

PHONETIC AND PHONOLOGIC CHANGES IN THE CONNECTED SPEECH OF CHILDREN USING A COCHLEAR IMPLANT

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INTRODUCTION

In excess of 5,000 children, with profound hearing impair-

ment, have received a cochlear implant hearing device. Researchers have recently begun to study the speech production

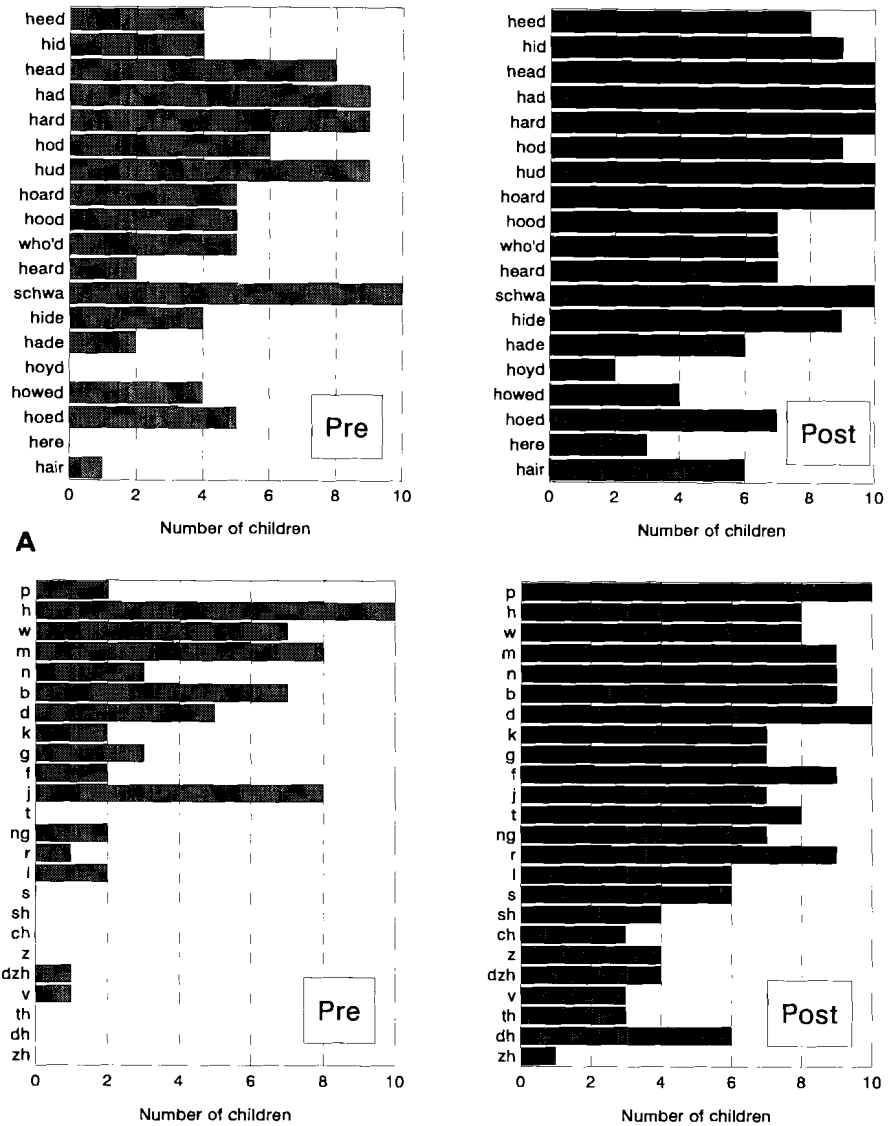


Fig 1. Group 1 phonetic inventories, before and after implantation. A) Vowels. B) Consonants.

