

**Universal Newborn Hearing  
Screening and Early  
Intervention Programme  
(UNHSEIP)**

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**National Policy and Quality  
Standards Appendix F  
Diagnostic and Amplification  
Protocols  
January 2009**

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**National Screening Unit**

# **UNHSEIP Diagnostic and Amplification Protocols**

## **Introduction and Acknowledgements**

This document is based on the work of a Technical Working Group which was formed to provide audiological advice and support to the Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP).

Members of the technical group:

- Andrea Kelly, PhD, MNZAS
- Suzanne Purdy, PhD, MNZAS
- Michelle Pokorny, MAud, MNZAS
- Duncan Hann, MAud, MNZAS
- Robyn McNeur, AuD, MNZAS

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The Ontario documents were developed and based on:

- a workshop in December 2000 involving 20 invited Ontario audiologists, many of whom have experience with electrophysiologic assessment
- systematic review of scientific and clinical literature, using the methods of the Canadian Task Force on Preventive Health Care
- consultations with experts worldwide
- extensive experience with tone pip/burst and other diagnostic tests, in Ontario centers.

Additional information was also taken from the Recommendations of the New Zealand Audiological Society (NZAS) Special Interest Group, New Zealand Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP) Amplification Guidelines, September 2005.

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## ABBREVIATIONS

ABR	auditory brainstem response
AC	air conduction
AD	auditory dys-synchrony/neuropathy
AODC	Adviser on Deaf Children
BC	bone conduction
BOA	behavioural observation audiometry
CM	cochlear microphonic
CPA	conditioned play audiometry
dB	decibels
DPOAE	distortion product otoacoustic emissions
DSL	Desired Sensation Level
EEG	Electroencephalography
EHL	estimated hearing level
IEC	International Electrotechnical Commission
ISO	International Standards Organisation
HL	hearing level
MRL	minimum response level
NICU	neonatal intensive care unit
NSU	National Screening Unit
nV	nanovolts
NZAS	New Zealand Audiological Society
PCHL	permanent congenital hearing loss
PEACH	parents evaluation of aural/oral performance of children
REAR	real-ear aided response
RECD	real-ear-to-coupler difference
RESR	real-ear saturation response
RNL	residual noise level
SDT	speech detection threshold
SPL	sound pressure level
UNHSEIP	Universal Newborn Hearing Screening and Early Intervention Programme
VRA	visual reinforcement audiometry

## **1.0 PROGRAMME CONTEXT**

### **1.1 Document Scope and Content**

This document addresses audiologic assessment and provision of amplification to babies and pre-school children identified in the UNHSEIP (Universal Newborn Hearing Screening and Early Intervention Programme).

Providing amplification includes the process of prescribing a hearing instrument based on appropriate assessment information, verification that the specified acoustical performance targets have been achieved, and evaluation of device effectiveness in daily life. Fitting of a hearing aid includes obtaining ear impressions for earmould fabrication, electroacoustic analysis of the prescribed hearing instruments, use of real ear measures, hearing instrument orientation and measurement of outcomes.

The document includes specifications of key procedural elements and technical appendices. All audiologists must practise diagnostic procedures in compliance with the requirements of this protocol.

Departures from these protocols may be appropriate in individual babies and under special circumstances. Their nature and rationale must be documented in clinical case records. The National Screening Unit (NSU) reserves the right to review documentation and clinical records involving any such departures from this protocol.

### **1.2 Personnel**

All services for assessment and amplification must be conducted by a qualified audiologist who meets criteria specified by the NSU. Support services such as assisting with BOA, VRA, CPA, distracting during RECD measurements, taking ear impressions and fitting earmoulds can be provided by appropriately trained and supervised support personnel.

### **1.3 Infection Control Standards**

All assessment and amplification services must comply with all pertinent standards of the facility relating to infection control. In the absence of specific facility standards, generally accepted standards must apply.

### **1.4 Clinical Records & Reports**

All assessment and amplification records must be maintained in a manner satisfying the requirements of audit processes. The assessment and amplification records must be maintained in electronic and/or hard copy.

