



College of Audiologists and
Speech-Language Pathologists of Ontario

Ordre des Audiologistes et
des Orthophonistes de l'Ontario

PREFERRED PRACTICE GUIDELINE FOR THE PRESCRIPTION OF HEARING AIDS FOR CHILDREN

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Approved: September 2002

Reformatted: September 2014

SUMMARY

Preferred Practice Guidelines are necessary to ensure quality care to the people of Ontario who need hearing aids. Hearing aid prescription is a controlled act under the Regulated Health Professions Act, 1991 in Ontario and as such, requires a high level of training and knowledge. Audiologists are the professionals singularly qualified to prescribe and fit all forms of amplification for children. Proper prescription of a hearing aid requires knowledge, education and experience in a variety of specialized and related topics as they relate to children. These topics include human anatomy and physiology, audiologic assessment, the audiologic (re)habilitation process, hearing aids and other specialized devices available, manufacturers' information and how it applies to each individual case, and the customized verification processes available to insure that the device is appropriate.

This guideline is based on the premise that paediatric hearing aid fitting calls for the highest levels of audiologic competence combined with a thorough understanding of child development, family dynamics, speech and room acoustics, and other relevant aspects of intervention. Moreover, the paediatric audiologist needs to know that departures from the ideal that are tolerable for the adult with acquired hearing loss may not be tolerable for the developing child. To this end, it is essential that audiologists determine that they have the necessary expertise, resources and equipment to assess and prescribe amplification for children. If they do not, audiologists should establish referral arrangements with audiology facilities, which do meet these requirements.

Hearing aid prescription is an inseparable part of the entire continuum of hearing aid provision, which includes assessment, prescription, dispensing and fitting of hearing aids. In circumstances where the audiologist dispenses hearing aids, dispensing is considered to be part of the hearing prescription process.

The prescription of amplification to children with congenital or prelingual hearing loss is the first step in an overall plan of treatment, which may include the development of goals in the areas of sensory and perceptual skill development, receptive and expressive language development, speech production, skill development, literacy skill development, academic performance and social-emotional growth¹. For children with post lingual hearing loss, goals will focus on the support of continued development of these areas. Early detection of hearing loss, prescription of amplification and participation in early intervention programs without question provide children with greater opportunity to reach their fullest potential.

RISK OF HARM

Inappropriate assessment of hearing problems or prescription and fitting of inappropriate hearing aids can result in harm to children, including but not limited to:

- contributing to significant delays in the development of speech, language, literacy, communication, socialization and learning in children²
- impairing hearing further due to inappropriate and/or excessive amplification^{3,4}

¹Carney, A., & Moeller, M. P. (1998). Treatment efficacy: Hearing loss in children. *Journal of Speech, Language and Hearing Research*, 41, S61-S84

² Carney, A., & Moeller, M. P. (1998). Treatment efficacy: Hearing loss in children. *Journal of Speech, Language and Hearing Research*, 41, S61-S84

- producing painfully loud sounds
- providing no measurable improvement in hearing
- negatively impacting on educational, vocational, social, communication, and emotional and psychological aspects of life
- delaying appropriate treatment for an otherwise treatable condition

A hearing aid prescription should state the type of aid, appropriate settings and applications that will result in an amplification system that will improve the quality of life for the individual who is hearing impaired. The audiologist, the child (where appropriate) and the family/caregivers will review the extent of the hearing loss and determine realistic goals for amplification, as required by each individual case. Information regarding hearing loss and (re)habilitation options should be provided to parents/ caregivers in a manner which is clear, unbiased and culturally sensitive.

While this guideline is recommended as the best practice standard for the majority of cases, the College recognizes that there will arise from time to time exceptional circumstances and/or conditions when guideline procedures cannot be followed and the professional may be required to modify recommended procedures. Audiologists should exercise professional judgment according to the clinical environment and individual child and must document all modifications.

³ Macrae, J. (1991). Permanent threshold shift associated with overamplification by hearing aids. *Journal of Speech and Hearing Research*, 34(2), 403-414.

⁴ Macrae, J. (1995). Temporary and permanent threshold shift caused by hearing aid use. *Journal of Speech and Hearing Research*, 38(4), 949-59.

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A) HEARING AID PRESCRIPTION

Hearing aid prescription is defined as the process of selecting the device, including the verification and validation of the selection. Hearing aid provision, including prescription and dispensing of hearing aids, is an ongoing process requiring the joint participation of the audiologist, patient/client, family/caregivers, dispenser and significant others.

Hearing aid prescription in the paediatric population differs qualitatively from the adult population for a variety of reasons⁵:

- Limited audiometric data are often available, either because of a limited ability to respond to test stimuli or because of poor test reliability
- Obtaining subjective feedback from the hearing aid user is generally not possible, and therefore validation of hearing aid fittings may be based on parent/caregiver or other observations, which may be biased, sketchy or unreliable
- The presence of multiple disabilities may make the assessment and hearing aid prescription process more difficult
- Hearing assessment may be complicated by the presence of otitis media, and similarly, prescription of electroacoustic characteristics may be complicated by fluctuations in hearing loss related to otitis media
- Physical differences in ear anatomy result in differences in ear canal resonance and RECD for children and adults

Therefore, the use of a systematic, well-researched approach to the fitting of amplification to children is imperative.

When working with a hearing impaired child and his/her family, service provision should be family-centred, allowing for family/caregiver choice, which is fully informed and based on unbiased information. The family's perspectives should be given primary consideration. Sensitivity to the family's cultural background must be demonstrated. The family must be a full partner in the development of an individualized pattern of required services and must be assisted in making choices among service options on the basis of information that is timely, comprehensible, relevant, complete, unbiased and based on scientific evidence. Interactions between the audiologists and families must reflect these core values.

⁵ The Pediatric Working Group of the Conference on Amplification for Children with Auditory Deficits (1996). Amplification for infants and children with hearing loss. *American Journal of Audiology*, 5(1), 53-68

B) PATIENT/CLIENT OR PROCEDURE DESCRIPTION/DEFINITION

This guideline is designed to provide audiologists with best practice recommendations for prescribing hearing aids as part of a comprehensive audiologic rehabilitation plan for children. For the purposes of this Practice Guideline, the definition of "children" has been kept consistent with the definition used by the Ontario Ministry of Health for the purposes of hearing aid provision, that is, an individual 18 years of age or under.

Provision of amplification is appropriate for any child who demonstrates a significant bilateral hearing loss (conductive, sensorineural or mixed). For the purposes of this guideline, "hearing loss" is defined as hearing thresholds in the range of 500 to 4000 Hz of 25 dB or greater. Children demonstrating ongoing conductive hearing loss related to chronic otitis media and children with unilateral hearing loss may also be candidates for amplification as determined on an individual basis. For children with low frequency hearing loss, high frequency hearing loss above 2000 Hz and/or milder degrees of hearing loss (i.e. hearing thresholds better than 25 dB), the need for amplification should also be determined on an individual basis.

Provision of amplification (by air conduction hearing aids) to infants aged less than three months is discretionary but not generally recommended. While this guideline endorses the provision and verification of amplification by six months of age, as recommended by the Joint Committee on Infant Hearing (JCIH, 2000), there is negligible scientific evidence of relative benefit from fitting earlier than three months of age. In addition, the first three months of life is a period of plasticity and rapid change in the acoustical and physical properties of the external acoustic meatus. This can cause difficulty in achieving a satisfactory and stable earmold fit, and may necessitate many follow-up visits for adjustment. Rapid anatomical maturation coupled with small and diverse canal volumes in neonates affect real ear sound pressure levels (SPLs) and have implications for the accuracy of prescriptive parameters based on group norms as well as for the stability of real ear measures over time. There is also rapid maturation of both the middle ear and the afferent auditory pathways and this may cause changes in hearing as well as increase the possibility of audiometric error. There is more possibility of error, fluctuation or change in audiometric thresholds for this age group. However, due to the need to provide amplification to children as early as possible to minimize delays in communication development, it is recommended that the process of fitting, verification and adjustment be completed by six months for infants diagnosed with hearing loss in the newborn period.

The need for the use of an amplification device is determined by joint participation of the audiologist, child and parent/caregiver. Participation in this process by other family members, caregivers, school personnel, significant others and managing professionals (e.g., speech-language pathologist, physician, psychologist, etc.) is strongly encouraged to provide ongoing support for the rehabilitative process.

