Heidi Olze*, Agnieszka J. Szczepek, Uta Reich, Stefan Gräbel and Florian Uecker

Tinnitus suppression using electrical stimulation

Abstract: Tinnitus is a phantom sound perceived only by the affected person. Although the causes for tinnitus may be very diverse (e.g. hearing loss, cardiovascular diseases, diabetes, Meniere's disease, otosclerosis), they all lead to pathological activation of the auditory pathway.

Cochlear implants are electronic inner ear prostheses used to restore the hearing abilities of hard of hearing people. It has been noticed that the cochlear implants not only enable hearing but also reduce tinnitus that usually accompanies deafness and hearing loss. One of the likely mechanisms behind the latter phenomena is thought to be the unknown properties of electrical stimulus.

This project was designed as a proof of concept for a device, which would be sending the tinnitus-suppressing electrical signal. To achieve this, the project was split into a preclinical part using experimental animals (guinea pigs) and a clinical trial part with tinnitus patients. In the preclinical part, together with Inomed Medizintechnik GmbH, we are testing the physical design and biocompatibility of anti-tinnitus implant. In the clinical part of the project, we use an electrical stimulation in the ear canal, through the eardrum (tinnitus patients), or via cochlear implant in a sample of cochlear implant patients (pre- and post-implantation). We ask the patients to mark the loudness of their tinnitus on a visual scale from 1 to 10 before, during and after routine electrical stimulation and quality of the tinnitus

The results obtained during our preclinical and clinical testing as well as future plans will be presented and discussed.

Keywords: tinnitus, inner ear, electrical stimulation

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1 Introduction

Tinnitus - the phantom sound - is estimated to be perceived by up to 15% of adult population and is considered to be a medical problem by some 3% of adult population [1]. Almost a quarter of individuals perceiving tinnitus as medical problem is severely affected and on a long-term disability. To date, there is no pharmacological treatment against tinnitus and the therapies are based on psychological and relaxation approaches that as a goal have achieving habituation of tinnitus [2]. Tinnitus may be a symptom of various diseases, majority of which induce hearing loss [1] and restoring the hearing abilities partially alleviates tinnitus-related distress [3-6]. The holy grail of tinnitus therapy is achieving total relief from a tinnitus sound.

The patients referred for cochlear implantation are unilaterally or bilaterally hard of hearing and many of them have a hearing-loss-associated tinnitus. Prior to cochlear implantation, brief electrical stimulation of the auditory nerve verifies the functional integrity of cochlear nerve. Two types of such stimulation are used in the clinical practice: ear canal stimulation (ECS), which is a non-invasive technique and promontory stimulation (PS), which is an invasive technique. In the hard of hearing patients with tinnitus, it has been observed that the electrical PS changes the properties of tinnitus [7]. This observation was later used for in an attempt to treat tinnitus in the non-heard of hearing patients [8]. However, the results of such stimulation are of short duration and the invasiveness of such repetitive treatment is clinically not satisfactory.

The goal of this project is to deliver proof-of-concept data verifying the idea that the electrical stimulation may be successfully used for therapy against tinnitus. To achieve this goal, new technology is being developed. We want to design an implantable device, which will be permanently placed near the inner ear. This device is expected to suppress tinnitus by continuously producing personalized electrical stimulation. The specific aims of the project are to develop animal model (guinea pig) for testing materials, parameters and biocompatibility of implant; to determine range of electrical parameters that could be used by the implantable device for people and to perform short-term stimulation as a proof of concept.

2 Preclinical part

The main goal of preclinical experiments was to establish surgical procedures necessary for the electrical stimulation using animal model and to design respective implantable device.

2.1 Exploring middle ear of guinea pig

The middle ear of guinea pig can be surgically accessed relatively well and in a short time. In these surgical experiments, we are using adult guinea pigs, which weigh up to 1000g. (Dunkin Hartley) All described experiments are approved by the local Ethics Committee (T0029/17) and are being performed on freshly sacrificed animals. The tympanic bulla is exposed by a retroauricular incision and is opened to visualize the middle ear structure including basal turn of the cochlea and the round window membrane (Fig. 1).

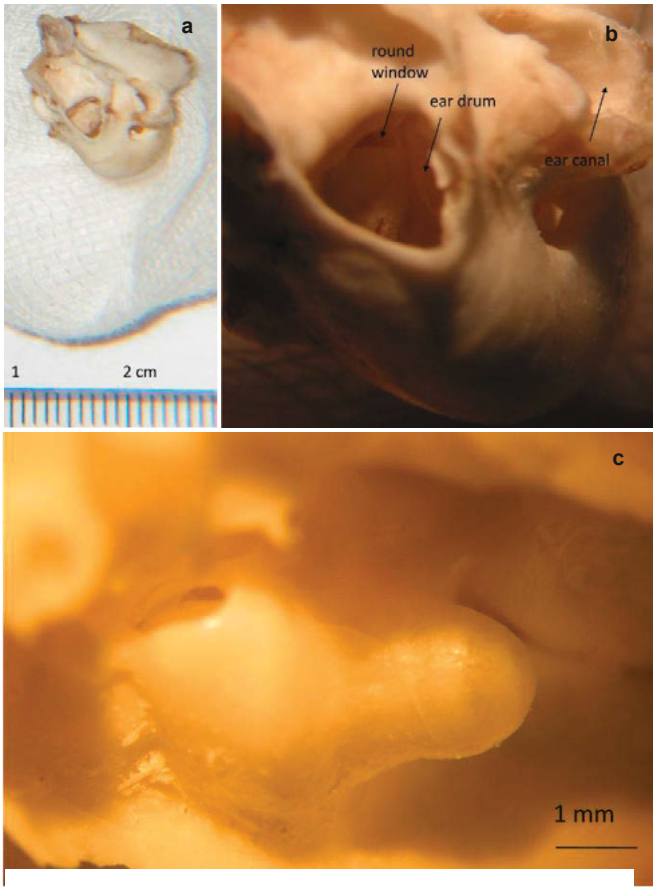


Figure 1: (a) Explanted tympanic bulla, **(b)** view in the middle ear, **(c)** view of the whole cochlea with round window.