Records must identify the child, tester, test date and location, test parameters. ABR waveforms, DPOAE graphics and data, immittance graphics and data, interpretation and contingent recommendations must be included in the file. The records must contain all the information required for the audit process.

The audiologist must complete the appropriate assessment report form and send it to the NSU in a timely manner. If the assessment requires a further appointment to complete, then the report may be deferred to follow the ensuing assessment.

The baby's audiological record should include details of the procedure used to calculate prescriptive targets (i.e. RECD values, DSL targets), a summary of the prescribed amplification including the settings of the device, make and model, earmould specifications, a record of the real ear measurement results and a synopsis of recommendations and information provided to the family and whānau.

It is also important to note progress that the baby is making with the amplification devices. The records must be fully sufficient to demonstrate compliance with the required elements of the UNHSEIP Amplification Protocol (for audit purposes). They should also be sufficient to facilitate consultative, clinical review and case conferencing.

The audiologist must complete the appropriate UNHSEIP amplification protocol summary report form and send it to the NSU or designated agency in a timely manner. If completion of the provision of amplification requires a further appointment, the report may be deferred to follow the ensuing appointment.

## **ASSESSMENT**

### **1.5 Assessment Goals**

The main goals of audiologic assessment are:

- i. to determine the presence or absence of permanent congenital hearing loss
- ii. to provide a sufficient audiometric basis to begin service options to improve hearing and/or communication development before six months of age, wherever feasible and elected by the family and whānau
- iii. to provide prompt audiometric services to eligible children at risk for permanent congenital hearing loss who pass newborn hearing screen or who are referred to audiology due to incidental or discovered risk up to the age of school entry
- iv. to provide an ongoing, sufficient audiometric basis for follow-up services, for children identified with permanent congenital hearing loss.

### **1.6 Assessment Objectives**

The specific objectives of audiologic assessment are to obtain valid and accurate estimates of ear-specific, frequency-specific hearing thresholds and to determine the type of any hearing impairment present (conductive, sensory, neural, or any combination of these). Hearing loss components must be specified and quantified to the fullest extent feasible with the procedures available.

## **1.7 Target Permanent Congenital Hearing Loss**

The nominal target permanent congenital hearing loss (PCHL) established by ABR testing includes any hearing threshold greater than 35 dB EHL at 500 Hz and greater than 30 dB EHL at any frequency in the range 1-4 kHz, in either ear. Although children with mild hearing losses of 25-30 dB HL may not be candidates for amplification these children should still be monitored audiotically, as they may be at risk for progressive hearing loss and the deleterious effects of additional temporary conductive hearing loss. The target permanent congenital hearing loss includes conductive impairment associated with structural anomalies of the ear but does NOT include temporary impairment attributable to non-structural middle ear conditions. The target permanent congenital hearing loss also includes auditory dys-synchrony/neuropathy (AD) and retrocochlear disorders affecting the auditory pathways.

## **1.8 Assessment Candidacy**

Audiologic assessment must be available in a timely manner to:

- babies who refer from screening through the UNHSEIP
- babies and children up to 30 months who are referred for risk factor follow up through the UNHSEIP
- babies and children up to 5 years who acquire high risk status incidentally or through post-natal risk indicator discovery.

## **1.9 Types of assessment**

Assessments are ABR-based and / or behaviour-based. The latter includes visual reinforcement audiometry (VRA), conditioned play audiometry (CPA), or conventional audiometry. The choice of approach is at the discretion of the audiologist, taking account of the individual characteristics of the child and the context and purpose of the assessment. This protocol must apply to initial and follow up assessments.

# **AMPLIFICATION**

## **1.10 Amplification Goals**

The main goals of amplification are to:

- (i) provide an amplified speech signal that is consistently audible across input levels
- (ii) avoid distortion of varying inputs at prescribed settings for the user
- (iii) ensure the signal is amplifying sounds in as broad a frequency range as possible
- (iv) include sufficient electroacoustic flexibility to allow for changes in the required frequency/output characteristics related to ear growth or changes in the auditory characteristics of the baby.

