INITIAL RESULTS FOR SIX PATIENTS WITH A MULTIPLE-CHANNEL COCHLEAR PROSTHESIS

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Introduction

A total of eight patients have been assessed with the multi-channel cochlear prosthesis at the University of Melbourne. The first two patients were implanted with a prototype device in 1978 and 1979, and their results with various speech evaluation procedures have been reported and summarized in detail elsewhere (Clark & Tong, 1982). Briefly, these results indicated that some very significant benefit could be obtained for these patients when using the cochlear prosthesis with external speech processing, particularly when using the device in conjunction with lipreading. It was also shown that some significant understanding of speech was possible without lipreading (open-set) for both patients, although this was fairly limited.

These encouraging results with the prototype prosthesis led to the development by Nucleus Limited of a more refined and sophisticated device using the same basic design principles. An external speech processor was also developed to give the patients a convenient portable device for everyday use of the prosthesis. This paper summarizes the speech evaluation and other results for six patients recently implanted (late 1982) with the Nucleus multiple-channel hearing prosthesis.

Method

Each patient underwent a six-month trial including training with a hearing aid or vibrotactile aid before surgery. Following this trial, patients were assessed with the aid using a modified version of the MAC battery (Owens *et al.*, 1981) of speech discrimination tests. These tests were carried out with recorded material of an unfamiliar speaker. Lipreading assessment was also carried out using videotaped material of an unfamiliar speaker with and without the aid to assess whether any significant benefit was being obtained from use of the aid. The tests used were CID everyday sentences, CNC monosyllabic words and SPIN test sentences. No significant improvement in lipreading performance was obtained on any test for any patient when using their aid in conjunction with lipreading over lipreading alone.

Following surgery and recovery, patients underwent a rehabilitation program of approximately ten weeks duration which included the psychophysical testing required for fitting the patient's speech processor, counselling in the use of the device, some auditory and auditory-visual training, and ongoing evaluation and testing. Speech tracking (DeFillipo & Scott, 1978) was used as a training and evaluation procedure during the program. Speech tracking requires the patient to repeat verbatim passages of text read by a tester. The tester uses a hierarchy of strategies to help the patient if the response is incorrect. Performance is measured in terms of words per minute repeated correctly and gives an indication of the patient's communication speed. This procedure was carried out under conditions of lipreading alone and lipreading with the cochlear prosthesis with the order of conditions alternated at each testing session to minimize intra-session practice effects. At the completion of the rehabilitation program, each patient was evaluated with their cochlear prosthesis using the MAC battery under the same conditions as the preoperative assessment with a hearing aid. The lipreading tests were also performed again (using different lists) with and without the cochlear prosthesis to assess the benefit obtained over lipreading alone when using the prosthesis.

Patients

Patient 1 was a 37-year old male who developed a severe to profound hearing loss after treatment with ototoxic drugs at the age of 4½ years. He gained some benefit from a hearing aid until the age of 21 years when he had a sudden total loss of hearing in the aided ear, leaving him with a total bilateral loss.

Patient 2 was a 62-year old female who had gradual progressive hearing loss associated with chronic otitis media in her teens. Her hearing deteriorated further during pregnancy until in her early thirties she was profoundly deaf in both ears. She has had no significant benefit from hearing aids since that time.

Patient 3 was a 22-year old female who had normal hearing until she developed acute bacterial meningitis when she was 18. This resulted in total bilateral hearing loss, severe tinnitus and temporary left-sided facial paralysis.

Patient 4 was a 23-year old female who as a child had multiple ear infections associated with chronic central perforations of the tympanic membrane in both ears. She had a number of operations on both ears including myringoplasties and tympanoplasties. By the age of 14 she had a total bilateral hearing loss.

Patient 5 was a 74-year old male who had a sudden loss of hearing at the age of 37 years, and became severely deaf. Since that time he lost hearing in steps, and became totally deaf nine years prior to surgery. Polytome x-rays showed resorption of bone over the apical and middle turns of the cochlea, and a narrow basal turn consistent with cochlear otosclerosis. At surgery, the round window niche was found replaced by bone, and the bone had to be drilled to a depth of approximately 3 mm before the scala tympani was entered. The electrode was then passed easily for a distance of 20 mm. At his first post-operative test session it was discovered that stimulating the more apical electrodes lying close to where the horizontal segment of the facial nerve crossed the apical and middle turns of the cochlea produced a facial twitch. The more basal electrodes away from this area produced sound sensations. The two most basal electrodes sited in the area drilled caused pain in the ear, presumably due to stimulation of the tympanic branch of the glossopharyngeal nerve. These unpleasant side effects have restricted the usable length of the electrode array from 16 mm to 5 mm for this patient.