For the purposes of this guideline, "hearing aid" is defined as any electronic device fitted to the ear and designed to amplify and deliver sound to the ear.⁶ These devices include hearing aids

⁶ Stach, B. A. (1997). *Comprehensive Dictionary of Audiology Illustrated*. Baltimore, Maryland: Williams & Wilkins

described as but not limited to body worn, behind-the ear, in-the-ear, canal, completely in the canal, BICROS, CROS, and eyeglass style hearing aids. Programmable and digital hearing aids must also be prescribed using this guideline. Any modifications in the prescription process must be documented in the patient/client's record. Prescription of a hearing aid requires consideration of electroacoustic and non-electroacoustic characteristics using an appropriate prescriptive formula, as well as verification and validation of the fitting (although actual procedures for programmable and digital hearing aids may vary from those used for conventional hearing aids). The general principles of this guideline are also intended to guide the fitting of nonconventional amplification devices such as implantable devices and vibrotactile devices. This guideline is also intended to guide the fitting of FM systems (see Appendix F). Other assistive and signaling devices may also be appropriate for children; however, for the purposes of this guideline, only FM systems have been included as the most commonly used assistive device for children.

C. RESOURCE REQUIREMENTS

As a minimal standard, audiometric testing and the prescription of hearing aids requires:

- an otoscope
- an audiometer that allows calibration of insert phones to ANSI 1996 standards
- appropriate equipment to conduct visual reinforcement audiometry (VRA) and conditioned play audiometry (CPA) (i.e. visual reinforcers, age-appropriate toys, etc.)
- insert earphones
- a sound-treated room
- an immittance system
- an electroacoustic analyzer for hearing instruments (including real ear measurement capability with the ability to measure and apply real ear to coupler differences (RECD))
- equipment necessary to adjust and modify the prescribed device (e.g., computer)

For the audiometric assessment of children under the age of 6 months, otoacoustic emission equipment is also required. Measurement equipment for evoked potentials is required to estimate thresholds for certain age ranges. The equipment should be calibrated at least annually and meet current American National Standards Institute (ANSI) standards.^{7, 8, 9, 10, 11, 12.}

Audiometric threshold testing should be routinely conducted in a sound-treated room, preferably with insert earphones. Under very exceptional circumstances, where patient/client needs¹³ dictate, assessment and prescription may be conducted in a quiet room. Use of a sound level meter to ensure that ambient noise levels are low enough to meet ANSI

⁷ American National Standards Institute (1981). Reference equivalent threshold force levels for audiometric bone vibrators. New York: Author

⁸ American National Standards Institute (1986). Artificial headphone for the calibration of audiometer bone vibrators. New York: Author.

⁹ American National Standards Institute (1987). Specifications for instruments to measure aural acoustic impedance

¹⁰ American National Standards Institute (1991). Maximum permissible ambient noise levels for audiometric test rooms (ANSI S3.1-1991). New York: Author.

¹¹ American National Standards Institute (1996). Specifications for audiometers (ANSI S3-1996). New York: Author.

¹² American National Standards Institute (1996). American National Standard Specification of Hearing Aid Characteristics (ANSI S3.22-1996). New York: Author.

¹³ For example, a child who is bed-ridden (i.e., sedated following surgery, intensive care) may require a bedside assessment rather than transport to a sound-treated room.

guidelines¹⁴ is strongly recommended. In these circumstances, use of insert earphones rather than TDH headphones is recommended to reduce testing error due to ambient noise. Such circumstances must be documented in the patient/client's record.

¹⁴ American National Standards Institute (1991). Maximum permissible ambient noise levels for audiometric test rooms (ANSI S3.1-1991). New York: Author.

D) REFERRAL REQUIREMENTS

Otolaryngologist referrals

Children diagnosed with a hearing loss, which requires the use of amplification, should be referred to an otolaryngologist (Ear, nose and throat (ENT) specialist) during the process of the prescription of amplification, as there is a need for a broad review of the child's health status in light of the hearing impairment. There may be need for investigation of the aetiology of the hearing loss and of any accompanying medical conditions (such as cochlear malformations or underlying syndromes) as well as radiologic, serologic, and ophthalmologic tests, genetic reviews and other cross-referrals.

Referrals to other audiologists

As with any audiological procedure, it is imperative that audiologists possess the necessary expertise and experience to perform the procedure. As the incidence of permanent hearing loss necessitating the use of amplification is much lower in children than in adults, audiologists in some settings may not see many hearing impaired children in their practice each year. Audiologists who do not feel that they have the necessary expertise, resources and equipment to assess and prescribe amplification for children should refer to audiologists with more paediatric experience in a timely fashion.

Interdisciplinary referrals

Areas of child development such as speech (articulation), receptive and expressive language development and pragmatic/ communication development will be affected by the presence of hearing loss. In addition, there may be other areas of concern for some children (for example in the areas of fine/gross motor skills, behaviour, cognition, academic skills, social skills, etc.), or concerns regarding family issues. Therefore, it is important for audiologists to be alert for these possibilities when working with hearing impaired children, and to initiate referrals to appropriate professionals when necessary. These professionals may include speech-language pathologists, occupational therapists, physical therapists, paediatricians, psychologists, social workers, teachers of the deaf/hard of hearing, special education teachers and others. Referral to parent/consumer groups should also be considered for families to obtain additional information and support.

E. PATIENT/CLIENT PROCESSES/PROCEDURES

Proper hearing aid prescription involves a number of stages to ensure that the most appropriate hearing aid(s) are prescribed and subsequently fit to the individual. These stages have been identified as consisting of the following steps:¹⁵

1. Assess – measure hearing thresholds as well as the real ear to coupler difference (RECD)
2. Derive targets for electroacoustic characteristics and pre-select hearing aid settings. The most appropriate hearing aid should be ordered (see sections 2.1 and 2.2).
3. Verify the hearing aid settings
4. Evaluate outcome and follow up. This may include behavioural evaluation, parent/caregiver report or other measures.

Children need to be seen in follow-up on a regular basis, as hearing thresholds and RECD need to be retested regularly (see Section F. Outcome statements and criteria/indicators for the evaluation of outcome – Follow-up). Audiologists working with children need to be always cognizant of the fact that audiological assessment and the prescription of amplification for children is not an event, but a process.

1. Audiological assessment procedures for children for the prescription of amplification

Recommended assessment procedures are listed by developmental age with three categories: 0 to 6 months developmental age, 6 to 30 months developmental age and greater than 30 months developmental age. The test batteries described include tests, which are needed to provide the necessary data for the prescription of hearing aids.

Any practice setting that does not possess the capability for either otoacoustic emission (OAE) or electrophysiologic assessment should not accept referral of children in the 0-6 months age range. Any practice setting that does not possess the capability for Visual Reinforcement Audiometry (VRA) should not accept referral of patient/clients in the 6-24 months age range.

Behavioural test procedures should be chosen which are consistent with the developmental age and cooperative ability of the child.

1.1 0 to 6 months developmental age

Required Battery:

- case history, including parent/caregiver and/or professional observation of child's behaviour
- otoscopy

¹⁵ Pediatric Working Group (1996). Amplification for infants and children with hearing loss. American Journal of Audiology, 5(1), 53-68.

- ear-specific threshold estimation with evoked potentials (including bone conducted stimuli if possible). Use of insert earphones for air-conducted stimuli is preferred. Threshold estimation with frequency-specific stimuli is preferred. However, in the event that reliable, accurate estimates cannot be obtained with frequency-specific stimuli, threshold estimation with broadband stimuli (clicks) are acceptable, when used in conjunction with otoacoustic emissions, behavioural observation, and frequent monitoring of the resulting hearing aid fitting.
- measurement of otoacoustic emissions (distortion product OAE or transient evoked OAE)
- immittance measures (a 660 Hz probe frequency is recommended for children under 6 months)
- measurement or age-appropriate prediction of the RECD prior to hearing aid selection

Additional tests used to cross-check diagnostic results:

- Behavioural Observation Audiometry (BOA): information should be obtained using insert phones (first choice), or loudspeakers (second choice)

As behavioural testing becomes increasingly accurate and specific, there should be a gradual transition from reliance upon electrophysiological measures in most infants to reliance on behavioural measures in most infants. For those infants with significant neurologic, cognitive or behavioural disorders, however, electrophysiological methods may remain the primary audiometric tool.

1.2 6 to 30 months developmental age

Required Battery:

- case history, including parent/caregiver and/or professional observation of child's behaviour
- otoscopy
- ear-specific and frequency-specific air-conducted Visual Reinforcement Audiometry (VRA)^{16, 17, 18, 19, 20, 21, 22} whenever possible. Use of insert phones (first choice) or TDH

¹⁶ Gravel, J. S., & Hood, L. J. (1999). Pediatric Audiologic Assessment: Chapter 10. In Musiek, F. & Rintelmann, W., (Eds.), Contemporary Perspectives in Hearing Assessment. Boston: Allyn & Bacon

¹⁷ Diefendorf, A. O. (1988). Behavioral evaluation of hearing impaired children. In F. Bess (Ed.), Hearing Impairment in Children. Parkton, MD: York Press.