### ***1.11 Amplification Objectives***

The specific objective of amplification is to improve functional auditory capacity and participation in hearing- and communication-specific situations. Published reports suggest that early improvement in hearing can facilitate the development of sensory and perceptual skills, receptive and expressive language, speech production and literacy, academic performance and social-emotional growth (Carney & Moeller, 1998).

### ***1.12 Target Impairments for Amplification***

The nominal target PCHL for consideration of amplification includes any hearing threshold equivalent to 30 dB HL or greater at any frequency in the range 0.5-4 kHz, in either ear. The target PCHL includes conductive impairment associated with structural anomalies of the ear but does not include impairment attributable to non-structural middle ear conditions. The target PCHL also includes auditory dys-synchrony/neuropathy (AD) and retrocochlear disorders affecting the auditory pathways.

### ***1.13 Amplification Candidacy***

For a baby to be considered a candidate for amplification, PCHL will have been identified through audiologic assessment as specified in the Diagnostic Protocol. The determination that amplification should be recommended on audiologic grounds is at the discretion of the audiologist. If amplification is indicated audiometrically, is elected by the family and whānau after review of the options and information, the process of amplification must be undertaken in a timely manner.

### ***1.14 Types of Amplification Assessment***

Assessments are ABR-based and/or behaviour-based. The latter includes Visual Reinforcement Audiometry (VRA), Conditioned Play Audiometry (CPA) or conventional audiometry. The choice of approach is at the discretion of the audiologist, taking account of the individual characteristics of the child and the context and purpose of the assessment. Both behavioural and evoked potentials assessments can provide ear- and frequency-specific information that must be used for the provision of hearing instruments to babies.

### ***1.15 Timing of Amplification***

Amplification should normally be provided within four weeks of diagnosis.

### **1.16 Calibration**

Real ear systems should be calibrated at least once a week. Real-ear and hearing aid test instrumentation must be calibrated on an annual basis.

### **1.17 Otoscopy & Cerumen/Debris**

Cursory otoscopy must be conducted at the start of any amplification appointment. Its main purpose is to detect foreign bodies, canal occlusion and any physical condition of the ear that indicates referral to medical practitioner.

### **1.18 Amplification Components**

Wherever feasible, provision of amplification must include at least ALL of the following:

1. a complete description of the baby's audiological results for both ears
2. a description of the acoustic characteristics of the baby's ear canal(s) in the form of a Real-Ear-to-Coupler Difference (RECD)
3. accurate ear impression(s) for the purposes of fabricating an earmould
4. an assessment of the non-electroacoustic needs of the baby
5. electroacoustic analysis of prescribed hearing instruments (ANSI test)
6. DSL v5 target ear canal sound pressure levels (SPL) for the amplified long-term average speech spectrum
7. DSL v5 target ear canal SPLs for defining the maximum saturation
8. response of the hearing instrument
9. DSL v5 target ear canal SPLs for soft and loud speech
10. verification that the electroacoustic characteristics of the hearing instrument adequately match the auditory needs of the baby
11. simulated measurements of the real-ear aided response (REAR) and the real-ear saturation response (RESR)
12. education and counselling sessions with the family and whānau when the hearing instrument is first fitted and at subsequent follow-up visits as needed
13. an evaluation of the outcome of the intervention (using the Auditory Skills Checklist-Revised and, where possible, PEACH)
14. appropriate follow-up schedule and adjustments to the amplification as required.

# **Diagnostic Protocol**

## **2.0 ABR-BASED ASSESSMENT**

### **2.1 *ABR Calibration***

ABR calibration values (dB SPL to HL offset) are specified in Appendix D. Manufacturers' default calibrations are not acceptable.

ABR instrumentation must be calibrated electro-acoustically annually. Listening checks for transducer malfunction or problems in leads and connections must be done at least weekly, or if the test interval exceeds one week, just before testing.

