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Cochlear Implants: New Perspectives

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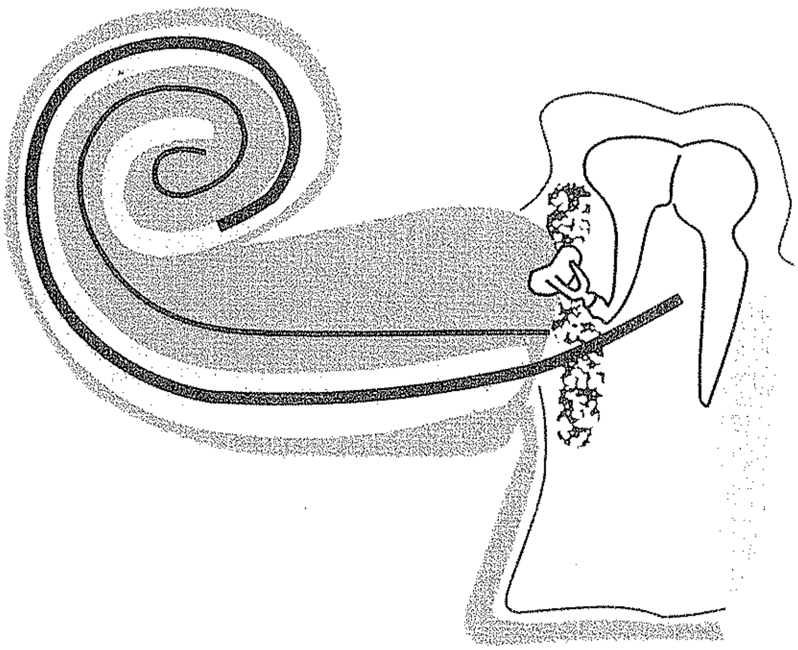

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Tinnitus Suppression in Cochlear Implant Users[1]

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Postlingually deaf adults may be severely affected by tinnitus. When the suitability of a cochlear implant is discussed, patients often wish to know if their tinnitus will change after surgery.

Over the past years, several studies have reported tinnitus relief in cochlear implant patients [1]. These studies were generally performed with a single-channel implant. With the 3M-House implant, Berliner et al. [2] observed a tinnitus improvement in 53% of users. With the implant developed in London, Hazell et al. [3] reported a tinnitus improvement in 54% of users. With some of the best single and multichannel implant users, Tyler and Kelsay [4] observed a tinnitus reduction in 81%. A recent study by Gibson [5] on patients with a multichannel implant claimed a reduction of tinnitus in 61% when the device was used for speech perception and 26% when the device was turned on.

Materials and Methods

This preliminary report is limited to 2 postlingually deaf adults implanted with the Nucleus device [6] and complaining of tinnitus. Their tinnitus annoyance was estimated at 22 and 43% in patients 1 and 2, respectively, on the Tinnitus Handicap Questionnaire [7].

[1] This work was supported by the French Ministère de la Recherche et de la Technologie, and the American Tinnitus Association.

We varied the current level, and investigated its relationship to (1) the loudness of stimulus, and (2) the loudness of the tinnitus. The speech processor, a MSP processor (Mini System 22) for patient 1 and a WSP III processor (an older version of the former) for patients 2, was controlled by the Nucleus DPI interface (version 6.53). For a given experiment, we first determined the threshold and the uncomfortable loudness level. Different current levels were selected within the range between threshold and uncomfortable loudness level. They were presented randomly to the patient, typically with 3 replications per current level. For each presentation, the subject was asked to rate on a 0 to 100 scale the loudness of the stimulus (i.e. the sound heard when the electrode was stimulated) and the loudness of his tinnitus.

Results

Figure 1 shows the relationship between the current levels and the loudness ratings of stimulus and tinnitus, using a bipolar stimulation of electrode 15 with a repetition rate of 250 Hz in patient 2 (subject L). The individual data points are given and the line goes through the average values. Two functions are thus obtained: the stimulus loudness growth (dotted line) and the tinnitus reduction curve (solid line). We can define the crossover point as the place where the two functions cross, here at 0.65 mA. Results are presented according to 4 parameters: electrode location, frequency of stimulation, interelectrode distance, and post-stimulus effect.

Electrode Location

In patient 1 (subject F), we first assessed the effect of electrode location, using a bipolar + 1 stimulation mode and a pulse rate of 250 Hz. The crossover point was lower with electrode 12 (0.55 mA) than with electrode 4 (0.7 mA), indicating that less current was needed with the former electrode to reduce tinnitus. Patient 1 reported two annoying tinnitus sounds, a cricket noise (high-pitched) and an ocean noise (lower pitched). He found basal electrode 4 more effective for the cricket and apical electrode 20 better for the ocean. We asked him to indicate the stimulus loudness which he preferred for tinnitus reduction: with both electrodes, the best stimulus loudness was between 20 and 30%, therefore the best current level was around 0.55 mA.

In patient 2, only electrodes 21 to 11 were available due to a severe labyrinthine fracture. We assessed the effect of electrode location with a bipolar stimulation (which he used for 2 years) and a 250 Hz pulse rate.

