Development of Spoken Language Grammar Following Cochlear Implantation in Prelingually Deaf Children

Thomas P. Nikolopoulos, MD, DM, PhD; Dee Dyar, MSc; Sue Archbold, MPhil; Gerard M. O’Donoghue, MD, FRCS

Objectives: To assess the development of grammar comprehension in spoken language in prelingually deaf children following cochlear implantation and compare their grammatical abilities with those of their hearing peers.

Design: A prospective study of 82 consecutive prelingually deaf children up to 5 years following implantation. The children were less than 7 years old at the time of implantation (mean age ± SD, 4.2 ± 1.3 years). All received the same multichannel cochlear implant system. No child was lost to follow-up and there were no exclusions from the study.

Setting: Tertiary referral cochlear implant center.

Methods: The children were assessed using the Test for Reception of Grammar. This individually administered, multiple-choice test designed to assess the understanding of grammatical contrasts in the English language also allows direct comparison of grammar comprehension between test subjects and their normal-hearing peers.

Results: Before implantation, only a small proportion (2%) of prelingually deaf children were above the first percentile of their normal-hearing peers. This percentage increased to 40% and 67%, respectively, 3 and 5 years after implantation; and 5 years after implantation, 20% of the children performed between the 25th and the 75th percentile or better. In the subgroup of children who received their cochlear device before the age of 4 years, this percentage reached 36%.

Conclusions: Spoken language grammar acquisition in prelingually deaf children with a cochlear implant was found to be considerably delayed. However, there was a clear trend toward the development of grammar skills following cochlear implantation, and the greatest advance was made by children who received their implant at a younger age. These findings support the present trend toward early implantation.

The aim of this study was to assess the development of spoken language grammar comprehension by prelingually deaf children following cochlear implantation, and to compare their grammatical abilities with those of their normal-hearing peers. We focused on the grammatical development of spoken English, rather than that of sign language, because one of the major aims of cochlear implantation is to give profoundly deaf children access to spoken language through hearing restoration.

METHODS

This prospective study involved 82 children who received the same pediatric cochlear implant through the same program. All were profoundly deaf (unaided thresholds ≥103 dB at 2000 and 4000 Hz) and received the Nucleus (Cochlear, Lane Cove, Australia) multichannel implant system; speech-encoding strategies were upgraded as new programs became available. The children were referred from all over the country and represented a full range of social, communication, and educational environments. All were prelingually deaf (age at onset of deafness <3 years and age at implantation <7 years). Forty-two (51%) were congenitally deaf, and 33 (40%) had been deafened by meningitis and 7 (9%) from other causes. Only children who did not have a known disability or learning difficulty and whose primary language was English were included. Of the 82, 39 (48%) were boys and 43 (52%) girls (mean ± SD age at implantation, 4.2 ± 1.3 years; average age at implantation 4.2 ± 1.3 years; median, 0 months; range, 0-34 months).

Children were assessed using the Test for Reception of Grammar (TROG). This is an individually administered, multiple-choice test designed to assess understanding of grammatical contrasts in English. It has been used to assess children with specific language disorders, deafness, mental delay, and cerebral palsy. It is appropriate for children aged 4 to 13 years and has been standardized with more than 2000 British children who did not have any known learning difficulty, hearing loss, or other disability. The results of the standardization were found to be valid even after controlling for social background.

The test consists of 20 blocks of 4 items. Each block assesses the child’s comprehension of a specific type of grammatical contrast (eg, nouns, verbs, negative, passive, singular/plural, and relative clause). The test is usually scored according to the number of blocks successfully processed.

Four 4-choice items test each grammatical contrast (block). In each item the subject is required to select from an array of pictures and point to the one that corresponds to a word order or grammatical construction spoken, written, or signed by the tester. We have used only the spoken presentation of TROG.

