Invited Convention Presentations

Editor's Note:
One of the highlights of the first annual convention of the American Academy of Audiology, held at Kiawah Island Resort, April 21-24, 1989, was a special session on cochlear implants in children. The session was chaired by Anne Marie Tharpe and included formal presentations by Mary Joe Osberger, Karen Berliner, and Steven Staller.

Collectively the following three papers represent a timely summary of performance data on deaf children, and the important clinical and research issues involved in this important work.

Perceptual and Production Abilities in Profoundly Deaf Children With Multichannel Cochlear Implants

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Abstract

A total of 218 children have been implanted to date with the Nucleus multichannel cochlear implant. All children have stimulated and there have been only 6 complications that required subsequent surgical intervention. After 12 months of experience with the device, significant improvements in auditory-alone speech perception were demonstrated by 66 percent of subjects tested on prosodic and closed-set measures and by 46 percent of subjects tested for open-set word recognition.

Key Words: Multichannel cochlear implant, deafness, child, perception, speech, supra-segmental, spectral, age-appropriate tests

Following successful completion of clinical trials demonstrating the safety and effectiveness of the Nucleus 22-channel cochlear implant in postlinguistically deafened adults (Dowell et al, 1986), investigation into the application of this device in profoundly deaf children was initiated in December 1985. Since that time, 87 adolescents (10 through 17 years old) and 131 young children (2 through 9 years old) have been implanted with the Nucleus device (Mecklenburg, 1987; Staller et al, 1988; Staller et al, 1989; Thornton and Raffin, 1978).

METHOD

Subjects were required to demonstrate bilateral profound deafness with no significant benefit from conventional amplification or vibrotactile devices. Although the children's educational settings were diverse, they had to include an oral component. Older subjects were required to demonstrate spontaneous differentiated speech during communication. Appropriate expectations on the part of subjects and their families were important as was the absence of any medical contraindications.

A single-subject repeated measures research design was used, with each child serving as his own control. An extensive evaluation battery was performed both preoperatively with hearing aids or vibrotactile devices and at 6-month intervals postoperatively with the Nucleus implant. Due to the diversity among the subjects, a hierarchy of test procedures was developed from which clinicians chose instruments that were considered to be the most appropriate for each child. Areas of assessment included sound detection, speech perception, speech production, lipreading enhancement, environmental sound identification, and language competence.

A normalized binomial model (Thornton and Raffin, 1978) was used to test whether a postoperative score was significantly different from a preoperative score on each measure for each subject. To summarize the data across subjects, tests were aggregated into the assessment areas described above. Improvement by a sub-

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ject within a given assessment area required statistically significant change ($p < 0.05$) on at least one-third of the tests administered. Although arbitrary, this "one-third rule" requires substantially more evidence of improvement than could be expected by chance (5 percent). However, it is not so high as to jeopardize the power of the analysis or to result in an unacceptably high false negative rate (Type II error rate).

An 8-week preoperative training period was conducted for children younger than 10 years of age to ensure that they were appropriately fitted with sensory aids and to teach the concepts necessary for programming the multichannel implant. In addition, the preoperative training period allowed assessment of the effects of training independent of the implant.

RESULTS

As of February 23, 1989, 218 children had been implanted at 43 investigational centers worldwide. All subjects with appropriately placed electrode arrays detected sound at normal conversational intensities, and only 4 children were considered to be minimal users or nonusers, wearing their devices less than 3 hours per day. The majority of subjects were deafened at an early age (mean age at onset of deafness: 2.3 years). The most common etiology of deafness was meningitis, which occurred in 50 percent of the subjects. In 38 percent of the subjects, the etiology was unknown.

Few surgical or postoperative complications have occurred. For the 200 subjects with at least 2 months of experience with the implant, only 6 complications required surgical intervention, and all of these have resolved. The remaining complications resolved spontaneously or through medical therapy, reprogramming of the speech processor, or replacement of external equipment.

Data are reported on 66 English-speaking subjects after 12 months of experience with the implant. Two additional subjects received bilateral implants (a single-channel in one ear and a 22-channel in the other) and are reported separately. No children have been lost to follow-up. Figure 1 represents the proportion of subjects who demonstrated significant postoperative improvement within each assessment area. Because of the diversity of test measures included in the clinical protocol, most subjects were tested in all assessment areas. The smallest numbers of subjects are represented in the open-set speech recognition category (n = 46) and in the speech production category (n = 50). Open-set measures were inappropriate for some of the younger subjects because of the language and cognitive requirements inherent in these tasks. In addition, speech production measures were not administered to some of the older subjects because of age-appropriate speech and language skills.