¹⁸ Liden, G., & Kankkunen, A. (1969). Visual Reinforcement audiometry. Acta Otolaryngologica, 67, 281 –292.

¹⁹ Moore, J. M., Thompson, G., & Thompson, M. (1975). Auditory localization of infants as a function of reinforcement conditions. Journal of Speech and Hearing Disorders, 40, 29-34.

²⁰ Moore, J. M., Wilson, W. R., & Thompson, G. (1977). Visual reinforcement of head turn responses in infants under 12 months of age. Journal of Speech and Hearing Disorders, 42, 328-334

headphones (second choice) is preferred as it cannot be assumed that both ears demonstrate the same degree or configuration of hearing loss based on behavioural sound field results. Conditioned play audiometry may be substituted for VRA if the child can perform the task.

- bone-conducted thresholds (pure tone thresholds are preferred). Ear-specific (masked) thresholds are preferred when possible
- measurement of otoacoustic emissions (distortion product OAE or transient evoked OAE)
- immittance measures (tympanometry, and acoustic reflexes where clinically relevant)
- measurement or age-appropriate prediction of the RECD prior to hearing aid selection

Frequency-specific loudness discomfort levels should be obtained when children are old enough to provide reliable responses (Gagne, Seewald, Zelisko & Hudson, 1991).

Team testing is often helpful in obtaining a detailed estimate of thresholds with the 6-48 month age/developmental range. Similarly, review of electrophysiological and otoacoustic emission of data by peers is also recommended to ensure accurate interpretation of data. Professional collaboration with peers at all stages of the assessment and prescription process is beneficial when results are equivocal or atypical.

Exceptions to the Required Assessment Procedures should be documented.

2.1 Considerations in selection of appropriate amplification – non-electroacoustic characteristics

2.1.1 General comments

The thoughtful selection of non-electroacoustic characteristics of amplification is crucial for children to ensure both the provision of optimal amplification (particularly of the speech signal) and to ensure the flexibility that is needed to allow for future changes in need. The goal of providing an optimal amplified speech signal should not be compromised in favour of cosmetics.

Selection of appropriate amplification should be based on the degree, configuration, and type of hearing impairment as well as a consideration of familial and economic factors, and the environment in which the child will function.

If the hearing loss is bilateral, binaural amplification should always be provided unless there is a clear, documented contraindication.

For the use of the real ear to coupler difference (RECD), measurement of the RECD is always preferred to the use of age-appropriate predictive values.

2.1.2 Selection of hearing aid type

²¹ Widen, J. E. (1993). Behavioral screening of high-risk infants using visual reinforcement audiometry. *Seminars in Hearing*, 11(4), 342-356.

²² Widen, J. E. (1993). Adding objectivity to infant behavioral audiometry. *Ear and Hearing*, 14, 49-57

Behind-the-ear (BTE) aids are most appropriate for young children for the following reasons:

- Rapid growth of the outer ear can result in acoustic feedback, necessitating the need for new
- earmolds. While recasing of in-the-ear hearing aids is possible, this can represent a greater expense and generally leaves the child without amplification while the manufacturer is performing the recasing.
- In-the-ear hearing aids are more prone to feedback because of their typically looser fit and closer proximity between microphone and receiver. Parents/caregivers and children may respond to feedback by decreasing the volume on hearing aids, resulting in poor amplification.
- The possibility of the need for compatibility with personal FM systems must always be considered. The use of telecoil circuitry with in-the-ear (ITE) hearing aids with teleloop/silhouette coupling to personal FM systems is not recommended unless there are no viable alternatives.
- BTE aids have greater durability.
- BTE aids may have the potential for greater electroacoustic flexibility. Hearing aids with flexibility of adjustment in terms of tone, gain, output limiting and signal processing are preferable.
- BTE aids allow for the need for repair, as loaner aids can be provided to be used with the child's own earmold(s).
- BTE aids provide less chance of injury to the pinna and ear canal due to a cracked or broken shell if the child is injured.

For young children, safety features should be considered. Hearing aid batteries are toxic and should not be ingested. Parents/caregivers should be informed of this and consideration given to ordering tamper resistant battery doors to safeguard against children obtaining access to hearing aid batteries. Volume control locks and covers should also be considered to ensure that the correct volume control setting is maintained.

As loss of hearing aids is common and problematic for children, retention devices in the form of commercial or informal devices should be considered. These can include commercially available devices such as "HuggieAids"TM, double-sided wig tape, and "Critter Clips"TM, or informal solutions such as the use of headbands, dental floss/ string attached to the earhook of the aid and pinned to clothing, etc. Parents/caregivers should be informed of the availability of insurance coverage through their own policies for loss of hearing aids.

Earmolds for children should be made of a soft material for comfort, safety, retention and acoustic seal. The advantages and disadvantages of various earmold materials should be weighed for each child (for example, an extremely soft silicone material may provide a better fit but may tear too easily to stand up to the daily wear and tear of a child's use)

Similarly, the advantages and disadvantages of earmold modifications (vents, tubing, canal modifications, etc.) should be considered for each child. Earmold modifications are limited by the size of the very young ear therefore, electroacoustic adjustments of the hearing aid program can be a more effective means to meet prescription goals.

The need for frequent replacement of earmolds to prevent acoustic feedback must be explained to the family/caregivers.

A bone conduction aid may be appropriate if the loss is conductive and BTEs cannot be used due to medical or physical contraindications. Body aids may be appropriate if the child has physical limitations preventing the use of BTEs (e.g., short neck or malformation of the pinna). Loaner body aids may also be used for a short time during early infancy to reduce feedback by affording a greater distance between microphone and receiver.

A cochlear implant may be more appropriate than conventional hearing aids for some infants and children. It is the audiologist's responsibility to inform families of this option and to ensure their own knowledge of current audiological referral criteria. A centre experienced in implantation should determine the child's candidacy.

2.1.3 Assistive device compatibility

For both pre-school and school-age children, consideration should be given to the availability of coupling options so that the child will be able to access the various forms of current assistive device technology. Hearing aids for most children should include a telecoil, and microphone-telecoil (M-T) switching options. All BTE hearing aids prescribed for children must include direct audio input (DAI), whether or not the child is presently using a personal FM system, as a child's educational and communication needs can change dramatically in a short period of time.

FM technology is the system of choice to improve signal-to-noise ratio. Currently, other signal enhancement technologies (e.g., directional microphones, microphone arrays, noise reduction) should not be considered an equivalent substitute for FM/remote microphone technology.

2.1.4 Counselling

Counselling is always a crucial part of the prescription of amplification for a patient/client of any age. Where the prescribing audiologist is also the dispenser, explanations of use, care and maintenance of amplification devices need to be provided in an understandable way, supplemented by print materials. Provision of written information regarding the warranty and trial period of the hearing aids is recommended. Information regarding the Ontario Ministry of Health Assistive Devices Program must be provided, preferably supplemented with a printed brochure or handout. All of this information needs to be presented and reviewed as necessary.

Children are often unable to report if their amplification system is malfunctioning. To this end, a maintenance kit for parents/caregivers, which contains the following items, is helpful:

- dry aid kit
- battery tester
- stethoclip
- "earmold blower" to remove moisture from earmold tubing
- instruction books for the amplification device
- warranty information

2.2. Selection of electroacoustic characteristics

2.2.1 Assessment issues related to selection and verification protocols

Selection and verification protocols are predicated on the availability of frequency-specific threshold data. In cases where full audiometric information is not available, the clinician must make a best estimate of the

residual hearing across the frequency range important for speech. The use of formulae may necessitate some extrapolation and interpolation of audiometric information from limited audiometric data, taking into account additional clinical and/or familial information that may be available. In such cases, continued observation and assessment of the child are mandatory.

Although none of the threshold-based selection procedures is guaranteed to ensure that a child will not experience loudness discomfort or that output levels are safe, the use of a systematic objective approach that incorporates age-dependent variables into the computations is preferred.

Accurate interpretation of threshold data necessitates a direct measure or age-appropriate estimation of the acoustic transform characteristics of the child's ear (RECD).

2.2.2 Principles for selection of electroacoustic characteristics

Minimally the hearing aid should:

1. Avoid distortion of varying inputs at user prescribed settings.
2. Allow frequency/output shaping to provide sufficient and appropriate audibility of the input signal consistent with an appropriate prescriptive method.
3. Allow frequency/output shaping to avoid loudness discomfort and reduce the possibility of further hearing loss due to over amplification as based on an appropriate prescriptive method.
4. Employ amplitude processing that ensures audibility of relevant sounds including speech.
5. Include sufficient electroacoustic flexibility to allow for changes in the required frequency/output characteristics related to either growth or changes in the auditory characteristics of the child (within reason).

