Delays in Sound Recognition and Imitation in Underinsured Children Receiving Cochlear Implantation

McKenzie Tolan, BS; Andrea Serpas, BS; Katherine McElroy, CCC, SLP; Patricia Craun, AuD; Christine Williams, AuD; Brian K. Reilly, MD; Diego Preciado, MD, PhD

IMPORTANCE
Barriers to early pediatric cochlear implantation in underinsured populations have been previously reported. However, to our knowledge, the effect of this delay on the development of auditory and speech-language objectives has not been evaluated.

OBJECTIVE
To determine if health care insurance status affects the achievement of proficiency in basic sound access and imitation tasks in children with cochlear implants.

DESIGN, SETTING, AND PARTICIPANTS
A retrospective review of 123 children aged 1 to 12 years receiving cochlear implants at the single tertiary referral academic free-standing Children's National Health System in Washington, DC, between January 1, 2008, and December 31, 2015.

MAIN OUTCOMES AND MEASURES
Auditory function after cochlear implantation, time to proficiency in Ling-6 scores, and number of speech therapy and audiological appointments, as well as current educational setting, were compared with patient age at diagnosis of hearing loss, age at cochlear implantation, cochlear implantation insertion technique, and health care insurance status for recipients of cochlear implants.

RESULTS
A total of 123 children aged 1 to 12 years (mean [SD] age, 64.0 [57.4] years) with cochlear implants were included in the study. Of 37 patients with complete and accurate Ling-6 test scores, 23 (62.1%) were able to have proficiency a mean of 5.1 months at follow-up. Despite equal auditory performance on pure-tone audiometry after cochlear implantation, publicly insured recipients had Ling-6 proficiency a mean of 6.0 months (95% CI, 5.5-6.5 months) later than privately insured recipients (11.0 vs 5.0 months). When controlling for patient age, time to cochlear implantation, number of therapy sessions, and cochlear implantation insertion technique, multivariable logistic regression analysis revealed health care insurance status to be the independent variable associated with inadequate Ling-6 discrimination scores (odds ratio, 46.2; 95% CI, 2.9-729.4).

CONCLUSIONS AND RELEVANCE
Despite equal speech detection scores, publicly insured recipients of cochlear implantation had a significant and critical delay in attaining proficiency in a fundamental measure of sound recognition and imitation.

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Hearing loss is a common congenital sensory deficiency, affecting 1 in 1000 births. Cochlear implantation is one tool that can provide patients with profound sensorineural hearing loss (SNHL) access to sound and the potential to develop spoken language. Previous studies have shown that implantation by 12 months of age is critical for optimal language development in prelingual children with profound SNHL. Early implantation has enabled children to develop speech and language skills at rates comparable to those with normal hearing.

The importance of speech and language development in children with cochlear implantation is well documented. A solid foundation in language is critical to the development of literacy skills, which are an important determinant of educational performance. Thus, maximizing language development in patients with cochlear implants is crucial for improving their academic performance and professional future.

A wide variety of clinical evaluations can be used to assess speech and language. The Ling-6 sound test is a basic method to measure a patient’s auditory perception of 6 speech sounds, each at particular speech frequencies. Although originally developed as a clinical tool for helping with measuring auditory thresholds for infants using simple speech sounds, it is used by the speech and language pathologists at our center as a fundamental measure of the ability for a child to hear and, more important, imitate the 6 simple speech sounds included in the questionnaire. Despite clearly not being a functional language acquisition test, a child’s ability to detect, discriminate, and imitate these sounds is a precursor to the development of speech and language skills. If children cannot appropriately complete this process, there is a strong likelihood that their speech-language skills will be delayed or disordered as they get older.

Our group has previously reported obstacles to early implantation, finding public or no health care insurance to be associated with delayed implantation. These obstacles can delay identification of hearing loss and increase the time between recognition and implantation. However, it is not currently known how these delays affect subsequent auditory and speech-language skills after implantation.

We wanted to determine if health care insurance status affects the achievement of proficiency in basic sound access and imitation tasks in children with cochlear implantation. By identifying health care insurance as a potential obstacle to the development of these skills, alternative or additional strategies can be established to ensure that patients are receiving appropriate rehabilitation.

