MEG Localization of the Suspected Cortical Generators of Tinnitus

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Objective: The purpose of the study was to determine the effect of electrical stimulation on specific areas of the auditory cortex in patients with tinnitus.

Introduction

Tinnitus is any sound perceived to be coming from the head or ears without an external sound source [1]. There is no known cure for tinnitus. Current conventional medical interventions fail to provide significant relief for most patients [2]. Hearing aids, maskers, noise generators, and combination devices (a hearing aid and noise generator) decrease tinnitus in some patients [3, 4]. The degree and frequency range of hearing loss can be important, as patients with higher degrees of hearing loss are sometimes unable to make use of certain sound therapies and the frequency range may have implications on what type of noise to use [3,4]. Tinnitus is often a distressing symptom affecting up to 50 million Americans and more than 300 million people worldwide [2]. This study proposes a methodology to significantly ameliorate tinnitus with low voltage electrical stimulation of the auditory cortex.

Methods

Two patients with debilitating tinnitus refractory to conventional therapies were treated. Each patient was evaluated with validated questionnaires and psychoacoustic measures to determine the frequency/pitch and loudness of their tinnitus. Tones at these frequencies and loudness were then represented to each patient while having magnetoencephalography (MEG) performed to determine the tonotopic map for these frequencies. MEG data was analyzed by Single Equivalent Current Dipole (figure 1). Functional magnetic resonance imaging (fMRI) was performed to identify the entire auditory cortex during the presentation of music (figure 2). fMRI data was analyzed by SPM. Each patient had bilateral tinnitus but both noted that occasionally tinnitus was worse in one ear.

Patient #1 rated his tinnitus at 8/10 for pitch and 9/10 for loudness prior to surgery, with frequencies at 6kHz and 8kHz. He noted that occasionally his tinnitus was worse in his right ear. Patient #1 had the tinnitus frequency locations localized by MEG on the right hemisphere (figure 1). The MEG images for Patient #1 were uploaded to the operating room neuronavigational system to guide the implantation of a Medtronics neurostimulator with a Pisces quadripolar electrode for electrical stimulation.

Patient #2 rated his tinnitus 10/10 for pitch and 9/10 for loudness prior to surgery, with frequencies at 8kHz and 10kHz. Patient #2 had his tinnitus frequencies localized by MEG and fMRI in the left auditory cortex and was also implanted with a quadripolar electrode.

Medtroincs neurostimulators have settings that can be varied [0-10 volts, pulse width 60-450 ms, and rate of 3-30 Hz]. The Pisces quadripolar electrode polairty configuration at each of the 4 contacts can also be modified. Stimulations are presented in a random pattern to the auditory cortex.

MEG

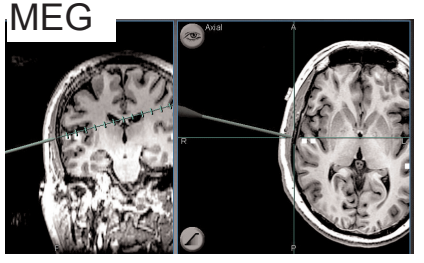

Figure 1. Patient #1's Surgical navigational MRI images with MEG tonotopic localizations for the 6,000 Hz and 8,000 Hz tones responses overlaid (grey squares; more medial square is the 8,000 Hz response).

fMRI

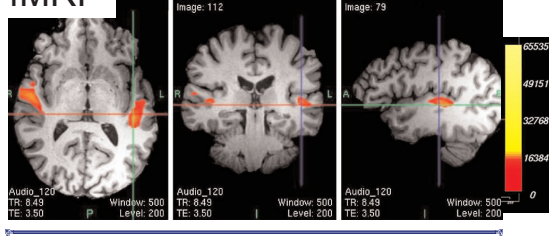

Figure 2. Patient #2's functional MRI localizations of the auditory cortex response to music.

Results

Patient #1 has had a significant reduction to near elimination of tinnitus. Nine months after the procedure, he rated his tinnitus as a 0-1/10 for both ears. He continues to experience this reduction in his tinnitus over two years after surgery.

Patient #2 has no longer has tinnitus in his left ear. In his right ear he now experinces increased loudness of his tinnitus. He is only 2 months since surgery.

Theory

The gate control theory of pain, put forward by Ronald Melzack and Patrick Wall [6], hypothesizes that physical pain is not just a direct result of activation of pain receptor neurons, but rather that its perception is modulated by interaction between different neurons. Neurostimulation delivers low voltage electrical stimulation to the targeted cortical area to block the sensation. Afferent pathways interfere with each other constructively, so that the brain can control the degree of pain that is perceived. The brain determines which stimuli to ignore over time. Thus, the brain controls the perception of pain quite directly, and can be "trained" to turn off forms of pain that are not "useful". Based on this, the results for patient #1 may indicate that he had more lateralized tinnitus and that patient #2 had more bilateral tinnitus.

Conclusion:

Currently there is no treatment that can eliminate or significantly reduce debilitating tinnitus. We have shown, in this pilot study of 2 patients, that the described methodology can significantly reduce tinnitus. These findings suggest that the perception and annoyance of tinnitus can be reduced through electrical stimulation of the auditory cortex identified by MEG.

References

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