Appropriate electroacoustic characteristics may include both linear (with output compression) and nonlinear processing in either an analog or digital format. Advanced signal processing schemes (automatic feedback suppression, expansion, multiple channels, noise reduction and speech enhancement algorithms) should be considered viable in paediatric hearing instrument fitting until such time as sufficient research data exist to exclude them.

The following principles should be applied in the selection of electroacoustical characteristics.

1. A systematic approach must be applied. This implicitly requires the use of a prescriptive process that takes into account the unique acoustic properties of a child's ear in the assessment, fitting, and verification processes. Minimally the prescriptive process should guarantee audibility of speech at a comfortable level across as broad a frequency range as possible, and avoid tolerance and over amplification issues.
2. Hearing aid frequency-gain and output characteristics should be determined based on the prescriptive process and its requirements (i.e. audibility etc).

3. Individual ear characteristics must be incorporated into the hearing aid selection process through measurement of the real ear to coupler difference (RECD) (see Appendix C for a recommended procedure). The acoustics of an infant's external ears significantly differ from those of the average adult (Kruger, 1987). In addition, RECD values are known to be highly variable among children of the same age (Feigin, Kopun, Stelmachowicz, & Gorga, 1989; Seewald & Scollie, 1999).
4. The acoustic properties of the earmold should be accounted for in the verification process through the use of probe microphone measures or simulated measures.
5. Probe-microphone measures of real ear hearing aid performance should be obtained whenever possible. This may include simulations that account for the unique acoustic properties of the child's ears (i.e. incorporating the child's own RECD). When probe microphone measures of real ear hearing aid performance are not possible, hearing aid performance can be predicted by applying age-appropriate average RECD values. However, the use of average RECD values is the least preferred method because these values are limited in four ways. First, individual real ear SPL values may differ substantially from group average values, even in age-matched groups. Second, average RECD data is based on research which used foam tips to measure RECDs (Feigin et al., 1989). Most children will be fitted with BTE aids, which require a custom earmold. Using predicted RECD values that assume a foam tip might result in less than accurate hearing aid prescription values when an earmold will be used for the hearing aid fitting. A third limitation of the average RECD values that are presently applied in paediatric fitting is that they are based on 12-month age ranges. The rate and magnitude of changes in external ear acoustics over the first year of life (Kruger, 1987) are such that the changes may not be adequately captured by a single value over a 12-month range. Finally, the average RECD values were derived from infants and children with normal middle ear status. Therefore, the predicted values will not reflect any acoustic changes that a fluid filled or perforated eardrum will display, in the individual ear.²³

Once the hearing instrument has been selected, verification of the selected acoustic parameters should be completed.

3. Verification of the hearing aid prescription and fitting

The hearing instrument should be adjusted to approximate the previously determined target values for gain and maximum output for each ear. Simulated real ear measurements using the child's RECD are the preferred method. Real ear measurement of gain and maximum output values may also be performed for each ear, particularly if the earmold is vented, in order to measure venting effects. The hearing aid should be adjusted to provide the best match to target values.

²³ 23 Bagatto, Marlene P., Scollie, S. D., Seewald, R. C., Moodie, K. Shane, & Hoover, B. M. (2002). Real-ear-to coupler difference (RECD) predictions as a function of age for two coupling procedures. *Journal of the American Academy of Audiology*, 13(8)

Probe-tube microphone measurements employing an output protocol are preferred to procedures using an insertion gain protocol.

There are several disadvantages to using an insertion gain protocol:

- a) targets are provided outside of any relevant context (i.e. threshold)²⁴
- b) targets assume an average adult Real Ear Unaided Response (REUR)
- c) targets assume a sound field audiogram
- d) inputs are generally not reflective of speech and may misrepresent the predicted benefit from any circuit that is actively in compression during speech.²⁵

Gain and maximum output characteristics should be verified using an in situ based probe microphone approach with a real ear simulation protocol employing individual RECD measures and or age- appropriate data if necessary.

Maximum output characteristics should be assessed with narrow band stimuli.^{26, 27, 28} This is extremely important since the small size of a child's ear canal will result in real ear output values, which are much higher than what is indicated in manufacturer's specifications.

As the infant's external ear canal grows, the acoustic properties of the ear will change substantially, especially in the first year of life. This change in ear size will necessitate a new earmold. Whenever a new earmold is made, an RECD measurement should be obtained and applied to the existing prescription of the hearing aid. Thus, the prescription must be updated with a new RECD measurement when a new earmold is obtained. The verification procedures described above must be carried out every time the prescription has been updated.

Aided sound field threshold measurements alone should not form the basis for the verification of electroacoustic characteristics of hearing instruments for children for several reasons:

- a) prolonged cooperation from the child is required
- b) frequency resolution is poor

²⁴ critical differences for aided sound field thresholds are too large to be useful for comparative purposes (e.g., comparing two gain control settings).²⁹

²⁵ Seewald, R. C., Hudson, S. P., Gagne, J-P., & Zelisko, D.L. (1992). Comparison of two methods for estimating the sensation level of amplified speech. *Ear and Hearing*, 13(3), 142-149.

²⁶ Revit, L. J. (1991). New tests for signal-processing and multi-channel hearing instruments. *Hearing Journal*, 44, 20-23.

²⁷ Stelmachowicz, P. (1991) Clinical issues related to hearing aid maximum output. In G. S. Studebaker, F. H. Bess & L. B. Beck (Eds.), *The Vanderbilt Hearing Aid Report* (pp. 141-148). Parkton: York Press.

²⁸ Stelmachowicz, P. Lewis, D. E., Seewald, R.C., & Hawkins, D.B. (1990). Complex versus pure tone stimuli in the evaluation of hearing aid characteristics. *Journal of Speech and hearing Research*, 33, 380-385.

- c) test-retest reliability is frequently poor²⁹
- d) misleading information may be obtained in cases of severe to profound hearing loss, minimal/mild loss, or when non-linear signal processing is used.
- e) critical differences for aided sound field thresholds are too large to be useful for comparative purposes (e.g., comparing two gain control settings).

²⁹ Seewald, R., Moodie, K. S., Sinclair, S., & Cornelisse, L. (1996). Traditional and theoretical approaches to selecting amplification for infants and young children. In F. Bess, J. Gravel & A.M. Tharpe (Eds.) *Amplification for Children with Auditory Deficits* (pp. 161-192). Nashville, Tenn: Bill Wilkerson Center Press.

F) OUTCOME STATEMENTS AND CRITERIA/INDICATORS FOR THE EVALUATION OF OUTCOME

The audiologist and the child/family/caregiver(s) shall meet to discuss satisfaction with the fit of the hearing instrument and the performance of the child with amplification. It is important to recognize that the process of observing the benefits of amplification for a child is likely to be much longer for a child than for an adult. Children are typically not able to provide subjective feedback on hearing aid performance, and therefore validation of the hearing aid fitting will often rely on observation of behavioural measures, both formal and informal. Evaluation of the child's performance with hearing aids may also require the involvement of other professionals (for example, a speech-language pathologist to assess changes in speech production).

Possible outcome measures may include formal/informal assessment or questionnaires. Examples of assessment tools include:

- auditory awareness (aided behavioural sound field testing; parent/caregiver/professional observation, IT-MAIS³⁰)
- audibility of speech as perceived by the child (aided speech recognition threshold, Glendonald Auditory Screening Procedure 1³¹, Ling 6 Sound Test³²)
- intelligibility of speech as perceived by the child (aided speech recognition scores, formal assessment of auditory skills)
- accuracy of speech production
- rate and pattern of language acquisition (formal and informal language assessment)
- suprathreshold loudness measures

Questionnaires and observations may include a description of:

- observation of social development
- progress within the educational setting (Screening Instrument for Targeting Educational Risk; Listening Inventories for Education, teacher report)

³⁰ Robbins, A.M., Renshaw J. J., & Berry, S. W., (1991). Evaluating meaningful auditory integration in profoundly hearing-impaired children. *American Journal of Otology*, 12, Suppl. 144-50

³¹ Erber, N. (1982). *Auditory Training*. Washington, D.C.: Alexander Graham Bell Association for the Deaf.

³² Ling, D. (1989). *Foundations of Spoken Language for Hearing Impaired Children*. Washington, D.C.: Alexander Graham Bell Association for the Deaf

- subjective feedback from older children (Hearing Performance Inventory for Children; Student Appraisal of Listening Difficulty from the Listening Inventories for Education; DIAL)

Appendix G provides a summary of inventories and questionnaires available to assist in the assessment of a child's performance with amplification.

Feedback from other individuals involved with the child before and after the fitting of the hearing instrument (such as the parent/caregiver, speech-language pathologist, teacher, auditory-verbal therapist, daycare provider, etc.) is extremely important to evaluate hearing aid performance in daily life. Assistive tools such as inventories, diaries or scales specifically designed for children are available to help the audiologist to determine the family's satisfaction with the hearing aid(s) as well as the child's capabilities with the hearing aid(s).

