Children with implants can speak, but can they communicate?

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English-language skills were evaluated in two groups of profoundly hearing-impaired children with the Reynell Developmental Language Scales, Revised. The first group consisted of 89 deaf children who had not received cochlear implants. The second group consisted of 23 children wearing Nucleus multichannel cochlear implants. The subjects without implants provided cross-sectional language data used to estimate the amount of language gains expected on the basis of maturation. The Reynell data from the group without implants were subjected to a regression by age. On the basis of this analysis, deaf children were predicted to make half or less of the language gains of their peers with normal hearing. Predicted language scores were then generated for the subjects with implants by using the children's preimplant Reynell Developmental Language Scale scores. The predicted scores were then compared with actual scores achieved by the subjects with implants 6 and 12 months after implantation. Twelve months after implantation, the subjects demonstrated gains in receptive and expressive language skills that exceeded by 7 months the predictions made on the basis of maturation alone. Moreover, the average language-development rate of the subjects with implants in the first year of device use was equivalent to that of children with normal hearing. These effects were observed for children with implants using both the oral and total-communication methods. (Otolaryngol Head Neck Surg 1997;117:155-60.)

Multichannel cochlear implants have been shown to provide substantial benefit to many children in the acquisition of speech skills.[1-3] Although improved speech production is often the focus of parents and teachers working with deaf children, speech skills do not necessarily ensure language competence. Speech refers to oral production, whereas language is the internalized, abstract knowledge system that is the basis for communication. Language ability is a very strong predictor of reading achievement and, hence, academic success in children.[4] If it could be shown that implants enhance language development, this would be compelling evidence as to the usefulness of cochlear implants in the pediatric population.

Assessing the effects of the use of cochlear implants on language development is difficult because some improvement in language skills occurs over time as a result of maturation. Because of the considerable variability in language scores over time, an ideal research paradigm would involve comparing the scores of a subject with implants to scores that the same child would have achieved if he had not received a cochlear implant. Given that this is impossible, an alternative method is to make informed predictions about each subject's language performance in the absence of a cochlear implant and then to compare those predictions with the scores the child actually achieves.

In this article we first describe a method used to predict the development of receptive and expressive language skills in deaf children that might be expected with maturation. Then we longitudinally compare predicted and observed language scores in a group of children who use multichannel cochlear implants to assess the effect of implant use on language development. If the observed language performance over time exceeds that predicted on the basis of maturation alone, this suggests that use of cochlear implants enhances language development.

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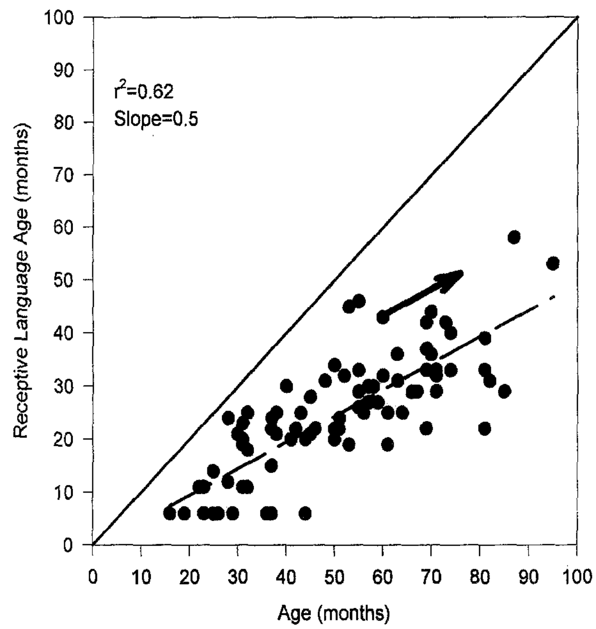

Fig. 1. Reynell receptive language data for 89 deaf children without implants. Chronologic age is plotted on *x*-axis and receptive language age is plotted on *y*-axis. Linear regression is shown by *dashed line*, and *solid, diagonal line* illustrates receptive language growth expected of child with normal hearing.

METHODS

Subjects

Two groups of hearing-impaired subjects participated in this investigation.

Subjects without implants. The first group consisted of 89 profoundly deaf children without implants ranging in age from 16 to 95 months. All subjects wore either a hearing aid or a tactile aid and were audiologically suitable for a cochlear implant. All had early onset of deafness; 62 subjects were congenitally deafened, whereas 27 of the 89 subjects were deafened between birth and 2 years 11 months of age. Sixty-one percent of the subjects used total communication (TC), and 39% used oral communication. The subjects in the group without implants provided cross-sectional data on language scores as a function of age that were used to generate predictive equations for language development in deaf children.

