Rehabilitation for Multiple-Channel Cochlear Prosthesis Patients

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Abstract

The postoperative program for multiple-channel cochlear prosthesis patients can be divided into four main areas: 1) Psychophysical evaluation is carried out to optimize the patient's speech processor for their individual needs. Measurements required include threshold, dynamic range and pitch ranking for each of the implanted electrodes. 2) Counselling is very important to ensure patients are able to effectively operate their speech processor and that they are aware of factors in the environment which may affect performance (e.g., noise). 3) Auditory training and training in conjunction with lipreading for tasks grading from simple (e.g., discrimination of word length) to more difficult (e.g., consonant discrimination) is of benefit in making patients aware of their capabilities with the prosthesis and helping them to improve communication skills. However, highly specific training (e.g., closed set vocabulary) does not seem to be of general benefit to patients. Speech tracking provides a training procedure relevant to normal communication but has some limitations due to the degree of familiarity reached with a particular speaker. 4) Assessment of patients is carried out at this stage in great detail as it is necessary to collect data about the effectiveness of cochlear implants and also to provide information about possible improvements to speech processing strategies and external hardware. The amount of assessment required will decline as the procedure becomes established, but some investigation will continue to be necessary.

The postoperative rehabilitation program for multiple-channel cochlear prosthesis patients is divided into four areas:

1) psychophysical evaluation
2) counselling
3) auditory and combined auditory-visual training
4) postoperative assessment and evaluation of the prosthesis

This paper discusses the first three areas; postoperative assessment is dealt with in another paper.

Psychophysical Evaluation

Psychophysical tests are necessary in order to produce a speech processor suitable for individual patients. Each patient receives the same basic speech processing strategy of fundamental frequency information coded on to pulse rate and second formant information coded
on to electrode position. However, it is necessary to measure the current level at which threshold and comfortable loudness sensations are elicited for each electrode for each patient. Patients make a first estimate of comfortable loudness but may later refine their judgments after more exposure to electrical stimulation. An electrode ranking is then obtained where electrodes are ordered from "sharpest" to "dullest".

Information about loudness levels and pitch ranking is then programmed into the speech processor (i.e., an E-PROM erasable programmable read only memory). Thus, each speech processor is optimized for the patient's individual needs. It is not possible for a patient to wear another patient's speech processor.

Some manipulation of the dynamic range programmed in the map is possible in order to eliminate some background noise if the patient finds this particularly annoying. Each speech processor has an automatic gain control (AGC) and external controls for sensitivity for use with different microphones or different acoustic environments, and a noise squelch to suppress background noise.

Counselling

The optimization of the speech processor map and controls during the psychophysical evaluation requires the patient to be guided and counselled by the audiologist. It is a two-way process since the information the patient gives to the audiologist about his percepts may give valuable clues about how to adjust the speech processor in order to produce a better and more acceptable sound.

Counselling is a very important feature of the postoperative rehabilitation process for three main reasons. Firstly, most patients have been totally or profoundly deaf for a great many years, with little or nothing to overcome their handicap other than traditional hearing aids. Patients invest a great many hopes and aspirations in the cochlear prosthesis program. There is usually great excitement at the first testing session as the patients are overjoyed and relieved that the device is functioning and they can hear sounds. Later, some patients may experience disappointment as they realise the limitations of the prosthesis. Secondly, with the present speech processing strategy, it is not expected that speech will be fully intelligible without the help of lipreading. Finally, patients may need to adjust to the sound sensations produced as the auditory nerve is stimulated in a new way.

It is the aim of counselling and rehabilitation to allow the patients to realise the capabilities and limitations of the prosthesis. This is done via practical demonstrations: exercises where patients listen to environmental sounds, listen to music, listen to the television, and learn how to use the telephone. Free field audiometry with the speech processor enables the audiologist to explain the effect that background noise, microphones, and distance from the speaker may have on the speech processor, and therefore on the patient's ability to hear speech distinctly.

Auditory and Auditory-Visual Training

A basic course of ten rehabilitation sessions was planned, each session consisted of three elements:

1) Speech training:
   a) speech tracking; b) vowel identification; c) consonant identification.
2) Auditory training exercise or demonstration.
3) Counselling.

It is felt that auditory training and auditory-visual training provides the patient with the best chance of gaining maximum information from the speech processing strategy and adjusting to the sound sensations produced by the cochlear implant. It is also necessary to provide training in a positive and rewarding atmosphere; repeated experience of failure or emphasis on the patient's or speech processor's limitations is felt to be contrary to the aims of rehabilitation.

Auditory training exercises were graded, beginning with simple tasks where the patient would have success, and proceeding to more difficult ones where the patient would have to rely more on his/her synthetic abilities in order to complete the missing information. Exercises progressed from closed set sentences which provided a lot of segmental and suprasegmental information, to closed set words which provided less suprasegmental information towards more open set materials where the patient would be given a clue. These exercises followed the rationale of Jeffers and Barley (2) for training speechreading.

Speech tracking (1) was felt to be a useful means of monitoring the patient's progress using the prosthesis with lipreading. It also has the advantage of providing long-term training with a communication strategy that simulates everyday conversation for the hearing impaired person. Figures 1-6 show the word per minute scores for each of the six patients under two conditions: 1) lipreading with speech processor and 2) lipreading alone. Patients were given ten-minute sessions in each condition. Conditions were alternated from session to session so the patient did not always begin with the same condition. Patient 5 found speech tracking excessively difficult despite some training in how to cope with the communication strategies when words were missed or mistaken. Three patients (patients 1, 3 and 4) show clear improvements of lipreading with the speech processor as compared with lipreading alone. Patients 2 and 6 had less dramatic but nonetheless consistent differences between conditions.

![Graph showing speech tracking scores in words per minute for multiple-channel cochlear prosthesis patient over eight test sessions.](image)

**Figure 1:** Speech tracking scores in words per minute for multiple-channel cochlear prosthesis patient over eight test sessions. Each session consisted of ten minutes of lipreading alone (LA) and ten minutes of lipreading with the cochlear prosthesis (L+CP). The order of conditions was alternated at successive sessions to control intrasession practice effects. Also shown are the mean scores for the two conditions over the eight sessions.
Figure 2: Speech tracking scores for patient 2.

Figure 3: Speech tracking scores for patient 3.

Figure 4: Speech tracking scores for patient 4.
When looking for an explanation of differences between patients, several possible factors come to mind. Three different speakers were used but, by coincidence, each speaker had one patient who performed well and one who performed not so well. The three patients who showed greatest improvement were also the three youngest patients (all being less than 38 years), while the other three were all over 62 years. Also, the number of speech channels available in the speech processor, which indirectly reflects the psychophysical and physical state of the cochlea, was considerably reduced for patient 5 and somewhat reduced for patient 6. This has undoubtedly had an influence on these and other speech results.

Speech tracking is an inaccurate measure of performance since it can be influenced by so many variables; speaker, text, patient's motivation, and large session to session fluctuations are not uncommon. Also, six patients are not a large enough or diverse enough sample of subjects to relate factors of age, aetiology, speech processing channels, to performance in rehabilitation.
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