

The Essentials of Fitting Hearing Aids to Babies

Marlene P. Bagatto, Au.D., Ph.D.¹

ABSTRACT

Fitting hearing aids to infants requires special consideration at each stage of the process. In the assessment stage, electrophysiological hearing threshold estimates must be adjusted appropriately so that an accurate hearing aid fitting can occur. Ear canal acoustics are also important to consider during the assessment stage of the hearing aid fitting process for infants. A strategy for measuring the real-ear-to-coupler difference in infants is described in this article. Clinicians must also take into account the electroacoustic and nonelectroacoustic characteristics of the hearing aids that are chosen for the infant with hearing loss. Following the selection stage, verification that the electroacoustic performance of the chosen hearing aid is meeting the auditory characteristics of the infant is a vital part of the process. Finally, evaluation of the effectiveness of the device completes the hearing aid fitting process for infants with hearing loss. Each stage of the process is described in this article so that clinicians have information about the essentials of fitting hearing aids to infants with hearing loss.

KEYWORDS: Hearing aids, infant, real-ear-to-coupler difference, verification, outcome measurement

Learning Outcomes: As a result of this activity, the participant will be able to: (1) list the four stages of the hearing aid fitting process for infants and (2) describe how fitting hearing aids to infants is different from fitting hearing aids to adults.

For infants with permanent hearing loss, pediatric audiologists strive to initiate intervention by 6 months of age,¹ and many families choose hearing aid fitting as part of an overall

intervention plan. Infants are not simply small adults who need hearing aids; they have different listening needs and present with unique physical and developmental challenges for

¹National Centre for Audiology, Western University, London, Ontario, Canada.

Address for correspondence and reprint requests: Marlene P. Bagatto, Au.D., Ph.D., National Centre for Audiology, Elborn College, Room 2262J, Western University, London, Ontario, Canada N6G 1H1 (e-mail: bagatto@nca.uwo.ca).

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fitting hearing aids compared to adults. For example, an infant's ear canal is constantly growing and changing, which impacts the sound pressure level (SPL) delivered to the ear. Additionally, an infant with hearing loss does not have experience with his or her native language like an adult with acquired hearing loss would. This means that the critical period for language learning must be accessed appropriately so that speech and language development are supported for the infant with hearing loss. Finally, infants are unable to provide verbal feedback about the hearing aid fitting; therefore distinctive strategies are required when adjusting the hearing aid to meet the listening needs of the young preverbal patient.

Thus, the challenging and important work of infant hearing aid fitting requires systematic and pediatric-specific procedures. It is vital, then, to have a comprehensive protocol for fitting hearing aids in infancy to support consistent approaches among clinicians, as well as to effectively reinforce the infant's development of speech and language. Evidence-based protocols and technology exist for the thorough assessment of hearing in infants as well as for accurate and suitable hearing aid fitting in this population. The essential components of fitting hearing aids to babies are the purpose of this article, which is presented in four sections. First, assessment considerations will be discussed in two sections: (1) using electrophysiological threshold estimates for the initial hearing aid fitting and (2) capturing the acoustic properties of infant ear canals. Next, a review of advanced hearing aid technologies and summaries of evidence about their potential use with infants will be provided. Third, a pediatric-friendly strategy for hearing aid verification will be discussed. Finally, an approach to the evaluation of device effectiveness (i.e., validation) will be presented. It is hoped that the clinical relevance of these topics will promote the use of effective strategies for fitting hearing aids to infants.

ASSESSMENT CONSIDERATIONS

Correcting the Auditory Brainstem Response

Protocols for infant hearing aid fitting indicate that threshold estimates be obtained for at least