### **2.2 *Natural Sleep***

ABR testing and, where feasible, OAE testing, must be attempted first during natural sleep, unless testing under general anaesthetic/sedation is strongly indicated. Exceptions that may merit initial assessment under sedation include prior failure to obtain adequate results in natural sleep, and long-distance family and whānau travel to the assessment.

### **2.3 *Baby Pre-Test State***

For assessments in natural sleep, every reasonable effort must be made to ensure that babies arrive for testing in an appropriate state. From a risk management standpoint, families who drive to assessments should be encouraged to be accompanied by a second family member to manage the baby. The probable futility of attempting assessment in a baby not prepared appropriately should be stressed to families.

### **2.4 *General Anaesthesia/Sedation***

All assessments must comply with all pertinent standards of the assessment facility relating to the administration of pharmaceutical agents, such as sedatives, for the specific purpose of conducting the assessment. In the absence of specific facility standards, generally accepted standards must apply.

### **2.5 *ABR Test Environment/Personnel***

The safety and comfort of the baby are paramount, and the baby must be closely monitored at all times. It is recommended that the tester and instrumentation be inside the soundroom. The presence of, or assistance by, family and whānau members has advantages and disadvantages, and is discretionary. When instrumentation is inside the soundroom, ambient noise measurements should be made with the instrumentation switched on to ensure that the test environment meets ambient noise requirements for AC and BC audiometry.

## **2.6 Order of Tests**

Excepting initial cursory otoscopy, the order of procedures within an assessment is discretionary.

## **2.7 Otoscopy and Cerumen/Debris**

Cursory otoscopy must be conducted at the start of any assessment. Its main purpose is to detect foreign bodies, canal occlusion and any physical condition of the ear that may invalidate the assessment or contraindicate the use of insert earphones or that indicates referral to a GP, paediatrician or otolaryngologist.

## **2.8 ABR-Based Assessment Components**

The initial ABR-based assessment must include all of the following procedures, in both ears, irrespective of whether the UNHSEIP screening referral was in one ear or both ears.

- (i) Cursory otoscopy.
- (ii) Tone burst ABR threshold estimation by air conduction (AC) at 2 kHz and 500 Hz and, where specified by this protocol, at 4 kHz and 1 kHz. Insert earphones must be used for all AC measurements, except where specifically contraindicated. Ipsilateral masking must not be applied.
- (iii) Tone burst ABR threshold estimation by bone conduction (BC), where specified by this protocol, at 2 kHz and, where indicated and feasible, at 500 Hz.
- (iv) High-intensity click ABR including cochlear microphonic potentials and stimulus artifact analysis, at 80 dB HL if tone burst thresholds are normal or at a higher level (95 dB HL) if tone burst thresholds are elevated.
- (v) DPOAE amplitude and noise floor measurements at 1.5, 2, 3 and 4 kHz.
- (vi) Immittance testing, which must include tympanometry and ipsilateral acoustic reflex testing. The probe tone frequency must be 1 kHz for babies under 6 months corrected age and using a broad band noise stimulus for reflex testing. For children aged 6 months and older the probe tone frequency must be 226 Hz and a minimum of a 1 kHz stimulus should be used for reflex testing.

Notes:

- If the baby passes the tone burst ABR protocol it is not essential to record the high level click ABR.
- If the baby passes the DPOAE protocol it is not essential to perform immittance testing.
- If the baby wakes after the ABR has been completed and passing levels are achieved and it is not possible to record DPOAEs or perform immittance testing the baby can be discharged at this point if there are no concerns.
- Regardless of whether the initial screening result was a pass for a particular ear, it is essential that both ears pass the ABR. If the baby wakes before the second ear is tested, an additional ABR appointment should be scheduled.

## **2.9 ABR Stimulus Transducers**

ABR measurements by air conduction (AC) must be done using insert earphones, except where specifically contraindicated, in which case supra-aural earphones (TDH/MX41) are optional. BC ABR testing must be done with careful transducer placement supero-posterior to the canal opening of the individual test ear. The BC transducer (B-71) must be secured firmly in place by a custom Velcro band or by correct hand holding of the transducer by one finger. Application force measurements are not required.