Patient 6 was a 65-year old man who had a progressive loss of hearing in both ears due to acoustic trauma and recurrent otitis media. He had been profoundly deaf in the left and totally deaf in the right ear since 1966. In 1979 he had a multiple-channel cochlear implant operation in the left ear, but the receiver stimulator and not the electrodes had to be explanted in 1982 due to infection around the package. This occurred following the creation of a sinus by pressure from the arm of his glasses on a prominent edge of the receiver stimulator. In view of encouraging speech perception results with the prototype device, this patient requested the improved cochlear prosthesis. In view of the infection in the left ear, it was considered desirable to operate on the right ear. This presented some difficulties as electrical stimulation of the promontory was negative, and he had a large exostosis in the auditory canal partly obscuring a scarred drum and central perforation. An operation was undertaken, the exostosis removed, the cochlea stimulated with a ball electrode placed on the round window, and the perforation grafted. The patient made a good recovery and a cochlear implant was subsequently performed. At surgery there was a lot of scar tissue in the middle ear and some had penetrated into the apical and middle turns of the cochlea through an area of resorbed bone. The electrode array was inserted for a distance of 20 mm. Following surgery it was found that electrodes in the apical half of the electrode array displayed high thresholds for auditory sensation and were not discriminated by the patient, whereas electrodes in the basal half of the array were well discriminated. This patient was able to effectively use 10 of the 22 electrodes in the array.

Results of speech testing

Results of the MAC battery tests, both preoperatively with hearing aid or tactile device and postoperatively with the cochlear prosthesis, are presented in the Table. For the closed-set tests a chance score is also given to allow the mean scores to be placed in perspective. Statistical analysis using a simple t-test showed that the results for each test were significantly better for the cochlear prosthesis than for the hearing aid or tactile device at the 95% level of confidence, except for the male/female speaker discrimination test and the question/statement test. This indicates that this group of patients is performing significantly better on a wide range of auditory discrimination tasks, including open-set speech tests, than was possible without the cochlear prosthesis. It should also be noted that it was necessary to present the test materials typically at levels above 90 dBA for patients to respond at all when

using their hearing aids, but that normal conversational levels (70 dBA) were sufficient for the cochlear prosthesis.

Description of test	Chance Score	Hearing Aid*	Cochlear Prosthesis#
A. Suprasegmental tests			
1. One versus two syllables	50	77	96
2. Noise/voice test	50	69	96
3. Accented word test	25	47	80
4. Male/female test	50	68	83
5. Question/statement test	50	49	46
B. Closed-set tests			
1. Spondee same/different test	50	70	88
2. Four choice spondee test	25	37	78
3. Vowel test	25	33	51
4. Initial consonant test	25	25	43
5. Final consonant test	25	27	48
C. Open-set tests			
1. Spondee recognition	-	1	14
2. Monosyllabic words	-	0	5
3. Phoneme recognition	-	6	25
4. CID everyday sentences	-	0	9
5. Environmental sounds	-	13	27

*Presented at MCL for hearing aid: typically 90-95 dBA.

#Presented at MCL for cochlear prosthesis: typically 70-75 dBA.

On the basis of the MAC battery results and other evaluation, the patients can be graded in terms of performance. Two significant points are evident from such an analysis: first, that patient 5, who has only a limited multiple-channel system, obtains lower scores than the other patients on most of the tests although still showing significant improvement over his preoperative results and, second, that patient 4 performs better, particularly on open-set testing than the others. Monitored live voice testing using AB words (Boothroyd, 1968) demonstrated that all patients were capable of some open-set recognition of sound with scores, in terms of correctly repeated phonemes, as follows: patient 1 - 40%, patient 2 - 32%, patient 3 - 63%, patient 4 - 63%, patient 5 - 20%, patient 6 - 24%. Patient 4 is able to use the telephone routinely in a normal fashion without resorting to special coding strategies. Patients 1, 3 and 5 have also used the telephone successfully, but are restricted to limited context situations.

Postoperative lipreading assessment using sentence and word materials with and without the cochlear prosthesis showed consistently better scores for lipreading with the cochlear prosthesis than for lipreading alone for each patient, although the magnitude of the improvement varied amongst patients and from test to test. The mean improvement for the lipreading with cochlear prosthesis condition over lipreading alone for these patients was 20-25% for each of the tests. Four patients were able to score above 90% correct for CID everyday sentence material when using the cochlear prosthesis.

