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SPEECH RECOGNITION PERFORMANCE OVER TIME WITH THE CLARION COCHLEAR PROSTHESIS

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INTRODUCTION

The amount and nature of aural rehabilitation that should be offered to adult, postlingually deaf recipients of cochlear prostheses remains uncertain. With the devices that have been available for the past decade, recovery of clinically useful levels of speech perception usually occurred gradually over several years, if it happened at all.[1,2] Systematic training has been applied only sporadically, and attempts to demonstrate its usefulness have been unsuccessful.[3] In principle, however, a well-fitted cochlear prosthesis should produce temporospatial patterns of auditory nerve activity that immediately produce perceptions of sounds that are recognizable from previous acoustic experience. The Clarion cochlear prosthesis provides both the Multi-Strategy speech processor[4] and the University of California–San Francisco radial bipolar electrode,[5] a combination that provides unique capabilities to fit the stimulation strategy to the auditory nervous system of each individual patient. Thirty-two of the first 46 patients (70%) fitted with the Clarion obtained moderate to excellent open-set speech recognition scores (30% to 100% on Central Institute for the Deaf sentence test) at 12 months. Nineteen of these successful patients (59%) had already achieved at least 80% of their 12-month performance level at the first postoperative test interval (3 months), minimizing their need for aural rehabilitation.

STUDY DESIGN

We analyzed the preoperative and 3-, 6-, and 12-month scores of all of the first 46 patients fitted with the Clarion under the auspices of the investigational device study approved by the US Food and Drug Administration. Speech perception tests included the open-set CID Sentences (100% maximum, 0% chance) and the open-set Northwestern University-6 (NU-6) monosyllabic words (100% maximum, 0% chance). The patients ranged in age from 20 to 81 (mean, 53) and had been profoundly deaf from various causes for 2% to 69% of their lives. At their initial and subsequent fittings, the patients were tested with a range of compressed analog (CA) and continuous interleaved sampled pulse (CIS) strategies[6] and sent home with the strategy that produced the best speech recognition; 85% were using the monopolar CIS strategy at the 12-month test interval reported here. Patients were grouped into three performance categories on the basis of their 12-month CID test scores (see Fig 1 and Kessler et al, this suppl, section 14): poor (0% to 30%), moderate (31% to 70%), and excellent (71% to 100%).

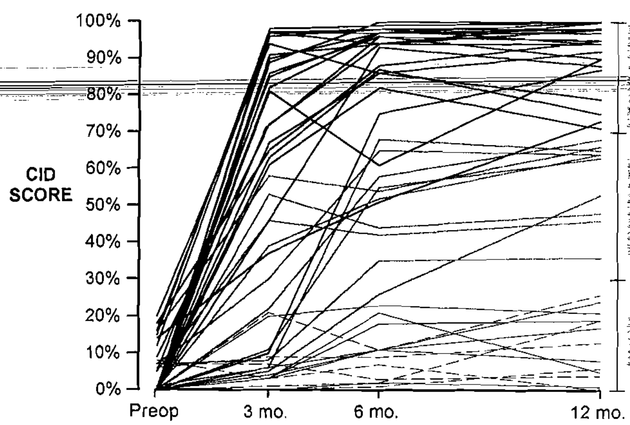

Fig 1. CID scores preoperatively (0 months) and 3, 6, and 12 months postoperatively for first 46 patients in Clarion clinical trial. Heaviest lines denote patients with excellent 12-month CID results (71% to 100%); gray lines denote moderate results (31% to 70%); fine lines denote poor results (0% to 30%); dashed lines indicate subjects with preoperative and immediate postoperative indicators of poor performance (see text).

RESULTS

Over half of the subjects had already achieved moderate (N = 10; 22%) or excellent (N = 16; 35%) CID results at the 3-month test period, leaving relatively little room for subsequent improvement on this test. A persistent minority (N = 14; 30%) never achieved better than poor results in the 12-month period of this study; possible causative factors for their results are discussed elsewhere (Kessler et al, this suppl, section 14). Only a few subjects had initially poor results that improved gradually over the following 3 to 9 months (N = 6; 13%).

In Figs 1 and 2, the "learning curves" for all of the patients on CID Sentences and NU-6 tests are shown, with patients

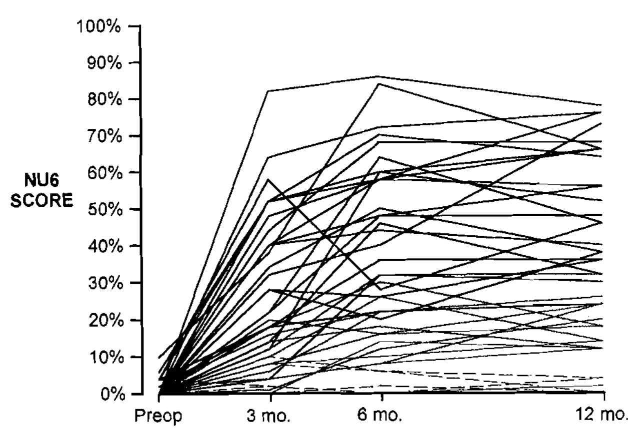

Fig 2. Successive NU-6 scores for 46 patients, with line types based on 12-month CID result categories as explained in Fig 1.