## **2.10 Electrodes and Impedances**

ABR recording electrodes must be placed on the high forehead as close as possible to the hairline and at or close to the midline (non-inverting), on each mastoid process (inverting) and on the lateral forehead at least 3 cm from the non-inverting electrode (common). Every reasonable effort must be made to obtain impedances of less than 5 kilohms for all electrodes, and impedance differences within each channel of less than 1 kilohm.

## **2.11 Recording Channels**

For AC measurements, the channel ipsilateral to the stimulated ear must be evaluated and plotted. For BC measurements, both ipsilateral and contralateral channels must be acquired, evaluated, stored and plotted.

## **2.12 Tone burst ABR Measurement Parameters**

All ABR testing must be conducted using the technical parameters detailed in Appendix C. Tone burst ABR threshold estimates must be obtained according to the following specifications, in each ear.

## **2.13 Number of Sweeps and Averages**

Except in special circumstances (see below), determination of 'response present' in the waveforms requires visual observation of the replicability of waveforms by the audiologist performing the assessment. Any threshold or minimum response level determination requires replication of responses at the 'threshold' level and replications of 'no response' waveforms at the level below any elevated threshold (i.e., replications typically 10 dB below threshold level, except if threshold is >70dB HL, where a final step size of 5 dB may be employed).

Recordings at levels below the passing response levels are not required and should not be pursued. Typically, each replication will have at least 2000 trials in each average, although averaging may either be stopped (i) early if waveform residual noise levels (see below) reach criterion levels or (ii) after more than 2000 trials if waveform noise levels are high. If two clear replications are obtained at the minimum passing level, it is recommended that the presence of a response is confirmed by doing one average at a higher intensity (typically 20 dB louder).

To reiterate: a single replication must not be used in the final bracketing of the estimated ABR threshold. If there is a hearing loss, ABR threshold is defined

by a response-positive pair of replications at some level, and a response negative pair of replications at 10 dB, or in some cases 5 dB, below that level.

A provisional response-negative decision may be made if a single average is subjectively flat and has no peak-to-peak excursion larger than 100 nV.

A provisional response-positive decision may be made on the basis of a single average if the location and shape of the waveform are appropriate and the presumed-response amplitude exceeds 250 nV and the Residual Noise Level is 40 nV or less.

If any RNL is less than 20 nV, given at least 2000 sweeps, a subjective decision about response presence or absence usually may be made with confidence.

It is strongly recommended that in protocol setup the maximum number of sweeps should be set to nominally 4000. This avoids repeatedly having to override the maximum number of sweeps after every increment of 256 sweeps beyond a lesser maximum. This matter arises when the audiologist is not satisfied with sweep quality despite the fulfillment of the RNL stop criterion. In this context, all averages must be terminated by the audiologist, with due regard to the current number of sweeps, the RNL values and the appearance of the records.

### ***2.14 ABR Threshold Definition & Bracket Step Size***

The final threshold bracket step size must be no greater than 10 dB. If the threshold estimate with that bracket is greater than 70 dB EHL, a 5 dB step size must be used for the final bracket. The increased precision is relevant to accurate prescription of amplification, if the residual dynamic range is very limited.

Response detection decisions must be made subjectively, using the strategies given in this protocol and, where appropriate, assisted by RNL values. The Fsp and Weighted ('Bayesian') Averaging options must not be used.

### ***2.15 Confirmation of Threshold Upper Bracket Response***

In the event that there is any residual uncertainty about the presence of response at the threshold upper bracket level, an average must be done at a level 10 dB above the upper bracket level (except if the bracket is at maximum level). Response presence must be confirmed in that average, in order to accept the threshold bracket as valid.

