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Intracochlear Electrical Tinnitus Reduction

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Several reports have indicated that some cochlear implant patients experience a reduction in their tinnitus while listening to noise or speech. In the present study, two patients reporting bilateral tinnitus were selected from a group of adults with the Nucleus cochlear implant. They rated their tinnitus loudness and severity and completed the Tinnitus Handicap Questionnaire. The stimuli for electrical stimulation were charge-balanced pulse trains of various repetition rates (frequencies) and interelectrode distances. A range of electrodes was chosen in each subject, including basal, medial and apical electrodes. For each condition, the hearing threshold level and the uncomfortable loudness level were determined. A range of stimulus levels between these two values were presented randomly. After each presentation, the patients rated the stimulus loudness and the tinnitus loudness on a 0 to 100 scale. These judgements were used to carefully determine the psychometric function between stimulus level and stimulus loudness, and between stimulus level and tinnitus loudness. All the parameters explored were important for maximizing the relationship between tinnitus reduction and stimulus loudness. First, the effectiveness of electrical stimulation in tinnitus reduction depended on the place along the cochlear partition. Second, a pulse rate of 125 Hz showed the greatest efficiency in terms of the current level needed to suppress tinnitus. Third, these two subjects showed rather poor performances in speech perception when using their speech processor in the usual condition and the hypothesis of an influence from tinnitus annoyance is suggested in addition to some more classical predicting factors of speech recognition in cochlear implant users. *Key words: cochlear implant, electrical stimulation, tinnitus, loudness.*

INTRODUCTION

Like in any form of sensorineural hearing loss, subjects suffering from profound deafness may have acceptable or unacceptable tinnitus. In the latter condition, the patient usually seeks clinical assistance. Two main factors contribute to whether or not tinnitus is acceptable: *i)* physiological factors, such as the number and rate of nerve fibers involved, and *ii)* psychological factors, such as the emotional state of the patient (1, 2).

Fig. 1 describes some features of the cochlear implant program which has been running at the University Hospital of Bordeaux over the last 4 years (3). All the patients received a multichannel intracochlear implant, either Nucleus (4) or Ineraid (5). Among these subjects, all but one were postlingually deaf. Two of them (patients 1 and 11) were bothered preoperatively by tinnitus and are included in this study.

MATERIAL AND METHODS

The annoyance related to tinnitus in the 2 patients (subject 1 or 'L' and subject 11 or 'F') was assessed on the day of the experiment by means of the Tinnitus Handicap Questionnaire (6).

During the session the speech processor was under the control of the Coclear DPI interface (7). The reason for this was to be able to change easily the parameters of the electrical stimulation and to evaluate the consequences of these changes on the stimulus and tinnitus perception.

Different current levels were selected between the threshold hearing level and the uncomfortable loudness level. They were presented randomly, usually with three replications. For each of them the patient was asked to rate on a 0 to 100 scale the loudness of the stimulus and the loudness of the most annoying tinnitus.

RESULTS

Fig. 2 shows the stimulus loudness growth and the tinnitus reduction curve in subject F, using a bipolar stimulation of electrode 20 and a repetition rate of 250 Hz. A crossover point can be described where the two curves cross, in this case around 0.55 mA. The variability of the tinnitus loudness was rather large, in contrast to that of the stimulus loudness. However, the patient consistently reported a preference to a stimulus loudness around 25%, which he found the best for his low-pitch ocean-noise tinnitus component (around 0.50 mA).

The 125 Hz pulse rate (frequency of stimulation) appeared to be the best with respect to both crossover point and preferred loudness level for tinnitus suppression. The current level required to sufficiently reduce the tinnitus without inducing too loud a sound was lower at 125 Hz than at 250 Hz, and the subject did not report any additional benefit when using a lower frequency (80 Hz). In the other patient (subject L) the frequency of 125 Hz also appeared the best in terms of the current level needed to reduce consistently the tinnitus.