Two examples of TROG blocks are now illustrated. The test consists of the following 4 items: (1) the girl is chased by the horse, (2) the elephant is pushed by the boy, (3) the horse is chased by the man, and (4) the cow is pushed by the man. Again, for each item, the child can choose 1 of 4 pictures. The 12th block assesses the child’s comprehension of reversible passive. This block consists of the following 4 items: (1) the girl is chased by the horse, (2) the elephant is pushed by the boy, (3) the horse is chased by the man, and (4) the cow is pushed by the man. Again, for each item, the child can choose 1 of 4 pictures. A block is passed only if the child responds correctly to all 4 items. The probability of passing a block by chance is .004.

To allow direct statistical comparison with scores of normal-hearing children of the same age, TROG results can be converted into percentile scores. A percentile score is an index of the percentage of normal-hearing children expected to obtain a score equal to or below that obtained by the subject. For instance, if a subject scores at the 10th percentile, it means that only 10% of normal-hearing children are expected to obtain a score equal to or below that score; and, conversely, that 90% of normal-hearing children are expected to obtain a higher score.

A restricted vocabulary is used in TROG sentences to minimize the possibility that not knowing the meaning of individual words would prevent children from passing blocks. With TROG no expressive speech is required. The test, which takes approximately 20 minutes to administer, enables the tester to consider not only how a child’s grammar comprehension compares with that of other children of the same age, but also to pinpoint specific areas of grammar comprehension difficulty. A detailed description of the test and the methods of scoring can be found elsewhere; the test has been found to be suitable for American as well as British children.

All children were administered TROG before implantation and, prospectively, 3 years following implantation. None were lost to follow-up 3 years following implantation. Moreover, 30 of the 82 children had reached the 5-year interval at the time of the study and their TROG data were investigated as well.

RESULTS

The results of TROG percentiles are shown in Table 1. Before implantation, 44 of the 82 children had reached the age of 4 years and were thus within the age limits (4-13 years) appropriate for TROG. The remaining 38 children were younger than 4 years and therefore could not be tested. At the 3-year interval all 82 children had reached the required age and were assessed using the TROG percentiles. Of the 82 children in the study, 30 had reached the 5-year postimplantation interval and all of them were within the required age limits for TROG percentiles. The results revealed that, before implantation, only 1 child (2%) scored above the lowest percentile of normal-hearing peers. This percentage increased to 40% (33/82) and 67% (20/30) 3 and 5 years following implantation (Table 1).

To investigate the effect of age at implantation on grammar comprehension, the children were divided into

<table>
<thead>
<tr>
<th>Study Children</th>
<th>Children Within the Age Limits for TROG</th>
<th>Children Scoring Below the 1st Percentile</th>
<th>Children Scoring Between the 1st and 25th Percentiles</th>
<th>Children Scoring Between the 25th and 75th Percentiles</th>
<th>Children Scoring Between the 75th and 100th Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before implantation</td>
<td>82</td>
<td>44</td>
<td>43 (98)</td>
<td>1 (2)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>At 3 years</td>
<td>82</td>
<td>82</td>
<td>49 (60)</td>
<td>27 (33)</td>
<td>3 (3.5)</td>
</tr>
<tr>
<td>At 5 years</td>
<td>30</td>
<td>30</td>
<td>10 (33)</td>
<td>14 (47)</td>
<td>5 (17)</td>
</tr>
</tbody>
</table>

*The test is based on the scores of normal-hearing children. Data are given as numbers or number (percentage).
2 groups, those who received their cochlear implant when they were 4 years or older and those who received it when they were younger than 4 years. This cutoff criterion also corresponded with the age at which TROG can be administered to young children. Table 1 and Table 2 and Figure 1 and Figure 2 show a marked difference between the groups. At the 3-year interval, a majority (60%) of the children who received their implant when they were younger than 4 years tested above the first percentile of their normal-hearing peers and at the 5-year interval most of them (86%) did. The respective percentages in children who received their implant after the age of 4 years were 23% and 50%. Statistical comparison of the distribution at the 3-year interval revealed that the difference between the 2 groups was statistically significant (P = .003) (Table 2 and Table 3).