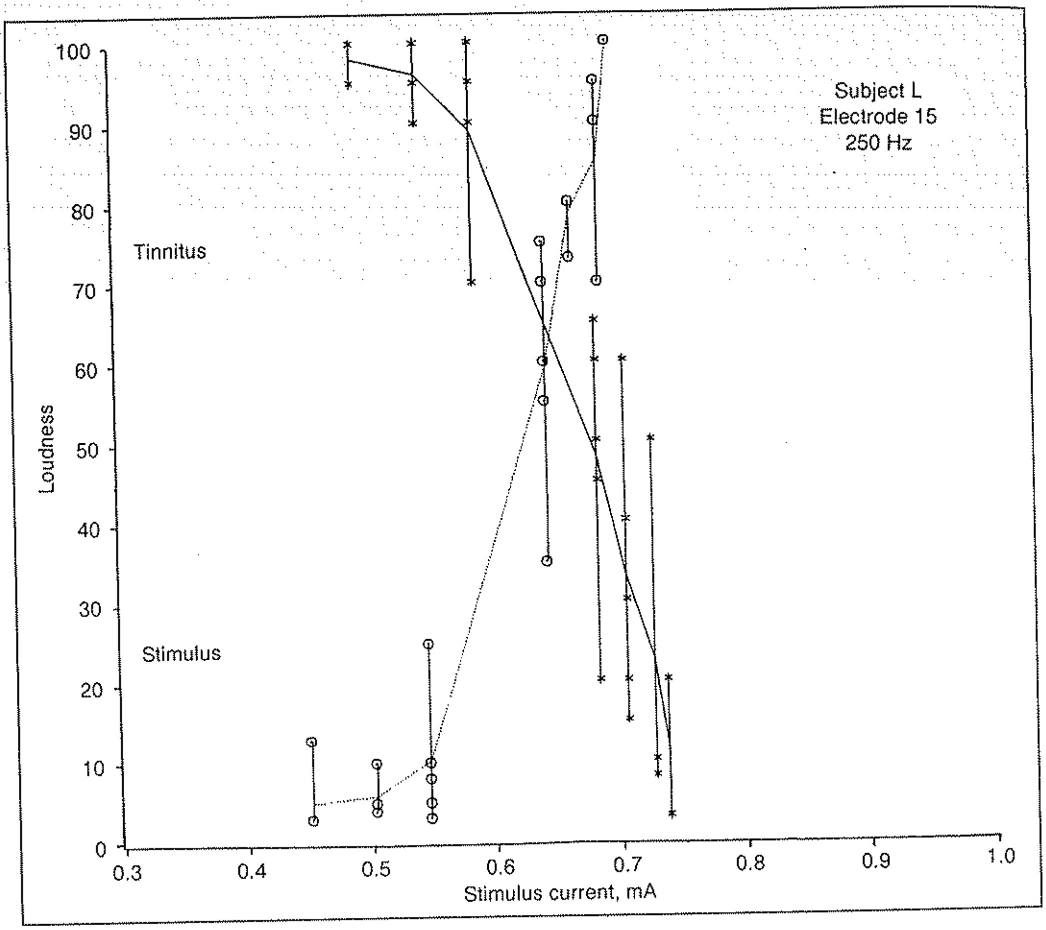

Fig. 1. The loudness of stimulus and of tinnitus is shown on the vertical axis on a 0–100 scale as a function of the current level expressed in mA. The dotted line in the figure shows the loudness of the stimulus, the solid line shows the loudness of the tinnitus. The crossover point, where the stimulus and the tinnitus have about the same loudness, is located around 0.65 mA. Results for subject L.

With electrodes 21 and 11 the crossover point was around 0.8 mA, therefore it required high current levels to suppress tinnitus. With stimulation of electrode 13, a very low level of current was needed to suppress tinnitus (crossover point around 0.4 mA), whereas with electrode 15 the preferred current level was around 0.65 mA.