skills of these children.¹⁻⁶ This topic is of interest because the speech of young prelingually or postlingually deaf children is in a constant state of development. The effectiveness of the implant, therefore, must be measured in its ability to provide enough auditory information for the child to develop intelligible speech. This is in addition to the maintenance of intelligible speech in the case of older postlingually deaf children or adults. The aim of the present study was to investigate some characteristics of the connected speech of a selected group of children from the University of Melbourne Cochlear Implant Programme. More specifically, the study aimed to determine how these characteristics changed over time. Studies of conversational speech samples are useful in that they do not depend on imitation yet they do reflect the child's everyday communication skills and are sensitive to co-articulatory effects. Analyses performed on the preoperative and postoperative data aimed to detect both the phonetic and phonologic changes in the segmental features of speech. The following questions were addressed: 1) What was the pattern of change in the phonetic inventories from before to after implantation?

2) Was there a difference in the correct production of consonants depending on their position in the word? 3) Did the group performance for correct production of phonemes change significantly from before to after implantation? 4) Did performance change over time for individuals? 5) What were the most common phonologic processes and was there a significant reduction in any of these processes from before to after implantation?

METHOD

Twenty children from the Melbourne Cochlear Implant Programme were selected for this study. The subjects were divided into two groups of 10 depending on their level of intelligible speech preoperatively. Intelligible speech was defined as being recognizable to the speech pathologists who analyzed all samples. Group 1 subjects had speech that was mostly babbled or unintelligible preimplant. Group 2 subjects had mostly intelligible speech preimplantation. Postoperatively, all subjects had speech that was mostly intelligible. Group 1 subjects' ages ranged from 1 year 6 months (1y6m)

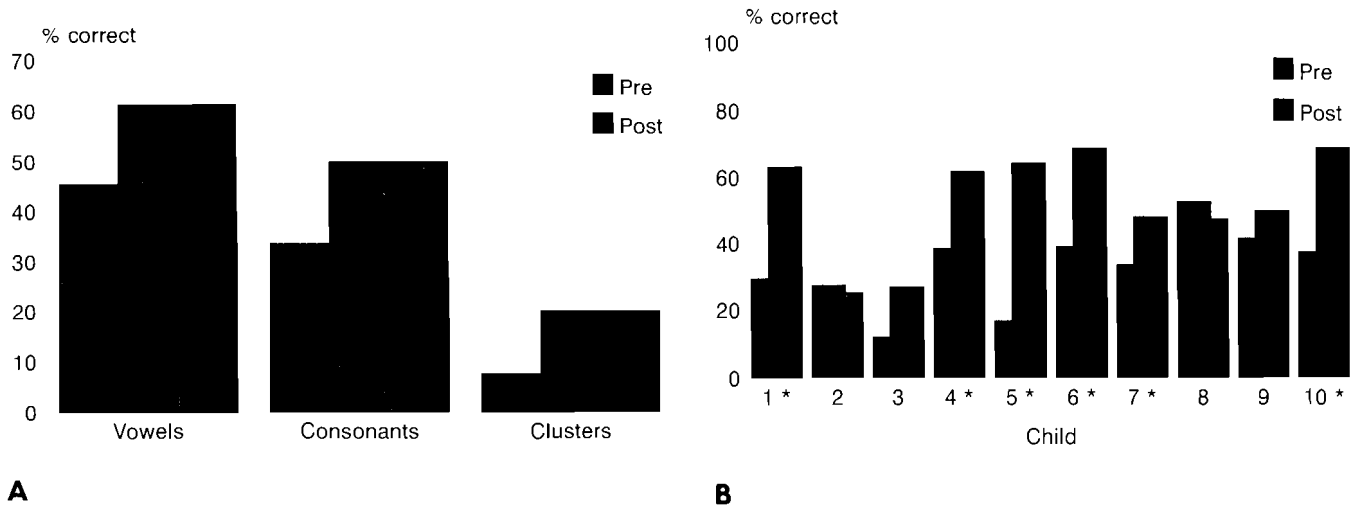


Fig 2. Group 2 results, before and after implantation. A) Combined, for percentage of correctly produced vowels, consonants, and clusters. B) Individual, for percentage of correctly produced consonants. Asterisks — subjects with significant improvement.

to 5y1m (mean, 3y4m) preoperatively and 3y5m to 8y2m (mean, 6y) postoperatively. The average length of use of implant was 2y6m. Five of the children were in an auditory-oral educational setting and 5 in total communication. The age range for the children in group 2 was 3y4m to 8y10m (mean, 6y3m) preoperatively and 5y1m to 11y10m (mean, 8y8m) postoperatively. Average length of implant use was 2y2m. Seven of the children were in an auditory-oral setting and 3 were in total communication.

