CHAPTER FIVE

Monitoring Outcomes of Infants and Children Who Wear Hearing Aids

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Abstract

Outcome measurement is a key component of the pediatric hearing aid fitting process that is often overlooked in clinical practice. An understanding of the types of outcome measures and how they can be implemented with children of various age groups and developmental abilities is necessary for successful clinical implementation. This chapter provides an overview of subjective and objective outcome measures used in our program with infants and children who wear hearing aids. The University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP) is a recently-developed guideline for evaluating auditory-related outcomes in infants and young children who wear hearing aids. It consists of functional outcome tools in the form of caregiver report questionnaires. These are supported by each child's hearing aid fitting information (i.e., Speech Intelligibility Index [SII]). The Ling 6(HL) detection task and the UWO Plurals test are a subset of tests derived from laboratory tasks that focus on the detection of speech sounds. These outcome measures have calibrated stimuli recorded on a compact disk for use with clinical equipment. The details of these tools will be discussed in order to support their inclusion in routine clinical practice.

The process of pediatric hearing aid fitting consists of sequential stages to support evidence-based intervention. For infants and children identified as having permanent hearing loss these steps include: the accurate assessment of hearing and ear canal acoustics, calculation of prescriptive targets, the selection of hearing aids and verification that the prescriptive targets are being approximated. Suitable technology and evidence-based hearing aid fitting protocols support the accurate and safe application of these stages (e.g., American Academy of Audiology [AAA], 2013; Bagatto, Scollie, Hyde & Seewald, 2010; King, 2010). Another important aspect of the pediatric hearing aid fitting process is assessing the device(s) effectiveness in daily life. Monitoring functional auditory outcomes of infants and children who wear hearing aids has been supported as a critical component of hearing aid intervention for infants and children (Joint Committee on Infant Hearing [JCIH], 2013). Hearing aid outcome measurement can lead to a better understanding of the infant's auditory progress, better family engagement and improved collaboration with other professionals. It may also assist with detecting issues with progress by identifying potential concerns before speech and language development is significantly affected. Outlining specific strategies to assess hearing aid(s) effectiveness in daily life may also facilitate the evaluation of overall Early Hearing Detection and Intervention (EHDI) program outcomes.

When considering clinical outcome measurement tools, it is important to keep in mind several factors. Firstly, ensure that the tools are suitable for the target population (i.e., infants and children who wear hearing aids). They should also be suitable for administration and interpretation by the managing audiologist to support successful clinical uptake. Statistical properties such as normative values, validity and reliability of the outcome measurement tools facilitate accurate interpretation of functional auditory outcomes. Finally, the clinical feasibility of an outcome measurement tool is a critical component of achieving the validation stage of the hearing aid fitting process. Outcome measurement tools should not be too time consuming for the clinician or child/family to complete and should result in meaningful information that can support the overall pediatric hearing aid fitting process. Tools that are appropriate for the developmental level of the child will also enable the application of outcome measures in a clinical context.

Outcome measurement tools can be designed to require the child's direct participation or use observation through caregiver report. An example of a tool requiring participation is the child's responses to low-level speech sounds in a sound treated room while wearing hearing aids. Also known as an objective measure, this strategy provides the clinician and family with an immediate demonstration of the child's auditory function in a clinical setting. The success of objective outcome measurement relies on the child's developmental level, mood and their ability to perform the task reliably for a period of time. In contrast, caregiver reports in the form of questionnaires offer a description of the child's real-world auditory function. These subjective measures can be completed independently by the caregiver in the waiting room or while the clinician is assessing the child's hearing aids. The developmental level of the child does not limit the completion of the tool. As a result, there is an opportunity to obtain a description of the auditory function of children with complex needs. Furthermore, it is important to administer questionnaires in the native language of the family and this may pose a barrier for some tools. However, offering interpretation services or a translated version of the questionnaire can alleviate this obstacle. For families with literacy issues, completing the questionnaire interview-style will gather the needed information to describe the child's auditory function. A multifaceted approach to monitoring outcomes of infants and children who wear hearing aids provides caregivers and clinicians with a way to describe the child's auditory function through the early months and into the later years of hearing aid use.