Over half of the subjects tested improved in each of the assessment areas except open-set word recognition, the most difficult perceptual category evaluated. Sixty-six percent (42/64) of the subjects tested improved in their perception of suprasegmental speech features, which requires accurate identification of time/intensity envelope information. Sixty-six percent (40/61) of the subjects tested also improved postoperatively on closed-set word identification tasks. Those tasks are typically more difficult for hearing-impaired subjects because they require the perception of spectral cues. Open-set word recognition was achieved by 21 subjects, which represents 32 percent of the entire sample and 46 percent of the subjects who were tested in this category. The open-set category assessed auditory-alone performance on recorded measures ranging from simple sentences (Glendonald Auditory Screening Procedure: GASP) to more difficult spondaic (MAC: Spondee Recognition) and monosyllabic (Phonetically Balanced Kindergarten: PBK/Northwestern University: NU #6) words. Recognition of at least two words on each measure was required to demonstrate statistical significance on open-set measures.

Data were also analyzed as a function of age of the subject (see Fig. 1). The children were equally distributed (33/66) into one of two age

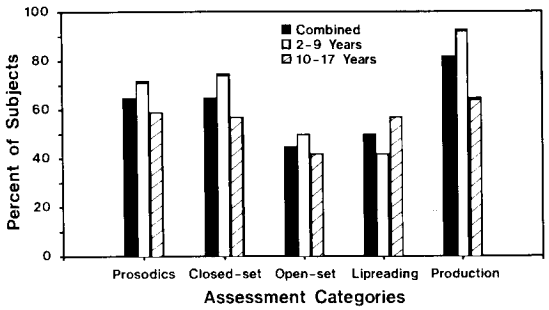

Figure 1 Percent of subjects tested demonstrating significant postoperative improvement for (1) the entire investigational sample (n = 66), (2) subjects under 10 years of age (n = 33), and (3) subjects between 10 and 17 years of age (n = 33).

groups, those less than 10 years and those 10 years and older. A greater proportion of the younger subjects improved in all assessment areas except lipreading enhancement.

DISCUSSION

Inferring clinical improvement from statistical significance is difficult when trying to determine the overall benefit to communication abilities from such a diverse battery of diagnostic measures. The impact of improved auditory perceptual abilities on speech production is of particular interest when considering the potential long-term benefits of cochlear implants in children. Geers and Moog (1989) attempted to address this issue by describing a series of perceptual categories that correlate with the potential of profoundly deaf children to develop spoken language. They developed four categories ranging from the inability to perceive suprasegmental patterns (Category 1) to consistent word identification (Category 4). A fifth category has been described that includes children with open-set word recognition (Category 5). According to Geers and Moog, children who exhibit word identification abilities (Categories 3–5) have greater potential to develop useful spoken language skills than do children who are limited to pattern perception skills (Categories 1 and 2).

Performance on several measures in the clinical protocol could be used to assign a perceptual category to 50 of the subjects. Figure 2 shows the distribution of subjects by perceptual category both preoperatively with hearing or vibrotactile aids and postoperatively with the Nucleus implant. The proportion of subjects with a good prognosis for the development of spoken language (Categories 3–5) increased from 23 percent preoperatively to 73 percent postoperatively. None of the subjects were consistently able to identify closed-set words or recognize open-set words preoperatively (Categories 4 and 5). In contrast, 54 percent of the subjects achieved Category 4 or 5 postoperatively with the implant.

SUMMARY

After 12 months' experience with the multichannel cochlear implant, children demonstrated improved performance in all perceptual and production assessment areas. With training, even the youngest children were conditioned to allow programming of the device within a few days or weeks of initial stimulation. Only four children do not wear their devices daily. The children continue to show improvement in sound detection, speech perception without lipreading, and in lipreading enhancement with the addition of sound from the implant. In addition, the quality and quantity of spoken utterances have improved with training and experience, particularly in the younger children.

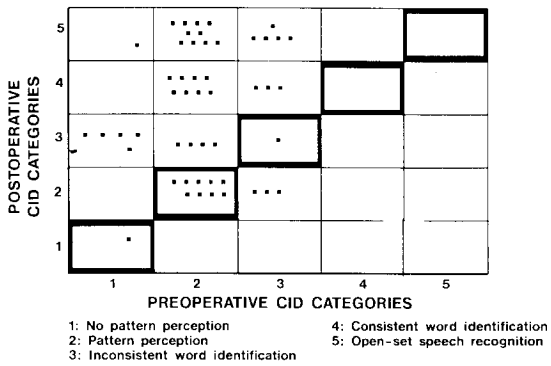

Figure 2 Preoperative and postoperative distribution of subjects (n = 50) by CID perceptual categories.

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