Two samples were chosen for each child on the basis that the preoperative sample was as close to the date of implant as possible and the other was as recent as possible. All samples featured the child on videotape interacting with a familiar adult. Props such as toys, family photographs, books, and pictures were used to facilitate a conversational speech sample of at least 6 minutes (mean, 13 minutes). A minimum of 50 utterances was transcribed for all samples, with the exception of 8 group 1 samples and 4 group 2 samples because the sample was less than 50 utterances. A computer program, written as part of a larger research project entitled Computer Aided Speech and Language Analysis (CASALA), was used to collate and statistically analyze the data. Phonetic inventories were plotted from the broad transcriptions from group 1 samples. A phoneme was considered present in the child's repertoire if it occurred at least once. The samples from group 2 were transcribed narrowly and the percentages of correctly produced phonemes for vowels, consonants, and clusters (initial, medial, and final positions) were compared. The relative occurrence of phonologic processes was also computed and investigated for this group.

RESULTS

The phonetic inventories for group 1 indicated that for vowels (Fig 1A), all monophthongs were represented preimplant, with the low-central vowels and schwa being present in the inventories of 8 or more children. Postimplant, all vowels, including diphthongs, increased in representation. High and mid-front vowels and some of the high and low-back monophthongs were now present in the inventory of 8 or

more children. Diphthongs were still relatively underrepresented. In Fig 1B, consonants were arranged in the order of acquisition for normal-hearing children.⁷ Preoperatively, 40% or more of the subjects used [w, m, b], [d], and [j] for manner characteristics and [b, d], [m], [h], and [w, j] for place. Voiceless phonemes were infrequently used. Postoperatively, only [ch, v, th, zh] were used by less than 40% of the children.

An analysis of variance on the group 2 data indicated that initial consonants were the most accurately produced, followed by medial and final, which were the least accurate ($p < .001$). The average total percentage of correctly produced vowels, consonants, and clusters indicated a significant improvement from before to after implantation ($p < .001$; Fig 2A). The χ^2 analyses of the preimplant and postimplant single-subject data for the number of correctly versus incorrectly produced phonemes showed that 80% of the subjects improved significantly on production of vowels, 60% on consonants (Fig 2B), and 30% on clusters ($p < .05$). The relative frequency of phonologic processes was also calculated from the group 2 data. The most frequently occurring processes for the group for both preimplant and postimplant samples were elongation, nasalization, and monophthongization for vowels and voicing, stopping, deletion, and cluster reduction for consonants. Consonant deletion was the only process that was significantly reduced from before to after implantation ($p < .05$ Wilcoxon signed-rank test).

DISCUSSION

The change in the phonetic inventories from before to after implantation indicated that over time, the acquisition of sounds became closer to that of normal-hearing children. Other researchers have studied phonetic changes in implanted groups of subjects. There are similarities in the general pattern of results, although direct comparison is difficult because of the wide range of methodologies and analyses used. In the present study, for vowels, monophthongs were used more frequently both before and after implantation with an increase in the use of diphthongs postimplant. Geers and Tobey,³ investigating vowel accuracy, reported that diphthongs were

generally less accurate than monophthongs. The results from the present study indicated that the most commonly used monophthongs preimplant were mid-front, mid-central, and low-central. Postimplant, 70% or more of the subjects used all the monophthongs. Osberger et al⁴ also found a higher percentage of central and middle vowels in their preoperative sample, with an increase in the high-front vowels postimplantation. In other words, the inventory became more like that of normal-hearing children, who initially use front vowels more than central or back, and high more than middle or low.⁴

