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Factors affecting outcomes in children with cochlear implants

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SUMMARY

Open-set speech perception tests were completed for a group of 52 children and adolescents who were long-term users of the Nucleus multiple channel cochlear prosthesis. Results showed mean scores for the group of 32.4% for open-set BKB sentences and 48.1% for phonemes in open-set monosyllabic words. Over 80% of the group performed significantly on these tasks. Age at implantation was identified as a significant factor affecting speech perception performance with improved scores for children implanted early. This factor was evident in the results at least down to the age of three years. Duration of profound hearing loss, progressive hearing loss, educational program and preoperative residual hearing were also identified as significant factors that may affect speech perception performance

INTRODUCTION

Multiple channel cochlear prostheses were first implanted in children in Melbourne in 1985 (Clark, 1995). Since that time, over 7000 Nucleus multiple channel cochlear prostheses have been implanted in children throughout the world. In more recent years, a larger proportion of young children have been implanted at most centres. This trend is due, in part, to the belief that younger children will have the best chance of developing speech perception and speech production skills through use of the cochlear implant. There are many arguments supporting this assumption including our knowledge of language development, physiological studies of the effects of sensory deprivation on animals, and the effect of age of hearing aid fitting on outcomes for hearing impaired children. It is certainly of interest, however, to establish whether the outcomes for children with cochlear prostheses are indeed enhanced by younger implantation. It would also be useful to know exactly how age of implantation and other factors affect the development of speech perception, speech production and auditory language. At the

University of Melbourne, a program of regular assessment of speech perception skills in implanted children over the long term has provided a large data set which can be used to help answer these questions.

This paper will focus on open-set speech perception results for implanted children. Many tests of speech perception have been used and developed for assessing children with cochlear implants, however, it is open-set tests of word and sentence recognition that probably provide the best measure of the effectiveness of the device in real-life situations. Open-set word and sentence tests are the typical speech perception assessments used in clinical audiology. Therefore the results of such assessments can readily be compared with data for other hearing-impaired populations. These tests also provide a measure of how much speech can be identified by a subject without additional cues such as context or lists of alternatives. Closed-set speech perception tasks provide important information about specific discrimination abilities and are invaluable for research studies. They are also useful for assessing children who score poorly on open-set tasks. However, scores on these assessments can sometimes be misleading and difficult to relate to communication benefit.

Open-set speech perception results for 52 children who were experienced users of the Nucleus cochlear prosthesis will be presented and analyzed. A number of possible predictive factors, including age at implantation, will be examined with reference to the speech perception results, and the implications for the future of cochlear implantation in children discussed.

MATERIALS AND METHODS

Subjects

The subjects in this study were 49 children and adolescents who received a Nucleus multiple channel cochlear prosthesis in Melbourne between 1985 and 1994 and 3 children who received their implant elsewhere but are now resident in Melbourne. The subjects were not selected in any way except that they needed the necessary cognitive and language skills to complete open-set word and sentence testing. In most cases, this meant that the children were over six years of age. This group of 52 children represented 75% of the implanted children and adolescents in Melbourne at 1st January, 1995. The mean age at the time of implantation for the group was 7.7 years with a range from 1.9 to 19.9 years. Thirty-four of the children (66%) had a congenital profound hearing loss. Twelve children had a profound hearing loss due to meningitis with onset of the hearing loss before the age of three years. Six children had progressive hearing losses with onset of profound hearing loss after the age of three years. All children had over twelve months experience with use of the cochlear prosthesis when assessed, with a mean of 3.7 years experience for the group. Most of the children were assessed using the MSP-MULTIPEAK speech processor during 1994 and 1995, but eight of the results were obtained using the SPECTRA-SPEAK processor. Results from Cowan et al (1995) showed that a group of twelve children showed significant improvement in speech perception when changed to the SPECTRA processor from the MSP. These improvements varied across the subjects with a mean improvement of 8.1% from 54.5% to 62.6% for the group on a combined open-set score. Thus, the different processors used in the current study may have some effect on scores, although the results mainly reflect performance using the MSP processor. As such, it is reasonable to assume that further improvements may occur when all children have changed to the SPECTRA system.

