Auditory Skills Checklist: Clinical Tool for Monitoring Functional Auditory Skill Development in Young Children With Cochlear Implants

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**Objectives:** The Auditory Skills Checklist® (ASC) was developed to address the need for tools to evaluate functional auditory skill progress in very young children with sensorineural hearing loss. We describe the development, validation, and utility of the ASC for use in young children with cochlear implants.

**Methods:** Using the ASC, we measured auditory skills in 37 subjects who received cochlear implants at no more than 36 months of age. Repeated measures analysis was conducted to determine expected auditory skill development after implantation. Interrater reliability was tested on a small subset. The ASC was compared to the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) to determine its validity in measuring functional auditory skills.

**Results:** The ASC had excellent internal consistency (Cronbach’s alpha, 0.98) and interrater reliability (intraclass correlation coefficient, 0.99), and was highly correlated with the IT-MAIS (r = 0.90). According to the repeated measures analysis, children who received a cochlear implant at 36 months of age or earlier were expected to increase their ASC score by 8 points every 3 months (beta coefficient, 8.3; p < .001).

**Conclusions:** The ASC is a clinically relevant and easily administered tool for assessing the functional auditory skills of young children with a cochlear implant. By assessing auditory skill development over time with the ASC, we can better realize expectations for a particular child based on his or her age, hearing loss level, and management strategies in place.

**Key Words:** cochlear implant, functional auditory skill, young child.

**INTRODUCTION**

As universal newborn hearing screening has been implemented in more than 92% of infants born in the United States, the early identification of infants with significant congenital hearing impairment has dramatically improved. As a result, clinicians are now confronted with the challenges of accurately and rapidly evaluating these infants with sensorineural hearing loss to provide them with early intervention that will allow them to develop age-appropriate language skills. However, this young population of infants and toddlers poses challenges to audiologists, speech pathologists, and early intervention providers in definitively determining what early auditory-verbal and language capabilities a very young child possesses and whether interventions are yielding the anticipated progress. The imperative to better assess infants and toddlers at even younger time points (eg, within the first 6 to 12 months of life) is made even more pressing by the clinical option of early cochlear implantation at 12 months of age or earlier. As a result of this movement toward very early cochlear implantation for some children with severe-to-profound hearing losses, the need for a valid and effective assessment tool that can be used at very early ages has become apparent. The Auditory Skills Checklist® (ASC) was developed and validated in order to address this specific need.

The American Speech-Language-Hearing Association Guidelines for the Audiologic Assessment of Children from Birth to 5 Years of Age encourage the inclusion of an age-appropriate functional auditory assessment. However, a limited number of tools exist to evaluate functional auditory skill progress in very young children with sensorineural hearing loss. Functional assessments are particularly important for children who have difficulties completing standardized testing, such as very young children and children with additional disabilities.

The ASC is a criterion-referenced assessment...
TABLE 1. QUESTIONS ON AUDITORY SKILLS CHECKLIST

DETECTION

Does your child...
1. wear the amplification device during his/her waking hours?
2. use body language to indicate when something is heard (ex. Turn head, and/or eye widening, quiets, stops action, changes facial expressions)?
3. show awareness (turns to the sound source, alerts or quiets in response to loud sound) of loud environmental sounds (ex. Dog barking)?
4. show awareness of soft environmental sounds (ex. microwave bell, clock ticking)?
5. show awareness of voices, spoke at typical loudness levels?
6. detect the Ling Six Sounds (M, AH, OO, E, SH, S)?
7. detect the speaker’s voice when background noise is present?
8. search to find out where a sound is coming from?
9. localize correct sound source (to the direction the sound is coming from)?

DISCRIMINATION

Does your child...
10. discriminate the voice of a speaker talking and sounds in his/her environment?
11. discriminate different types of environmental sounds (ex. dog barking versus a telephone ringing)?
12. discriminate a speaker using a soft voice (whisper) and a loud voice (conversational level)?
13. discriminate a person singing (ex. “Happy Birthday”) from a person having a conversation?
14. discriminate family members voices (ex. Dad’s voice versus Mom’s voice versus a sibling’s voice)?
15. discriminate minimal pair words (Similar sounding words such as pat, bat, and mat)?
16. discriminate similar sounding phrases and sentences (ex. “How old are you?” versus “How are you?”)?

