TRANSCUTANEOUS ELECTRICAL STIMULATION FOR TINNITUS.*†

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ABSTRACT

The use of electrical stimulation to treat tinnitus was evaluated in a two-experiment study. The stimulator was a low amplitude, low frequency variable square wave applied to 13 sites on the auricle of the ear with similar results. The sites were selected on the basis of increased electrical conductivity as measured by low electrical resistance readings. Experiment 1 results defined improvement as either a complete cessation of the tinnitus or a decrease in the frequency of the tinnitus. Experiment 2 involved 53 ears with tinnitus. Eighty-two percent of the 53 ears showed improvement by either of the two criteria. The premature of the improvement ranged from 20 minutes to at least six months. The variables associated with this procedure were discussed. The adverse effects from the stimulation were minimal.

Electrical stimulation is not a new therapeutic modality. It is most commonly utilized for pain and healing of bone fractures. Electrical stimulation for the treatment of tinnitus is a concept that is attracting attention from several sources. House reported reduction of tinnitus as a beneficial side-effect after cochlear implantation. The alleviation of tinnitus by direct electrical stimulation of the auditory nerve has also been described by Portmann, et al. Recently the idea of non-invasive transcutaneous electrotherapy for severe tinnitus was explored with some success by Chevallard, et al.*

Advances in electronic technology appear to make this treatment more effective than previous reports of such treatment for human ear pathology. The effectiveness of electrical stimulation depends upon the characteristics of the electrical stimulus and the anatomical area of stimulation. The significant characteristics of the electrical stimulus are polarity, frequency, waveform, and intensity.

This paper presents clinical data on the use of transcutaneous electrical stimulation as a treatment for tinnitus. The data is presented in two experiments: Experiment 1 to establish methodology and Experiment 2 to validate the procedure.

Experiment 1

MATERIAL AND METHODS

Subjects
Seven males and three females served as subjects. Their ages ranged from 23 to 60 years with a mean of 41 years. These subjects reported a total of 19 ears with tinnitus; individual subject information being shown in Table I.

Otolaryngological and Audiological Evaluation
The subjects received otolaryngological and audiological evaluations. All subjects had varying degrees of hearing loss, except subject 8 who had normal hearing. The tinnitus was then matched with simulated sounds from a Norwest SGI 1 Tinnitus Synthesizer, the tinnitus matching consisting of the experimenter adjusting the frequency and intensity levels of the synthesizer according to the subject's instructions. An ascending procedure was utilized.

Stimulation Technique
A pulse generator with a sensing mode (Alpha Stim 2000) was used. The points of stimulation around the auricle were located by their peculiar property of very low electrical resistance with resulting high conductance of electrical current relative to the surrounding area. Emperically, through a series of trial and error, 13 ears points (Fig. 1) were located which appeared to be very effective in reducing tinnitus when stimulated electrically. The sensing mode of the Alpha Stim 2000 functioned initially as a 36 ohm to record relative electrical skin resistance via a probe at the point of contact, the subject holding a ground in the ipsilateral hand (Fig. 2). The probe was moved around each of these 13 locations until a very low relative electrical resistance value was found. This value was displayed simultaneously on a 0-100 unit meter on the stimulus panel and by an LED display on the probe handle. The locations on the auricle were specific and identical for each subject. Absolute electrical skin resistance was not measured. The electrical stimulus was then delivered to each point transcutaneously with the hand-held probe utilizing the treatment mode of the same device. Duration of stimulation in each point was between 24 seconds and two minutes. The electrical stimulus waveform was a modified square DC bipolar pulse with a frequency of 5, 10, 2, or 2.5 Hz changing polarity at 0.4 second intervals. The current intensity was 50 mA with a maximum 36 volts. The number of treatments ranged from one to 17, the treatment schedule extending three per week. The tinnitus was measured after each treatment.