two frequencies in each ear.^{2,3} For infants under the age of 6 months, as well as those children who are unable to perform behavioral audiometry reliably (e.g., children with developmental delay), electrophysiologic procedures are conducted. This can include the auditory steady-state response (ASSR), which is calibrated in decibels hearing level (dB HL), or the auditory brainstem response (ABR), which provides an estimate of dB HL (e.g., referenced in decibels normalized hearing level [dB nHL]). At this stage, the ABR is a more commonly used procedure to estimate hearing thresholds in infants given that the ASSR requires more investigation for its use in infants with hearing loss.^{1,4} Obtaining threshold estimates using the ABR provides an appropriate starting point for hearing aid fitting in infants; intervention is not postponed for the collection of behavioral data. An important characteristic of ABR threshold estimates in infants with hearing loss is that they are typically higher (i.e., worse) than what would be obtained through behavioral testing. This is due to various factors such as calibration techniques, level at which the auditory system is assessed, and the duration of the test signal (i.e., long duration pure tones compared with short tone bursts). This discrepancy results in the need for an adjustment to the ABR threshold estimates to better predict behavioral thresholds for the purposes of calculating the prescriptive hearing aid targets. Failing to apply the appropriate correction can result in inaccurate and unsafe hearing aid fittings to infants.

The correction is frequency-specific and is subtracted from the ABR threshold estimate in nHL to better represent a hearing threshold in dB HL (Fig. 1).

The corrected ABR threshold estimate is referred to in decibels estimated hearing level (dB eHL). The dB eHL value represents an ABR threshold estimate that has been corrected for the purposes of intervention. The correction values are based on the equipment being used to conduct the ABR as well as the collection parameters. A common set of corrections range from 20 at 500 Hz to 5 at 4000 Hz.⁵ Subtracting these values from the dB nHL value serves to better predict the behavioral threshold. This is important because hearing aid prescriptive formula uses behavioral threshold information

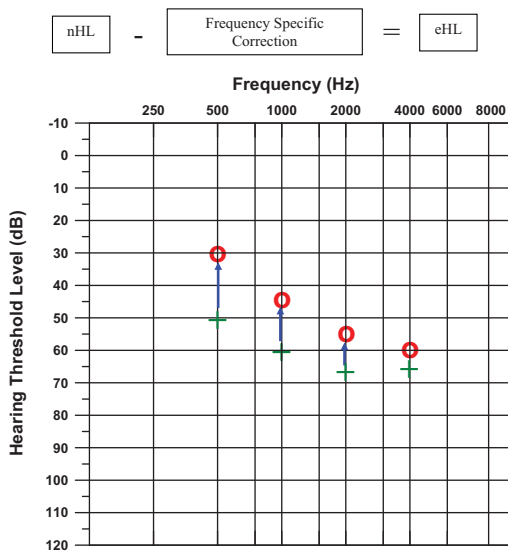


Figure 1 Schematic of how correction factors are applied to auditory brainstem response (ABR) normalized hearing level (nHL) threshold estimation data to estimate behavioral thresholds for the purposes of infant hearing aid fitting. On the audiogram, the plus signs indicate the ABR threshold estimate in nHL, and the circles indicate the corrected value in estimated hearing level. It is important to note that the subtracted corrections *improve* the initial thresholds estimated by the ABR.

to calculate the prescription. This is because behavioral thresholds are a measure of “true” hearing and not an estimate based on an electrophysiological response (for more on this see Bagatto⁶). Properly adjusting the ABR prior to intervention is a key component in the assessment phase of the hearing aid fitting process for infants.

Capturing Ear Canal Acoustics

Another assessment consideration when fitting hearing aids to infants is the unique characteristics of the infant ear canal. Growing and changing ear canals impact the SPL delivered to the eardrum and must be accounted for in the hearing aid fitting process. This ensures safe, accurate, and effective levels of sound are being delivered to the infant’s tiny ears. It is an important consideration at the assessment stage because the external ear is present and resonates during any audiometric procedure. Therefore, the SPL at the eardrum will vary across indi-

viduals for the same hearing level (or estimated hearing level).⁷ Clinically, the way to capture the infant’s ear canal acoustics is to measure the real-ear-to-coupler difference (RECD). This is a procedure whereby the SPL in a 2-cm³ coupler is subtracted from the SPL measured in the infant’s occluded ear canal.⁸ The resulting values are obtained across frequency and referred to as the RECD. The RECD is used in several places in the hearing aid fitting process:

1. To convert audiometry obtained using insert earphones to SPL near the eardrum
2. To convert real-ear gain and output requirements to 2-cm³ coupler targets
3. To convert test box measurements of hearing aid output to estimated real-ear measurements

Sample findings from young infants show large variability (i.e., ranging from ± 12 to ± 16 depending on frequency) for infants aged 2 to 6 months, which stresses the importance of obtaining the RECD measurement, especially in the first year of life.⁹ Due to the value of measuring the RECD in infants, a useful clinical technique was evaluated to support the clinical application of the measurement, especially in the youngest of patients.¹⁰ This technique involves connecting the probe tube to a small ear tip or the infant’s earmold for insertion into the ear canal simultaneously (Fig. 2).

