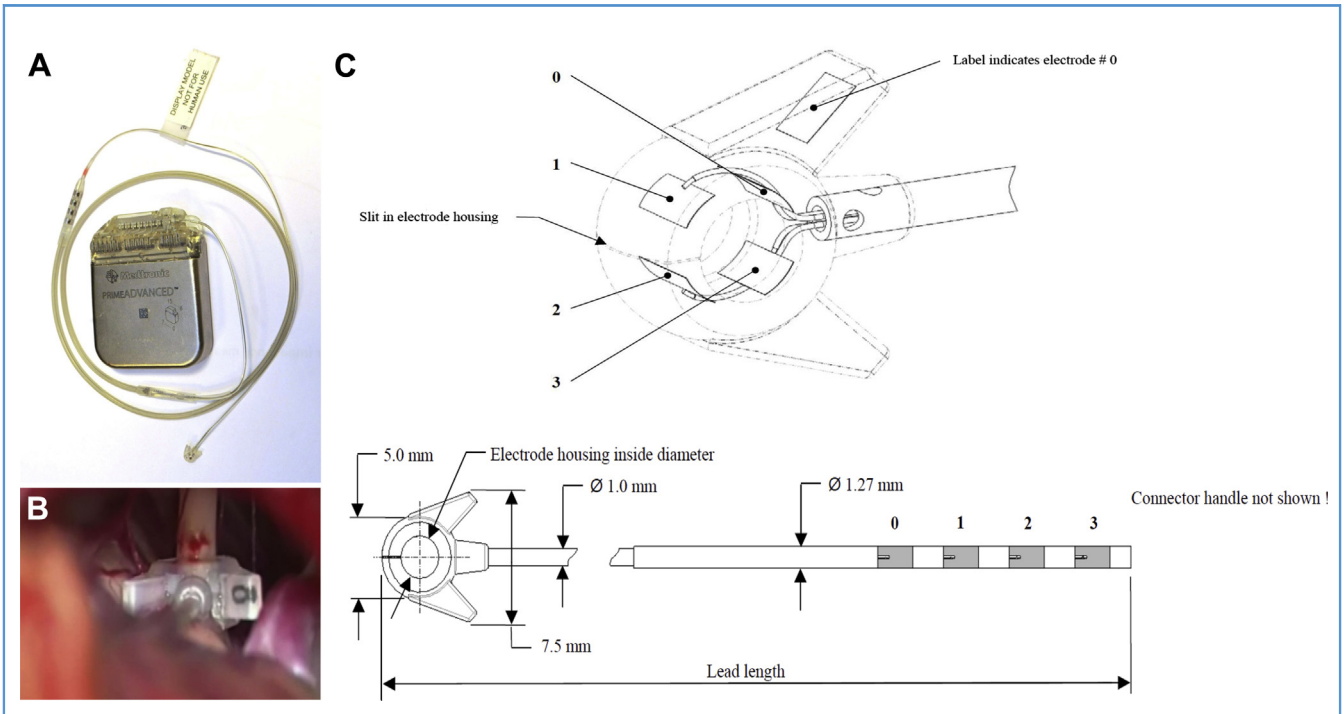

Figure 1. (**A**) Total implant system. The total implant system consists of the pulse generator, extension cable, and cuff electrode at the distal end of the electrode. In the latter cohort, an updated version of the pulse generator was used (Activa version [Medtronic]). (**B**) Implantation of the cuff electrode. The cuff electrode is placed around the cochleovestibular nerve, as close to the brainstem as possible. (**C**) Details of the quadripolar cuff and the lead of the electrode (custom-made by Medtronic). Numbers 0–3 indicate the 4 different electrodes. The inside diameter of the cuff was variable from 2.50, 2.75, 3.00, to 3.50 mm. (Reproduced with permission of Medtronic.)