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</table>

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RESULTS

The results are shown in Table 1. Six of the 10 subjects reported improvement in 8 of 18 ears with tinnitus. Three additional subjects (three ears) were undecided whether improvement had occurred. Tinnitus matching confirmed a decrease in the frequency of the tinnitus in the above eight ears. The six subjects (eight ears) who reported changes in tinnitus perceived the changes as an improvement and showed a minimum 60% decrease in frequency. Tinnitus was eliminated in three of those ears. The two subjects who were not certain showed a 10% to 13% decrease in frequency. The sensation levels of the tinnitus could not be calculated because the synthesizer is not calibrated to audiometric zero. The permanence of the improvement in tinnitus was not investigated although of those subjects who reported on permanence, it varied from eight hours to two months (last contact with the experimenter).

CONCLUSIONS

The results of this study indicate that 1. electrical stimulation of specific loci of the auricle ipsilateral to the tinnitus was successful in the amelioration of tinnitus in most of the cases, 2. amelioration was reported by subjects when the tinnitus was eliminated completely or reduced in frequency, and 3. an investigation of the validity and some of the parameters of auricular electrical stimulation is warranted.


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The stimulus duration was either 15 or 30 seconds. Following the monaural or bilateral stimulation, the subject was asked whether he thought improvement had occurred. The tinnitus was again analyzed. The above protocol was followed for each treatment session. The number of treatment sessions ranges from one to seven and are listed in Table IV.

Control Group Stimulation. The auras of the subject were cleansed with alcohol. After the alcohol had evaporated, the probe was used to locate the 13 stimulation points. They were marked with a felt pen. The subject was then told that the treatment would consist of two stimulation procedures. Unknown to the subject, the continuous cable attached to the ground rod was replaced with an open cable. The 13 points were “stimulated.” Because the ground cable was open, the circuit was not complete and current was not delivered from the probe. Following the stimulation, the subject was asked whether the tinnitus had improved. The tinnitus was again analyzed. Without the subject’s knowledge, the open cable was replaced with a continuous cable and the stimulation repeated. The subject was again asked whether the tinnitus had improved and the tinnitus was analyzed. Thus, the control subject always received the control stimulation prior to the actual stimulation.

RESULTS.

The data was analyzed for changes in tinnitus frequency. Because both groups received the stimulation, the data for this protocol were analyzed for each group and then pooled. The number of treatments referred to the number of sessions because many subjects received more than one stimulation per session.

The data in Tables IV and V compare the after-stimulation tinnitus frequency to the before-stimulation frequency. The frequency notations with a plus sign for subject 16 in Table V signify that the tinnitus was higher in frequency but there was insufficient sound pressure from the synthesizer to override the hearing loss at a higher frequency. The sensation level of the tinnitus could not be calculated because 1. the synthesizer is not calibrated to audiometric zero and 2. the tinnitus frequencies were not usually at frequencies utilized in discrete-frequency audiometers.

Experimental Group. Of the 17 ears treated, two (subject 8, both ears) were perceived as not having improved by stimulation. Thus, 9 of 10 subjects (90%) corresponding to 15 of 17 ears (88%) reported the stimulation as having improved the tinnitus. The decrease in tinnitus frequency for the subjective improvement ranged from 45% (after stimulation frequency was lower) in subject 3 to complete remission (none) in the six ears combined for subjects 5, 7, 9, and 10. Subject 8 did not perceive a 19% decrease as being significant.

Control Group. Of the 15 ears administered the control stimulation, in only one ear did a subject (subject 18, right ear) believe that there had been a change. Measurement indicated a 19% decrease in frequency. The range of change for the 15 ears was from +10% (after stimulation frequency was measured as higher) to 32% (after stimulation frequency was lower). The pre-stimulation tinnitus frequency ranged from 2700 Hz for patient 13 to 14,000 Hz for patient 17. Subject 14 did not receive the control protocol in the right ear because he was not aware of tinnitus in that ear until the tinnitus in the left ear had improved.

