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AN EXTRA COCHLEAR ELECTRO-STIMULATING DEVICE (ECME) USING ATRAUMATIC EXTERNAL MEATAL ELECTRODES AS A COMMUNICATION AID FOR THE DEAFENED

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We describe an auditory prosthesis for totally deafened people which stimulates both cochlear via ear canal electrodes. The device emits a square wave pulse matched to the first formant frequency and transposed below 10 Hz. It acts as an aid to lipreading, creates an awareness of environmental sounds, and reduces the isolation of total deafness. It is a cheap non-surgical alternative to cochlear implantation.

Autorzy przedstawiają protezę słuchową dla osób z całkowitą obustronną nabytą głuchotą. Urządzenie, zaopatrzone w atraumatyczne elektrody w obu przewodach słuchowych zewnętrznych, przetwarza sygnały akustyczne na falę prostokątną. Amplituda tej fali jest proporcjonalna do chwilowej intensywności głosek dźwięcznych, ze znacznym ograniczeniem dynamiki, a częstotliwość fali jest proporcjonalna do częstotliwości przejść przez zero pierwszego formantu tych głosek. Z zachowaniem proporcjonalności, częstotliwość na wyjściu jest transponowana w zakres (dobierany indywidualnie) poniżej 100 Hz, tj. w zakres słuchowego reagowania pacjentów na pobudzenie elektryczne przez skórę kanałów usznych. Proteza poprawia sprawność czytania mowy z ust, daje informację o dźwiękach w otoczeniu, zmniejsza wrażenie izolacji. Jest prosta w użyciu i nie wymaga zabiegu chirurgicznego, nawet na uchu środkowym. Może być zastosowana w przypadkach gdy "implant ślimakowy" jest nieosiągalny, lub przeciwwskazany. Koszt protezy jest niski, porównywalny z ceną konwencjonalnej protezy elektroakustycznej.

1. Introduction

Post lingually totally deafened people depend on lipreading to communicate. In speech the number of phonemes exceeds that of vizemes and many efforts have been made to use other sensory modalities to aid lipreading skills [7, 9]. Although Volta [12] in 1800 described the auditory sensation that could be achieved by stimulating the ear with an electric current, it was not until the late 1950's that it was used as a communication aid [8, 10]. Since then many different strategies have been employed at different research centres around the world. These include various single and multi-channel extra and intra cochlear electrode placements as well as many different strategies for speech processing to produce a signal that will be useful to the patient. In all cases the signal must bypass the damaged cochlea to reach the more central, intact, part of the auditory pathway. Our research in this field started in 1976 with electrical stimulation via a transtympanic needle electrode on the promontory overlying the basal turn of the cochlea (BOCHENEK et al [5]).

2. Method

Our philosophy has been that external atraumatic electrodes will avoid any long term ill effects that may arise from internal invasive placement [1, 6]. Tests have been carried out using different electrode positions, but the best results were always obtained with an electrode in each ear canal. These are constructed by passing wires through hearing aid moulds to which is attached a small piece of gauze dipped in saline which lies in contact with the meatal skin (Fig. 1). The system has been tested on subjects with normal hearing, and with moderate and complete deafness. The responses vary, some subjects reporting only a "tweaking" or pressure sensation in the ear. We have already reported on the electrophysiological responses produced by

FIG. 1

such stimulation [4]. The device produces an alternating square wave pulse which is an analogue of the speech signal, after frequency transposition to below 100 Hz. Above 100 Hz such transdermal stimulation was found to be ineffective in most individuals. This output is excellent in coping with the narrow (and variable) electrical dynamic range of the ear (Figs 4 and 5).

Various speech processing strategies have been tried:

1. The amplitude of the stimulating signal depends upon the short time average power of the voiced sounds, and its frequency is proportional to the first formant frequency. The voiceless sounds do not produce a signal.

2. The amplitude of the signal depends upon the short time average power of the speech signal filtered by a high pass filter with a cut off frequency of 770 Hz. The frequency of the stimulus is proportional to the second formant of the voiced sounds and to the zero crossing frequency of the voiceless sounds.

3. The frequency of the signal is constant (chosen by the subject) and its amplitude is modulated as in mode 1.

4. The frequency of the signal is constant (chosen by the subject) and its amplitude is modulated as in mode 2.

The frequency of the first and second formant is estimated by analogue filtering and a zero crossing method [3]. The frequency is then divided in order to fit the restricted frequency of electrically evoked auditory sensation.