Test Technique

The BKB sentence test (Bench and Bamford, 1979) and PBK word test (Haskins, 1949) were presented, using live voice in most cases, by an audiologist or speech pathologist working with the child. For older children, tape-recorded presentation was used. Material was presented only once and strict precautions were taken to prevent any visual cues being available to the child. For older children, written responses were made for each item and scored after the session. For the majority of children, verbal responses were videotaped and scored by two independent listeners at a later time. These scores were averaged to give the final score for the test. If the independent scores differed by more than 5%, a third scorer was enlisted to view the videotape. Scoring difficulties resulted mostly from ambiguities arising from speech production errors.

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RESULTS

Open-set sentence assessments

Figure 1 shows results for 50 of the 52 children for the open-set BKB sentence test using audition alone. Two of the young children in the group failed to complete the task successfully. The mean score for this group was 32.4% with a range from 0% to 94%. Eighty-six percent of the group performed significantly on this task. Half of the group exceeded a score of 25% and 13 children (26%) scored above 50%.

These results were analysed using multiple linear regression including the following predictive variables: age at implantation; congenital, meningitis or progressive hearing loss; duration of profound hearing loss; experience with implant use; and postoperative educational program. These variables were used based on the results of previous studies by Dowell et al (1995). One of the problems with this type of analysis is that some of the predictive variables are interrelated. In particular, as most of the children in the study were congenitally deaf, their age and duration of hearing loss were the same. For this reason, age and duration of profound hearing loss were included in separate analyses with the other variables.

This analysis showed that shorter duration of profound hearing loss ($p<0.001$), an oral/aural educational setting ($p<0.01$), progressive hearing loss ($p<0.01$) and significant preoperative residual hearing ($p<0.05$) were associated with better scores for the BKB

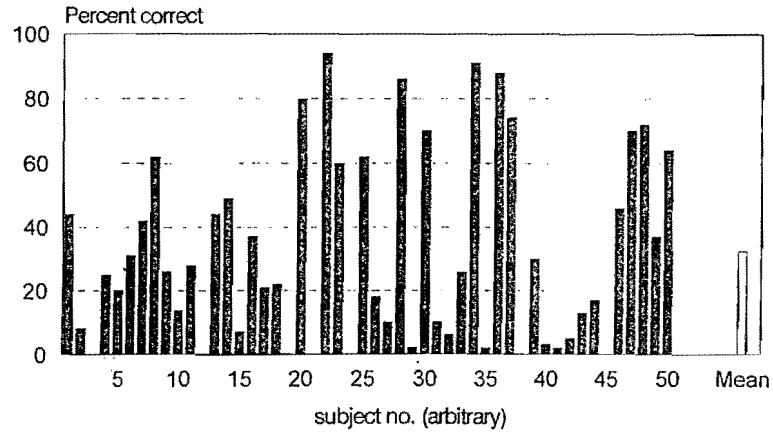

Figure 1

Individual results for 50 children and adolescents implanted with the Nucleus multiple channel cochlear prosthesis on the BKB open-set sentence test using audition alone.

open-set sentence test. Younger age at implantation was also associated with better scores, although the duration of hearing loss was more effective in explaining the results for acquired deafness. There was no significant difference in results for the meningitis group compared with the congenital profound deafness group. Experience with the prosthesis did not show a significant effect although it should be pointed out that all children in the group had over 12 months implant use and most had considerably more. The four significant factors accounted for approximately 50% of the variance in the sentence scores.

Open-set word assessments

Figure 2 shows results for the 52 children on the open-set PBK word test using audition alone. The scores are given in terms of percentage of phonemes correctly identified. This treatment provides more information about the children's speech perception than a whole word score. Word scores would typically be significantly lower than the phoneme scores for a particular test and when scored by phonemes this test has a chance score of approximately 5%. The mean score for this group was 41.8% with a range from 5% to 93%. Ninety-four percent of the group performed significantly on this task. Half of the group exceeded a score of 40% and 18 children (34%) scored above 50%.