The purpose of this article is to outline some available outcome measurement tools that possess the necessary characteristics to support successful clinical administration and interpretation within the pediatric hearing aid fitting process. Both subjective and objective outcome measurement tools will be described, to cover a variety of strategies with which to monitor the auditory function of infants and children who wear hearing aids.

The University of Western Ontario Pediatric Auditory Monitoring Protocol

An outcome measurement guideline for use with infants and children six years of age and younger is available for clinical use. The University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP) was developed and evaluated with the participation of a network of pediatric audiologists (Bagatto, Moodie & Scollie, 2010; Bagatto, Moodie, Malandrino, Richert, Clench & Scollie, 2011; Moodie, Bagatto, Miller, Kothari, Seewald & Scollie, 2011). In the development of these tools, the appropriate statistical properties were considered along with clinical feasibility and utility. The result is a guideline that has been implemented in a clinical context with few barriers. The UWO PedAMP consists of several tools that aim to measure auditory-related outcomes in infants and children who have permanent hearing loss and may or may not wear hearing aids. Specifically, these tools: 1) assess early auditory development and performance; 2) describe the acceptance and use of hearing aids; and 3) define the effectiveness of service delivery. The questionnaires are supported by each child's hearing aid fitting information (i.e., real-ear-to-coupler difference (RECD), Speech Intelligibility Index [SII]) so that the quality of the hearing aid fitting can be involved in the overall interpretation of the functional outcomes obtained through the questionnaires. To maximize efficiency and clinical interpretation of results, visual tools to permit rapid scoring and data to support interpretation are available. A training manual, score sheets and a list of pertinent publications can be found at www.dslio.com.

The specific outcome measurement tools included within the UWO PedAMP are listed in Table 1. The Amplification Benefit Questionnaire is a satisfaction survey which assesses the caregiver's acceptance and use of hearing aids and overall satisfaction with the management services provided (Bagatto et al., 2010). It consists of eleven items using a five-point rating scale. Normative values or a score sheet are not currently available; efforts are in progress to examine caregiver responses from an EHDI program in Ontario, Canada.

The LittlEARS Auditory Questionnaire (Tsiakpini, Weichbold, Kuehn-Inacker, Coninx, D'Haese & Almadin, 2004) is a 35-item questionnaire that assesses receptive

Tool	Purpose	Description
Amplification Benefit Questionnaire	• Acceptance & use of hearing aids • Satisfaction with services	11 items 5 point rating scale
Hearing Aid Fitting Details	• Quality of hearing aid fitting	RECD, MPO, Speech Intelligibility Index (SII)
LittlEARS Auditory Questionnaire ***Tsiakpini et al, 2004***	• Receptive & semantic auditory behaviour • Expressive vocal behaviour	35 items Yes/no response
Parents' Evaluation of Aural/Oral Performance of Children (PEACH) ***Ching & Hill, 2005***	• Communication in quiet & noise • Responsiveness to environment	13 items 5 point rating scale

Table 1: Outcome measurement tools included within the UWO PedAMP.

and semantic auditory behaviors and expressive vocal behavior. The caregiver responds to a yes/no paradigm and the overall score is compared to average and minimum age-dependent values which have been validated in several languages (Coninx, Weichbold, Tsiakpini et al., 2009; Bagatto, Brown, Moodie & Scollie, 2011; Wang, Sun, Liang, Chen & Zheng, 2013). An example of an infant's outcome on the LittlEARS Auditory Questionnaire is presented in Figure 1. Since the score is within the 95% confidence intervals, it can be concluded that the child is meeting auditory development milestones for her age.