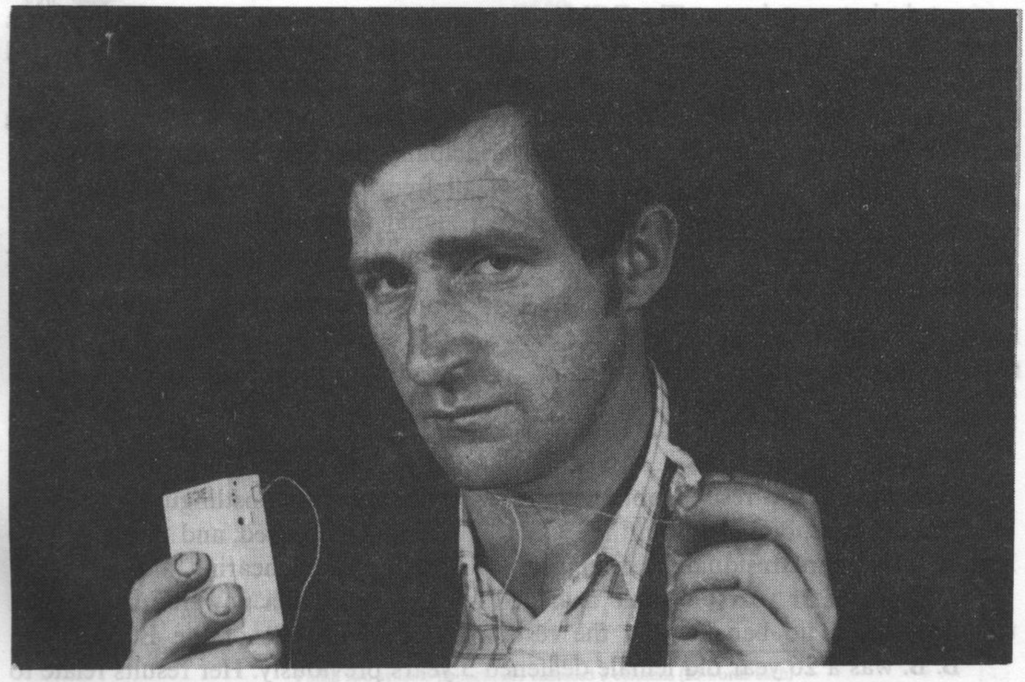

FIG. 2

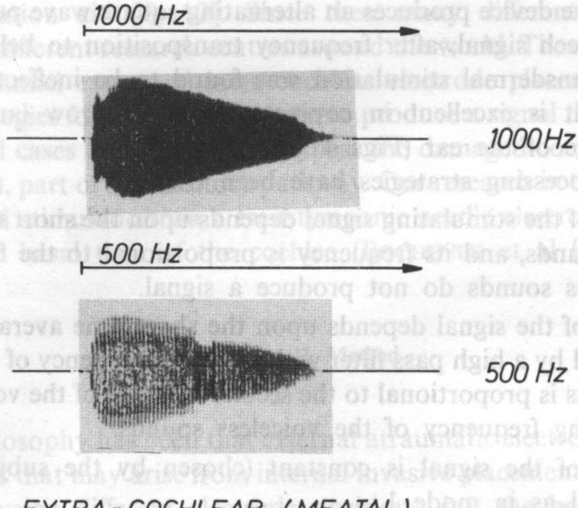

FIG. 3

We have reported on tests made on three patients with total acquired deafness [2]. Signal processing mode 1 was the most successful and has been adopted in current devices now in use. The ECME (Extracochlear (Meatal) Electro-stimulator) is shown in Fig. 2. The device is also being developed and tested at the Royal National Institute for the Deaf, London. The device has the following features:

1. Filtering of the incoming acoustic signal between 200 and 770 Hz. This filters out the fundamental frequency leaving principally the first formant.
2. Variable downard transposition of all frequencies to below 100 Hz.
3. Strong compression of the electrical signal (adjustable).
4. A dynamic threshold to reduce environmental background noise so that continuous signals rapidly decay (Fig. 3).

3. Results

We present the results obtained in two patients with postlingually acquired bilateral deafness, one in whom the ECME device was employed, and the other who had slightly more residual hearing using a high powered hearing aid.

J. Z. was a 31 year old male deafened for 11 years. High powered hearing aid trials produced no benefit, and the results relate to his use of the ECME.