For an accurate RECD measurement in young infants, the probe tube was noted to be extended beyond the ear tip by ~ 2 to 4 mm.



Figure 2 Example of simultaneous probe-tube insertion strategy for use with infants. Insertion depth guidelines are also provided if the clinician chooses to insert the probe-tube independently from the ear tip.

Alternatively, the probe tube could be inserted into an infant's ear canal ~ 10 mm from the opening of the ear canal. This work provides a clinical strategy for measuring the RECD on those patients where it is most critical. The RECD will need to be obtained several times for the same infant given that his or her ear canal is constantly growing. Clinicians should measure the RECD whenever the infant requires a new earmold. This occurs because the infant's ear has grown, which likely results in a change in acoustic properties. Therefore, an RECD is required to account for the changes.

There are, however, practical realities to fitting hearing aids to infants that make measuring the RECD a challenge. Cerumen in the ear canal, middle ear discharge, or an active child may preclude a clinician from obtaining the measurement. Predicted RECD values are available for those instances where the measurement cannot be obtained.⁹ These are provided in applications of the desired sensation level (DSL) method and offer RECD values to the nearest age in months.^{5,11} This is an improvement over previous predicted values that were estimated to the nearest year. Additionally, the current RECD predictions are provided for foam ear tip and earmold coupling.⁹ Limitations of using the predictions are that all children involved in the work had normal middle ear function and high variability was noted in RECD measures associated with children of the same age.⁹ Therefore, whenever possible, predicted values should not replace the more precise RECD measurement when fitting hearing aids to infants.

HEARING AID TECHNOLOGY

When selecting a hearing aid for an infant with hearing loss, nonelectroacoustic and electroacoustic characteristics are considered. This section will focus on the electroacoustic characteristics; however, it is essential to give mention to the nonelectroacoustic characteristics such as the following:

1. Behind-the-ear (BTE) style
2. Pediatric filtered ear hook
3. Direct audio input

4. Locking mechanism on the battery door and volume control
5. Ability to deactivate advanced features
6. Choice of bright colors
7. Access to loaner devices

These characteristics are mentioned in many pediatric hearing aid fitting protocols and should be considered for every child fitted with a hearing aid.^{2,3}

General electroacoustic characteristics of the BTE hearing aid should include the following:

1. Avoid distortion
2. Allow frequency/output shaping and flexibility to provide audibility and prevent loudness discomfort
3. Apply wide dynamic range compression for most hearing losses
4. Apply compression output limiting

Pediatric hearing aid fitting protocols support these recommendations based on evidence.^{2,3} The recommendations are achieved by applying an evidence-based prescriptive formula to calculate targets for various levels of speech and maximum power output. Examples of commonly used pediatric prescriptive methods are the DSL method and the National Acoustics Laboratories Nonlinear (NAL-NL2) formula.^{11,12} Through this portion of the selection phase of fitting hearing aids to infants, targets are calculated so that a hearing aid with the appropriate gain characteristics can be chosen. The hearing aid will commonly include advanced technologies for consideration. Unfortunately, the technologies are lacking the research to support their use for infant hearing aid fittings. These technologies include, but are not limited to, feedback management, digital noise reduction, and directional microphones.

Some feedback management strategies work effectively to control feedback without reducing high-frequency output significantly. This is an essential consideration because audibility is a goal for pediatric hearing aid fittings. Applying a feedback manager may be a better option than reducing high-frequency gain manually in the hearing aid fitting software or the

infant being without a hearing aid while waiting for a new earmold, for example. Consistent hearing aid use may be supported by the application of a feedback-free hearing aid fitting. It should be noted that when feedback management is applied, verification of the output of the hearing aid should be conducted to ensure appropriate audibility across frequencies.¹³ This also is recommended when digital noise reduction (DNR) is applied.