### ***2.16 50 Hz Artifact and Notch Filtering***

Records must be inspected carefully for 50 Hz artifact. If suspected, such artifact must be confirmed by inspection of an average with a 0 dB stimulus level. Standard procedures to identify and eliminate the source of the artifact must be implemented. If large, irreducible 50 Hz artifact is present, contaminated records must not be interpreted for response presence or absence. Otherwise, threshold estimation may proceed using the 50 Hz notch

filter. The use of that filter must not be routine and must be documented. If 50 Hz artifact is a frequent problem, the test environment, instrumentation, electrodes and cables should be evaluated and electrode application procedures should be reviewed.

### ***2.17 Residual Noise Level and 50 Hz Artifact***

In the event that the RNL is very large and inconsistent with the subjective impression of noise variability in the average, the RNL must be disregarded and averaging strategy must revert to replicated averages of at least 2000 sweeps. If large values of RNL are a frequent problem, the test environment, instrumentation, electrodes and cables should be evaluated and electrode application procedures should be reviewed.

Note that a 0 dB average with notch filtering on strongly suggests presence of significant 50 Hz artifact if the notch-filtered RNL is more than 10 nV less than the unfiltered RNL.

### ***2.18 Amplifier Gain and Artifact Rejection***

Amplifier gain must be 100,000. A gain that yields 5-10% rejection in quiet EEG conditions is optimal, typically 20-25  $\mu$ V, or less. Gain must not be decreased if the EEG noise level increases during the test. Artifact rejection must not be disabled.

### ***2.19 Strategy for Stimulus Levels***

The general, default strategy for threshold bracketing includes starting at the minimum required level, followed by ascent in steps of at least 20-30 dB and descent in 10 dB steps. This is efficient, since many initial assessments will reveal normal hearing. Ascent by 10 dB must be avoided unless there is questionable positive (replicated) response at the minimum level for a given stimulus route and frequency or at the upper bracket level for estimated ABR threshold. The protocol specifically does not involve routine use of an input-output function approach to threshold estimation. The smaller the number of levels used for a given threshold estimation, the more efficient is the test.

### ***2.20 Stimulus Frequency Test Strategy***

Strategy is multi-factorial and in part discretionary, subject to the following specifications. The initial, primary importance of results at 2 kHz must be considered.

### ***2.21 Air Conduction at 2 kHz***

In the absence of prior assessment results, testing must begin by AC at the minimum level (30 dB HL) at 2 kHz. Non-response at 30 dB must be followed by an appropriate threshold bracketing procedure, as noted above.

### ***2.22 Air Conduction at 500 Hz***

AC at a minimum of 40 dB HL at 500 Hz, with threshold bracketing if no response, must be done. Testing at 500 Hz is a mandatory component of initial assessment.

### **2.23 Bone Conduction at 2 kHz**

BC at 30 dB 2 kHz must be done if there is no response by AC at  $\geq 40$  dBnHL at 2 kHz, with threshold bracketing if no response.

### **2.24 Bone Conduction at 500 Hz**

BC at a minimum of 30 dBnHL at 500 Hz is recommended, where time permits, but is not mandatory if BC at 2 kHz has been obtained. If the only AC abnormality is at 500 Hz, BC 500 Hz is mandatory where the AC 500 Hz threshold is  $\geq 50$  dB HL. Slight elevations of AC thresholds at 2 kHz or 500 Hz do not trigger mandatory BC testing. This protocol assumes that immittance testing is also performed.

### **2.25 Bone Conduction at Other Frequencies**

BC testing must not be done at any frequency other than 500 Hz and 2 kHz. Currently, the UNHSEIP does not provide calibration values for other frequencies.

### **2.26 Bone Conduction Stimulus Artifact**

At 500 Hz, at the highest stimulus levels (typically 50 dB) stimulus artifact can be very large and may obscure half of the average. Appropriate procedures to minimize BC stimulus artifact must be used. The maximum BC level is discretionary in the presence of large, irreducible artifact. The use of 'blocked points' which is available in some commercial evoked potential systems can assist in dealing with excessive stimulus artifact.