B. B. was a 26 year old female deafened 5 years previously. Her results relate to the use of a high powered hearing aid.

Table 1

Audiograms

Subject	Auditory Thresholds [kHz]			
	0.5	1	2	4
JZ	100	110	125	–
BB	80	100	105	115

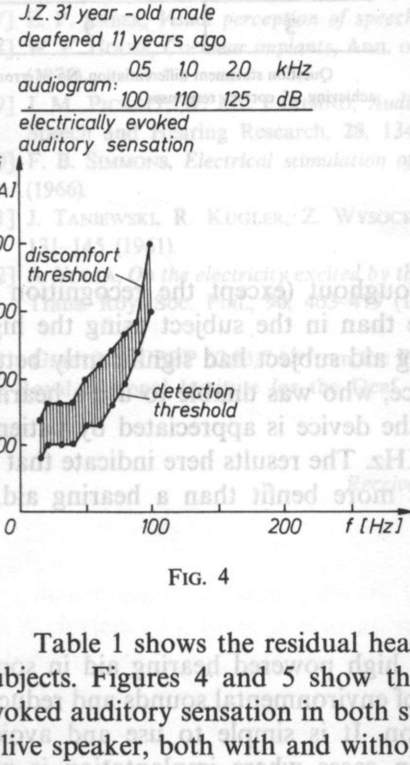

FIG. 4

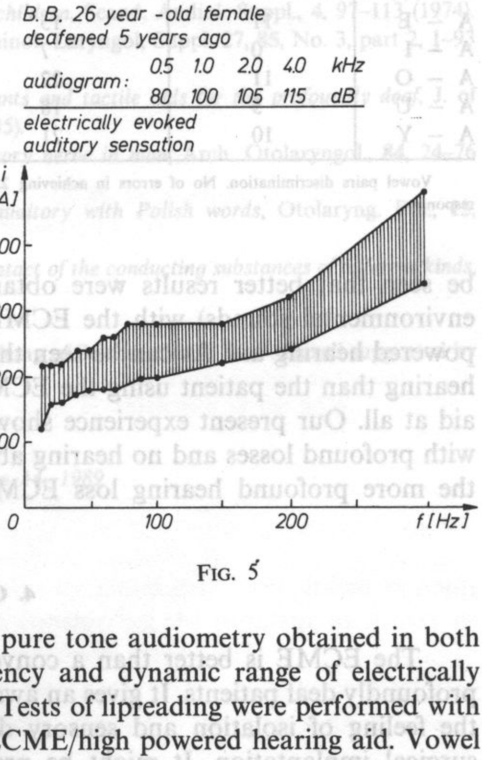

FIG. 5

Table 1 shows the residual hearing on pure tone audiometry obtained in both subjects. Figures 4 and 5 show the frequency and dynamic range of electrically evoked auditory sensation in both subjects. Tests of lipreading were performed with a live speaker, both with and without the ECME/high powered hearing aid. Vowel paired discrimination tests were performed. In each case these were presented until 25 correct responses were obtained. The number of incorrect responses was noted

Table 2

Discrimination tests

	JZ (ECME)	BB (Hearing Aid)
Lipreading alone	61%	70%
Lipreading & device	79%	76%

Polish two syllable phonetically balanced 5 columns (20 words each)
TANIEWSKI et AL (1961) [11].

and the results displayed in Tables 2, 3 and 4. These results indicate that in the case of J. Z. where hearing aids were useless, better discrimination was achieved with ECME than in the case of B. B, a marginal hearing aid user. The same strategy was employed for differentiation between questions and statement presentations. It can

Table 3

	JZ (ECME alone)	BB (Hearing aid alone)
A – E	11	15
A – I	0	7
A – O	11	22
A – U	5	18
A – Y	10	21

Vowel pairs discrimination. No of errors in achieving 25 correct responses.

Table 4

JZ (ECME alone)	BB (Hearing aid alone)
3	9

Question statement differentiation. No of errors in achieving 25 correct responses.

be seen that better results were obtained throughout (except the recognition of environmental sounds) with the ECME device than in the subject using the high powered hearing aid. As can be seen the hearing aid subject had significantly better hearing than the patient using the ECME device, who was unable to use a hearing aid at all. Our present experience shows that the device is appreciated by patients with profound losses and no hearing above 2 KHz. The results here indicate that in the more profound hearing loss ECME gives more benfit than a hearing aid.

4. Conclusion

The ECME is better than a conventional high powered hearing aid in some profoundly deaf patients. It gives an awareness of environmental sounds and reduces the feeling of isolation and sensory deprivation. It is simple to use and avoids surgical implantation. It might be preferred in cases where implantation is not available or contra indicated. It may be useful in a cochlear implant programme to aid assessment and counselling pre-operatively. Its low cost compares favourably with that of a conventional hearing aid.

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