Subjects with cochlear implants. The group with cochlear implants consisted of 23 children wearing multichannel cochlear implants. All subjects with cochlear implants were prelingually deafened; 11 of the 23 subjects were congenitally deafened, whereas 12 had early, acquired deafness, before the age of 3 years. The average age at onset of deafness was 10 months, and the average age at time of implantation was 4 years 11 months. Fourteen of the subjects with cochlear implants used TC; the remaining nine subjects used oral communication. The oral and TC groups were well matched for age at onset of deafness (mean = 0.72 years for oral subjects and 0.9 years for TC subjects) and age at implantation (mean = 4.98 years for oral subjects and 4.86 years for TC subjects). All subjects wore the Nucleus multichannel cochlear implant (Cochlear Corp., Englewood, Colo.); five used the FO/F1/F2 strategy, 11 used the multipeak strategy, and seven used the spectral peak strategy.

Test Instrument

The Reynell Developmental Language Scales, Revised (RDLS)[5] was used to assess the English-language abilities of the subjects. This assessment tool was chosen for several reasons: It evaluates receptive and expressive language independently, an important criterion, according to child language experts. It has been used extensively with deaf children.[6] It is appropriate for a broad age range, 1 to 8 years of age, allowing repeated test administrations during a relatively long period. Normative data are available on 1319 hearing children.[5] In addition, the test format involves object manipulation and description based on questions that vary in length and complexity. This format reflects real-world communication to a greater degree than do many other language tests.[7] Thus RDLS results are considered to portray a child's communicative competence more accurately than does, for example, a single-word vocabulary test.[6,8]

Prediction of Language Development in Deaf Children Without Cochlear Implants

The RDLS was administered once to each of the 89 subjects in the group without implants. The test was administered in whatever modality of English each child used, including spoken English, TC (i.e., simultaneous spoken English and signing exact English[9]), or cued speech. Each child's responses were converted to a receptive and expressive language age in months. We then performed separate linear regressions of receptive and expressive language as a function of age at the time of testing. This allowed us to estimate the rate of language development in deaf children without implants. In other words, we used cross-sectional data from a group of deaf children to obtain regression slopes that could be used to predict the longitudinal changes in individual subjects. We shall refer to the slopes obtained from this regression analysis as "deaf slopes," one for receptive and one for expressive language. The prediction method used in this study assumes that the language age of children with implants would follow a straight line, starting at the child's language age and chronologic age at the preimplant testing session and increasing according to the corresponding deaf slope.

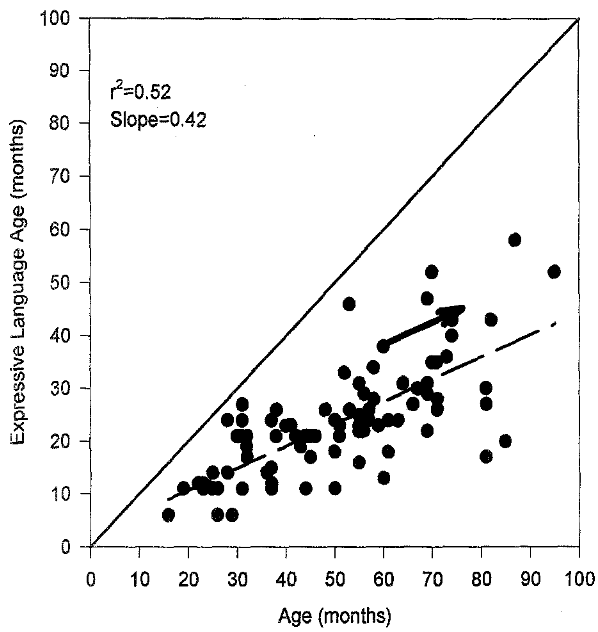

Fig. 2. Reynell expressive language data for 89 deaf children without implants. Chronologic age is plotted on *x*-axis and expressive language age is plotted on *y*-axis. Linear regression is shown by *dashed line*, and *solid, diagonal line* illustrates expressive language growth expected of child with normal hearing.