Of the 16 ears administered the actual stimulation, four (subjects 11, one ear; 13, one of two ears; 19, two ears) were perceived as not having improved. Thus, of 10 subjects (90%) representing 12 of 16 ears (75%) reported the stimulation as having improved the tinnitus of at least one ear. The measured decrease in tinnitus frequency for those subjects reporting improvement ranged from 28% in subject 18 to complete remission (none) in subjects 12, 14, 15, and 18. Of the four ears not perceiving a change,
the tinnitus frequency changed from −15% (subject 11) to +13% (subject 19).

Combined Groups: Actual Stimulation. Improvement was perceived by the 20 subjects in 27 of 33 ears (82%). In 10 cases of these ears, there was complete remission. In the remaining 17 ears, the range of frequency decrease was from 28 to 92%. Thus, six or 18% of the tinnitus ears were reported to have not improved by stimulation.

Permanence of Improvement. The permanence duration of change ranged from 20 minutes to at least six months (last contact with experimenter). Subject 7 reported that the tinnitus improvement has remained constant since the stimulation of six months ago. Subject 14 reported that his tinnitus returned to prestimulation level the moment he turned on the air-conditioning in his automobile, this occurring 20 minutes after complete remission. Subject 2 reported that the improvement duration increased after each stimulation session. Individual subject data can be seen in Tables IV and V.

Effect of Subject Characteristics. Neither age nor duration of tinnitus prior to stimulation, nor frequency of the tinnitus appeared to be a determinant to the success of electrical stimulation on tinnitus.

Effect of Number of Treatment Sessions. Most of the subjects received a maximum of two treatment sessions. It became apparent quite early that improvement would occur within two sessions if it were to occur at all. There was insufficient data to assess the relationship between the number of sessions and the overall success of the stimulation.

Effect of Electrical Stimulation Parameters. Different parameters of the stimulation were utilized in an informal procedure: frequency was varied from 0.5 to 2.0 Hz; current at 50 or 100 µA; duration of 12 or 24 seconds per stimulation point. There was insufficient data to obtain conclusions or trends relating to the effectiveness of the parameters.

Adverse Effects of Electrical Stimulation. Some subjects reported the current of 100 µA as "pins pricking," but were able to tolerate that sensation. Others could not tolerate greater than 50 µA. The subjects each appeared to have individual most sensitive auricular areas to electrical stimulation. There were no other adverse effects reported either during or immediately following stimulation.

DISCUSSION.
The 82% success rate in improvement in tinnitus implies a feasible treatment procedure. It might be argued that the strength of the data is weakened by 1. the control subjects not having received the control and actual stimulations in a counterbalanced procedure so as to allow evaluation of possible influence of one stimulation on the other, and 2. lack of double-blind procedure. Neither of these two procedures could be utilized. If the actual stimulation had been administered first, continued or deterioration of the improvement from the actual stimulation would have contaminated the effects of the control
stimulation. A double blind procedure was not pos-
sible because a complete electrical circuit was re-
quired to locate each of the 13 auricular points im-
mediately prior to its stimulation. The experimenter
could not have been "blind" while utilizing an open
circuit because the 13 points could not have been
located. Three procedures were evolved to minimize
these two variables: 1. the experimenter (Engelberg)
was careful to not bias the subjects by his behavior,
2 the subjects were asked for their perception of any
innutis change after each stimulation, and 3. the
control subjects were not allowed to see the changes
of the cables.

