Speech perception and speech intelligibility in children after cochlear implantation

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Summary Objective: This study aimed to evaluate the long-term speech perception and speech intelligibility of congenitally and prelingually deaf children after cochlear implantation. It was a longitudinal study following 63 congenitally or prelingually deaf children up to 5 years after implantation. They each received a nucleus multichannel cochlear implant before they were 10 years old.

Methods: Perception is evaluated using the Test for the Evaluation of Voice Perception and Production (TEPP) and concerns closed- and open-set word and sentence perception without lip-reading. The intelligibility is classified according to the Speech Intelligibility Rating (SIR). The evaluations have been made every 3 months for 1 year, then at 18 months, 2 years, 3 years and 5 years after the cochlear implantation.

Results: After 5 years of implantation, the median percentage of closed-word speech perception (CSW) is 95.5%—93.67% for closed-sentence speech perception (CSS) and 76.3% for open-sentence speech perception (OSS); the median Speech Intelligibility Rating is 3.83.

Conclusions: Congenitally and prelingually deaf children who receive cochlear implant before the age of 10 years develop speech perception and speech intelligibility abilities. The closed-set perception progresses quickly and seems to reaching a plateau at 5 years post implantation. The improvement of open-sentence perception is not significant until the first year post implantation. The speech intelligibility improves regularly the five first year post implantation.

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1. Introduction

Severe and profound hearing-loss in young children results in poor speech perception and production skills. Multichannel cochlear implantation of these children permits significant improvement in both speech perception and production following implantation [1—4]. The ability to perceive speech could be considered the single most important primary outcome measure of cochlear implantation. However, the acquisition of an intelligibly spoken language must be a challenge of this technique [5]. The evaluation of the speech perceptual abilities and the speech intelligibility of young deaf children needs adapted tests and long-term follow-up after implantation. The aim of this study is to evaluate the speech perception and the speech intelligibility of a homogenous group of young profoundly deaf children up to 5 years after implantation using reproducible and appropriate tests.
2. Methods

2.1. Subjects

All children in the study were implanted in our department at the same pediatric cochlear implant program. To improve the validity of our results, we have excluded children with less than 1 year of follow-up and the results after 5 years of implantation. This study includes 63 children. Of these children, 36 were male and 27 were female. The median of the duration of the deafness at the time of implantation was 40 months (range 9–110 months). All the children were between 1 and 10 years of age at the time of implantation (median: 45 months). These children were congenitally deaf or deafened before 2 years of age. In all cases, the deafness was profound and not evolving.

Audiologic assessment, speech therapy, psychological evaluation and a petrous bone CT scan have been made for all children. All children received the nucleus multichannel cochlear implant. They were programmed with the speech processing strategy recommended at the time and upgraded with new encoding strategies as they became available.

2.2. Evaluation tests

Speech perception and speech intelligibility were determined at 3, 6, 9, 12, 18 months, 2, 3 and 5 years after implantation.

The speech perception was determined using three tests from the Test for the Evaluation of Voice Perception and Production [6]. The first test determines the closed-set word perception, the second the open-set word perception and the third one the open-set sentence perception. The choice of the words used varied according to the level of children’s language and not according to their age.

Speech production was determined using the Speech Intelligibility Rating (SIR) [7]. The SIR is a time effective global outcome measure of speech production in real-life situations. Each assessment was undertaken by the child’s own implant team speech (the evaluations were done by the same language therapist at each interval). The criteria used are described in Table 1.

3. Results

3.1. Evolution of speech perception after cochlear implantation

The results are resumed in Fig. 1. They are expressed in median percentages of good responses for every type of test.

The median percentage of closed-word speech perception (CSW) is 15.76% for 3 months post implantation; 54.26% for 1 year post implantation; 74.9% for 2 years post implantation; 88.13% for 5 years post implantation.

Table 1: Speech Intelligibility Rating (SIR) criteria

<table>
<thead>
<tr>
<th>Category</th>
<th>SIR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Connected speech is unintelligible. Prerecognizable words in spoken language, primary mode of communication may be manual.</td>
</tr>
<tr>
<td>2</td>
<td>Connected speech is unintelligible. Intelligible speech is developing in single words when context and lip-reading cues are available.</td>
</tr>
<tr>
<td>3</td>
<td>Connected speech is intelligible to a listener who concentrates on lip-reading.</td>
</tr>
<tr>
<td>4</td>
<td>Connected speech is intelligible to a listener who has little experience of a deaf person’s speech.</td>
</tr>
<tr>
<td>5</td>
<td>Connected speech is intelligible to all listeners.</td>
</tr>
</tbody>
</table>

Fig. 1: Evolution of mean perception according to time (CSW: closed-set words; CSS: closed-set sentences; OSS: open-set sentences).
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for 3 years post implantation; 89.95% for 4 years post implantation and 95.3% for 5 years post implantation.

There was a significant improvement of these performances between 3 months and 1 year ($P = 0.007$, test of Spearman), 1 and 3 years ($P = 0.001$), and 3 and 5 years post implantation ($P = 0.026$).

The median percentage of closed-sentence speech perception (CSS) is 14.8% for 3 months post implantation; 45.62% for 1 year post implantation; 72.42% for 2 years post implantation; 86.54% for 3 years post implantation; 90.83% for 4 years post implantation and 95.5% for 5 years post implantation.