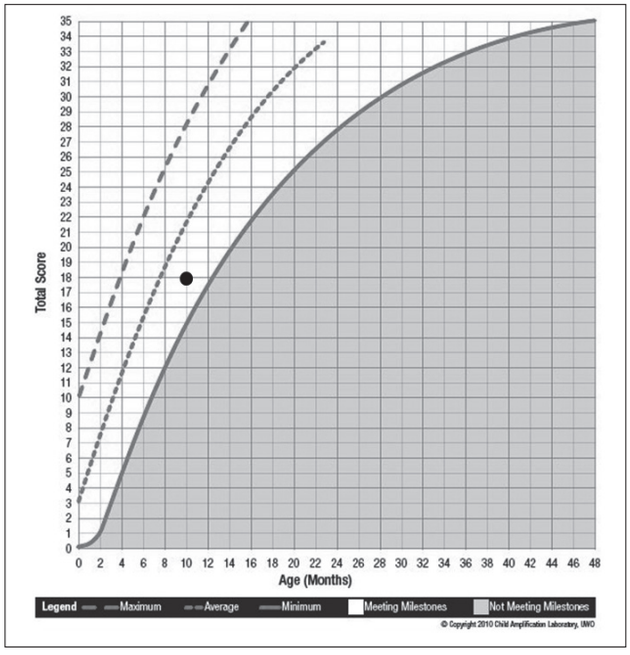

Figure 1: A ten month old infant's outcome on the LittlEARS Auditory Questionnaire. The middle dashed line indicates average LittlEARS values for normal hearing children and the upper dashed line and lower solid line indicate the upper and lower bound 95% confidence intervals. The score, represented by the filled circle, falls within the non-shaded region and therefore indicates the infant is meeting auditory development milestones for her age.

A longitudinal clinical observation study was conducted using the LittlEARS as part of the UWO PedAMP (Bagatto, Moodie et al., 2011). Through this work, it was determined that caregivers and clinicians found it feasible to complete the questionnaire within a clinical setting (Moodie et al., 2011). In addition, the questionnaire has been shown to be sensitive to medical issues other than hearing loss (Bagatto, Moodie et al., 2011). Specifically, the majority of typically-developing children who have been fitted with hearing aids following an evidence-based protocol are meeting auditory development milestones similar to their normal hearing peers (Bagatto, Moodie et al., 2011). Children in this study who were identified as having other medical issues (i.e., cerebral palsy) or complicating factors that may impact auditory outcomes with hearing aids (i.e., inconsistent hearing aid use) demonstrated lower scores on the LittlEARS Auditory Questionnaire compared to average values (Bagatto, Moodie et al., 2011). Further data for these subgroups is required to obtain a better understanding of their auditory development. However, this work has provided important evidence about the functional auditory outcomes of infants and children fitted with hearing aids using an evidence-based process.

The UWO PedAMP supports the use of both the LittlEARS and Parents' Evaluation of Aural/Oral Performance of Children (PEACH; Ching & Hill, 2005) in a two-stage process by developmental level. It is suggested that the LittlEARS be used for children from birth to approximately 48 months of age, depending on their score on the tool. During the development of the UWO PedAMP, a comparison of items on the LittlEARS and the PEACH, which has items more appropriate for older children, indicated a stopping rule was needed to make the application of these tools feasible to utilize in a clinical population. Therefore, when a minimum score of 27 or better is achieved on the LittlEARS, the child's performance is considered to be at a ceiling score. If ceiling is reached, the tool should no longer be administered. Instead, the clinician can begin to administer the PEACH. Children who are younger than 24 months of age and achieve the ceiling score on the LittlEARS may not yet be in the developmental range of the PEACH (Bagatto, Moodie et al., 2011), therefore, the clinician may desire to continue to administer the LittlEARS until the child is 24 months of age, or interpret low scores on the PEACH knowing the child may not yet be within the developmental range of the tool as supported by recent work (Bagatto, Moodie et al., 2011).

The PEACH assesses functional auditory performance in quiet and noisy listening situations. There are 13 items rated by the caregivers using a five-point scale. The rating scale version has been shown to be more acceptable to clinicians and caregivers when compared to the diary version due to lower respondent and administrative burden (Moodie et al., 2011). As caregivers rate their child's auditory performance over the past week, the overall score is summed, along with summed scores for the quiet and noise subscales. Total scores (overall,

quiet, noise) are then converted to percentages. An accompanying score sheet provides assistance with interpretation of individual scores (Figure 2).

