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Tinnitus Suppression via Cochlear Implants: Review and Remarks

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I would like to thank you for coming today and listening to us, in spite of the fact that most of you are using only a single-channel hearing system, albeit bilateral. I refer, of course, to your ear canals.

Now obviously, this is not intended to be a serious scientific comment on cochlear implants. Without thinking much about the matter, many of you might be inclined to dismiss such a remark as clever at best, but flawed, or perhaps misleading.

However, I think a few moments of clear thinking will reveal that my use of the term *single channel* is precisely as scientific—and as mistakenly pejorative—as the manner in which the term usually is used. This is primarily because of the confusion between the *processing* of sounds, which occurs in the external processor, and the *presentation* of those processed signals, which occurs in the cochlea, where the electrodes are. Electrodes are about presentation, not about processing.

As well, this pertains to the subject under discussion, because tinnitus suppression via cochlear implants appears to have to do with the signal used, not the electrode configuration. Nothing prevents us from having a multichannel (processing), single-electrode (presentation) cochlear implant.

GENERAL REMARKS

I was asked to mention a few things about the amelioration or suppression of tinnitus through the use of a cochlear implant and to refer to a study that we are about to launch.

There is a large and growing number of articles about this subject of the suppression of tinnitus through the use of cochlear implants, but, as far as I know, no cochlear implant has been approved by the U.S. Food and Drug Administration (FDA) for this specific purpose. We did a cursory literature review to discover something about the general subject of electric signals as applied therapeutically to humans, for several reasons.

First, to attempt to identify the parameters of stimulus that are safe, and second, to gain an understanding of the previous literature regarding the more general subject of tinnitus suppression via such signals. While by no means an exhaustive review, we identified more than 90 such articles of interest, the earliest of which dates from 1958.

Our third area of interest was of course tinnitus suppression as it is associated with cochlear implants. A number of articles mentioned or had this as their primary subject; several are referenced [7-15].

Of these, suppression of tinnitus by cochlear implants was generally reported to be successful. Most of the pertinent articles are reports of observations regarding patients who, as a side effect of implantation, have experienced less (or in some few cases more) tinnitus. Researchers reporting in a few articles tried to use the implant as a platform for providing signals which the implant did not normally produce [i.e. 12]. One article reported the implantation of a normally hearing individual for the suppression of tinnitus [13].

UNCERTAINTY

One thing that emerges from such a review is that a wide variety of results have been reported for the use of all forms of electrical stimulus, both internal and external, along a spectrum from near-total failure to high degrees of success. All studies reported on relatively small populations, which is likely one source of this variation. As well, a diversity of methods for determining the existence and severity of tinnitus were used, and the repeatability of some of these may be open to question. Finally, evidence of suppression was often provided by patient reports, without rigorous measurement.

Tinnitus can be caused by a wide variety of insults to different parts of the auditory system. Even if we eliminate those cases for those patients where we believe we know the source of the tinnitus, those remain-

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ing seem to have a number of causes and their tinnitus seems to arise from a number of sources. By all evidence, tinnitus appears to be a fundamental response to injury or insult to almost any part of the hearing system.

In part because of the difficulty in identifying the cause of tinnitus, no one seems to be sure whether a given means of suppression is more effective on a given variety of tinnitus. Obviously, then, no one knows whether any single form of suppression will ever be found that will be effective against the whole universe of varieties.

In sum, one of the primary problems in exploring the suppression of tinnitus by any means is the more exact characterization of the cause of the symptom. Beyond that lie the difficulties of matching that characterization with whatever can be discovered about the kinds of suppression that are effective against it.

ELECTRODES

In the face of all this uncertainty it seems to me unlikely that patients with a substantial or significant degree of hearing of any kind—indeed perhaps even if they are suicidal as a result of the severity of their symptoms—would generally be considered good candidates for implantation with long electrodes for the attempted suppression of that tinnitus.

It is widely accepted that the destruction of hearing after implantation is the result of iatrogenic trauma at the time of surgery [1–4]. Long electrodes (i.e., longer than 10 mm) have been implicated in rupture of the basilar membrane, damage to the spiral ligament, and even fracture of the modiolus [5]. Short electrode implants currently are a better bet, because they are inherently safer [5,6].

No one has asserted that tinnitus has a tonotopic organization (i.e., that it is, for some reason, important to stimulate the cochlea at various points along the basilar membrane when suppressing tinnitus). This literature review did not offer any obvious difference between the suppressive effect reported in the literature for long-electrode versus short-electrode devices. Thus there does not seem to be any theoretical or any practical reason for using either multiple electrode or long electrode implants for the suppression of tinnitus.

SIGNALS AND IMPLANTS

While some researchers have found that DC current may be effective in the suppression of tinnitus, it can also be damaging to tissue. Thus, long term, electrically balanced stimulation must be used, whether analog or pulsatile. The current AllHear internal device design is completely passive and is well suited to exploring signals that are analog (at frequencies <30 kHz), but is less well suited to the delivery of short-period pulsatile stimulation.

This is because the central element of this design is a coil, and all stimuli must be induced in the coil by an external alternating magnetic field, generated by the processor. The more rapid the changes in that external field, the higher the frequency of the internal signal. Short period square-wave pulses may be thought of as being composed of a set of very high-frequency sine-wave signals. Even if there were no other barrier to undertaking pulsatile stimulation via the current design, it would be sufficient that the titanium case surrounding the coil tends increasingly to mask or block signals exceeding 40 KHz, reducing signal strength. However, most of the beneficial results reported in the literature arose from the use of low-frequency analog stimulation.

If further research proves the superior utility of signals which are difficult to produce via inductively coupled coils (high frequency analog or short-period pulsitile), then active devices (those with more complex internal electronics) may be tried. As yet, however, no one knows whether such stimulation may eventually prove more or less useful than lower frequency analog stimulation. We are, in essence so ignorant, and there is such an abundance of sufficiently promising avenues of research using simpler alternatives that the whole question is highly premature.

PLANS

Given these thoughts, our current plan is to undertake an exploration of suppression or amelioration of tinnitus through cochlear implantation—after approval by the FDA—by using low-frequency analog signals of various kinds in the attempt to discover a set or sets of signals that appear to have the most beneficial effect. To this end, we are developing a computer system through which we will explore the implied questions. The computer system uses digital signal-processing boards that can create a broad universe of signals. The output from the computer will be shunted through an isolation box, designed to provide passive but highly effective electrical limits to any such output for patient safety.

The output signal, having passed through the isolation box, might then be presented acoustically (either through headphones or speakers), inductively (through an external coil that will mate with the coil in the implant), electrically (through skin electrodes), or vibrationally (through piezoelectric bone-conducted vibrators, primarily intended for high-frequency acoustic stimulation).

For various reasons, we are beginning only with acoustic and inductive outputs. In other words, in the initial phase of this exploration, we intend only to examine suppression by sound or by signals delivered via the cochlear implant. As time passes, we believe as well that we can use this or a very similar system to explore signal-processing strategies that can provide patients with ever greater access to the speech signal through full-time, full-spectrum, pure analog stimuli. Assuming that we can identify such signals, devices can be built to provide those signals to the patients from a wearable device, and a longer-term study will then be undertaken.

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