Moreover, at the 5-year interval, 36% of the children in group 1 performed at a level similar to (range, 25th–75th percentile) or better than (>75th percentile) the average normal-hearing child of the same age. The respective percentage in group 2 was 6%. Statistical analysis at the 5-year interval was not performed because of the small number of children.

Figure 3 shows the prospective, longitudinal progress of all the children who had reached the 5-year interval, whereas Figure 4 shows the progress of children who received their implant after the age of 4 years and Figure 5 shows the respective progress of children who received theirs before the age of 4 years.

Language development is one of the most important outcomes of cochlear implantation for prelingually deaf children. Most of the research reported in the literature has evaluated speech perception or speech production skills. However, unless the child understands the grammar of the language, good perception and production skills are of little use. The ability to repeat intelligibly what is heard does not necessarily imply understanding or mastery of the language.

Hearing is essential in learning grammatical rules. For instance, a child who cannot hear the sound “ss” will not understand the use of the plural form. However, by enhancing speech perception, cochlear implantation has allowed children to develop their use of spoken language.

Studies addressing the language development of children with implants have used the Reynell Developmental Language Scales to assess improvement in language skills 6 and 12 months after implantation. However, these studies did not assess long-term language development and did not report specifically on the critical issue of grammar development. Svirsky et al found that the rate of language development after implantation exceeded that expected from deaf children without an implant and was similar to that of normal-hearing children. They included data collected up to 2 1/2 years after implantation. Tomblin et al compared 29 children using a cochlear implant with 29 children who, although

Table 2. Test for Reception of Grammar (TROG) Percentile Distribution of Children Who Received a Cochlear Implant After the Age of 4 Years*

<table>
<thead>
<tr>
<th>Study</th>
<th>Children Within the Age Limits for TROG</th>
<th>Children Scoring Below the 1st Percentile</th>
<th>Children Scoring Between the 1st and 25th Percentiles</th>
<th>Children Scoring Between the 25th and 75th Percentiles</th>
<th>Children Scoring Between the 75th and 100th Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before implantation</td>
<td>44</td>
<td>44</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>At 3 years</td>
<td>44</td>
<td>44</td>
<td>34 (77)</td>
<td>9 (21)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>At 5 years</td>
<td>16</td>
<td>16</td>
<td>8 (50)</td>
<td>7 (44)</td>
<td>1 (6)</td>
</tr>
</tbody>
</table>

*The test is based on the scores of normal-hearing children. Data are given as numbers or number (percentage).
candidates, had not received an implant. They used simultaneous communication, ie, 2 different modalities, oral and gestural. The assessment tool was the Index of Productive Syntax as a measure of expressive English grammar. They found that children with implants outperformed those without implants. However, the stories used varied, and children who were assessed with longer stories were more likely to obtain higher scores because they had more opportunities to use new grammatical tokens and types.

In this study identical test materials were presented in exactly the same order to all of the children to prevent scoring inconsistencies. Moreover, we used exclusively the spoken language modality, although this may have led to underestimate the overall grammatical achievements of the children. Preliminary work in our department showed encouraging results in the grammar development of deaf children with cochlear implants. However, it studied a mixed population of prelingually and postingually deaf children and did not take into account age at implantation. The present study of a homogeneous group of young prelingually deaf children with cochlear implants further explored the issue and investigated age at implantation as a factor. Moreover, using strict entry criteria, it followed up longitudinally specific groups of children—as shown in Figures 3, 4, and 5.