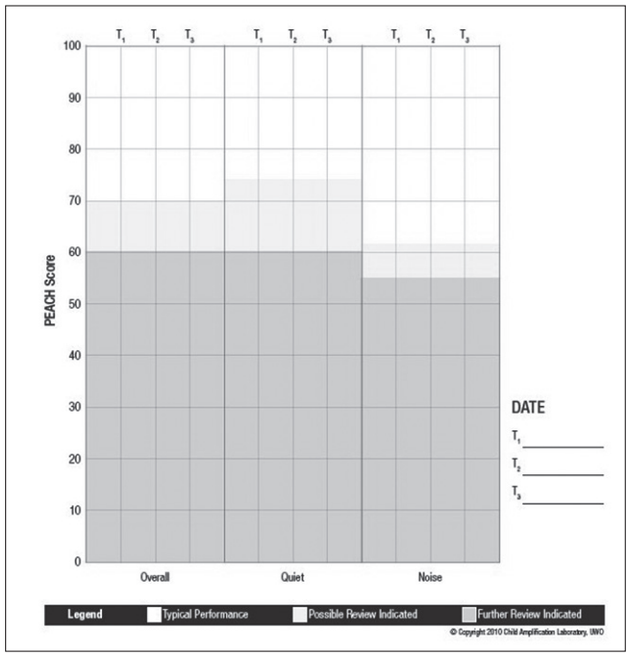

Figure 2: The PEACH Rating Scale score sheet from the UWO PedAMP. Percentage scores are listed on the y-axis and plotted within each subscale (overall, quiet, noise) on the x-axis. Scores plotted in the non-shaded region indicate typical auditory performance. Scores plotted in the shaded regions indicate aspects of hearing aid intervention should be reviewed.

Using the score sheet, percentages can be compared to those derived from children with hearing loss who wear hearing aids. This tool can assist in identifying whether a child is or is not performing typical auditory behaviors. Results from the clinical observation study indicate that the PEACH Rating Scale is appropriate for use within the UWO PedAMP with children who wear hearing aids after they have met a certain criteria on the LittlEARS Questionnaire (Bagatto, Moodie et al., 2011). In particular, the study revealed that the majority of typically-developing children with hearing aids who have good quality hearing aid fittings show typical auditory performance while children with hearing aids who have other medical issues or complex factors related to hearing aid use have lower scores on the PEACH (Bagatto, Moodie et al., 2011). The group differences were not statistically significant, though the trend was evident. Further evidence gathering is being pursued to characterize these important clinical subgroups.

The clinical observation study using the UWO PedAMP provided important information about the previous stages of the pediatric hearing aid fitting process: when a systematic, evidence-based protocol for the selection and fitting of hearing aids to infants and children is applied, good functional auditory outcomes are possible. The application of the UWO PedAMP in this work also supports the clinical feasibility of the tools included in this outcome measurement guideline. The UWO PedAMP contains mainly subjective outcome measurement tools which have several advantages. These tools provide rich and important real-world information for children with hearing loss and complex needs and can support more objective clinical testing. Very little equipment is required for the caregiver to complete a questionnaire and they can be accomplished while caregivers are waiting for the clinician to execute hearing tests or hearing aid verification procedures. This situation holds the possibility of adding information to the pediatric hearing aid fitting process without fully adding time and space requirements to the situation. In addition, by routinely completing auditory-related questionnaires, caregivers may become good observers of their child's auditory behaviors and a shared language will be developed with the clinician. For infants and children who can reliably perform behavioral testing, there are some objective tests available for the validation of hearing aid fittings. These can be used in combination with questionnaires for some children as part of a comprehensive approach to monitoring hearing aid outcomes. Our ongoing program of research with the UWO PedAMP includes continuing to develop a large database of children from within a typical pediatric audiologist's caseload. Our goals include the development of typical performance ranges by hearing level for children who use hearing aids.

Detection of Speech Sounds

For some children, we also use objective clinical outcome measures that have been derived from laboratory tasks: The Ling 6(HL) task (Scollie, Glista, Tenhaaf, Dunn, Malandrino, Keene & Folkeard, 2012) and the UWO Plurals test (Glista & Scollie, 2012). These two tests focus on the detection of speech sounds through tasks that are administered to the child in a clinical setting. Neither test assesses suprathreshold speech sound recognition or discrimination. The calibrated stimuli for these tests are available on a compact disk which can

be obtained through Phonak. Calibration and administration instructions are also supplied. Each test serves a unique purpose, but both are considered objective outcome measurement tools which assess the child's capacity to perform with their hearing aids in a controlled clinic environment.