The application of DNR for pediatric hearing aid fittings has been the topic of some recent research. Results indicate that for children ages 5 through 12 years, DNR does not degrade speech recognition abilities and may improve ease of listening in normal hearing children.^{14,15} Similarly for directional microphone use in children, a directional advantage was noted when speech was in front and a disadvantage when speech was behind.¹⁶ Infants and children do not consistently display appropriate head-turning behaviors, which is vital to ensure optimum directional microphone benefit (i.e., nose to the talker).^{17,18}

Limited evidence exists for the impact of advanced technologies on infants, so the technologies should be considered individually, applying solutions with caution and monitoring and verifying their effects. For each technology, it is important to consider the available evidence as well as the individual characteristics of the infant. Additionally, the clinician should consider whether the infant's caregiver can use the technology appropriately and that the infant's access to incidental learning is not compromised as this plays a role in speech and language development.^{19,20} Thus, some pediatric hearing aid fitting protocols have recommended that advanced technologies be considered on a case by case basis.^{2,3} Once the characteristics of the desired hearing aid have been chosen, verification of the output of the hearing aid is required.

HEARING AID VERIFICATION FOR INFANTS

The main goal of hearing aid verification for infants is to ensure access to the long-term levels of conversational speech while maintaining comfort for loud sounds.⁵ This is done by

viewing verification on a sound pressure level (SPL)-ogram for comparison of the hearing aid's output to the infant's thresholds and upper limits (in SPL) as well as for comparison to aided speech targets (Fig. 3).

Viewing hearing aid output on an SPL-ogram using a real-ear aided response approach allows the clinician to inject meaning into the fit-to-targets. Speech-based equipment supports the verification of the hearing aid with meaningful signals for all types of digital hearing aids. Additionally, many hearing aid verification systems support the measurement and application of the RECD so that coupler-based or simulated-real-ear verification can be conducted. This involves placing the BTE hearing aid on a 2-cm³ coupler and applying the RECD values (measured in the assessment stage) so that the output of the hearing aid can be viewed on an SPL-ogram without the need to have the hearing aid placed on the infant's ear while adjustments are being made. This is critical because infants cannot sit quietly facing a loudspeaker for the duration of actual real-ear verification. Simulated real-ear verification also employs a controlled test-box environment, which is accurate and reliable in children when the RECD is applied.²¹ It is a commonly used procedure for the verification of hearing aids for infants to support early intervention.¹ Following hearing aid verification, evaluation of the effectiveness of the device is conducted through a systematic and evidence-based validation process.

VALIDATION OF THE HEARING AID FITTING

The role of validation in the infant hearing aid fitting process is a critical one. Validation allows the clinician to evaluate the outcome of the hearing aid for the infant. Outcomes are important for caregivers and clinicians as well as early hearing detection and intervention (EHDI) programs to track the infant's progress with hearing aids. Until recently, no systematic approach to outcome evaluation has been available for the infant population. The University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP) is offered as a guideline for pediatric audiologists to validate hearing aid fittings for children up to