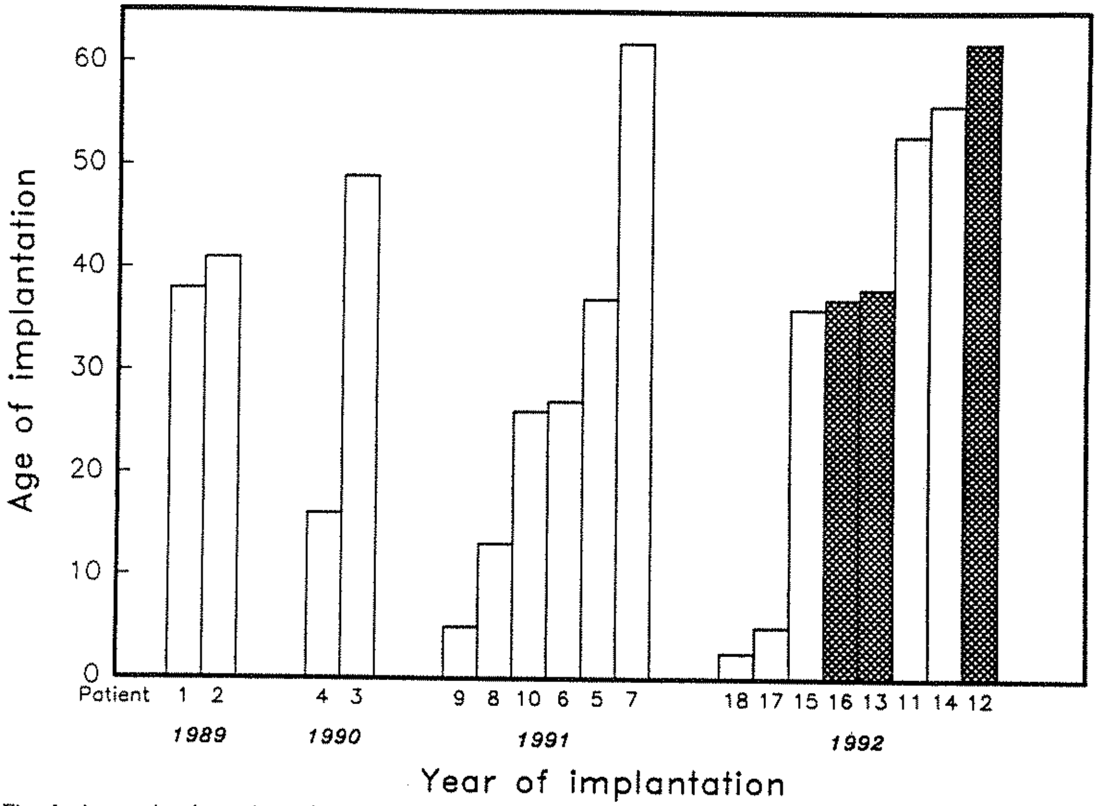


Fig. 1. Age at implantation of the profoundly deaf patients operated on between 1989 and 1992 at the University Hospital of Bordeaux. Nucleus patients are presented in *empty bars* and Ineraid patients in *cross-hatched bars*. The number appearing under each column indicates the chronological order of the surgery. The tinnitus patients studied in this report are subjects 1 and 11.