The Ling 6 sounds, including /m/, /u/, /a/, /i/, /ʃ/, and /s/, have historically been used by therapists to probe whether the child can detect, discriminate or identify the sounds based on a hierarchy of listening (Ling, 1989). This can be done informally using live voice or be played through an audiometer using calibrated stimuli. The Ling 6(HL) task was developed to probe phoneme detection using pre-recorded female utterances; normative values are available (Scollie, et al., 2012). It has been successfully administered to children who are able to participate in visual reinforcement audiometry (VRA) and conditioned play audiometry (CPA). To support clinical uptake, the authors developed a score sheet which depicts normative ranges for comparison. Performance ranges for different degrees of hearing loss are currently under investigation as are the impact of different listening conditions (i.e., insert earphones and different speaker azimuths). This outcome measurement tool allows clinicians to confirm the reception of sound while the infant is wearing hearing aids in addition to demonstrating the efficacy of the devices to the caregiver. The Ling 6(HL) test supports reliable estimation of sound field speech sound detection thresholds using phonemes that span a broad frequncy range and may be used as a measure of hearing device outcome. In addition, the Ling 6(HL) task can been used to demonstrate if the hearing aid bandwidth or processing (e.g., frequency lowering technology) provides access to the all six Ling sounds. Finally, the Ling 6(HL) task has the potential to provide information about device function for bone conduction hearing aids or cochlear implants where the fitting cannot be verified using real-ear measurements. Although this outcome measurement tool does not assess speech sound discrimination or identification, future modifications may be available for these purposes.

The UWO Plurals test is based on research evaluating aided high-frequency hearing ability (Glista, Scollie, Bagatto, Seewald, Parsa & Johnson, 2009; Stelmachowicz, Pittman, Hoover & Lewis, 2002). It consists of 15 English nouns presented in the singular and plural form. The clinical version of the test includes pre-recorded lists of 30 stimuli to test the child's ability to correctly identify word-final plurality. Picture flip cards accompany the stimuli to engage the child in the task and help the clinician record the child's response. Children as young as four years old have been successful in completing this task. A score sheet presenting critical difference scores offer clinicians a systemtic way of comparing two different listening conditions (i.e, aided listening with and without frequency lowering active). The UWO Plurals test may offer a way of assessing performance of hearing aid technology designed to enhance audibility of high-frequency sounds beyond what conventional amplification can offer. Similar to the Ling 6(HL) task, the UWO Plurals test is limited to measuring speech sound detection and does not provide information regarding speech recognition or discrimination.

Outcome measurement tools such as these require the child's participation and provide a direct measure of the child's hearing in the aided and unaided conditions. They may also be used to help demonstrate auditory abilities to the the family (for example, through the use of an aided speech-sound audiogram-like chart). Another advantage of the tools mentioned above includes the clinical feasibility of such measures. Most clinics are already equipped with the necessary devices to execute the task, including an audiometer and CD player. The developmental level of the child may limit the administration of objective outcome measurement tools. Therefore, it is important to combine them with subjective tools to give a comprehensive description of the child's auditory outcomes.

Summary

This document has offered several options for evaluating the impact of hearing aid intervention in infants and children with hearing loss. Characteristics of good outcome measurement tools were also highlighted to summarize key issues to consider in selecting an outcome measure. Although this set of tests does not probe all aspects of auditory development or aided hearing, they are examples of measures that we have been able to incorporate in routine practice, and that can provide helpful information for monitoring. Monitoring auditory outcomes following a pediatric hearing aid fitting is an important stage in the intervention process. Validation should involve a multi-dimensional approach of evidence-based and clinically feasible subjective and objective outcome measurement tools appropriate for children of various ages and developmental levels. A demonstration of the child's progress with hearing aids supports a systematic monitoring schedule for the child with hearing loss, en-

gages parents as participants in the process and allows for outcome evaluation of the program as a whole. These key aspects of the pediatric hearing aid fitting process have been suggested as components of a comprehensive program of care for children with permanent childhood hearing loss (AAA, 2013; JCIH, 2013).

Acknowledgements

This work was supported with funding from the Canadian Institutes of Health Research [Marlene Bagatto: 200811CGV-204713-174463 and Sheila Moodie: 200710CGD-188113-171346], the Ontario Research Fund, Early Researcher Award [Susan Scollie], the Children's Corporate Systems Branch of Ontario's Ministry of Children and Youth Services in Canada, Siemens Hearing Instruments, Canada, The Masonic Foundation of Ontario, Help-2-Hear Project, the American Academy of Audiology New Investigator's Award [Danielle Glista] and Phonak AG.

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