IDENTIFICATION

Does your child...
17. identify his/her name when called?
18. identify an item with an associated sound (ex. a train goes choo choo)?
19. identify one-syllable words versus two and three-syllable words (ex. ball vs. hotdog vs. computer)?
20. understand if the speaker is happy, angry, or surprised by the change in their vocal tones?
21. identify or recognize commonly used words (varies from child to child)?
22. identify the Ling Six Sounds (M, AH, OO, E, SH, S)?
23. identify familiar songs (ex. “Happy birthday”, “Itsy Bitsy Spider”, “Old McDonald”)?

COMPREHENSION

Does your child...
24. follow one-step directions (ex. “Get your shoes.”)?
25. follow two-step directions (ex. “Get your shoes and open the door.”)?
26. follow three-step directions (ex. “Get your shoes, open the door, and walk outside.”)?
27. have an auditory memory for # items (ex. being able to remember boat, apple, cup, and shoe would be 4 items)?
28. have an auditory memory for phrases/sentences (ex. “The girl jumped over the fence to get the ball.”)?
29. auditorily sequence a story with # events, #4 events, #4+ events (ex. 1st event = Steve went to the store; 2nd event = He bought dog bones; 3rd event = Steve took the bones home to the dog)?
30. understand the question forms _ What, _ Where, _ Who, _ Why, _ When (ex. “Where is the dog?”; “Who broke the cup?”)?
31. understand concepts in phrases and sentences (ex. in, under, between, in front)?
32. understand the use of negatives in phrases and sentences (ex. no, not, no more)?
33. understand frequently heard phrases/sentences (ex. “Brush your teeth and get ready for bed.”)?
34. acquire information incidentally through audition alone?
35. understand most of what is said through audition alone?

A tool that uses a combination of a structured parent interview and clinician observation to obtain information about functional auditory skill development (Table 1). This tool was based on theory of auditory skill development, current evaluation tests, and clinical experience. The ASC is administered to a child over time to clinically track a child’s progress, monitor effectiveness of amplification, and identify a loss of skills due to a progressive hearing loss. On the basis of combined information from both the parent and the examiner, the examiner assigns a rating regarding the child’s skill: 0, does not have the skill; 1, emerging skill development; 2, consistently demonstrates skill.
The objective of this article is to describe the development and utility of a recently developed checklist for measuring functional auditory skills in children with hearing impairment.

METHODS

ASC Development. In order to select an appropriate set of items that accurately detect a wide range of auditory skills, we developed the ASC on the basis of a review of relevant literature, current standard test measures, and expert clinical judgment from a multidisciplinary team consisting of audiologists, aural rehabilitation therapists, a speech pathologist, a developmental pediatrician, and a pediatric otologist. The items on the ASC were evaluated, and those that were deemed as not having strong clinical relevance to the population were eliminated. The final checklist consisted of 35 items representing 4 domains: detection (9 items), discrimination (7 items), identification (7 items), and comprehension (12 items).

ASC Administration. Children enrolled in aural rehabilitation therapy have baseline auditory skills evaluated by standardized test protocols. These tests may provide information that can become the basis for initial skills entered on the ASC. Additionally, behaviors and skills observed during testing or interactions with the child were also entered on the checklist. Parent reports of a child’s current skills in natural settings also contributed to the scoring. The ASC was administered without reliance on other test results, and thus the need for a child to have the ability to complete standardized testing was eliminated. The full administration of this tool takes approximately 10 minutes to complete, with less time required for very young children.

Reassessment at 3-month intervals was conducted to follow the progression of auditory skill development, although our clinicians also administered the tool more frequently when it was deemed necessary (e.g., suspected loss in auditory skills). Regardless of a child’s achieving a particular auditory skill on the ASC, each question was completed during each administration to ensure that no loss of skills had occurred. Limited progress after 3 to 6 months of intense therapy may be an indication that the child should be considered for alternative therapeutic methods such as candidacy for a cochlear implant or methods that include more visual information for communication (i.e., sign language or cued speech).

At the time of administration, each item of the scale was rated as one of the following: does not have skill, emerging skill, and developed skill. These levels of skill were then quantified respectively as 0, 1, or 2. The 35 questions on the ASC were quantified to yield a total possible raw score of 70, with a range of the total score to fall between 0 and 70 (detection = 18 points, discrimination = 14 points, identification = 14 points, comprehension = 24 points). Higher scores reflect higher or more-developed functional auditory skills.

This study was divided into 3 phases: 1) a validation study of the ASC in measuring auditory skills in toddlers and young children; 2) a reliability study; and 3) a description of use of the ASC for young children who had received a cochlear implant.