The reliability of tinutis matching is worthy of
discussion because it could have accounted for a sig-
ificant part of the control stimulation test-retest
variability being as high as 22%. On most subjects,
was it very difficult to obtain an extremely close tin-
utis match without the expenditure of considerable
time. Four factors were involved: 1. the complexity
of the tinutis acoustic spectrum, 2. the inability of
the tinutis Synthesizer to duplicate exactly the
tinutis spectrum, 3. the difficulty of some subjects
to understand the difference between frequency and
intensity, and 4. the difficulty in the subject's per-
ception of frequency. First, few if any of the subjects
reported a tonal tinutis of only a single frequency.
The large majority of the tinutis consisted of multi-
frequencies sometimes being perceived as more than
one distinct sound or a periodic or aperiodic pattern
described as "cricketers," "ham-
ing," "hissing," and "waves of water." In these
instances, the subject was asked to match the domi-
nant frequency and intensity. Second, the tinutis
Synthesizer, although containing three separate
channels of selective intensity, frequency, and noise
capabilities with mixing into both ears separately
and simultaneously, was not able to duplicate exact-
ly the tinutis of the subject. It is possible that by
expenditure of an unreasonable amount of time, a
closer duplication could have been accomplished.
Third, some subjects could not separate either the
innutis or the stimulus from the tinutis Synthe-
sizer into frequency and intensity. To them, sounds
consisted of a single dimension. To others, the inten-
sity of the sound influenced the perception of fre-
quency and vice versa. This placed a greater burden
on the experimenter to obtain a reliable matching of
the tinutis. Fourth, there were many instances
where the subject perceived a tinutis as being of
low frequency when it was actually high frequency.
Generally speaking, a pre-stimulation frequency
perceived as less than 1000 Hz was actually above
8000 Hz. The difficulty of tinutis matching has
been documented by other investigators.10,11

It is unfortunate that the permanence of improve-
ment was not greater. The majority of the subjects
reported that the improvement lasted three days or
less. There are four areas that may influence the per-
manence of improvement: 1. the parameters of the
electrical stimulus, 2. the number of treatments, 3.
the etiology of the tinutis, and 4. the overall health
of the patient. First, present research is being di-
rected toward varying the parameters of the electri-
cal stimulus: frequency, microamperage, and stimu-
lus duration. It may be that all tinutis is not treated
maximally with the same parameters. Second, the
number of treatments needs to be investigated.
Most of the subjects had either one or two treat-
ment sessions. Subject 2 was seen for seven treat-
ment sessions, each session tending to increase the
duration of improvement. He concluded after the
seventh session that he could now "live" with his
tinutis and requested discharge from the program.

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**TABLE IV**

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**Experimental Procedure**

**Subject Selection**

**Percent Change**

**Number of Treatment Sessions**

**Permanence of Charge**
It is conceivable that periodic reinforcement stimula-
tions will be necessary. Third, there are numerous
electrodes of tinnitus reported in the literature. It
would not be surprising to find that some electrodes
are more resistant than others to electrical stimula-
tion. The sample of 20 in this study is too small to
statistically relate electrode to improvement. Fourth,
a significant number of patients reported that their
general health, both physical and emotional, signifi-
cantly influenced their tinnitus. As examples, sub-
jects 14 and 6 reported that their tinnitus was more
severe when they did not sleep well. Subject 15 re-
ported that he "notices it occasionally, usually after
tension situations or pressure." The holistic ap-
proach to tinnitus has been discussed by Yasson. He
discusses the adverse effects that stress, inade-
quate diet, exercise, and nutrition can have on an
injured part of the body and rehabilitation. Goodye
evaluates tinnitus patients for diet and restricts spe-
cific foods. The effect of the personality of the tini-
tus sufferer to the tinnitus has been investigated. A
Although a rigorous protocol was not followed, there
were numerous reports from the subjects that their
hearing improved following actual stimulation.
Five of the 20 subjects accounting for 9 of the 28
ears reported improvement in speech discrimination
ability. Two subjects accounting for four ears also
reported improvement in both the intensity and high-
frequency range of hearing. An analysis of pre-
and post-stimulation audiological responses re-
vealed insignificant changes. These patients were
admirable and specific regarding the improvement.
Melding and Goodye and Shea and Harel reported
this same inconsistency.

CONCLUSIONS:
Electrical stimulation appears to alleviate tinnitus
either by altering the acoustic pattern of the tin-
nitus to one that is less annoying or by complete re-
mission of the tinnitus. The permanence of the im-
provement varies greatly. The adverse effects are
minimal. A significant number of subjects reported
improvement in hearing ability but this could not be
verified by objective evaluation. Considerable re-
search is needed to determine the specific paramete-s of the treatment.

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