There was a significant improvement of these performances between 3 months and 1 year ($P = 0.007$, test of Spearman), 1 and 3 years ($P < 0.001$), and 3 and 5 years post implantation ($P = 0.026$).

The median percentages of open-sentence speech perception (OSS) is 8.77% for 3 months post implantation; 16.54% for 1 year post implantation; 34.33% for 2 years post implantation; 58.56% for 3 years post implantation; 68.42% for 4 years post implantation and 76.3% for 5 years post implantation.

The improvement of this performances is not significant between 3 months and 1 year post implantation. However, there was a significant improvement of these performances between 1 and 3 years ($P = 0.0022$, test of Spearman), 1 and 3 years ($P < 0.0007$) and 3 and 5 years post implantation ($P < 0.0001$).

3.2. Evolution of speech intelligibility after cochlear implantation

The results are resumed in Fig. 2. They are expressed in median rating of intelligibility.

The median of Speech Intelligibility Rating is 1—3 months post implantation; 2—1 year post implantation; 3—2 and 3 years post implantation; 4—4 and 5 years post implantation.

There was a significant improvement of these performances between 3 months and 1 year ($P = 0.0038$, test of Spearman), 1 and 3 years ($P = 0.0001$) and 3 and 5 years post implantation ($P < 0.0001$).

Table 2 Numbers of children in each SIR category at 3 months, 1, 3 and 5 years after implantation

<table>
<thead>
<tr>
<th>Category</th>
<th>3 months</th>
<th>1 year</th>
<th>3 years</th>
<th>5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52</td>
<td>25</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>9</td>
<td>25</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>5</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>4</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
<td>60</td>
<td>48</td>
<td>29</td>
</tr>
</tbody>
</table>

($P = 0.0001$) and 3 and 5 years post implantation ($P < 0.0001$).

We have combined the categories 1 and 2 as unintelligible speech and the categories 3, 4 and 5 as intelligible speech. Three years post implantation, more than half of children has an intelligible speech (71%), 5 years post implantation, these categories concern 80% of implanted children with 34% which a Speech Intelligibility Rating maximum (SIR of 5) (Fig. 3, Table 2).

4. Discussion

This study reports the speech perception without lip-reading and the speech intelligibility of a group of 63 congenitally deaf children up to 5 years after implantation. The median percentage of closed-word perception increase of 16% of good responses at 3 months after implantation to 95% 5 years after implantation. Likewise, the median percentage of closed-sentence perception increase of 15—94% at the same delay and of 9—76% for the open-sentence perception. These data demonstrate the ability of these children to achieve significant and usable open-set perception following implantation. A lot of studies have also indicated
that congenitally or prelingually deaf children reach much higher levels of speech perception performances after implantation \[8,9\], especially in open-set tests \[10\]. O’Donoghue et al. \[11\] reported the closed- and open-set speech perception in a prospective study on a group of 119 congenitally and prelingually deaf children implanted. These children have developed significant closed-set speech perception abilities during the 3 years after implantation reaching a plateau after this date. Their ability to perform open-set tasks without lip-reading is limited in the first 2 years but shows significant improvement, not reaching a plateau at the 4–5 year interval after cochlear implantation. In the same way, Waltzman et al. \[10\] has studied the evolution of open-speech perception of 38 implanted children and demonstrated that the implantation provides significant and usable open-set speech perception. These results permit to the implanted children to use oral language as their sole means of communication. Richter et al. \[2\] showed the same results on 106 implanted children.

In order to evaluate these skills, a number of tests are available with largely similar contents \[12\]. In our study, the tests used are adapted to the children’s age but are limited by their difficulty. This notion is illustrated by the plateau which seems to be obtained after 5 years post implantation for the closed-set performances near for 100%. However, a longer evaluation must be done to confirm the evolution.

Quick progress is noted after implantation for the closed-set words and closed-set sentences. The open-set sentence perception develops later and seems to be significant after 1 year of implantation. The evolution of the perception acquisitions follows the difficulty of the tests, open-set speech perception is the more complex acquisition \[13\]. It has been shown in a number of studies published so far on this subject that the receptive skills are the most frequently applied criteria for the assessment of hearing and language progress after cochlear implantation. In our study, we have also evaluated the expressive language skill using the Speech Intelligibility Rating. Our results showed that 3 months after implantation the speech of the majority of implanted children is unintelligible to a listener who has a little experience of a deaf person’s speech even when their speech became intelligible 5 years after implantation (SIR median rating). If we want to compare these results with others speech intelligibility studies, we are limited by small subject groups, short follow-up or heterogeneity of children characteristics. In the study of Richter et al. \[2\], the mean values of speech production of 106 implanted children were significantly higher after implantation (2-year interval) than before implantation. One of the most comparable study is that of O’Donoghue and coworkers \[7\]. This study shows the evolution of the speech intelligibility evaluated with the SIR of a group of 118 implanted children until 5 years post implantation. The results are exactly the same as ours. In these two studies, intelligible connected speech began to develop around 3 years after implantation and continued to develop over the 5-year period. The decision to use a "real-life" descriptive rating scale was made because a practical clinical measure applies to all children and because the results are uniform, children have the same speech and language therapist at each evaluation.

5. Conclusion

The current study shows the significant development of the speech perception and the speech intelligibility of 63 congenitally and prelingually implanted children. The closed-set perception has progressed more quickly than the open-set. The speech intelligibility improves regularly during the 5 years after implantation and seems to continue progression after this interval.

References


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