Study Subjects. Subjects were included in this retrospective study if they were born between January 1, 2001, and December 31, 2005, and had received a cochlear implant before 36 months of age. Although the ASC was designed to monitor development among children with all forms of hearing impairments, this analysis was focused on a subset of children who had received cochlear implants. Parents were recruited for the reliability study if their children were seen at our institution for aural rehabilitation. With the exception of the reliability study, data were extracted from a database containing ASC information and from charts containing audiological information. This study was approved by the Institutional Review Board at Cincinnati Children’s Hospital Medical Center.

Validity. In the initial assessment of the validity of the ASC, we investigated the association of ASC scores with the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS).6,9 A commonly employed auditory assessment tool. The IT-MAIS is similar to the ASC in that it also measures auditory behaviors regarding environmental and speech sounds on the basis of parental report. The IT-MAIS uses a structured interview technique to obtain information about the frequency with which a child demonstrates auditory and speech behaviors through the use of 10 questions or probes. In our institution, both the IT-MAIS and the ASC are administered as part of the routine cochlear implant candidacy process. Pearson’s coefficients were used to examine the correlations between the ASC scores and the IT-MAIS scores. Higher scores reflect higher or more-developed auditory skills on either tool. Children were included in this part of the study if they had both ASC and IT-MAIS scores that were administered within a span of 1 month.

Reliability. Internal reliability, or internal consistency, was determined by use of Cronbach’s alpha for the 35 items on the ASC, as well as the separate domains of the ASC (detection, discrimination, identification, comprehension). Cronbach’s alpha is a statistic with a range of 0 to 1 that is used to deter-
mine whether a set of questions measure the same idea.\textsuperscript{10}

To assess interrater reliability, we conducted a small study to determine whether the ASC is interpreted the same way with 2 different therapists. An initial rater administered the ASC at the beginning of a therapy session, and a second rater, who had never seen the subject, readministered the tool at the end of the session. The second rater had no exposure to the ASC before this study and was given brief instructions (approximately 20 minutes) on how to administer the tool. Eight subjects completed this phase of the study. The kappa statistic, which can be used when there are 2 or more raters and when there are 2 or more outcome categories, was used to assess the measure of agreement between these 2 raters with individual checklist items. Kappa values vary from $-1$ to $1$, where $+1$ indicates complete agreement, 0 indicates chance agreement, and values less than 0 indicate agreement less than chance alone. Excellent agreement is considered at a kappa value of more than 0.75, and good agreement is considered at a kappa value of at least 0.6.\textsuperscript{11} For the total ASC score, intraobserver correlations were assessed by calculating the intraclass correlation coefficient.

\textbf{Auditory Skill Development Over Time.} The medians and interquartile ranges for the overall ASC score and the scores for each individual domain were calculated at each postimplantation time point. A repeated measures model (generalized estimating equations) was used to estimate the expected auditory skill progression, or trajectory, over time after cochlear implantation (description phase). Auditory skill development was evaluated before implantation and every 3 months thereafter for up to 18 months after implantation. The results of the model were reported as beta coefficients (standard errors), which were interpreted as a rate of auditory skill development progression over time. Other variables, such as age of implantation, age of hearing loss identification, race, sex, and the existence of an additional disability, were all evaluated as potential confounders that influence auditory skill development over time. The purpose of this analysis was to understand how the ASC measures auditory skill development over time. The regression results surrounding other covariates or confounders were beyond the scope of this particular study, although they will be reported as part of another study.

\textbf{RESULTS}

\textit{Study Subjects.} Forty-three subjects were identified as being eligible for this analysis. Five subjects were excluded because they received their aural rehabilitation therapy elsewhere, and 1 subject was excluded because the implantation had taken place at another institution and the subject only received some therapy at our institution. A total of 37 subjects were thus included in this retrospective study. The median age of hearing loss identification for this cohort was 4.5 months (range, 0 to 25 months) and the median age of cochlear implantation was 16.3 months (range, 12.3 to 35.6 months). A little over half of the cohort was female (57%), and most were white (89%), with 5.4% (n = 2) African-American and 5.4% (n = 2) of other races. Fifteen subjects (41%) had a disability in addition to their hearing loss. These disabilities were quite variable, including cognitive delays, cerebral palsy, autism spectrum disorder, vision impairment, and mild motor coordination difficulties.