2.2 Working with demonstrator

In the first experiments, we used PI-(polyimide)-based carrier as a demonstrator (Fig. 2), kindly provided from our project partner (Fraunhofer Institute for Biomedical Engineering, St. Ingbert, group of Prof. K.-P. Hoffmann). This type of electrode is frequently used for peripheral nerve stimulation.

Figure 2: Explanted tympanic bulla with test implant.

Following testing this implant on the explanted tympanic bulla, we inserted the PI-carrier in the intact middle ear (Fig. 3)

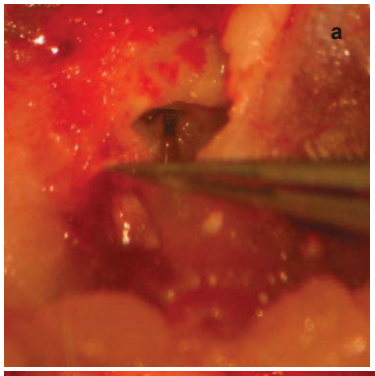
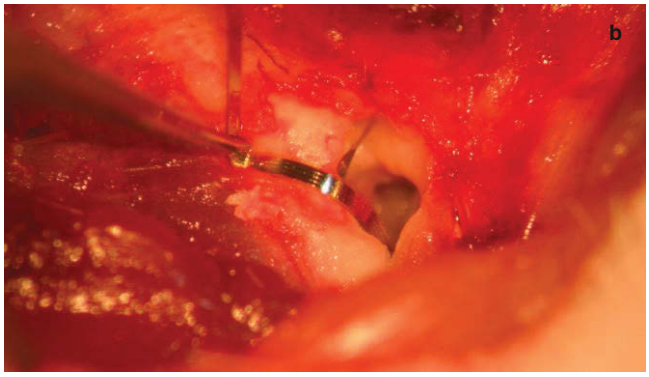


Figure 3: Insertion of the PI-carrier in the middle ear of the guinea pig. (a) PI-carrier placed on the round window, (b) fixation of the carrier on the bony wall of the tympanic bulla.



2.3 Physical design of the tinnitus-suppressor

We have developed a protocol for testing carrier handling during implantation. In addition, we researched the optimal material properties such as shape, size and the degree of flexibility. These tests provided information important for the design of a round window implant for preclinical experiments. The round window implant will have several independent contact points on a small surface, which will preserving the flexibility of carrier. This kind of design seems to be optimal for the middle ear of guinea pig. Apart from the size, implant must have certain degree of flexibility to provide good handling during the implantation procedure as well as a flawless electrical performance.

3 Clinical part

In the clinical part of this project, we are presently using the standard diagnostic test of electrical stimulation used prior to cochlear implantation. This is not an experimental but a routine test, approved as a standard procedure. The patients are either stimulated via ear canal electrode or via already implanted cochlear implant.

3.1 Visual Analogue Scale (VAS)

To test the quality of tinnitus we use visual analogue scale (VAS). The patients use VAS to indicate tinnitus loudness before, during and after electrical stimulation.

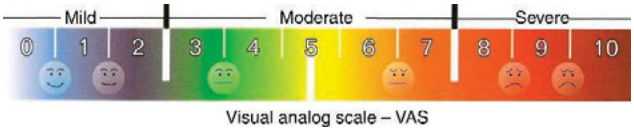


Figure 4: VAS used by patients to describe the loudness of tinnitus

3.2 Stimulation parameters

The stimulation parameters differed depending on a type of stimulation used. For the patients prior to implantation, ECS was used (biphasic rectangular pulses); two patients were tested using this method. For the patients after implantation, direct cochlear stimulation was used (square waveform); four patients were tested.

The total duration of stimulation was 500 ms in each case.

Table 1 Stimularion parameters

Pulse Shape:	Square waveform	Biphasic rectangular pulses
Frequency	62 Hz	1000 Hz
Duration		40 µs
Total duration of stimulation pulse packets	500 ms	500 ms
Number of patients tested to date	4	2

3.3 Preliminary results

Of two patients stimulated with ECS, on reported decrease in loudness of tinnitus during and after electrical stimulation whereas the other patient has not reported any changes.

Of four patients stimulated using CI, two reported no changes, on reported temporary decrease of tinnitus loudness and one reported an increase of tinnitus loudness - not during but after stimulation.

4 Conclusion

We are developing a new system as a proof of concept for the idea of electrical stimulation being able to suppress tinnitus.

The animal model delivers the data, which will be translated to the clinic, whereas the clinical data obtained presently is used to design a set of stimulatory parameters for tinnitus patients without major hearing loss.

Author Statement

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