These results were submitted to a similar multiple linear regression analysis to the sentence scores as detailed above. This analysis showed that shorter duration of profound hearing loss ($p<0.001$) and an oral/aural educational setting ($p<0.01$) were associated with better phoneme scores for the PBK open-set word test. Younger age at implantation was also associated with better scores, although the duration of hearing loss was again more effective in explaining the results for acquired deafness. No significant effect was evident for preoperative residual hearing, in contrast to the results for sentences, but the progressive hearing loss group performed significantly better ($p<0.01$) than the rest of the group. There was no significant effect for the meningitis group or for the implant experience variable as was found for the sentence score analysis.

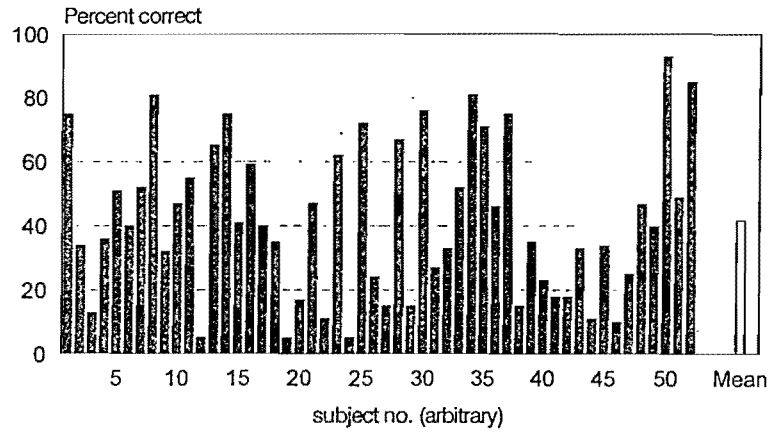

Figure 2

Individual results for 52 children using the Nucleus multiple channel cochlear prosthesis on the PBK open-set word test using audition alone. Scores are percentage of phonemes correct.

DISCUSSION

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These results for a group of children using the Nucleus multiple-channel cochlear prosthesis show that open-set speech perception is not only possible for implanted children with profound deafness but should be considered the norm. Postlingually deaf adults have shown good open-set results for some time. These adults learn to fit a novel or unusual auditory input to their internal model of auditory perception and language. This can be somewhat difficult but is facilitated by the wealth of stored experience and processing abilities built up prior to the onset of profound hearing loss. It is particularly significant to see children with little or no auditory experience prior to implantation learning to understand speech using the implant alone. Many of these children have had to develop their auditory processing and auditory language abilities exclusively through use of the implant and the fact that this can be achieved represents an important step in the clinical application of cochlear prostheses.

The results also show that not all children achieve good open-set speech perception. The mean scores for sentence perception (32.4%) and phonemes in words (41.8%) are moderate and the range of performance is large. The regression analyses described above provide some clues to the reasons for this variation. The strong effect of duration of deafness and age on results is not surprising. This appears to reflect both the detrimental effect of sensory deprivation for those with an acquired deafness, and enhanced learning ability in younger children with congenital deafness. Thus, a child who has a congenital profound hearing loss or is deafened early in life will have a much better chance of learning to understand speech if they are implanted as young as possible. The results do not suggest that there is a crucial age, beyond which implantation is not useful, but that the chances of developing good open-set speech perception decrease with age. To illustrate this point, it is noted that three children with congenital deafness, who were implanted after the age of ten years, scored over 25% for the BKB open-set sentence test.