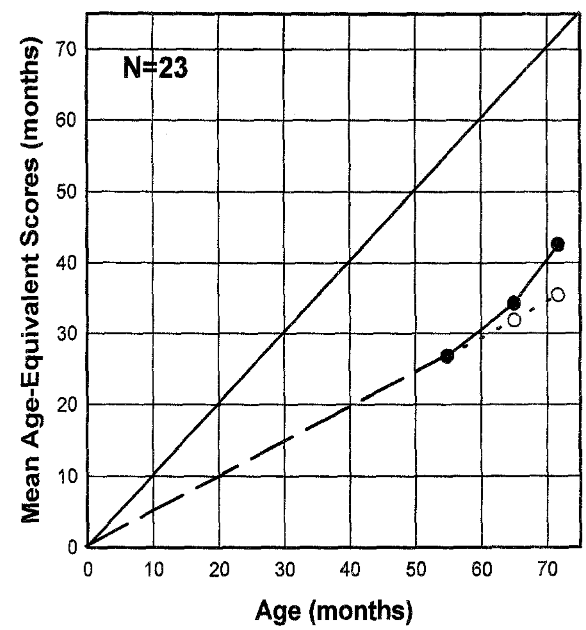

Fig. 3. *Open circles* show receptive language development predicted for children without implants, and *filled circles* show actual scores obtained from 23 subjects with cochlear implants. *Solid, diagonal line* illustrates receptive language growth expected of child with normal hearing.

Comparison of Observed and Predicted Language Performance in Children With Cochlear Implants

The RDLS was administered to the 23 children with implants at three intervals according to the administration and scoring procedures described above. The preimplant measure was obtained approximately 0 to 3 months before initial hook-up. The two postimplant assessments were carried out approximately 6 and 12 months after implantation (referred to as the POST1 and POST2 intervals, respectively). These three assessments yielded "observed" language scores for each child. Predicted scores were generated for each subject at the same test intervals according to the regression equations calculated in the previous analysis. That is, we assumed that these subjects' language scores would have increased over time at a rate described by the deaf slopes, if they had not received a cochlear implant. Therefore predicted scores for a given subject over time are described by a straight line that starts at the preimplant score and age and increases according to the deaf slope. At the preimplant interval, predicted scores are, by definition, identical to observed scores. With these data, we performed a two-way repeated-measures analysis of variance (repeated measures on both the "interval" and the "observed vs predicted" variables).

One difficulty in comparing the observed and predicted language scores of the children with implants is that the communication mode varied across subjects. It is possible that the relationship between observed and predicted scores in the TC and oral groups were different. To investigate this possibility, we performed an additional analysis. We first separately calculated the average receptive and expressive language gains that were made by each one of the TC and oral groups from the preimplant to the POST1 interval and from the POST1 to the POST2 interval. These gains then were compared with the language progress that would have been predicted by maturation alone (with the "deaf slopes" used to make this prediction) within the oral and TC groups separately.

RESULTS

Prediction of Language Development in Deaf Children Without Cochlear Implants

In Fig. 1, each of the 89 subjects' chronologic ages is plotted against his or her receptive language age. The solid, diagonal line indicates the language change expected by a child with normal hearing (i.e., language age and chronologic age increase in synchrony). The slope of the normal-hearing, diagonal line is 1. The dashed line shows a regression by age of the Reynell receptive language data, expressed in age-equivalent scores. The r^2 of this regression was 0.62 and the slope

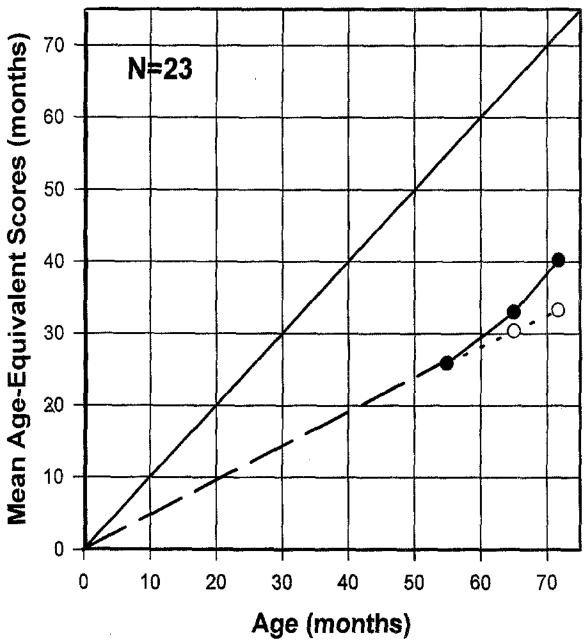

Fig. 4. *Open circles* show expressive language development predicted for children without implants, and *filled circles* show actual scores obtained from 23 subjects with cochlear implants. *Solid, diagonal* line illustrates expressive language growth expected by child with normal hearing.

was 0.5, suggesting that the receptive language gains to be expected from profoundly deaf children are roughly half those of peers with normal hearing. Thus we predict that deaf children will show about 6 months' growth in receptive language skills in 1 year. The prediction method described above is illustrated by the arrow in Fig. 1, showing the prediction line that corresponds to one specific subject.