The audiologist may also devise his/her own, providing that feedback from any source is documented in the records.

Follow-up

The need for continuing follow-up of a child may be dictated by:

- age of the child
- severity of the hearing loss
- need for new earmolds based on growth of pinna and ear canal
- need for continued orientation to hearing aid use
- need for continued review of hearing aid performance
- need for provision of replacement amplification
- need for continued assessment of need for and benefit derived from amplification

For children between the ages of 0-36 months, and for children receiving amplification for the first time (regardless of age), follow-up visits may be recommended as often as every 3 months. From preschool age to grade 1, follow-up visits may be necessary as often as every 6 months. For school age children, follow-up visits are recommended once a year as a minimum. The schedule for follow-up should be re-assessed on an ongoing, individual basis, with appropriate documentation. At each follow-up visit, an incremental history should be obtained from the family, including information on the child's reactions to amplification (positive or negative) and changes in speech, language and learning skills and overall development. Otoscopy and middle-ear analysis should be done. Where indicated and feasible, hearing levels should be checked. A RECD should be re-measured to account for growth and development, if the earmold has changed or if there has been a change in middle ear status. Subsequent adjustments should be made to the hearing instrument as needed.

G) DOCUMENTATION

Documentation is mandatory for the protection of all parties involved in the prescription process. The details of procedures including results, summary and recommendations should be documented in the patient/client's records in full at the time of each patient/client contact. Audiologists are directed to the Proposed Records Regulation drafted by the College of Audiologists and Speech-Language Pathologists of Ontario to obtain the requirements for record keeping.

Throughout the prescription process, the audiologist shall document all pertinent information in patient/client files. The rationale for any recommendation that amplification should or should not be considered by the child and family should be fully documented. Proper documentation is essential in the prescription process to ensure continuity of hearing health care.

It is important to note that the (re)habilitation process for hearing impaired children is a multidisciplinary one. Professionals who may be involved with a hearing impaired child in addition to the managing audiologist include physicians (paediatricians, otolaryngologists, etc.), educational audiologists, speech- language pathologists, teachers of the deaf/hard of hearing, auditory-verbal therapists, occupational therapists, physical therapists, classroom teachers, psychologists, social workers and others. It is crucial that families, professionals in clinical settings and in educational settings work together to provide a comprehensive and coordinated (re)habilitation program for the hearing impaired child. Therefore, where appropriate and with the consent of parents/caregivers, information regarding audiological and hearing aid status should be shared with other professionals. Proper documentation of parental/caregiver consent to communicate clinical information is essential as outlined in the Draft Regulation for Records Section 8(3).

Professionals and others involved with the hearing impaired child need to understand the results and implications of the hearing aid prescription process. Therefore, reports need to be easily understood and interpreted by individuals with limited knowledge of audiological procedures. For example, provision of a real ear measurement printout without explanation does not allow an individual such as a teacher to understand how a child can be expected to hear and perform with amplification, information that is critical for the classroom. Appendix E provides a suggested outline of information, which should be included in reports for other habilitation and educational professionals.

In the event of exceptional circumstances and/or conditions when guideline procedures cannot be followed, the audiologist is required to document such exceptions and any modified procedure that might have been used.

H) COMPETENCIES

Prescription of a hearing aid is a controlled act which audiologists are authorized to perform under the Audiology and Speech-Language Pathology Act, 1991. Any audiologist prescribing hearing aids must be a registered, practicing audiology member of CASLPO. Members engaged in the prescription of hearing aids should also ensure that their commitment to CASLPO's Continued Education Program includes continuing education in the area of hearing aid technology, prescription and fitting of amplification for children.

Clinicians with expertise in the prescription of hearing aids to children are strongly encouraged to share their knowledge by providing mentorship opportunities to less experienced members.

Hearing aid prescription cannot be delegated. Audiologists are directed to the CASLPO position statement "Delegation of the Controlled Act of Prescribing a Hearing Aid for a Hearing Impaired Adult" for further information. Prescription of amplification to children requires a significant profession-specific scope of knowledge and specialized experience in order to provide appropriate amplification to children. The risk of harm to public is considerable if the appropriate knowledge base and skill set for prescription of amplification to children is not present. As a result, prescription of amplification to children is a clinical activity, which should not be delegated.

It is also essential that audiologists use this PPG to determine that they have the necessary expertise, resources and equipment to assess and prescribe amplification for children. Paediatric hearing aid fitting is a specialized area of audiological care and requires the highest levels of audiological competence combined with a thorough understanding of child development, family dynamics, speech and room acoustics, and other relevant aspects of intervention. An audiologist prescribing hearing aids to children must understand that departures from the ideal that are tolerable for the adult with acquired hearing loss may not be tolerable for the developing child. Audiologists without the expertise, resources and equipment to assess and prescribe amplification for children, as stated in this guideline, should refer paediatric patient/clients to audiology facilities able to meet these requirements.

APPENDIX A: GLOSSARY

The following definitions are taken from Stach (1997).

Attack Time – The time between the abrupt increase from 55 to 90 dB SPL and the point where the level has stabilized to within 3 dB of the steady value for the 90 dB input SPL.

Band – Range of frequencies.

Channel – In a hearing aid, a frequency region that is processed independently of other regions, typically refers to a region of compression processing.

Circuit – (1) Path or line of an electric current; (2) combination of electric components that carry an electric current.

Compression – In hearing aid circuitry, nonlinear amplifier gain used either to limit maximum output (compression limiting) or to match amplifier gain to an individual's loudness growth (dynamic range compression).

Compression Amplification – Hearing aid with compression limiting and/or wide-dynamic-range- compression circuitry.

Dispensing – The act of filling the prescription to the specifications provided and distributing it.

Dispensing Audiologist – An audiologist who dispenses hearing aids.

Distortion – Undesired product of an inexact, or nonlinear, reproduction of an acoustic waveform: can be of many types: amplitude, harmonic, transient etc. For the purposes of hearing aid measurement the percentage of total harmonic distortion is calculated according to the ANSI S3.22-1996 definition.

Electroacoustic – Pertaining to the conversion of an electric signal to an acoustic signal or vice versa

Electroacoustic Analysis – Electronic measurement of various parameters of the acoustic input of a hearing aid.

Fitting – The process of ensuring the comfortable fit of the dispensed device and teaching the user about care and maintenance of the device.

Frequency Response – Output characteristics of a hearing aid, expressed as output (dB SPL) or gain as a function of frequency.

Functional Gain – F.G.; Difference in decibels between aided and unaided hearing sensitivity thresholds.

Gain – In hearing aids, the amount in dB by which the output level exceeds the input level.

In Situ – In position; e.g., in the case of hearing aids, on the patient in position for use.

In Situ Audiometry – Assessment of hearing in which pure-tone thresholds and loudness discomfort levels are measured and expressed in ear canal SPL.

In Situ Measurement – Evaluation of hearing aid performance while the hearing aid is being worn.

Linear Amplification – Hearing aid with circuitry that provides the same amount of gain for every input level until the maximum output level is reached.

Maximum Output – The highest level of output that can be measured from a hearing aid, regardless of input level; may be measured in the coupler (see OSPL) or the ear (see RESR).

Microphone Location Effects – MLE; measurement of the difference, in dB as a function of frequency, between the SPL at the hearing aid microphone and the SPL at a field reference point for a specified sound field with the hearing aid in place.

OSPL90 – SPL developed in a 2-cm³ earphone coupler when the input SPL is 90 dB, with the gain control of the hearing aid full-on.

Otoscopy – Inspection of the external ear, auditory canal and tympanic membrane with an otoscope.

Prescriptive fitting – Strategy for fitting hearing aids by the calculation of a desired gain, frequency response and maximum power output based on any of a number of formulas that incorporate pure-tone audiometric thresholds and may incorporate uncomfortable loudness information.

Real Ear Aided Gain – REAG; Measurement of the difference, in dB as a function of frequency, between the SPL in the ear canal and the SPL at a field reference point for a specified sound field with the hearing aid in place and turned on.

Real Ear Aided Response – REAR; Probe-microphone measurement of the sound pressure level, as a function of frequency, at a specified point near the tympanic membrane with a hearing aid in place and turned on; expressed in absolute SPL or as gain relative to stimulus level.

Real Ear Coupler Difference – RECD; Measurement of the difference, in dB as a function of frequency, between the output of a hearing aid measured by a probe microphone in the ear canal and the output measured in a 2-cc coupler.

Real Ear Insertion Gain – REIG; Probe microphone measurement of the difference, in dB as a function of frequency, between the real ear unaided gain and the real ear aided gain at the same point near the tympanic membrane.

