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SHORT SCIENTIFIC COMMUNICATION

Deep brain stimulation effects in patients with tinnitus

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

ABSTRACT

OBJECTIVE: To report deep brain stimulation (DBS) effects in patients with tinnitus.
STUDY DESIGN: Case series with chart review.
SETTING: Tertiary medical center.
SUBJECTS AND METHODS: Seven patients implanted with DBS systems for movement disorders who also reported having tinnitus were interviewed about their tinnitus conditions. Four were available for testing in a specialized tinnitus clinic with their DBS systems turned off or on. Testing included matching of self-rated and psychoacoustically measured tinnitus loudness to measure the impact of DBS on tinnitus.
RESULTS: Three of the seven patients reported reduced tinnitus loudness when DBS was turned on. Of the four patients tested in the clinic, results indicated that DBS of the ventralis intermedius nucleus of the thalamus caused decreases in tinnitus loudness in two patients with relatively prolonged residual inhibition.
CONCLUSION: These results suggest that DBS of nonauditory thalamus structures may provide tinnitus relief for some patients.

One of 20 Americans has severe tinnitus.[1] Current tinnitus management with acoustic therapy, medications, psychological interventions, and alternative medicine approaches fail to help approximately 20 to 40 percent of those seeking treatment.

Tinnitus appears to involve increased excitability in the CNS.[2] Stimulation of deep brain structures may disrupt abnormal neural firing patterns that perpetuate and enhance tinnitus perception. Thalamic deep brain stimulation (DBS) has been used to treat neurological disorders including movement disorders and chronic pain, and may prove helpful for tinnitus. This communication is the first report of the effects of DBS on tinnitus perception.

SUBJECTS AND METHODS

Seven patients (three females and four males, aged 67.4 ± 15.7 years) receiving DBS implants for movement disorders also reported having tinnitus. None had received tinnitus treatment prior to this evaluation. DBS electrodes were placed unilaterally or bilaterally in the ventral intermedius nucleus of the thalamus. Stimulus settings controlled involuntary tremors. Four patients were evaluated at the Oregon Health & Science University (OHSU) Tinnitus Clinic by completing questionnaires and undergoing audiometric and tinnitus testing. Tinnitus testing included loudness matching and loudness rating on a visual numerical scale. Tinnitus testing was done with DBS units turned on, then off, then on again. In each patient, the testing was repeated three to five times. Comparisons were made between the three stimulation conditions. Three patients were unable to come to the clinic but answered written questions about tinnitus loudness with DBS turned on and off. The study protocol was approved by the OHSU Institutional Review Board.

RESULTS

Three of the seven patients reported quieter tinnitus with DBS turned on rather than off. None reported stimulation-related changes in hearing. Of the four individuals tested in the clinic, decreases in matched tinnitus loudness exceeding the range of normal test–retest variations at our facility (±2 dB) were found in two patients (patients 1 and 4 in Fig 1), who had parallel decreases in rated loudness (Fig 2). The results in the tested patients agreed with their subjective impressions about their DBS-related tinnitus changes. For the two tested patients whose tinnitus responded to DBS, the tinnitus remained suppressed for 15 to 20 minutes after DBS was turned off. No hearing threshold changes were identified by audiometry.

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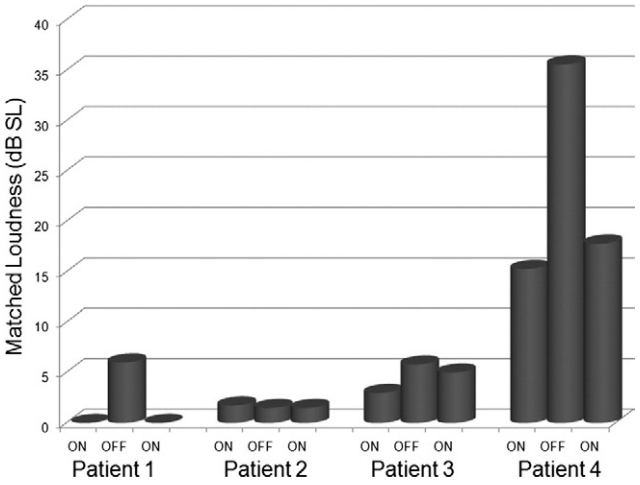

Figure 1 Matched loudness (measurements in dB sensation level) in the four patients evaluated with the DBS stimulator turned on, off, and on again. The results are consistent with changes of subjective loudness rating on the 1 to 10 scale shown in Figure 2.