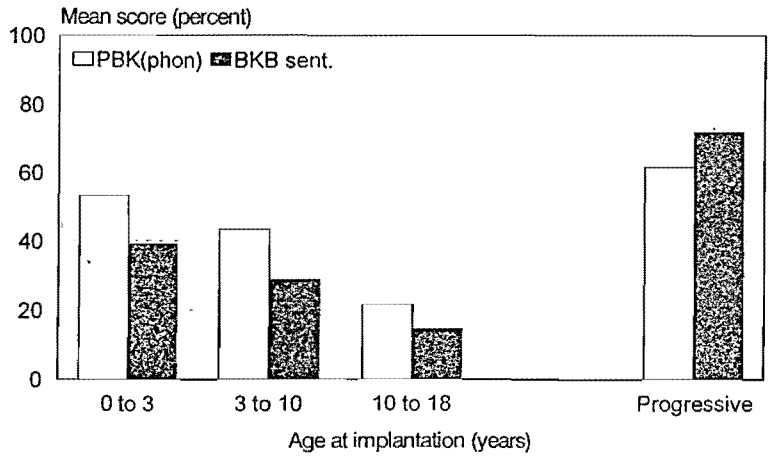

Figure 3

Mean open-set speech perception results for a group of 52 children implanted with the Nucleus multiple channel cochlear prosthesis grouped according to age at implantation and type of hearing loss (see text).

The small group of children with a progressive hearing loss perform significantly better on word and sentence tests than the rest of the group (see Figure 3). This can be explained quite simply, in that all of these children had relatively good hearing during the important language development phase up to three years of age, thus their situation when implanted was more like postlingually deaf adults than the children with a congenital profound loss.

Figure 3 summarizes the effect of age at implantation on results for the word and sentence tests. The progressive hearing loss group has been separated out here to highlight the significant difference for this group. The mean scores for this group of 72% for sentences and 62% for phonemes in words compare favourably with results for postlingually deafened adults using the Nucleus prosthesis. Mean scores for adults using the MSP-MULTIPEAK processor were 59% for open-set sentences and 48% for phonemes in monosyllables at their six months postoperative assessment (Hollow et al, 1995).

It is clear for the early deafened children that there is a relative advantage in speech perception performance for those implanted before three years of age. It should be highlighted again, however, that these mean results can be misleading in that they hide a large amount of variation in performance in all groups. It is likely that other factors, some of which have been identified in this study, and others that may be difficult to quantify, play a role as important as age of implantation in outcomes.

The educational management of implanted children was significant in the analyses for both sentence and word tests. In essence, this result is suggesting that children in an oral/aural school for hearing-impaired children or in a mainstreamed setting may be developing speech perception skills more effectively than those in a Total Communication setting where a visual supplement is used for communication. Before such evidence is used to dismiss the use of manual communication methods for implanted children, we must remember that the communication needs of young children should be considered carefully in addition to the development of auditory skills. In individual cases, manual communication may provide the only useful interaction for a profoundly hearing-impaired child prior to implantation and during many months or years postoperatively as they learn to use the prosthesis. On the other hand, the available evidence suggests that if a child has a cochlear implant, parents should be encouraged to progress towards an educational setting which encourages the use of audition for communication.

Preoperative residual hearing was also identified as a significant factor in the analysis of sentence results but not for the words. It is reasonable to assume that the more hearing a child has prior to implantation, the greater chance they have of developing some auditory language skills. This depends, of course, on how well this hearing is utilised with appropriate amplification and early intervention strategies. The auditory language skills of the child, however minimal, may contribute to faster or more effective learning once they receive a cochlear implant.

CONCLUSIONS

Results for children and adolescents who are long term users of the Nucleus multiple channel cochlear prosthesis show that the majority develop significant open-set speech perception using the device without lipreading or other cues. Mean scores for BKB open-set sentences were 32.4% (n=50) and for phonemes in PBK monosyllabic words, 48.1% (n=52). Children with progressive hearing losses with onset of profound deafness after the age of three years performed significantly better on these tasks. The age of implantation for congenitally deaf children or duration of profound hearing loss for those with acquired hearing loss, had a significant effect on performance with younger age and shorter duration of deafness associated with better open-set speech perception. This effect was evident down to the age of three years. An oral/aural educational program following implantation and preoperative residual hearing were also associated with better scores. With improved techniques for the early diagnosis of hearing loss and technical improvements in all aspects of cochlear prostheses we can expect most young children with implants to develop good open-set speech perception in the future.

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