For consonants, preimplant, 40% or more of the subjects used one or two members of the stop, nasal, glide, and fricative categories. The most common place characteristic was bilabial, and for manner and voice characteristics, voiced stops were predominant. These results are supported by those found in other studies,⁴⁻⁶ although none reported the frequent use of the fricative [h] found in the present study. Researchers have concluded that more visible consonants were easier for subjects to produce than the less visible,⁶ and that the acquisition of fricatives, liquids, glides, voiceless consonants, and high-front vowels were the most difficult for hearing-impaired children.⁴ The preimplant results reported here would support these notions. There was an increase in almost all the consonants postimplant. For place characteristics, alveolars had the greatest relative increase in representation, followed by velars, labiodentals, interdental, bilabials, and palatals, respectively. For manner characteristics, the greatest increases were in liquids, followed by stops, fricatives, nasals, affricates, and glides, respectively. The frequency of voiceless cognates increased more relative to voiced and particularly voiceless fricatives. In summary, use of liquids, alveolars, and voiceless fricatives was more likely to increase with time, followed closely by stops and velar consonants. Other studies have reported similar findings, although some have reported a higher production of stops and nasals relative to other features postimplant, despite increases in fricatives, liquids, and glides.⁴⁻⁶ It is clear that the spread of results in the postimplant inventory in Fig 1B more closely resembles the pattern of consonant acquisition of children with normal hearing (ie, decreasing from top to bottom) than the preimplant inventory.

A significant difference was found for the correct production of consonants, depending on their position in the word. Initial consonants were found to be more accurately produced than medial, and final consonants were the least accurately produced. This is an important finding, as other studies on phoneme accuracy did not differentiate between initial, medial, and final positions. The reason for the apparent difficulty in accurately producing final consonants is an area for further study. Murphy and Dodd⁸ reported that a high number of deletions of final consonants is common in the speech of hearing-impaired children, as opposed to initial and medial, and this may, at least in part, be the reason for significantly more final consonant errors.

The group performance for correct production of vowels, consonants, and clusters did significantly improve from before to after implantation. Other studies on phoneme accuracy in implanted subjects confirm this result.^{1-3,6} Individual results in the present study provide further information on

differences among the three groups of phonemes. Eighty percent improved significantly on vowel accuracy and 60% on consonants. Thirty percent of the subjects improved on vowels and consonants, and a further 30% on vowels, consonants, and clusters. No subjects improved on consonants or clusters alone. This suggests that vowels are easier to produce than consonants. Clusters are clearly the most difficult for implanted subjects to produce accurately.

The most common phonologic processes occurring both preimplant and postimplant for vowels were elongation, nasalization, and monophthongization. Deletion, voicing, stopping, and cluster reduction were most common for consonants. The reduction in consonant deletion postimplantation was the only process to reach statistical significance for the group, despite the fact that several other processes were reduced considerably for individual subjects. Possibly because of the relatively small number of subjects, consonant deletion had the most opportunity to occur, whereas other processes affect only a small number of targets. The above list of processes was compared to one described by Murphy and Dodd⁸ in relation to hearing-impaired speakers with similar results. A more narrow classification system such as final and initial consonant deletion, prevocalic voicing, and postvocalic devoicing was used by Murphy and Dodd, and these may be useful in future studies in order to study more closely the patterns of phonologic changes over time.

The results from this study suggest that as a group, children receiving a multichannel cochlear implant improve on their segmental features of speech production in everyday conversation over time. Younger children acquired more phonemes with time and used speech that had a greater proportion of recognizable words. Certain vowels and consonants were more likely to be acquired, depending on the place and manner of articulation. Older children's production of phonemes became more accurate with time. Gains are most likely due to a combination of maturation, habilitation, and implant experience.

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