Real Ear Insertion Response – REIR; Probe-microphone measurement of the difference, in dB as a function of frequency, between the real ear unaided response and the real ear aided response at the same point near the tympanic membrane.

Real Ear Saturation Response – RESR; Probe-microphone measurement of the SPL, as a function of frequency, at a specified point near the tympanic membrane with a hearing aid in place and turned on, with sufficient stimulus level to drive the hearing aid at its maximum output.

Release Time – The interval between the abrupt drop from 90 to 55 dB SPL and the point where the signal has stabilized to within 4 dB of the steady-state value for the 55-dB input SPL

Speech Recognition – The ability to perceive and identify speech targets. SYN: speech intelligibility, speech discrimination.

SRT – Speech reception threshold; threshold level for speech recognition, expressed as lowest intensity level at which 50% of spondaic words can be identified.

Speech Level Input – A range of input levels that correspond to the average level of real speech. The overall level of conversational speech typically ranges from 60 to 70 dB SPL in the free field. The frequency response of conversational speech is low frequency weighted.

Telecoil – T. Coil; An induction coil often included in a hearing aid to receive electromagnetic signals from a telephone or a loop amplification system.

Telecoil Switch – T. Switch; Switch circuit on some hearing aids that permits use of an induction coil to receive electromagnetic signals from a telephone or loop amplification system.

Word Discrimination Score – Word recognition score, speech recognition score, speech discrimination score; percentage of correctly identified words.

APPENDIX B: SUMMARY CHECKLIST FOR THE PRESCRIPTION OF AMPLIFICATION FOR CHILDREN

The process of prescribing amplification for children should consist of the following steps:

- a) Obtain as complete a description of the child's hearing levels for both ears as possible. For infants and younger children, it will likely be necessary to begin the process of prescription of amplification with incomplete data, with the understanding that fine-tuning of the amplification characteristics will be an ongoing process as more information is obtained.
- b) Recommend a consultation with an otolaryngologist and obtain medical clearance for the prescription of amplification.
- c) Obtain a description of the acoustic characteristics of the infant's ear canal by measuring the RECD.
- d) Perform an assessment of the non-electroacoustic needs of the child.
- e) Calculate the target ear canal sound pressure levels (SPL) for the amplified long-term average speech spectrum for each ear (generally done via software).
- f) Calculate the target ear canal SPLs for defining the maximum saturation response (RESR) of the hearing aid.
- g) Select a hearing aid, which best provides the desired electroacoustic and non-electroacoustic characteristics in partnership with the child and family. The audiologist will determine electroacoustic characteristics; however, a full explanation of the rationale for these decisions should be given. For example, the audiologist may feel that a certain type of circuit provides the best electroacoustic characteristics. The rationale for this decision should be discussed with the child and family in terms of the impact this decision will have on cost and on how the child might function with this type of amplification.
- h) Obtain an accurate ear impression for the purposes of fabricating an earmold (this may be done by a dispenser or dispensing audiologist).
- i) Set/program the hearing aid to the correct settings and ensure that the hearing aid is providing the desired electroacoustic characteristics, using the child's own earmold(s).
- j) Ensure that instruction and counselling sessions with the parent/caregiver are provided when the hearing aid is first fitted and at subsequent follow-up visits as needed. The prescribing audiologist may provide this information; if not, the audiologist should check with the family to ensure that the dispenser or dispensing audiologist has done this.
- k) Evaluate the child's progress with and benefit from amplification on a regular basis. In partnership with the family, establish an appropriate follow-up schedule for ongoing assessment of hearing and evaluation of amplification.

APPENDIX C:

Procedures for predicting real ear performance of a hearing aid using the Real Ear to Coupler Difference

Background:

In 1994, Moodie, Seewald, and Sinclair^{33, 34} described a procedure for predicting the real ear performance of a hearing aid using coupler measures of the device. This procedure uses the Real Ear to Coupler Difference (RECD) measure in the calculation of a transform that converts coupler measures to the real ear. Two related procedures are used; one for speech-level measures, and one for maximum output measures.

The procedures listed below are often implemented automatically in real ear systems and/or hearing aid related software. This protocol is provided so that audiologists will have access to the recommended procedure so that they may ensure its correct use, whether manual or automatic.

Speech-level measures:

- a) Measure the hearing aid's gain in the 2cc coupler for a speech-weighted, speech level input signal.
- b) Measure the patient/client's RECD using an insert phone. If the patient/client will use an earmold, couple the earmold to the insert phone for this measurement.
- c) Use the following equation to predict the Real Ear Aided Response (REAR) at each frequency. Note that Microphone Location Effects (MLE) are different for each style of hearing aid. In particular, MLE for Completely in the Canal (CIC) hearing aids are much larger than for other hearing aid style. Use of style-specific values is important:

$$\text{REAR (dB SPL)} = \text{gain} + \text{RECD} + \text{MLE} + \text{speech input level (dB SPL re: free field)}$$

Maximum output measures:

- a) Measure the hearing aid's output for a high-level input. Minimally, this input level should be 90 dB SPL. For WDRC devices, this may not be sufficient to fully saturate the hearing aid. In these cases, a 100 dB input level may be used. When the hearing aid is fully saturated, MLE are not included in the formula.
- b) Use the following formula to predict the Real Ear Saturation Response (RESR):

$$\text{RESR (dB SPL)} = \text{output} + \text{RECD}$$

³³ Moodie, K. S., Seewald, R. C., & Sinclair, S. T. (1994). Procedure for predicting real ear hearing aid performance in young children, *American Journal of Audiology*, 3, 23-31.

³⁴ Seewald, R. C., Moodie, K. S., Sinclair, S. T., & Scollie, S. D. (1999). Predictive validity of a procedure for pediatric hearing instrument fitting. *American Journal of Audiology*, 8, 143-152.

APPENDIX D:

RECD Tips and Guidelines³⁵

Obtaining an accurate RECD measurement starts with learning what a typical RECD looks like. Typically, RECD values measure on an ear with normal middle ear status are positive across frequencies, and increase in the high frequency region:

- To convert from the real ear to the coupler, SUBTRACT the RECD
- To convert from the coupler to the real ear, ADD the RECD

By convention, positive RECD values indicate the extent to which levels measured in the real ear exceed levels measured in the coupler for the same test signal. Values in the low frequency region will generally be in the range of 0 dB to 10 dB and increase up to 20 dB in the high frequency region. In infants and small children, the size of the ear canal is much smaller than adults; therefore, the values will be larger i.e. the smaller volume, the greater SPL, and thus greater the RECDs. The general shape of the RECD is the same for both children and adults, but the values are different within and between these populations.

You can attempt to measure an RECD on an infant while the parent/caregiver cradles him/her or while the patient is still sedated from the ABR. The following steps outline some hints that will help you obtain an accurate RECD measurement.

1) Proper Probe Tube Placement

Mark the probe tube about 15 to 25 mm from the medial tip. When inserting the probe tube, the mark should stop at the intertragal notch. The insertion depth marks are to guide you in placing the probe tube to within 5 mm of the eardrum. This can also be done by measuring 5 mm from the medial tip of the infant's earmold.

Always use otoscopy before placing anything in the patient's ear canal. This helps you to determine the shape and length of the canal, and establish if there is any cerumen blockage. An otoscopic examination is helpful when placing the probe tube in order to ensure appropriate insertion depth.

2) Lubricate

Apply earmold lubricant (e.g., Otoease, Otoferm, etc.) to the portion of the tube that will be inserted into the ear canal. Be careful not to go right to the end, as the lubricant may plug the tube. The lubricant will help keep the probe tube resting on the floor of the ear canal. In addition, applying some lubricant to the foam tip or earmold will reduce friction when inserting the tip in the ear canal while the probe tube is in place. It will also help to insure that the tube does not move further into the ear canal.

3) Coordinate

³⁵ Bagatto, M. (2001). Optimizing your RECD measurements. *The Hearing Journal*, 54(9), 32-36.

When the probe tube is in place, insert a foam tip or earmold carefully without altering the position of the tube. When inserting the earmold or foam tip into the ear canal, stabilize the probe tube at the intertragal notch with your little finger. Use your thumb and index finger of the same hand to insert the mold/tip. Stabilize your hand against the infant's cheek and/or head when inserting the tube or insert/mold, so that sudden movements will not catch you by surprise. Also, make sure you are familiar with your equipment and the procedure before trying to measure an RECD on an infant or young child. If you are confident, they will be less anxious.

4) Troubleshoot Your Measurement

Check the real ear portion of the RECD before you "accept" it as your measurement. Look for negative values in the low frequencies, and roll offs in the high frequencies. The next section will describe some possible causes of inappropriate RECD measurements, and some solutions.