The results for the expressive language scores on the RDLS are shown in Fig. 2. Note the similar pattern to that for receptive skills, although the r^2 is 0.52 and the expressive deaf slope is only 0.42, lower than the receptive deaf slope. Based on these expressive language data, we predict that deaf children will show about 5 months of progress in expressive language skills in 1 year.

Comparison of Observed and Predicted Language Performance in Children With Cochlear Implants

The predicted and observed mean receptive language scores for the group of subjects with implants are shown in Fig. 3. The horizontal axis represents chronologic age and the vertical axis shows receptive age-equivalent scores, measured in months. The solid diagonal line running through the graph represents the language development expected of a child with normal hearing. The first filled dot is the group average of age-equivalent scores obtained by the children at the preimplant interval. The open circles represent the mean scores that would be predicted 6 and 12 months after implantation according to the prediction method described above. The slope of language growth predicted for the children without an implant is shown by the broken line. Notice the shallowness of this line relative to that for the child with normal hearing (the solid diagonal line). The two later filled circles represent the language scores actually observed in these children with implants when they were tested 6 and 12 months after implantation. As a group, these subjects showed language growth that, 1 year after implantation, exceeded by 7.1 months the predictions that were made on the basis of maturation alone.

The pattern of results for expressive language in the subjects with implants was similar to that for receptive language (Fig. 4). Note the preimplant score and the two open circles that are the scores predicted based on the formula described earlier. The actual scores that the subjects with implants achieved are represented by the filled circles. Comparing the predicted with the actual scores after 1 year of implant use, there is a 6.9-month advantage of the actual over the predicted score. Note that, although the implant subjects' language scores are higher than the corresponding predictions for deaf children without implants, their language scores remain significantly below those of their peers with normal hearing. This may be seen in Fig. 4 by comparing the position of the closed circles (postimplant language performance) relative to the solid line (subjects with normal hearing).

The variables used in the two-way repeated-measures analyses of variance were interval (6 or 12 months after implantation) and observed/predicted. There were significant ($p < 0.05$) interaction effects for both receptive and expressive language scores, indicating that the difference between observed and predicted values depends on the interval. Post hoc Student-Newman-Keuls tests indicated that both receptive and expressive observed scores were significantly higher than the corresponding predicted scores at the 12-month interval ($p < 0.05$). At the 6-month interval, however, the difference between observed and predicted scores failed to reach statistical significance.

Fig. 5 illustrates the average amount of language growth that occurred in the oral and TC groups with implants beyond that expected on the basis of maturation. If the progress achieved was equivalent to that expected by maturation, the bars would be at zero. Fig. 5*A* indicates that 6 months after implantation, the TC children had made 3 months' progress beyond that expected on the basis of maturation. The oral subjects also made progress beyond that expected by maturation, but only 1 month beyond. Twelve months after implantation both the TC and oral groups averaged 6 months of language gain beyond that expected through maturation alone. Findings for expressive language for the two communication groups are shown in Fig. 5*B*. Note the mixed pattern of progress seen in the oral and TC groups at the two intervals, although by 12 months after implantation both groups show considerable increases in expressive language beyond those as a result of maturation.

DISCUSSION

These data suggest that the English-language skills of profoundly deaf subjects without cochlear implants improved at a rate that was markedly slower than that of children with normal hearing, a finding that is in agreement with previously reported studies on language development in deaf children.[10,11] Data from the subjects without implants allowed us to calculate rates of language development (deaf slopes) that would be predicted for a deaf child on the basis of maturation alone. Recall that these deaf slopes were 0.5 for receptive and 0.42 for expressive language, respectively, suggesting that deaf children would be expected to make gains in language skills at half or less the rate of children with normal hearing.

