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Electrical stimulation of hearing in totally deaf humans

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Problem and objective

Auditory sensations have been known to result from electrical stimulation of the human body since 180 years. However, in constrast to conventional acoustic hearing aids, the majority of studies aimed at the restoring of useful hearing by electrical stimulation of the auditory system have remained experimental. One of the major obstacles to the successful development of a hearing aid based on an intraaural electrode is the signal transformation and the encoding of the signals which are supposed to stimulate the fibers of the auditory nerve. Our attempt to develop an electrical hearing aid has to solve the following questions:

- What is the normal neural activation of the auditory nerve following acoustic stimulation?
- How can this pattern be reproduced, when the normal transfer function of the inner ear transducer is altered?
- What constitutes a comprehensive rehabilitation program for patients with a electrical stimulation hearing aid, and how can its success be assessed?

Method

Based on theoretical considerations of the inner ear function, a model of the signal transformation in the normal ear has been implemented on a general purpose minicomputer. Accordingly, a portable signal processor has been developped. Different coding options are available, that had to be tested for optimal perception of speech sounds, when electrical (square or sine wave) stimuli activated the remaining fibres of the hearing nerve. The signals were fed to the auditory nerve via transcutaneous plug to a .2 mm diameter bipolar electrode implanted in the cochlea. A later version used a wireless transcutaneous inductive coupling system to avoid the risks of infection of the skin window. The electrode tip is placed on the round window membrane, outside the cochleac coil, in order not to produce further damage likely to occur in the inner ear, when entered by foreign materials. Until 1982, 4 patients have been provided with this single channel monopolar system. By a programable minicomputer, loudness and pitch discrimination, psychophysical scaling experiments and discrimination tests of speech materials have been carried out over a period of up to 15 months. The findings will be compared to the performance of the normal ear and should explain the nature of electrical hearing percepts in the deaf human in terms of information capacity of the auditory nerve.

Results

The preliminary results are comparable to previous and reported experiments with intracochlear inplantations. Discrimination between test stimuli is attributable mainly to the periodicity-perception in the frequency range below 500 Hz. No rejection of the implanted material has been observed and interactive training of speech discrimination with different encoding algorithms has resulted in increasing performance over a time of over 1 year.

Discussion and conclusions

Our method of cochlear implantation is comparable to studies of Fourcin et. al. (Brit. J. Audiol. 13, 1979: 85, 103) who have presented the first comprehensive report of results of extracochlear single channel electrodes in the deaf. This method uses a surgical procedure to place the electrode and the receiver in the middle ear, while the risks of a hard wired access to the inner ear are avoided. Therefore, a safe application even in children is conceivable in order to compare the speech development between electrode-aided and conventionally aided profoundly deaf youngsters.

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