\textit{Validity Study.} Twenty-three subjects (62%) had both ASC and IT-MAIS data available for the analysis, and 12 subjects had more than one IT-MAIS evaluation on file, for a total of 40 evaluations. There appeared to be no differences between subjects who had IT-MAIS data available and those who did not with regard to age at implantation, gender, or race. Pearson’s coefficients were used to examine the association between the scores on the ASC and the scores on the IT-MAIS for each child. The correlation between the ASC and the IT-MAIS was high ($r = 0.90$; $p < .0001$). Figure 1 illustrates this relationship. When we analyzed the most recent scores available for each child ($n = 23$), the correlation coefficient remained high ($r = 0.87$; $p < .0001$).

\textit{Reliability Study.} Internal consistency was assessed by Cronbach’s coefficient alpha. The ASC was found to have an overall reliability of 0.98, which is an extremely high reliability coefficient, greater than Nunnally’s suggested value of 0.70.
### TABLE 2. MEDIANs AND INTERQUARTILE RANGES OF AUDITORY SKILLS CHECKLIST SCORES OVER TIME

<table>
<thead>
<tr>
<th>Months After Cochlear Implantation</th>
<th>Detection</th>
<th>Discrimination</th>
<th>Identification</th>
<th>Comprehension</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>12 (10-17)</td>
<td>3.5 (0-7)</td>
<td>1 (0-4)</td>
<td>0</td>
<td>16 (12-26)</td>
</tr>
<tr>
<td>6</td>
<td>20 (12-18)</td>
<td>8 (3-10)</td>
<td>6 (1.5-8.5)</td>
<td>0.5 (0-4)</td>
<td>34.5 (20-40)</td>
</tr>
<tr>
<td>9</td>
<td>14 (15-18)</td>
<td>9.5 (4-10)</td>
<td>7 (4-8)</td>
<td>1 (0-5)</td>
<td>36 (29-40)</td>
</tr>
<tr>
<td>12</td>
<td>10 (17-18)</td>
<td>10 (7-13)†</td>
<td>10.5 (7-13)§</td>
<td>6.5 (1-12)</td>
<td>47.5 (41-51)</td>
</tr>
<tr>
<td>15</td>
<td>5 (17-16.5)</td>
<td>10.5 (10-12)</td>
<td>13.5 (12-14)</td>
<td>11.5 (9-15.5)</td>
<td>55 (37-63)‡</td>
</tr>
<tr>
<td>18</td>
<td>5 (18-17.8)</td>
<td>10 (10-12)</td>
<td>14 (8-14)§‡</td>
<td>14 (9-15)</td>
<td>57 (51-57)</td>
</tr>
</tbody>
</table>

Maximum score
Interquartile ranges are in parentheses.

*Total number of subjects who had Auditory Skills Checklist information at this postimplantation time point.
†Total range is shown; interquartile range for discrimination is 10-10.
§Total range is shown; interquartile range for total score is 55-55.
‡Total range is shown; interquartile range for identification is 14-14.

This coefficient remained high when we assessed internal consistency with each of the 4 domains (range, 0.91 to 0.96). On a sample of 8 parents, retesting by a different examiner (audiologists, nontherapists) occurred at the end of a therapy session. Of all of the questions administered on the ASC, 55% of the questions had perfect agreement, and the vast majority had kappa values of greater than 0.75 (excellent agreement). The intraclass correlation coefficient between 2 different raters was 0.99 (95% confidence interval, 0.98 to 0.99), indicating a high degree of repeatability with regard to the total ASC score.

**Auditory Skill Development Over Time.** The ASC was used to measure functional auditory skills before implantation and auditory skill progress after implantation on the 37 study children who had received a cochlear implant before 36 months of age. The median preimplant ASC score for this population was 3 (interquartile range, 2 to 6.5), with 75% of the population scoring 6 or below (Table 2). Four children (11%) had skills that were above detection skills according to the ASC. At 3 months after implantation, the median score for the group increased to 16 (interquartile range, 12 to 26). Scores beyond 12 months after implantation should be interpreted with caution, as the number of subjects who contributed auditory skill information at those time points was fairly limited.