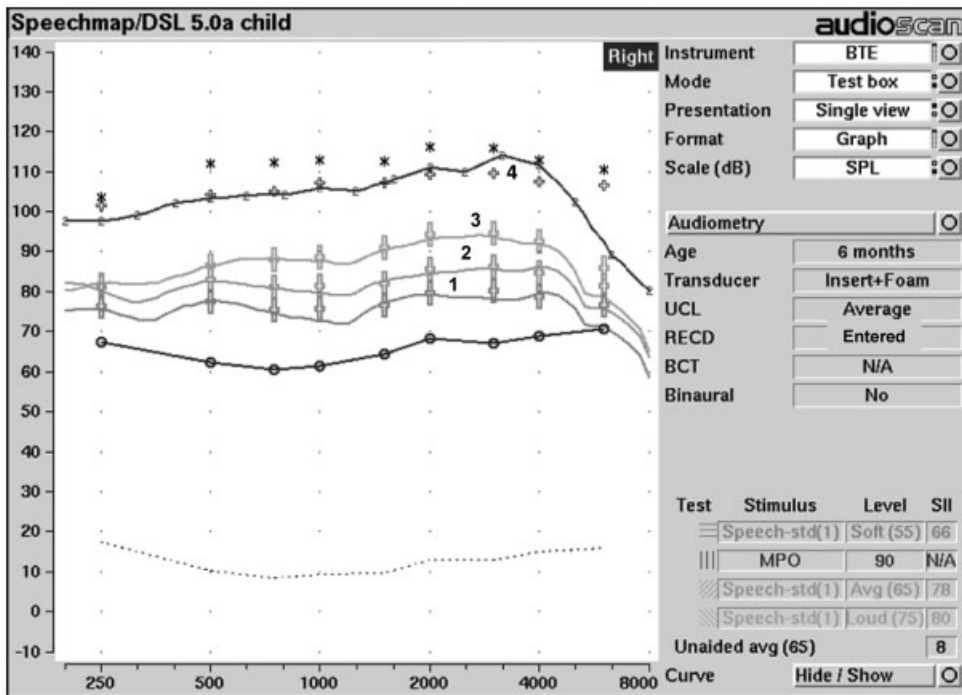


Figure 3 Sound pressure level (SPL)-ogram display of hearing instrument performance in relation to pediatric Desired Sensation Level (DSL) v5.0a targets. The solid lines represent the output of the hearing instrument for soft (1), average (2), and loud (3) speech inputs and maximum power output (4) in relation to the various speech targets (large +) and maximum power output targets (small +). Thresholds (O) and upper limits of comfort (*) are also displayed. Abbreviations: BTE, behind the ear; SPL, sound pressure levels; MPO, maximum power output.

the age of 6 years.²² The purpose of the UWO PedAMP is to measure the impact of the hearing aid fitting for infants, toddlers, and preschool children. The protocol was developed to be administered and interpreted by the audiologist who fit the hearing aid(s). The tools included within the UWO PedAMP were chosen because they have good statistical properties and are clinically feasible and meaningful.²³ These characteristics support the clinical uptake of the guideline.^{24,25} The UWO PedAMP includes visual tools to permit rapid scoring of the questionnaires, which helps support its effectiveness and efficiency in clinical practice. In addition, the questionnaires included in the protocol are supported by data from normal hearing as well as hearing-impaired infants who wear hearing aids.^{22,25-27}

The UWO PedAMP consists of a tool to assess the clinical process of hearing aid verification (i.e., speech intelligibility index (SII) worksheet) and caregiver-report questionnaires that assess functional outcomes such as auditory

development (i.e., LittEARS) and auditory performance (i.e., Parents' Evaluation of Aural/Oral Performance of Children). Clinical process outcomes are important to consider when interpreting functional outcomes because good quality input from the hearing aid impacts the functional auditory outcomes of the infant. The functional auditory questionnaires were chosen because of their good statistical properties, and they are clinically feasible to administer, score, and interpret for the family.²³ Details about where to locate each tool within the UWO PedAMP can be found at www.dslio.com. Including a validation protocol in the infant hearing aid fitting completes the process by providing a way to systematically measure the impact of the device for the infant. It also involves caregivers in the process by teaching them to become good observers of their infant's auditory behaviors and fosters a shared language with the audiologist. Outcome evaluation is also important for EHDI programs because it provides a way to measure how the

program is doing and helps describe patterns that affect infants within the program.

SUMMARY

Fitting hearing aids to infants with hearing loss is important work for clinicians. Considerations for electrophysiologic testing and unique and changing infant ear canal acoustics must be considered in the assessment stage of the process. Selecting a hearing aid and its appropriate features requires careful consideration of the critical period of speech and language learning as well as the individual caregivers and patients for which the technology is being considered. A crucial stage of the infant hearing aid fitting process involved verifying that the performance of the hearing aid is appropriate for the infant's hearing loss. This will foster good outcomes with the hearing aid that can be systematically evaluated through the use of a newly developed outcome evaluation guideline known as the UWO PedAMP. The significant role of pediatric audiologists is supported by evidence-based and clinically feasible strategies to foster the speech and language skills of hearing-impaired infants.

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