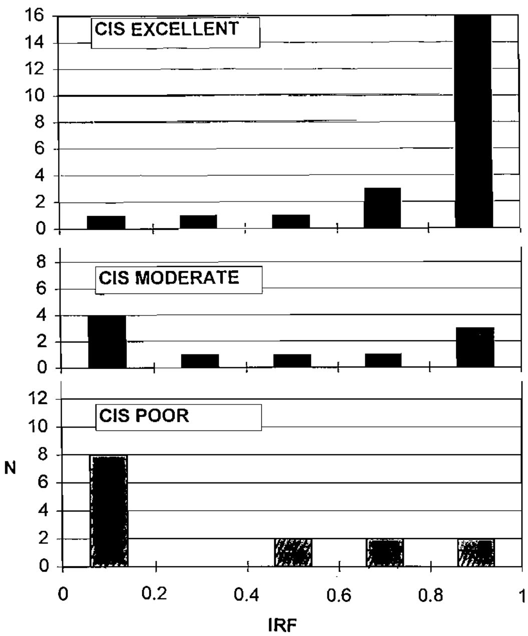

Fig 3. Histograms of improvement rate factor (IRF) based on comparing 3-month to 12-month results, grouped according to 12-month CID performance categories. Cross-hatching denotes subjects with various preoperative and postoperative predictors of poor prosthesis performance (Kessler et al, this suppl, section 14).

grouped by line weight according to their 12-month CID performance categories (see above). The dashed lines denote patients with prognostic indicators associated with poor outcome that could be determined before, during, or immediately after implantation, including etiologic factors such as duration of deafness as percentage of life span and biophysical indicators of poor neuronal survival (Kessler et al, this suppl, section 14). The CID curves (Fig 1) suggested that objective criteria might be used to distinguish discrete patterns of learning in Clarion users. These learning patterns could, perhaps, be recognized early in the course of postoperative treatment in order to identify those patients who would or would not be likely to benefit from intensive training.

In order to categorize these learning curves objectively, we developed an improvement rate factor (IRF) based on the ratio of the improvement of CID score at 3 months versus preoperatively to that eventually achieved at 12 months:

$$IRF = \frac{CID(3\ mo) - CID(preop)}{CID(12\ mo) - CID(preop)}$$

The distributions of IRFs are shown separately in Fig 3 for patients who ultimately achieved poor, moderate, and excellent CID results. The majority of patients with either excellent or poor results achieved most of their ultimate performance almost immediately after fitting. A small group of patients with moderate to excellent results improved substantially from initially poor results. Of interest, this group was composed exclusively of patients with no prognostic indicators for poor results.

DISCUSSION

The high IRF (80% to 100% in 19 of the 32 patients obtaining moderate to excellent CID results) suggests that the Clarion provides speech percepts that are recognized and interpreted correctly in most of those patients who have reasonably intact auditory pathways. This agrees with subjective impressions that most patients already had substantial open-set speech recognition at their initial fitting, although the first objective measures were not obtained until 3 months. For the more demanding NU-6 test (Fig 2), improvement was more gradual, suggesting that systematic aural exercises might enhance learning. Even for this more difficult test, however, most of the improvement occurred in the first 6 months, with scores leveling off in the latter 6 months, particularly for the better performers. Of the patients with relatively poor CID results at 3 months, a subgroup of patients with poor prognostic factors was readily identified. These patients never achieved substantial NU-6 scores during the 12-month period of this study, although some seemed to be improving very gradually in their CID scores. Longer follow-up is needed for this group. The remaining poor performers at 3 months included an apparently indistinguishable admixture of patients who did not improve substantially, along with those who learned over time to make moderate and occasionally even excellent use of their prosthesis. This would seem to be the most appropriate group to receive intensive aural rehabilitation. It remains to be seen whether improvements in rehabilitative procedures and/or more appropriate speech processor strategies can accelerate the rate at which these patients derive functional benefit from their cochlear prostheses.

In postlingually deaf adult subjects, the IRF presumably relates to the ability of the cochlear prosthesis to reproduce key features of the temporospatial pattern of auditory nerve activity that the subject learned to interpret before becoming deaf. If these patterns are unfamiliar, then the subject must learn what amounts to a new language. Together with the bimodal distribution of speech perceptual results reported elsewhere for the Clarion (Kessler et al, this suppl, section 14), the high IRF suggests that the limiting factor in speech performance in many of these patients is the condition of their peripheral auditory nervous systems,[7] rather than their ability to apply high-level cognition to overcome technological limitations of the device.

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