Repeated measures analysis was conducted to determine the expected auditory skill progression as measured on the ASC for children who have received a cochlear implant. Functional auditory skill data were available for up to 18 months after implantation. The results are reported as beta coefficients and standard errors. The beta coefficient represents the expected change in the ASC score over time. A positive number indicates an increase over time, and a negative number indicates a decrease in scores over time. The results of the regression analysis, after controlling for the age of the child at the time of hearing loss identification and whether the child had an additional disability, indicated that children who received a cochlear implant before 36 months of age were expected to increase their ASC score by approximately 8 points every 3 months (beta coefficient, 8.3 [SD, 0.58]; p < .0001). The age of the child at the time of implantation was not statistically significant in the analysis. When we analyzed the change in ASC scores separately for each 3-month postimplantation assessment, the largest increase in skills appeared to have occurred within the first 6 months after implantation (Fig 2). Figure 3 shows the median scores and interquartile ranges over time for the cohort of children, divided into the individual domains of detection, discrimination, identification, and comprehension.

**DISCUSSION**

The ASC has been shown to be a clinically relevant and easily administered tool for assessing the functional auditory skills of young children who...
have received a cochlear implant. The ASC has excellent interrater reliability within a small sample of parents, and excellent validity when compared to the commonly used IT-MAIS, a tool also designed to measure auditory skills in children who have received implants. It is also important to note that in this context, in which most existing tools have not been validated in very young children, validity studies are challenged by the fact that there are no measures that can be held in comparison as the "gold standard" for a newly developed tool.

The results from our current study provide guidance with regard to the functional auditory skill development that should be expected from most children who have received a cochlear implant by 36 months of age. However, differences in progress do exist with different subsets of children with hearing loss. Children who have a coexisting disability in addition to deafness have different auditory skill expectations that were not addressed in this particular study. We intend to address this topic in a parallel study on the expectations of postimplant auditory outcomes among children with additional disabilities. We also did not investigate age-specific ASC scores in this study. Our current sample size of young children with implants was not large enough to confidently address any potential age-specific scores. However, as we continue to monitor the auditory skill progress among this population, more data will soon be available for this discussion.

We have found the use of information obtained by parent report to be helpful in assessing a child's abilities in more "typical" or home environments (as compared to the clinical setting) and have also used this information to design interventions and therapy that are more relevant to a specific child's natural environment. In several instances, information from parents has been integral in initiating evaluations that subsequently identified other developmental disabilities. Furthermore, because of the dearth of information that can be obtained from infants and very young toddlers, parent report is a well-established technique that has been used in many behavioral, emotional, and language screens and evaluations with fairly good sensitivity and specificity for the issues being evaluated. In addition, the ASC solicits information from parents regarding a child's current skills and abilities. Studies examining this type of data acquisition show that parents are most accurate when asked about a child's current skills as compared to their recollection of developmental milestones. On the basis of these studies as well as our clinical experience, we believe that families can become quite accurate in their descriptions of their child's auditory skill progress and are valuable sources of information concerning these very young patients. Future studies would validate the accuracy of a parent’s ability to describe auditory skill progress.

The comparison of the ASC with the IT-MAIS provides evidence supporting the validity of the ASC in measuring auditory skills in young children who have received cochlear implants. However, the ASC allows for a more detailed assessment of smaller increments of change in auditory skills, giving credit for responses to sound through changes in body language, detection of the Ling Six Sounds, and responses to voice detected in background noise. Because this tool measures higher auditory skill sets, its utility lasts beyond that of the IT-MAIS, and it thus provides a bridge to more formal assessment measures. In our study, children who were achieving a high level of auditory skills as reported on the IT-MAIS (with scores of at least 35) still had room for significant progress to be made according to the ASC, particularly with the higher-level skills of comprehension (Fig 1). The ASC is not meant to replace standardized assessment batteries, but to enhance the understanding of auditory progress at more frequent intervals without spending the majority of a therapy session on assessment. Therapists and early intervention providers have also found the ASC helpful in developing goals for therapy.

Although this study focused on young children who have received a cochlear implant, our institution has been using the ASC to test all children with various degrees of hearing loss who have been seen in aural rehabilitation therapy. Within the course of clinical care, the ASC has been able to detect progressive hearing loss, allowing the therapist to reevaluate intervention strategies. It has application in specialized populations, such as children too young for standardized testing and children with additional
disabilities. This application of the ASC is particularly important because of the lack of tools for measuring auditory skills, as well as the paucity of validation studies, in this population of children.

It is important to gain a better understanding of the variability in progress of auditory skills in children with sensorineural hearing loss, particularly very young children. By assessing auditory skill trajectories (skill development over time) as measured by the ASC, we can better realize expectations for a particular child based on his or her age, hearing loss level, and management strategies in place. Further studies are warranted to determine what can be considered as “appropriate” or adequate auditory skill developmental progress for an individual child, which would assist clinicians in making early management and intervention decisions.

REFERENCES