Speech tracking assessment

The speech tracking procedure (De Fillipo & Scott, 1978) was used during rehabilitation as a training technique and to attempt to give some idea of the effect of the cochlear prosthesis on the patient's communication speed. Intrasession practice effects were controlled by alternating the order of conditions (lipreading alone and lipreading with prosthesis) at successive test sessions. The mean results of eight test sessions (6 for patient 5) showed improvements of between 55% and 126% when using the prosthesis for these six patients.

Patient usage

The wearable speech processor is used all day every day by five of the patients and four hours a day by the sixth patient. Patients report the prosthesis as being useful for communication in one-to-one and group situations, for recognition and discrimination of environmental sounds, for watching television, and (for four patients) for using the telephone. Although all of the patients display some ability for open-set recognition of speech at the phoneme level, only one patient (patient 4) is able to perform well enough to have a fairly normal conversation without lipreading. Patients have not reported any uncomfortably loud sounds from the prosthesis, although some sounds have been reported as unpleasant, particularly continuous high frequency noise. Loud sounds are not encountered as each speech processor is programmed individually for a particular patient and restricts all stimulation on any electrode to below the patient's "comfortable" level for that electrode. Patients find that listening to music does not give very successful results although they are able to discriminate it from other sounds and can generally pick up the rhythm of the music.

Environmental sounds

Environmental sounds have been a continued source of enthusiasm for the multiple-channel cochlear prosthesis patients as they are able to learn to recognize a wide variety of sounds around them without problem. This is probably because most environmental sounds are peculiar to a certain situation or context (e.g., at an airport one is likely to interpret a loud roar as an airplane engine rather than a waterfall which sounds similar). Patients are always anxious to relate stories about new sounds that they discover. The important thing about this multiple-channel system is that the patients are able to perceive quite a large range of sounds because of the pitch information available by stimulating different electrode positions. Some of the sounds reported by the patients as being recognized consistently are: telephone ring, dial tone and engaged signal; cars passing, turn indicator, car horns while driving; kettle whistles; door bells, bird calls and many others. Four patients are able to recognize their name when called from another room or from behind.

Tinnitus

The patients who had tinnitus preoperatively have found that their tinnitus is reduced on the implanted side when using the speech processor. The tinnitus has not disappeared in any case and tends to return to the preoperative level when stimulation is stopped. In no case has tinnitus been increased or initiated (for patients with no preoperative tinnitus) by the electrical stimulation.

Speech production

No formal studies have been carried out regarding speech production as yet, but reports from family and friends of the patients indicate that control of voice level has greatly improved. Other changes have been noted in terms of naturalness and clarity, and one patient has been able to learn how to say a number of new words (this patient went deaf at 4½ years and thus has some limitations in vocabulary). All patients' speech was recorded on audio tape preoperatively, and a formal study of their speech production changes is to be undertaken.

Problems with the multiple-channel cochlear prosthesis

All six patients implanted in 1982 made good recoveries from surgery and have had no medical complications or problems since then. Once patients had been fitted with their speech processors, two problems became evident with the system as it was. The positioning of the external coil unit was not firm enough for continued operation of the device during physical activity and the understanding of speech was severely affected by quite moderate levels of background noise. This second problem is not a new one to anyone who has been involved with hearing aids, and not unexpected. It has been overcome to a certain extent by the development of a special miniature directional microphone mounted on the headset which holds the external coil. The positioning problem has been solved by the development of a headset and coil unit which holds the coil firmly enough to retain positioning during physical activity, but is light enough and unobtrusive enough to be aesthetically acceptable and comfortable for all day use. Only one patient (patient 5) has had non-auditory sensations elicited by electrical stimulation, and this is easily controlled by not using the electrodes concerned in this patient's speech processor. However, this leaves him with a limited multiple-channel system compared with the other patients and he shows poorer speech discrimination.

Conclusion

Results of the pre and postoperative testing using the MAC battery tests showed significant improvement for all six patients on closed set and open set tests when using the cochlear prosthesis as compared to conventional hearing aids. Results varied from patient to patient with factors such as age, length of deafness and aetiology contributing to overall performance. Lipreading assessment showed improved results for all patients when using the cochlear prosthesis over lipreading alone for word and sentence material. Speech tracking also showed improvement over lipreading alone in a communication situation. All patients are daily users of the device and report help with communication and environmental sounds. No adverse side effects have been reported from use of the cochlear prosthesis at this stage.

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