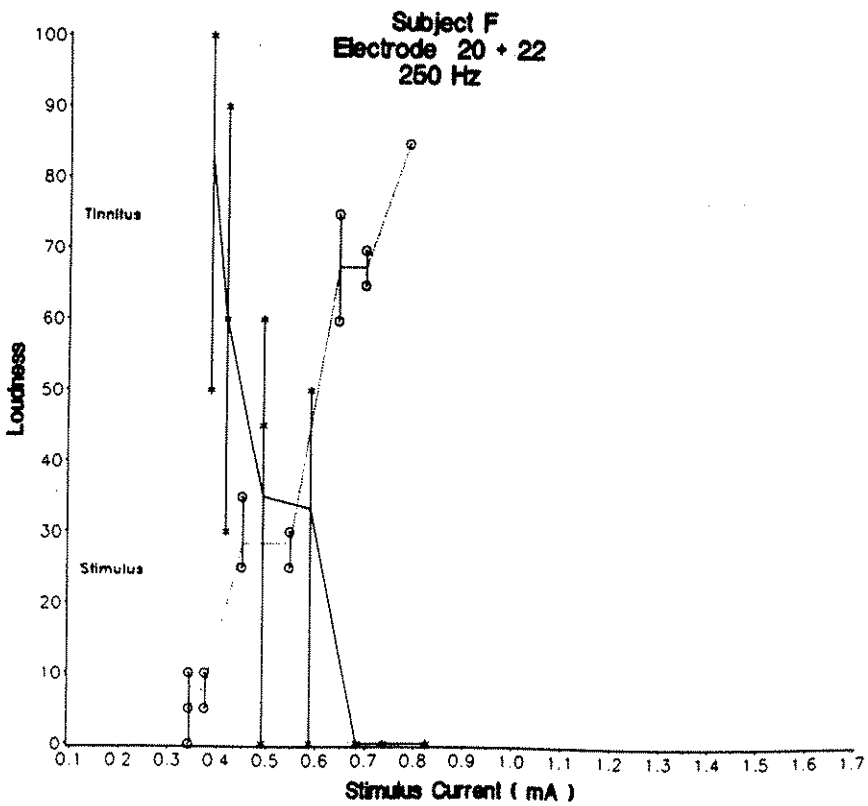
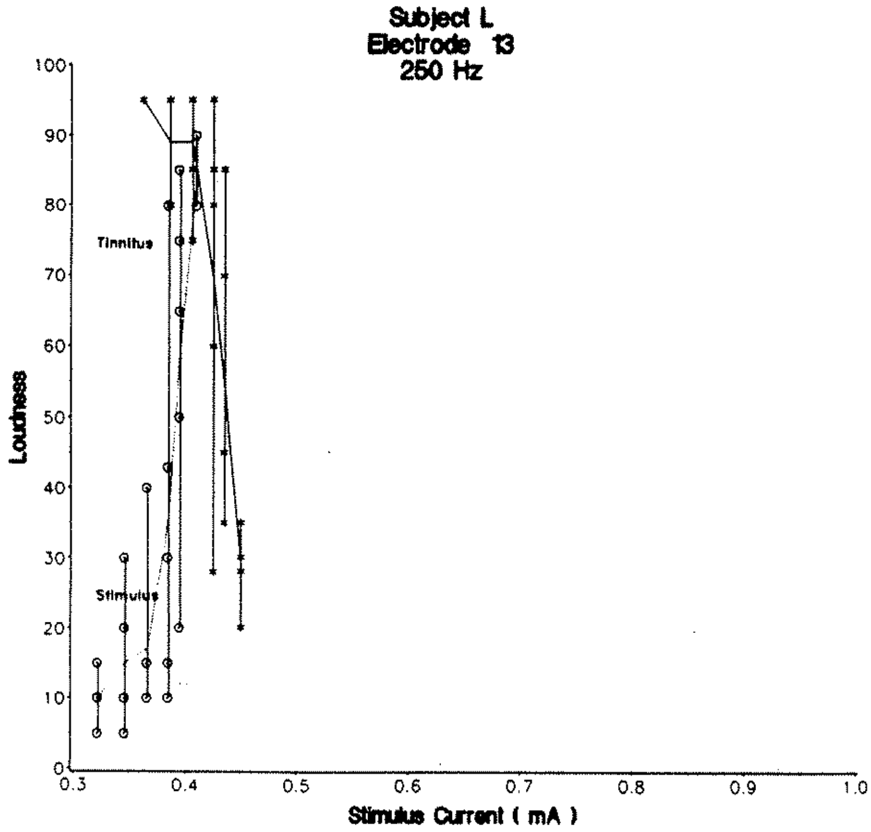


Fig. 2. Stimulus loudness growth (in *dotted line*) and tinnitus reduction curve (in *solid line*) in subject F, using bipolar stimulation of electrode 20 and a repetition rate of 250 Hz. The individual data points are given and the line goes through the average values.