When the probe tube and foam or impedance tip is situated in your patient's ear, start the test signal and WAIT. Check the accuracy of your measurement while the signal is on. Before "accepting" the measurement, take note of the following:

a. High frequency roll off at around 2 to 3kHz

Possible Cause:

Earmold or Foam Tip Measurement

The probe tube may be too shallow.

Solution:

Reinsert the probe tube to within 5 mm of the tympanic membrane and remeasure.

b. Negative values between -1 and -9 dB in the low frequency region

Possible Cause:

Earmold Measurement: The probe tube may be causing some of the low frequency sound to escape from around the earmold. Also, the earmold may have a vent larger than 1 mm which will cause sound to leak out.

Foam Tip Measurement: The foam tip may not be fully expanded in the ear canal or the size of the foam tip is too small. Also, the foam tip may not be inserted deep enough into the ear canal. In all cases, low frequency sound will leak out.

Solution:

Use earmold lubricant (e.g., Otoease, Otoferm, etc.) on the foam tip or earmold to create a better seal around the ear canal. Plug the medial side of the earmold vent when doing the measurement. Also, if you have the appropriate size of foam tip, make sure the most lateral end of the tip is flush with the opening of the ear canal and the foam has completely expanded.

c. Negative values between -10 and -15 dB in the low frequency region

Possible Cause:

Earmold or Foam Tip Measurement

The patient may have a perforated eardrum or a myringotomy tube in place.

Solution:

Perform an otoscopic examination and check acoustic impedance results. It is normal to see extreme negative values in the low frequency region when a tube is in place or there is a perforation in the patient's eardrum.

d. Increased positive values in the low and mid frequency region

Possible Cause:

The patient may have middle ear effusion. The increased mass and stiffness of a fluid-filled ear will cause increases in the RECD in the low and mid frequency regions, compared to a measurement obtained in an ear without middle ear effusion (Martin et al., 1996). ??? MISSING REFERENCE When a patient has middle ear effusion, the RECD results are more variable making it even more important to obtain this measurement.

Solution:

Check acoustic impedance results. It is normal to see increased positive values in the low and mid frequency regions when the patient has middle ear effusion.

Summary

The Real Ear to Coupler Difference measurement is used to capture an individual's occluded ear canal acoustics for the purposes of selecting and fitting amplification. Obtaining an accurate measurement is important for matching the appropriate electroacoustic characteristics of your patient's hearing aid.

APPENDIX E:

Recommendations for Report Writing for Children

It is important for parents, teachers and professionals in other disciplines to understand the implications of the hearing aid fitting to develop appropriate strategies and expectations. It is recommended that the following information be included in audiological reports.

Hearing aid information

1. Make and model of hearing aids
 - This will allow ordering of the correct accessories for FM systems.
2. Serial number
 - This is helpful for the ordering of FM systems and to ensure that the correct hearing aid is fitted to the correct ear if they become switched.
3. Date of purchase and date child is eligible for new aids under ADP
 - These two pieces of information are useful as the replacement period for educational FM systems may or may not coincide with the replacement period for new hearing aids. The fitting of new hearing aids and a new FM system may need to be coordinated.
4. Are hearing aids compatible with direct audio input?
5. Internal hearing aid settings (including settings for digital/ programmable hearing aids). If settings have been changed, this should be noted.
 - This is useful information for the educational audiologist to troubleshoot hearing aid or hearing aid/FM system interaction problems.
6. Recommended volume control settings (if applicable)

Hearing aid performance

1. Parent/ child concerns about hearing aids
2. Are hearing aids working according to specifications?
3. Is the fit of the earmolds satisfactory? If not, what recommendations have been made to address this?
4. Methods used to determine aided performance – real ear measurement, simulated real ear measurement, sound field threshold testing, predicted sound field aided thresholds, aided speech testing
5. A brief description of how the child can be expected to perform with hearing aids in everyday life (for example “this child should be able to detect all speech sounds, provided that the speaker is close to the child in a quiet environment, or using an FM system.”)

APPENDIX F:

Fitting of FM Systems and Assistive Listening Devices for Children

FM systems and other assistive listening devices are designed to assist in reducing the adverse effects of distance, noise and reverberation. These recommendations are based on the assumption that appropriate personal amplification has already been fitted and verified. The purpose of the FM system, then, is to enhance the performance of the child's personal amplification. Appropriate use of a personal FM coupled to the child's hearing aids allows for optimal reception of the parent/caregiver's voice when the child is at a distance greater than 6 feet away or when noisy conditions abound.

The appropriateness of recommending an FM system for home or school use should always be considered by audiologists in partnership with children and parents/caregivers. Use of FM systems with infants and preschool children to enhance the auditory signal can be beneficial to optimize use of residual hearing for speech, language and communication development.

It is important to provide clear and comprehensive information to parents/caregivers when recommending an FM system. This should include an explanation of the benefits of FM systems and a demonstration of how the FM system will be used with the child's hearing aids. If an actual FM system cannot be demonstrated, written material with pictures can help parents/caregivers develop an understanding of how the FM system will look and how it will be used. If an FM system is being recommended for home use, it is crucial to determine who will provide in-servicing and orientation to the FM system, including basic listening check and troubleshooting procedures. FM systems can be more complicated to check and troubleshoot, and therefore it is imperative that parents/caregivers receive sufficient instruction in their use to feel comfortable using the FM system at home.

The child's clinical and/or educational audiologist is the most qualified person to prescribe an FM system. In the educational system in the province of Ontario, a recommendation for an FM system from an audiologist is required to access funding for equipment to be used within the classroom.

The need for coordination of services between the clinical setting and the educational setting is crucial when an FM system is to be used. When a personal FM system is recommended for use in the educational setting, audiologists should include a statement, which states the need for an electroacoustical check of the FM system in combination with hearing aids by an audiologist. This statement should also explain the need for this testing – i.e. that overamplification, poor frequency responses and distortion can result from a poor electroacoustical coupling of the hearing aids and FM system, producing an acoustic signal which is actually detrimental, rather than improved.

There are many factors, which need to be considered in selection of an FM system.

- The use of direct audio input with personal amplification should always be the first choice (where possible). Auditory trainers used with earmolds and button transducers instead of personal FM systems are not recommended due to issues related to appropriateness of gain/frequency response/output limiting characteristics and environmental microphone location. Direct audio input coupling provides a clearer, more consistent and more appropriate signal than couplings using auditory trainers with earmolds and button transducers, silhouette couplings or teleloop couplings.

-
- Boom microphones for transmitters should be considered as opposed to omnidirectional microphones to provide a clearer, more intact signal with maximum high frequency capture.
- The hearing aid's environmental microphone must have the capability to remain active when the FM system is in use, to allow child to monitor his own voice. However, the capacity for transmission of the FM signal in FM ONLY mode can be advantageous in some situations. The potential need for an FM ONLY option should be considered when recommending the FM system as there may be situations where it is appropriate (e.g., for testing purposes)
- Fitting of an FM system must include measures of gain and output through Hearing Aid (HA) + FM combination to determine the FM receiver gain/volume setting (if applicable) and to ensure that the signal is treated in a fashion consistent with that of the HA only condition, and in reasonable agreement with aided targets for average and loud sounds. Appropriate corrections for the signal level as a factor of FM transmitter microphone position should be applied. Protocols for the assessment of FM system-hearing aid interactions are available.
- Consideration needs to be given to the classroom/ learning environment and to the psychosocial development of the child to ensure that the most appropriate FM system is recommended.
- Audiologists should also consider practical issues regarding durability of the FM system being considered, availability of extended warranties, and ease of use for a particular child and family. FM systems can be more complex and require more training of parent/caregiver and child to be used effectively.

Recommendations for the verification of FM system fittings have undergone significant modifications in the past few years. The most recent guidelines for the verification of FM fittings can be found in a document entitled "Readings on FM Amplification" which is can be found in Appendix A of the article "Guidelines for Fitting and Monitoring FM systems" in ASHA Desk Reference (2000). This document is available to download from the American Speech-Language Hearing Association website, www.asha.org. The document "Fitting and verification of FM systems using the AudioScan RM500 hearing aid analyzer/real ear measurement system", available from AudioScan, may also be helpful.

APPENDIX G:

Summaries of Children's Outcome Measures for the Assessment of Amplification³⁶

GENERAL PURPOSE MEASURES/HOME LISTENING: The following tools are designed for assessing performance with hearing aids in real-world use, in general listening environments. They are not specific to the educational environment, although some include a question or two about school listening (APHAP), or can be modified by the audiologist to specifically target the classroom (DIAL/FEW):

- a. The Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) And The Infant-Toddler Meaningful Use of Speech Scale (IT-MUSS)

BACKGROUND: The IT-MAIS and IT-MUSS were originally developed for assessing young children who have recently received a cochlear implant. They are a series of questions, administered to parents. Items focus on observed behaviours and reactions that indicate that the infant or toddler is hearing and processing auditory stimuli in the environment.