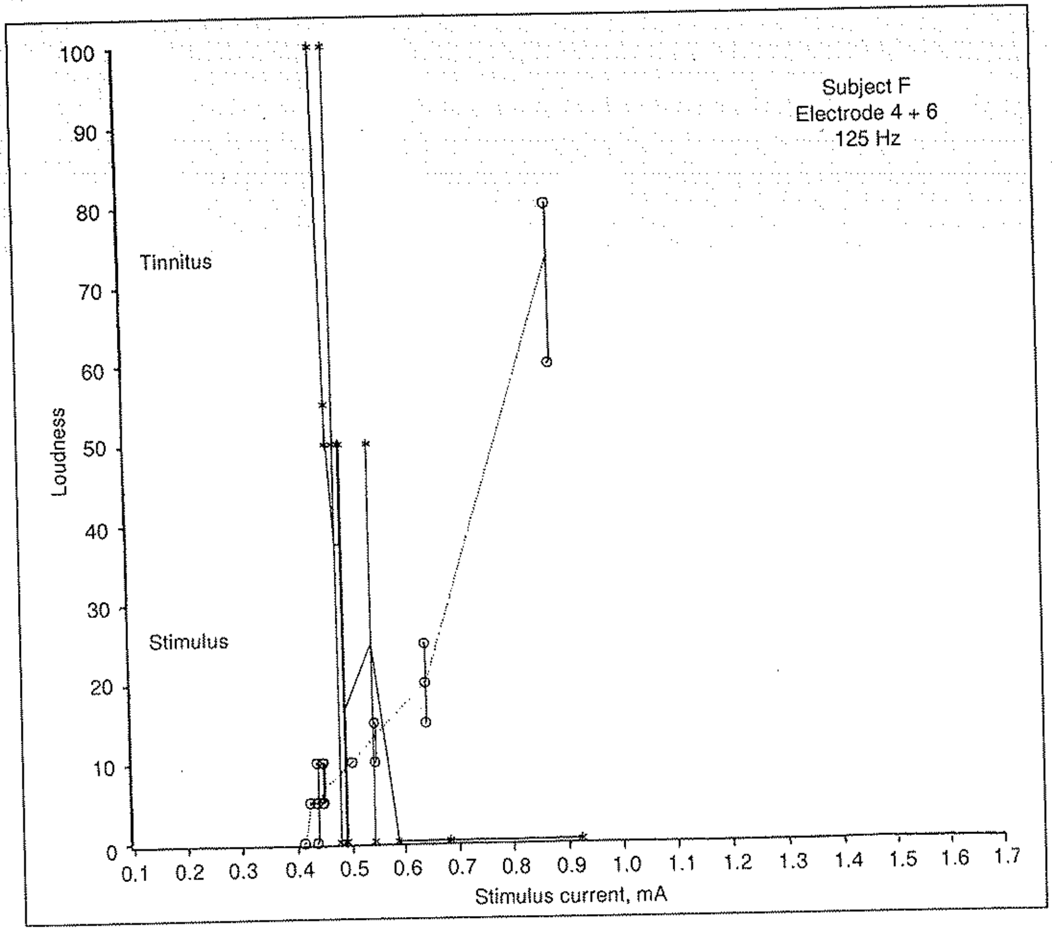

Fig. 2. Stimulus (dotted line) and tinnitus (solid line) loudness as a function of current level for subject F. Tinnitus suppression is obtained at low current levels and a low stimulus loudness of 15%.

Frequency of Stimulation

In patient 1, we examined the effect of changing the frequency of stimulation on tinnitus suppression, using electrode 4 and a bipolar + 1 stimulation (fig. 2). With a pulse rate of 125 Hz, the reliability of tinnitus ratings was not very good at very low current levels for this patient, but tinnitus suppression was obtained with low stimulus loudness: at 20% of the stimulus loudness the tinnitus was completely suppressed. The crossover point was lower at 125 than 250 Hz. We also tried lower and higher frequencies (80 and 500 Hz), but the patient did not report any additional benefit.

In patient 2 we tested the same 4 frequencies, but with another electrode, apical electrode 21. As in patient 1, a pulse rate of 125 Hz required less current to suppress tinnitus than the frequencies of 80, 250 or 500 Hz.

Interelectrode Distance

Our third area of interest was the effect of the interelectrode distance. In subject 1 the bipolar + 3 stimulation (electrode 4–8) had a crossover point of 0.4 mA, and the bipolar + 1 stimulation (electrode 4–6) had a crossover point of 0.7 mA. In general, the greater the interelectrode distance, the less current was required to suppress tinnitus, at least for the electrodes we tested.

In patient 2, similarly, the bipolar + 3 stimulation (electrode 18–22) took less current to suppress tinnitus than the bipolar + 1 stimulation (electrode 20–22).

Poststimulus Effects

Finally, we were interested in studying these effects during and after a prolonged electrical stimulation. Before stimulation the tinnitus loudness was 100% and the stimulus loudness was obviously 0%. We presented the stimulus at 125 Hz on electrode 21 to patient 2, at the preferred loudness level of 50%, for a duration of 300 s. The stimulus was rated at 60% loudness, and the tinnitus was reduced to around 40% during the stimulation. After stimulation, tinnitus loudness was reduced even lower (to 30%) for a few minutes, and then it returned progressively to 100% after 15 min.

Discussion

Preliminary results show that the electrode position in the cochlea influences the current level required to suppress tinnitus in cochlear implant patients. For instance in patient 2, the stimulation of the extreme electrodes 21 and 11 needed much more current to suppress tinnitus than the stimulation of electrode 13 or, to a lesser extent, 15. This suggests that the effectiveness of current in suppressing tinnitus appears related to a particular electrode location. The findings in patient 1 also indicate that the stimulation of a deeply inserted electrode may be needed in some patients rather than the stimulation of a short insertion. Regarding the pulse rate, if we consider the criteria that the lowest current level is the best for the patient, the frequency of 125 Hz appeared substantially better for tinnitus suppression than 250 or 80 Hz for the 2 subjects examined. In general, the greater the interelectrode distance, the less current was needed to suppress tinnitus. We hope to provide cochlear implant patients with a stimulating program that they could select in a quiet environment or when their tinnitus is especially bothersome.

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