**Methods**

A retrospective analysis of children aged 1 to 12 years who received cochlear implants at Children’s National Health System in Washington, DC, between January 1, 2008, and December 31, 2015, was completed. Patients’ conditions were identified from an existing cochlear implant surgical registry. Institutional review board approval was obtained for this study from Children’s National Health System.

**Table 1. Demographics of Patients Receiving Cochlear Implants at Children’s National Health System**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>123</td>
</tr>
<tr>
<td>Age at implantation, mean (SD), mo</td>
<td>64.0 (57.4)</td>
</tr>
<tr>
<td>Health care insurance status</td>
<td></td>
</tr>
<tr>
<td>Public and/or none</td>
<td>78</td>
</tr>
<tr>
<td>Private</td>
<td>45</td>
</tr>
<tr>
<td>Race/ethnicity</td>
<td></td>
</tr>
<tr>
<td>African American</td>
<td>41</td>
</tr>
<tr>
<td>White</td>
<td>26</td>
</tr>
<tr>
<td>Hispanic</td>
<td>24</td>
</tr>
<tr>
<td>Other</td>
<td>32</td>
</tr>
<tr>
<td>Language</td>
<td></td>
</tr>
<tr>
<td>Prelingual</td>
<td>92</td>
</tr>
<tr>
<td>Postlingual</td>
<td>31</td>
</tr>
<tr>
<td>Time to cochlear implantation (prelingual), mean (SD), mo</td>
<td>29.5 (34.1)</td>
</tr>
</tbody>
</table>

*Data are given as number of patients unless otherwise noted.

Patient medical records were reviewed for age at diagnosis of SNHL, age at implantation, health care insurance status, educational setting, and the number of speech therapy and audiological appointments attended. The age at diagnosis of SNHL was determined from the first recorded auditory brainstem response showing SNHL. Age at implantation was based on the surgery date for children who received a unilateral cochlear implant or simultaneous bilateral cochlear implant or the date of the first cochlear implant surgery for those who received sequential bilateral cochlear implants.

Proficiency in the Ling-6 sound test for prelingual recipients of cochlear implants was determined based on reports from patient speech therapy sessions and was defined as 100% identification and imitation of all 6 Ling sounds. The speech-language pathologist evaluated and recorded patient performance. Auditory function after cochlear implantation was determined from cochlear implantation-assisted testing for speech reception threshold and pure-tone average results as documented by the audiologist. A speech reception threshold or pure-tone average of 20 dB (dB) or less, with 500, 1000, 2000, and 4000 Hz, was classified as auditory competence.

**Key Points**

**Question** Does insurance status affect time to proficiency in Ling-6 scores after cochlear implantation?

**Findings** In this medical record review, despite equal auditory testing after cochlear implantation, publicly insured children had Ling-6 proficiency a mean of 6 months later than privately insured children.

**Meaning** We have shown a correlation between patient health care insurance status and the achievement of proficiency in sound access and imitation tasks in our publicly insured cochlear implant population. These data suggest that certain populations may be at risk for language delay after implantation and, therefore, may require increased speech and language support.
A survival curve was created with Kaplan-Meier analysis and used to examine the documented time required to have auditory competence and proficiency in the Ling-6 test. Two-tailed t and Mann-Whitney tests were performed to determine if there were significant differences in Ling-6 proficiency as well as auditory competence between privately and publicly insured patients. χ² Tests were conducted, in which the outcome of each categorical variable was either enrollment in a mixed educational setting or a deaf and hard of hearing program. For multivariable analysis, logistic regression was performed with effect sizes reported as odds ratios with corresponding 95% CIs. A mixed educational setting was classified as either a regular school or a deaf and hard of hearing magnet program in a conventional school environment. A specialty deaf and hard of hearing program was defined as an institution designed exclusively for individuals with hearing loss. P < .05 was statistically significant.

Results

The records of 123 children aged 1 to 12 years with cochlear implants were identified and met inclusion criteria. Table 1 shows the demographic data of our patients. Ninety-two children were prelingual recipients of cochlear implants, whereas 31 received implants postlingually. Of these patients, 41 identified as being African American, 26 white, 24 Hispanic, and 32 were of other various ethnicities. Seventy-eight of our patients had public or no health care insurance. The mean (SD) age of patients at implantation was 64.0 (57.4) months. The mean (SD) time from diagnosis of SNHL to cochlear implantation in our 92 prelingual recipients was 29.5 (34.1) months. A statistical difference was observed in the mean time between diagnosis of SNHL and implantation for private vs publicly insured patients (28.2 [95% CI, 16.9-39.5] vs 41.0 [95% CI, 31.4-50.5] months; P = .01), consistent with previously published results.