One limitation of TROG is that 38 of the 82 children in the present study could not be assessed before implantation because they were younger than 4 years. However, this limitation would occur with any grammatical test because of the difficulty of assessing grammar development in very young children. Moreover, most profoundly deaf young children without an implant who would be administered TROG in the spoken modality only would score below the lowest percentile of normal-hearing children. In addition, TROG compares the outcomes of the studied children with the standardized outcomes of normal-hearing children of the same age, and therefore allows direct comparisons at all intervals irrespective of the children's performance at previous intervals. Nevertheless, in the present study, the outcomes of children who received their implant after the age of 4 years (and who were thus within the required age limits at all intervals) were presented separately (Table 2 and Figures 1 and 4). This allowed for the investigation of age at implantation, which is a known determinant of cochlear implant outcomes, and verified that children who receive a cochlear implant before the age of 4 years perform closer to their normal-hearing peers than those who receive their implant later (Table 3 and Figures 2 and 5).

Assessing the effects of cochlear implant use on language development is difficult because some improvement occurs over time as a result of maturation, even without an implant. If deaf children wearing a cochlear implant catch up with their normal-hearing peers with regard to spoken language at preset intervals following implantation, it follows that the device enables them to use audition effectively. This reasoning is in agreement with

<table>
<thead>
<tr>
<th>Study</th>
<th>Children Within the Age Limits for TROG</th>
<th>Children Scoring Below the 1st Percentiles</th>
<th>Children Scoring Between the 1st and 25th Percentiles</th>
<th>Children Scoring Between the 25th and 75th Percentiles</th>
<th>Children Scoring Between the 75th and 100th Percentiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before implantation</td>
<td>38</td>
<td>0</td>
<td>15 (40)</td>
<td>18 (47)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>At 3 years</td>
<td>38</td>
<td>38</td>
<td>15 (40)</td>
<td>18 (47)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>At 5 years</td>
<td>14</td>
<td>14</td>
<td>2 (14)</td>
<td>7 (50)</td>
<td>4 (29)</td>
</tr>
</tbody>
</table>

*The test is based on the scores of normal-hearing children. Data are given as number or number (percentage).
Svirsky et al., who suggested that patterns of language development can be strongly affected by the acoustic input and with Geers et al., who found that cochlear implants have a dramatic impact on the linguistic competence of profoundly deaf children. However, the effect of maturation cannot be totally excluded.

Nevertheless, the studies that compare, with encouraging results, profoundly deaf children using implants with normal-hearing children, may signal that the time has come to move from comparisons between deaf children using implants or hearing aids.

The present study showed that deaf children using implants got “closer” over time to normal-hearing children of the same age with regard to comprehension of grammar. Before implantation, only a few (2%) of the prelingually deaf children were above the lowest percentile of their normal-hearing peers. Five years after implantation, the proportion increased to 67% (Table 1). Furthermore, 36% of the young children using implants who reached this interval performed at a level similar to or better than that of a normal-hearing child of the same age. Although the progress of children with implants is evident, the results also indicate significant delays in spoken language development in the years following implantation. Szagun, after 2 interesting preliminary reports on language development in 2 children with implants, studied longitudinally 22 children following implantation. Ten of the children showed grammatical progress in spoken language at pace with normal-hearing children while 12 remained well behind. The latter children may require more intensive rehabilitation or continue to rely on sign language for everyday communication after implantation.

In conclusion, spoken language grammar acquisition in prelingually deaf children using cochlear implants was found to be considerably delayed. However, there was a distinct trend toward the development of grammar skills following implantation. Improvement was greatest in children who received an implant under the age of 4 years, and this finding supports the trend toward device implantation at a younger age if grammatical competence in spoken language is to be achieved.

Submitted for publication July 7, 2003; final revision received January 27, 2004; accepted January 28, 2004.

Corresponding author and reprint requests: Thomas P. Nikolopoulos, MD, DM, PhD, 116 George Papandreou St, Nea Philadelphia, Athens 143-42, Greece (e-mail: Thomas.Nikolopoulos@Nottingham.ac.uk).

REFERENCES