We found that observed language scores for the subjects with cochlear implants were significantly higher than the predictions made for the same subjects if they had not received cochlear implants. Specifically, after about 1 year of device use, the implant subjects' mean receptive and expressive language scores were approximately 7 months better than those predicted on the basis of maturation. This suggests that the cochlear implant promoted both receptive and expressive language development to a greater extent than would be predicted by maturation alone. In addition, the findings show that the longer the children used the implants, the greater the difference between the observed and predicted scores. Both of these findings are in agreement with our earlier investigations.[8,12]

Both children using oral language and those using TC demonstrated an increased rate of language learning with the cochlear implant. Given that the implant is an auditory sensory aid, one might expect to see greater benefit for oral subjects, whose language learning is mediated primarily through the auditory modality, than for TC subjects, whose language learning is strongly, although not exclusively, visual. That the cochlear implant provided language benefit for both groups is

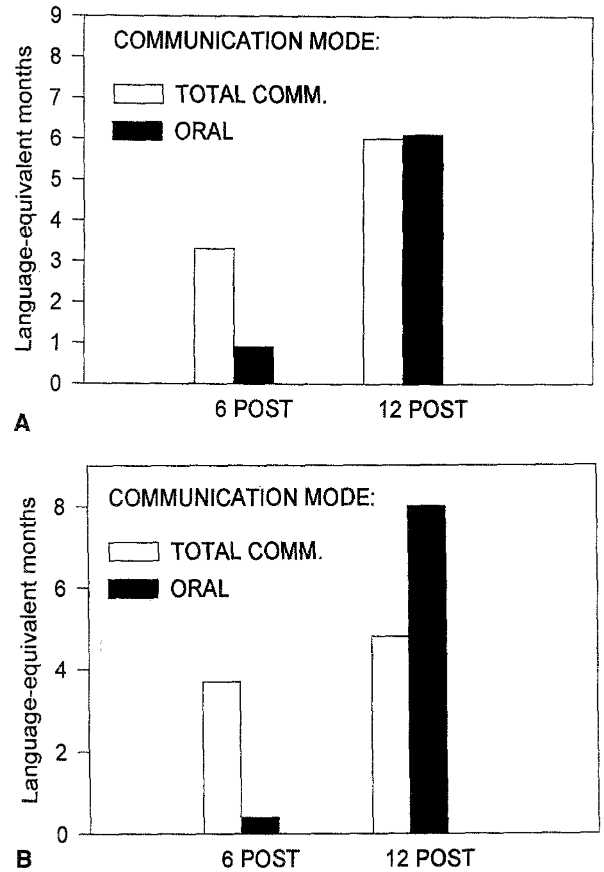

Fig. 5. Average amount of language growth beyond that as result of maturation in subjects with implants who use TC *(open bars)* and oral communication *(solid bars)*. **A,** Receptive language results; **B,** expressive language results.

particularly encouraging in light of the fact that at least 75% of deaf children in the United States are educated in TC programs.

The possibility also exists that the cochlear implant has a global, multisensory effect on language learning. This would be consistent with the recent findings of Quittner et al.,[13] who reported increases in selective visual attention in children after cochlear implantation, and with anecdotal reports by parents and teachers of children's improved attention to task after implantation. Such an effect might explain the benefit demonstrated by both oral and TC subjects in this study.

It is also possible that the rapid change in the rate of language learning after implantation may relate to the children's new-found ability to acquire language incidentally, through the overhearing of everyday conversations. This natural exposure to spoken language communication is the avenue by which children with normal hearing learn their language skills and is generally unavailable to profoundly deaf children, who must be directly and explicitly taught every spoken language structure they know. Access to natural conversation through the implant would allow these children the exposure to language that previously was unaccessible.

It is interesting to note that, at least for the first year after implantation, increases in receptive and expressive language scores for children with implants matched those of the group with normal hearing. In consequence, the gap in absolute scores between children with implants and normal children remained roughly constant during the first year after implantation, instead of increasing. If this result happened to be true for subjects given implants earlier, and was consistent beyond 1 year after implantation, the case for earlier implantation would be strengthened considerably. The younger a deaf patient is, the smaller the gap between his language age and chronologic age. If the auditory information provided by a cochlear implant prevented the language gap from increasing (as our data suggest), children given implants early would have an excellent chance of achieving near-normal language development. In consequence, it is crucial to extend these studies in two directions: looking at subjects given implants earlier in life and following them for longer periods after implantation.

The results of this study demonstrate an important consequence of cochlear implants (i.e., the foundation of language development above and beyond that anticipated from maturation alone). Thus not only do children display improvement in speech perception and speech intelligibility with cochlear implants but they also show significant increases in the rate of language development.

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