Figure 1 shows the time for 112 recipients of cochlear implants to have auditory competence (defined as speech reception threshold or pure-tone average of ≤20 dB) after cochlear implantation. No significant difference was observed in the time required by publicly vs privately insured patients to have a speech reception threshold or pure-tone average 20 dB or less, with a median time to auditory competence of 7.9 (95% CI, 5.7-10.1) months for privately insured and 12.0 (95% CI, 7.4-16.5) months for publicly insured patients (P = .43). Furthermore, the mean number of audiological visits per month was similar between health care insurance groups.

Postimplantation analysis of Ling-6 proficiency concentrated exclusively on prelingual patients (n = 92), with implantation occurring before children had any oral speech and language abilities develop. Postlingual children were not included in further analyses because they may have had fundamental speech and language skills develop before implantation.

Of 37 patients with complete and accurate Ling-6 test scores, 23 (62.1%) were able to have proficiency a mean of 5.1 months at follow-up (Figure 2). Publicly insured recipients had Ling-6 proficiency with a mean of 6.0 months (95% CI, 5.5-6.5 months) later than privately insured recipients (11.0 vs 5.0 months). Despite this difference, the mean

Table 2. Postimplantation Rehabilitation Data

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. of Speech Therapy Visits per Month</strong></td>
<td></td>
</tr>
<tr>
<td>Insured, mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Publicly</td>
<td>2.1 (2.6-1.5)</td>
</tr>
<tr>
<td>Privately</td>
<td>1.8 (2.4-1.2)</td>
</tr>
<tr>
<td><strong>No. of Audiological Visits per Month</strong></td>
<td></td>
</tr>
<tr>
<td>Insured, mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Publicly</td>
<td>0.4 (0.2-0.5)</td>
</tr>
<tr>
<td>Privately</td>
<td>0.4 (0.3-0.7)</td>
</tr>
</tbody>
</table>

* A total of 76 settings were examined.
number of speech therapy sessions per month was similar between public and privately insured patients, with children with public health care insurance having a mean of 0.3 more sessions per month than those with private health care insurance (95% CI, 0.2-0.3) (2.1 sessions for private vs 1.8 for public) (Table 2).

Logistic regression multivariable analysis of independent variables potentially affecting Ling-6 proficiency was performed and is summarized in Table 3. Overall, public health care insurance status correlated the most with the inability to have Ling-6 proficiency, with an estimated odds ratio of 46.2 (95% CI, 2.9-729.4). Other independent variables analyzed included age at cochlear implantation (odds ratio, 1.0; 95% CI, 1.0-1.1), mean number of speech therapy sessions per month (2.8 [0.8-9.7]), months between SNHL identification and cochlear implantation (1.0 [1.0-1.0]), months to auditory competence (1.1 [0.9-1.3]), and insertion technique (2.6 [0.2-29.6]).

Table 2 reveals that the rate of publicly insured patients aged 5 to 18 years enrolled in a specialty school for hearing loss was 33% lower than it was for privately insured patients (8% [4 of 48] for public and 41% [7 of 17] for private).

Table 3. Multivariable Analysis of Variables on Ling-6 Proficiency

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value (SE)</th>
<th>Odds Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-5.7 (2.3)</td>
<td>-</td>
<td>.01</td>
</tr>
<tr>
<td>Age at cochlear implantation</td>
<td>-0.0 (0.0)</td>
<td>0.1 (1.0-1.1)</td>
<td>.91</td>
</tr>
<tr>
<td>Mean No. of speech sessions per month</td>
<td>1.1 (0.6)</td>
<td>2.8 (0.8-9.7)</td>
<td>.09</td>
</tr>
<tr>
<td>Months between hearing loss ID and cochlear implantation</td>
<td>0.0 (0.0)</td>
<td>1.0 (1.0-1.1)</td>
<td>.39</td>
</tr>
<tr>
<td>Months to auditory competence</td>
<td>0.1 (0.1)</td>
<td>1.1 (0.9-1.3)</td>
<td>.26</td>
</tr>
<tr>
<td>RW insertion</td>
<td>0.9 (1.3)</td>
<td>2.6 (0.2-29.6)</td>
<td>.46</td>
</tr>
<tr>
<td>Health care insurance</td>
<td>3.8 (1.4)</td>
<td>46.2 (2.93-729.4)</td>
<td>.01</td>
</tr>
</tbody>
</table>

Abbreviations: ID, identification; RW, round window insertion.