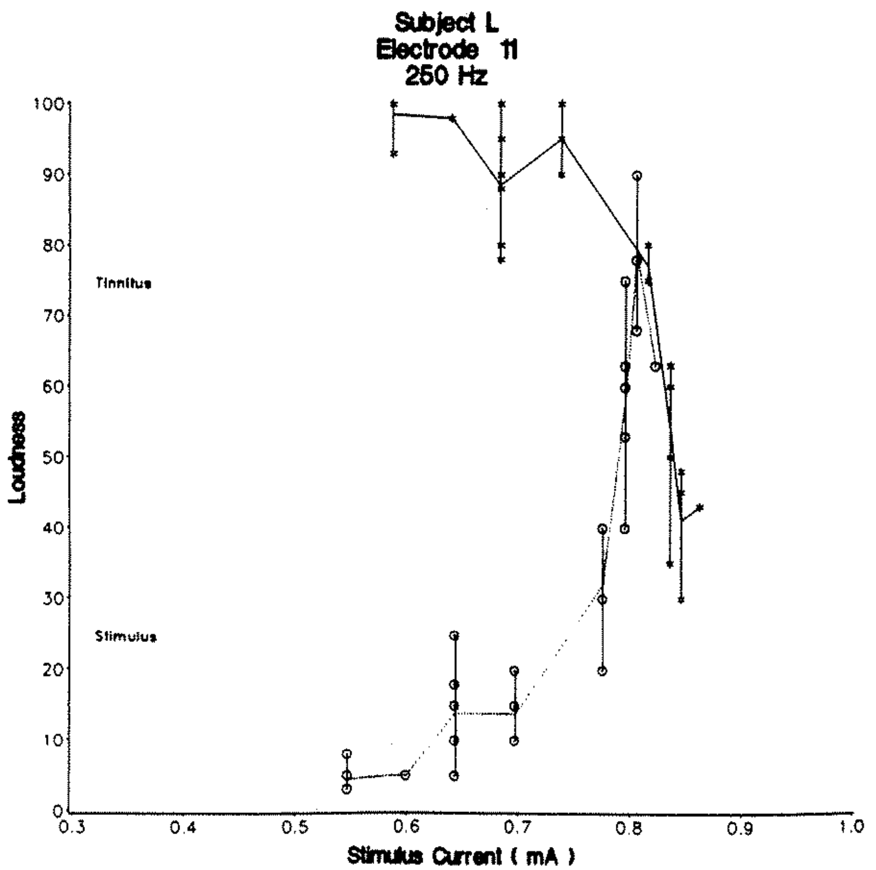


Fig. 3. Stimulus and tinnitus loudness curve obtained in subject L, using a bipolar +1 stimulation of electrode 13 (*a*) and 11 (*b*). The current level corresponding to the crossover point of the curves is clearly different with the two electrodes. In subject L, the current level corresponding to the crossover point was twice as low with electrode 13 (0.4 mA) (*a*) as with electrode 11 (0.8 mA) (*b*).

With respect to electrode location, important differences were observed in the current level required to suppress tinnitus. For instance in subject L, the current level corresponding to the crossover point was 50% lower with electrode 13 (0.4 mA in Fig. 3*a*) than with electrode 11 (0.8 mA in Fig. 3*b*), although these two electrodes were close to each other. Similarly, electrode 15 appeared better than electrode 21. In subject F, electrode 4 was the best (using a pulse rate of 250 Hz) for the cricket-noise tinnitus component, whereas, as seen in Fig. 2, electrode 20 was the best for the ocean-noise component.

We also looked at the effect of the interelectrode distance. The larger the distance, the less current was needed to reduce tinnitus. For instance in subject F, the crossover point with the bipolar +3 condition was much lower (0.35 mA) than with the bipolar +1 condition (0.7 mA).

The last section of this study inquired into a possible relationship between tinnitus annoyance in cochlear implant users and their ability to perceive speech. Many reports on postlingually deafened patients have pointed out the wide range of results in speech understanding and the difficulty in predicting pre-operatively the performances (8, 9). However, results seem to be influenced by *i)* the age at onset and the duration of profound deafness, which both affect in some way the amount of auditory memory (10, 11) and the pre-existing language ability in children (12); *ii)* the surgical patency of the cochlea (13); and *iii)* possibly, the preoperative ability in lipreading the consonants (14). Nevertheless, many uncertainties remain in predicting reliably the cognitive processing abilities.

Auditory capabilities were assessed in subjects 1 and 11 by means of a test battery derived from the Iowa protocol of evaluation (9). They showed a reasonably good perception of familiar noises (around 70%) and some improvement in their lipreading. However, their understanding of words was poor, both with single-syllable words (less than 5%) and word recognition in sentences (less than 5%).

DISCUSSION

These results are preliminary and need to be confirmed in a larger group of cochlear implant users complaining of tinnitus. Nevertheless, significant changes were observed in tinnitus perception according to the parameters which were investigated (pulse rate, electrode location, interelectrode distance). Hopefully, they might be of some value in helping to improve the design of a stimulation procedure which would be available to the Nucleus implanted patients, giving them the opportunity to select on their speech processor an appropriate stimulation of the electrode array when they are bothered by their tinnitus, e.g. in a quiet environment. Indeed, residual inhibition of tinnitus is rare when patients with multichannel cochlear implant switch off their speech processor (15) or are in a silent environment.

Second, the precise effect of cochlear implantation on tinnitus is not yet known (16). Our results may explain in part the difficulty in obtaining consistent suppression of tinnitus with a single-channel extracochlear implant, although encouraging findings have been reported over the last years (17, 18).

Finally, further research is needed to determine whether pre- and postoperative tinnitus severity may influence speech understanding in multichannel cochlear implant users.

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