AVAILABILITY: These forms are available in textbooks and in conference handouts. See Harrison (2000) and Robbins, Renshaw, and Berry (1991) references, below.

USAGE NOTES: Some researchers recommend giving the questionnaire to parents after the initial fitting of amplification, and asking them to use it to perform structured observations of real-world function (Harrison, 2000). Because the listening "tasks" in the IT-MAIS are very low level, it can assist in scaling appropriate expectations, and focusing parental observations to the appropriate developmental level. A companion tool, the Infant-Toddler Meaningful Use of Speech Scale, is also available. Data (from cochlear implant users) reported by Robbins et al. (1991) indicate that the MAIS is correlated with speech perception abilities, and the MUSS is correlated with the intelligibility of the child's speech. The MUSS appears to be sensitive to the effects of cochlear implantation. Test and retest scores (inter-rater) for the MAIS and MUSS were .9 and .91, respectively.

Harrison, M. (2000). How do we know we've got it right? Observing performance with amplification. In R. Seewald, (Ed.) *A Sound Foundation Through Early Amplification: Proceedings of an International Conference* (pp. 119-40), Phonak AG.

Robbins, A. M., Renshaw, J. J., & Berry, S. W. (1991). Evaluating meaningful auditory integration in profoundly hearing-impaired children. *American Journal of Otology*, 12, Suppl:144-50, 1991.

Robbins, A. M., Svirsky, M., Osberger, M. J., & Pison, D. B. (1998). Beyond the Audiogram: The role of functional assessments. In F. Bess: Ed. *Children with Hearing Impairment: Contemporary Trends* (pp. 105-124). Nashville TN: Vanderbilt Bill Wilkerson Center Press.

Osberger, M.J., Geier L., Zimmerman-Phillips, S., & Barker, M. J. (1997). Use of a parent-report scale to assess benefit in children given the Clarion cochlear implant. *American Journal of Otology*. 18(6 Suppl), S79-80.

³⁶ Susan Scollie, Personal communication

b. Children's version of the APHAP:

BACKGROUND: Researchers at Boystown National Research Hospital modified the questions of the adult version of the Abbreviated Profile of Hearing Aid Performance/Benefit for use with school-aged children (suggested age: > 9 years). The modified questions were chosen to be age-appropriate, and to reflect the subscales of the APHAP (Ease of Communication, Background Noise, Reverberant Environments, and Aversive Sounds). They tested it on 50 children with mild to severe losses who used DSL-fitted hearing aids. Norms were similar to those for the Adult version of the APHAP. Norms and the questionnaire are provided in the publication. (Kopun, J.G., & Stelmachowicz, P.G. (1998). Perceived Communication Difficulties of Children With Hearing Loss. American Journal of Audiology, Vol 7(1), 30-38.

AVAILABILITY: The American Journal of Audiology is online through the ASHA website (<http://professional.asha.org/resources/journals/AJA-index.cfm>).

USAGE NOTES: Twenty-four questions, some scoring is required, may be administered to the parent or to the child or both. Questions may be asked with reference to "Aided" listening only (this measures "performance"), or to "Aided" versus "Unaided" (this measures "benefit"). Children who are full-time hearing aid users may have difficulty answering "unaided" questions if they have not encountered a given listening situation without their hearing aids (e.g., hearing the cashier in a grocery store). In these cases, it is acceptable to only score the "Aided" portion of the questionnaire, and thereby assess performance only.

c. Children's version of the COSI: (the DIAL and the FEW)

BACKGROUND: Researchers at the Pittsburgh Children's Hospital modified the Patient/client Oriented Scale of Improvement for use with children. The COSI is typically used by asking the adult hearing aid user to name 3-5 listening situations in which they wish to hear better. Post-fitting, the adult rates the improvement offered by the hearing aid in these situations. This assesses benefit, but does not look at usage and/or problems: these aspects of outcome are usually assessed by a companion questionnaire called the Hearing Aid Usage Questionnaire. In modifying this approach for children, the researchers developed the Developmental Index of Audition and Listening (DIAL). The audiologist shows this list to parents, and together they create the Family Expectation Worksheet (FEW), a COSI-like list of 3-5 developmentally appropriate listening goals for the child who uses hearing aids. Real-world performance is rated post-fitting.

AVAILABILITY: Downloadable from the Educational Audiology website, for members only, in the "good and practical" section. Instructions are included. No scoring, no norms. (<http://www.edaud.org>)

USAGE NOTES: This is a rather informal approach, but is a good way to combine counselling with outcome assessment. The adult version is a valid, reliable approach, and is derived from "Goal Attainment Scaling" methodology, which allows for highly individualized goal setting. The advantage to this approach is that the parent/child does not have to rate listening performance in situations that they have never encountered, and there are very few questions. The disadvantage is that it does not assess listening performance in a standard set of situations.

d. Children's Home Inventory of Listening Difficulties

BACKGROUND: The CHILD was developed by Karen Anderson, of the Educational Audiology Organization, to be "a family-centered instrument designed to reveal the communication needs of children within the context of their home environment." It is not only for use with children who use hearing aids, but rather addresses listening skills in general. The authors suggest that when used in a pre/post manner, it can monitor improvements in listening skill at home. Suggested age range is 3-12.

AVAILABILITY: Downloadable from the Educational Audiology website, for members only, in the "good and practical" section. Instructions are included. Easy to score (no subscales), no norms (<http://www.edaud.org>).

USAGE NOTES: Fifteen questions, and the child rates their answers using a child-friendly "Understand-o-meter". Questions are easy to understand. One question regarding hearing the alarm clock in the morning may need to be omitted for many children who are hearing aid candidates, unless they use non-auditory alarm clocks. The authors state that the test-retest reliability is 0.82. No published data exist on this tool yet.

TARGETED AT THE CLASSROOM: The following tools are designed for assessing performance with hearing aids in real-world use, in the classroom specifically.

a. Listening Inventory for Education (LIFE)

BACKGROUND: This is a detailed assessment tool developed by Karen Anderson and Joseph Smaldino, of the Educational Audiology Association. A series of cartoons depict ten classroom listening situations and five non-classroom situations. These pictures are printed in a small flip chart. They are shown to the child, who then rates his/her listening difficulty on a picture scale. A five-point scale is used for older children, and a three-point scale is used for preschoolers. A companion set of four questions for teachers, on a one-page form, is also included. The LIFE is sensitive to changes in hearing aid technology, such as the difference between omni- and dual- microphone hearing aids (Kuk, Kollofski, Brown, Melum, & Rosenthal, 1999).

AVAILABILITY: The LIFE may be purchased from the Educational Audiology Association (<http://www.edaud.org>).

USAGE NOTES: Fifteen questions appropriate for school-age children. Detailed administration, development, scoring, and norms are provided in the user's manual. The intended use is as a pre/post tool for assessing the efficacy of assistive listening technologies and/or efforts to improve classroom acoustics.

Kuk, F. K., Kollofski, C., Brown, S., Melum, A., & Rosenthal, A. (1999) Use of a digital hearing aid with directional microphones in school-aged children. *Journal of the American Academy of Audiology*, 10(10), 535-48.

b. Screening Inventory for Targeting Educational Risk (SIFTER)

BACKGROUND: This one-page checklist is given to teachers, and was developed by Karen Anderson and Noel Matkin, of the Educational Audiology Association. The teacher rates the child's level of performance and abilities in 15 listening tasks, skills, and behaviours. The ratings are scored by the audiologist, and the score is placed in either the "at-risk" or "pass" category. It is suggested for use when identifying children who require management of listening difficulties in the classroom. May be used as a monitoring tool over time for individual children, or in a pre/post format to track the effect of intervention. The SIFTER is

sensitive to the effects of minimal sensorineural hearing loss (Bess, Dodd-Murphy & Parker, 1998) and unilateral hearing loss in school-aged children (Dancer, Burl & Waters, 1995).

AVAILABILITY: May be purchased in pads from the Educational Audiology Association (<http://www.edaud.org>).

USAGE NOTES: The SIFTER is suggested for use when identifying children who require management of listening difficulties in the classroom. May be used as a monitoring tool over time for individual children, or in a pre/post format to track the effect of intervention. Norms are provided with this tool. Age range: 3 – Kindergarten, and school-age).

Bess, F. H., Dodd-Murphy, J., & Parker, R. A., (1998). Children with minimal sensorineural hearing loss: prevalence, educational performance, and functional status. *Ear & Hearing*, 19(5),339-54.

Dancer, J., Burl, N. T., & Waters, S. (1995). Effects of unilateral hearing loss on teacher responses to the SIFTER. *Screening Instrument for Targeting Educational Risk*. *American Annals of the Deaf*, 140(3), 291-4.

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