Discussion

The benefits of early implantation for speech and language development have been well documented.2,6,9 However, to our knowledge, whether certain obstacles with this procedure continue to influence postimplantation auditory and speech-language development has not been investigated. Analysis of our prelingual children with cochlear implants revealed that health care insurance status affects the achievement of speech and language goals postimplantation.

When examining the auditory performance of patients after implantation, we discovered no statistical difference in the time required for publicly and privately insured children to have auditory competence. Furthermore, the mean number of audiological visits per month was statistically similar, which suggests comparable levels of hearing in our patients.

The auditory performance between the 2 health care insurance populations did not result in similar speech and language outcomes as measured on the Ling-6 sound test. We observed a significant delay in publicly insured patients having proficiency in the Ling-6 sound test. Furthermore, a higher percentage of the publicly insured population did not have this basic speech and language goal (61% [14 of 23] public vs 14% [2 of 14] private) in a mean follow-up of 14 months. Because the Ling-6 sound test is a precursor necessary, but not sufficient, for future speech-language development, it does not concentrate on patient proficiency in more complex linguistic measures, such as conversational competency, expressive and receptive language, and comprehension. However, the delay observed in acquiring these basic speech and language skills correlates with deficits in patients having age-appropriate linguistic competence. Without the appropriate intervention, the implications of this delay are profound, including, but not limited to, decreased academic performance and employment opportunities.5

The mean number of speech therapy visits per month was similar between our privately and publicly insured patients, which suggests that the number of visits is not affected by health care insurance status. Furthermore, results of multivariable analysis indicate that health care insurance status also
Thus, the adapted hearing services offered by these institutions were designed for hearing loss. The analysis revealed that a higher percentage of privately insured patients were enrolled in a special school for hearing loss. Based on an educational setting, our recipients of cochlear implantation depend on the type of education they receive.10 Based on an educational setting, our analysis revealed that a higher percentage of privately insured patients was enrolled in a specialty school for hearing loss. Thus, the adapted hearing services offered by these institutions are less available to our publicly insured patient population, which we have determined to be at risk for delays in speech and language development. Furthermore, it is possible that some of these children may be enrolled in a regular school setting before their auditory and linguistic skills have developed for them to succeed in that environment, thus perpetuating their delay.

Limitations of this study include the retrospective type and small sample size; a longitudinal investigation of the data with a larger population would provide more reliable results. Furthermore, additional factors affecting auditory performance after implantation, such as preimplant residual hearing, outside hearing loss resources used, and socioeconomic status, should be examined. The auditory and Ling-6 test scores were characterized subjectively because we depended on the audiologists’ and speech-language pathologists’ interpretation of patient performance. The abundance of language in the patient’s home and educational level of the parents also were not analyzed in this study. More important, the Ling-6 is not an exact test of language function; therefore, our study would be improved if we had data of stronger language testing performed in the same cohort of children.

Conclusions

The development of auditory, speech, and language skills after cochlear implantation is critical for successful outcomes. We have shown a correlation between patient health care insurance status and the achievement of proficiency in sound access and imitation tasks in our publicly insured population. From the data collected, it is unclear from where this correlation is coming, particularly whether the health care insurance status is an indication of fewer supplemental support services or variations in home language involvement and exposure. However, it is critical for caregivers and health care professionals to identify this discrepancy. By recognizing at-risk patients and using methods to assist them, we may be able to reduce the effect of this delay.

ARTICLE INFORMATION

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Author Contributions: Drs Preciado and Reilly had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Preciado.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Tolan, Serpas, Preciado.
Critical revision of the manuscript for important intellectual content: Tolan, McElroy, Craun, Williams, Reilly, Preciado.
Statistical analysis: Tolan, Serpas, Preciado.
Administrative, technical, or material support: Serpas, McElroy, Williams, Reilly, Preciado.
Study supervision: Preciado.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Williams reported receiving personal fees from Advanced Bionics. No other disclosures were reported.

REFERENCES