DISCUSSION

Recent studies show that the CNS plays a key role in chronic tinnitus. Altered activity patterns along the auditory pathway following hearing damage can produce tinnitus. Involvement of nonauditory centers has also been indicated in chronic tinnitus.[3] Modification of abnormal activities may change tinnitus-related firing and tinnitus perception. Peripheral electrical stimulation, transcranial magnetic stimulation, and stimulation through cochlear implants have been shown to suppress tinnitus in some patients. Thalamic DBS has been used to treat multiple neurological symptoms. Since tinnitus may share mechanisms similar to those of other neurological symptoms such as chronic pain, DBS may also be effective for tinnitus. Individuals with a wide range of treatment-resistant neurological symptoms have indications of abnormal neural firing patterns including low-threshold Calcium spike burst activity on single-unit recording and increased coherent low-frequency activity in the θ band of brain activity, which are evidence of thalamocortical dysrhythmia that can be disrupted through ablative thalamotomy or electrical stimulation.[4]

Changes of activities in nonauditory systems that are involved in generation and maintenance of tinnitus from thalamic stimulation may explain the DBS-related tinnitus reduction in some of the patients in this study. It is interesting that stimulation for movement disorder of the ventral intermedius nucleus of the thalamus, a nonauditory structure, produced changes in an auditory perception. In the context of music perception, a "natural link" between the auditory and motor systems (probably in the premotor cortex) has been suggested to affect music-related actions and rhythm-related listening preference.[5] It is not clear whether electrical stimulation of motor centers in the thalamus can affect the auditory system through this or a similar link, although this is not entirely impossible. Spread of DBS current to adjacent auditory pathways or structures to affect tinnitus is possible but unlikely because none of the patients in this study experienced auditory sensation during stimulation as reported elsewhere. A placebo effect seems unlikely because of the patients' ability to reliably and repeatedly perform complex psychoacoustic tinnitus tests.

Each tinnitus patient represents a unique combination of heritage, pathophysiology, and psychoperceptual factors. It is unlikely that any treatment will provide relief for all tinnitus sufferers. It is probable that the structures stimulated by DBS were not involved in generating tinnitus perception in the nonresponding patients in this study. Tinnitus onset in the two nonresponding subjects occurred more than 20 years before our testing, but 10 years or less in the two responding subjects, suggesting possible decreased plasticity in factors related to tinnitus perception over very long periods of time; this effect was also indicated in transcranial magnetic stimulation and microvascular decompression studies.

Responding patients in this study exhibited prolonged tinnitus suppression after DBS was turned off, longer than typically seen following acoustic masking. Tinnitus relief by DBS, which is composed of discrete electrical impulses, may be achieved through a different mechanism than that provided by acoustic stimulation (typically continuous stimulation with random acoustic energy distribution over frequencies).

CONCLUSION

The results from the few cases in this study indicate that electrical stimulation of the ventral intermedius nucleus in the thalamus can cause a decrease in the perceived and matched tinnitus loudness in some patients, warranting fur-

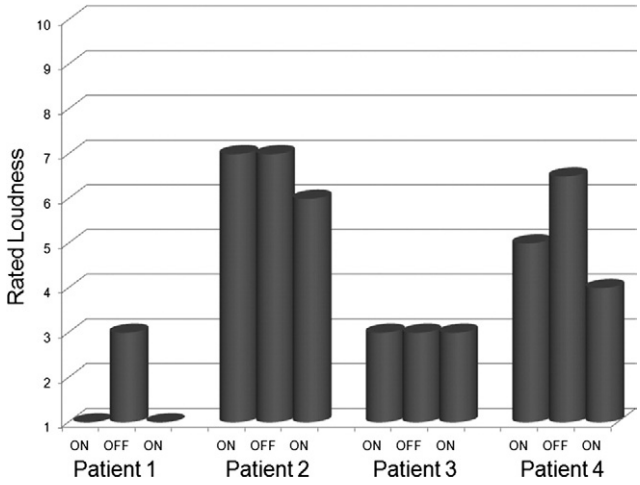

Figure 2 Subjective tinnitus loudness rating on a 1 to 10 scale ("1" being "very quiet" and "10" being "very loud") by the four patients evaluated with their DBS stimulators on, off, and on again. The results are consistent with changes in matched loudness shown in Figure 1.

ther evaluation of potential utility of DBS in tinnitus treatment.

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DISCLOSURES

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