The Growing Edge

MULTIPLE-ELECTRODE COCHLEAR IMPLANT FOR PROFOUND OR TOTAL HEARING LOSS: A REVIEW

G. M. CLARK
Y. C. TONG

Med J Aust, 1981, 1 428-429.

PATIENTS who have developed a profound or total hearing loss cannot receive help with a conventional hearing aid. A promising way of restoring usable hearing and helping them communicate, however, is by electrical stimulation of residual auditory nerve fibres.

Recently, single electrodes have been used to globally stimulate the auditory nerve, and patients have been helped in distinguishing voiced from unvoiced speech sounds, and in hearing the rhythm and intonation of speech.^{1,2} However, it is generally agreed that, if more speech information is to be conveyed to the patient, a multiple electrode system which selectively stimulates small groups of auditory nerve fibres will be required.

For this reason, multiple electrode cochlear implants have been carried out on two patients at the University of Melbourne; the patients' subsequent ability to understand speech has been evaluated by a variety of audiological procedures. The patients were adults who had developed profound and total hearing losses. The fact that they had previously heard before going deaf (postlingual deafness) was an advantage for evaluation purposes, as they could compare the sensations produced by electrical stimulation with those induced by sound. Furthermore, the first patient had a sudden hearing loss 20 months before his operation, while the second patient had been losing hearing gradually for 20 years and had had no useful hearing for 13 years before his implant.

The first patient underwent operation on August 1, 1978,³ and for many subsequent months participated in psychophysical studies. These showed that he could perceive real pitch sensations with electrical stimulation, and that multiple electrode

stimulation resulted in different pitches being perceived depending on which electrode was stimulated. The pitches produced by stimulating the various electrodes could be ranked from low to high along the length of the cochlea. Stimulating the electrodes also produced different vowel like sounds.⁴

As a result of these studies a computer program was developed that could process speech and send appropriate signals to the receiver stimulator.⁵ This was done by extracting the voicing frequency and the frequency of sound energy in the range 750 Hz to 4000 Hz (second formant), and converting voicing frequency to rate of electrical stimulation, and the second formant to the place of stimulation or electrode site.^{*} The voicing frequency was extracted as it helps distinguish words; for example, "pack" and "back" look exactly the same on the lips and the main difference acoustically is that *p* is unvoiced and *b* is voiced. The voicing frequency also helps in understanding the general sense of what is said; for example, if the phrase "You are sick" is spoken with a rising voicing frequency it is understood as a question, whereas if it is spoken with a steady voicing frequency, it is understood as a statement of fact. In addition, the second formant is extracted as it is the most important acoustic cue in understanding the meaning of words, for example, "pack", "shack", "sack", "tack" and "hack" differ primarily with respect to the frequency of the second formant.

The speech processing strategy developed in treatment of the first patient was used with the second patient at his first test session three weeks after his operation. This patient was immediately able to recognize speech sounds, and could, after being made familiar with the subject material, understand passages read from the daily paper without any recourse to

lipreading. The fact that this patient had not heard any sounds for 13 years suggests that patients' memories for speech sounds can be preserved intact for long periods of time. Furthermore, as the speech processing strategy used is consistent with the way normal hearing subjects process speech, long periods of rehabilitation may not be required.

The computer based speech processor was evaluated on the two patients, using standard audiological tests to see objectively how effective it was in helping the patients to communicate. Open set phonetically balanced words and everyday sentence tests were administered, using multiple channel electrical stimulation alone, lip reading with vision alone, and electrical stimulation plus lipreading. The results showed that the computer-based speech processor produced very significant improvements in word scores, when used in conjunction with lipreading, and they were at levels which indicated that the patient could perceive everyday speech.⁶ Using electrical stimulation alone there were also significant word recognition scores; this correlated with the clinical observation that it was possible to have a conversation with the patient using electrical stimulation alone, providing the subject material was very familiar.

As a result of the successful tests on the first two patients a wearable unit was designed which had similar speech processing strategies to the computer-based device.⁷ The unit was assessed with our first patient through the use of standard audiological tests in a monitored soundfield. The results compared to lipreading alone again demonstrated the value of the multiple electrode implant in helping patients communicate, and showed that when used in conjunction with lipreading the implant enabled patients to perceive running speech and to engage in nearly normal conversations.

These results indicate that a multiple-channel cochlear implant and wearable speech processor can be of real value to patients who are postlingually deaf. Although single channel implants can also

G. M. Clark is Professor of Otolaryngology, and Y. C. Tong is a Research Fellow at the University of Melbourne.

Address for reprints: Professor G. M. Clark, Department of Otolaryngology, University of Melbourne, The Royal Victorian Eye and Ear Hospital, 32 Gisborne Street, East Melbourne, Vic. 3002.

* Readers who are unfamiliar with phonetic theory and terminology may wish to consult a work such as *Introducing Practical Phonetics* by I. R. A. MacKay (Little, Brown and Co., Boston, 1978) which was reviewed in the December 15, 1979, issue of this Journal (p. 666).

help, audiological tests have shown that a multiple-channel device is more effective in helping them understand speech.^{7, 8} Furthermore, our work demonstrates that patients with minimal hearing could also benefit from a cochlear implant. They would, however, need to have a phonetically balanced word score less than 10%. Our clinical experience has shown that before patients should be considered for an operation they need to have polytome X-ray examinations of the temporal bone to help determine whether bony obliteration of the cochlea has occurred, and electrical stimulation of the promontory to see if there are functioning residual nerve fibres. The number of residual hearing nerves required before cochlear implantation can be considered has not been definitely established.

A recent study of viable spiral ganglion cells in congenital and acquired profound

hearing loss has shown that more than one third of the ganglion cells were present in 90% of human temporal bones.⁹ This finding, together with the speech processing results, is encouraging, and indicates that a high proportion of patients with a profound or total hearing loss may benefit from a cochlear implant. More work is required to determine the value of the device for patients who are born deaf (prelingually deaf), and further research should be done before it is used for children.

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Author/s:

Clark, Graeme M.; Tong, Y. C.

Title:

Multiple-electrode cochlear implant for profound or total hearing loss: a review

Date:

1981

Citation:

Clark, G. M., & Tong, Y. C. (1981). Multiple-electrode cochlear implant for profound or total hearing loss: a review. Medical Journal of Australia, 1, 428-429.

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