### **2.27 Bone Conduction Two-channel Recording**

For BC ABR measurements, the channels Cz-M1 and Cz-M2 must always be recorded, displayed and plotted contiguously.

### **2.28 Bone Conduction Inferring Which Cochlea is Responding**

BC measurements must be done with the transducer placed on the mastoid of each test ear separately. The responding cochlea for BC measurements must be inferred by comparisons of response amplitude and latency in the records ipsilateral and contralateral to the test ear. In the event of equivocal interpretation, stimulus levels should be reduced in an attempt to isolate the responding side, even below minimum required levels.

### **2.29 Air Conduction and Bone Conduction Contralateral Masking**

Given the use of insert transducers and the two-channel BC method, the need for contralateral masking to provide satisfactory audiometric interpretation is minimal. If an asymmetrical hearing loss is diagnosed with an asymmetry greater than 60 dB (IAA of insert phones) then the use of contralateral masking noise is indicated. The addition of 40 dB masking noise should provide adequate masking; additional masking noise is not recommended because of the risk of cross over and central masking.

### **2.30 Air Conduction at 4 kHz**

AC at a minimum of 30 dB HL at 4 kHz, with threshold bracketing, must be done if there is no response at 30 dB for 2 kHz. Given abnormality at 2 kHz, the likelihood of significantly different abnormality at 4 kHz is high. An exception is that initial testing at 4 kHz is not mandatory if there is a significant conductive component at 2 kHz, because subsequent re-testing is strongly indicated.

### **2.31 DPOAE Indicator for 4 kHz ABR**

In the event that DPOAE records in any ear are available and normal at mid-frequencies but clearly depressed or absent at a nominal F2 of 4 kHz, tone burst ABR testing must be done at 4 kHz, despite normal ABR results at 2 kHz. In the event that DPOAE testing was done after the ABR, then further ABR testing is mandatory, unless under exceptional circumstances such as gross inconvenience to the family and whānau.

### **2.32 Air Conduction at 1 kHz**

AC at a minimum of 30 dB HL at 1 kHz, with bracketing if there is no response, must be done if there is a difference of 30 dB or more in the dB HL thresholds at 500 Hz and 2 kHz. If the difference is less than 30 dB, testing at 1 kHz is discretionary but not recommended unless all mandatory thresholds have been obtained and time permits. An exception is that initial testing at 1 kHz is not recommended if there is a significant conductive component at 500 Hz or 2 kHz.

### **2.33 Deferring Air Conduction at 1 and 4 kHz in Conductive or Mixed Losses**

If a significant conductive component is demonstrated clearly at 500 Hz or 2 kHz and the tympanometry and any feature of the recent history suggest a middle-ear disorder, the determination of AC thresholds for 4 kHz and 1 kHz is discretionary unless and until their respective UNHSEIP indications are fulfilled at a follow-up assessment, after a waiting period that may or may not include medical treatment of a potentially transient/treatable middle-ear condition.

### **2.34 Auditory dys-synchrony / Retrocochlear Lesion Click ABR Sub-protocol**

If there is no detectable ABR with identifiable wave V to tonebursts at the highest available intensity levels at all frequencies measured in any ear, or wave V thresholds at severe-profound levels by AC or BC (if indicated), then an AC click ABR test must be done at 95 dB HL (or the maximum intensity permitted of the evoked potential system) in that ear. Condensation and rarefaction records must be plotted separately. To ensure these results are interpretable, records must be replicated, have at least 2000 sweeps per average with an overall noise criterion at or below criterion. ABR measurements using clicks have a secondary role, but an important one. There are three aspects of diagnostic inference that may be clarified by the use of click stimuli: retrocochlear pathology, AD, and residual hearing. If there is any repeatable deflection in the first 5 ms of any such average, the click

records must be repeated with the tubing detached from the transducer and positioned as far as possible from it. The insert and transducer must not be moved from their positions for the previous 95 dB recordings.

### **2.35 Auditory Dys-synchrony Inference**

The high-intensity click records must be assessed for presence of cochlear microphonic (CM) and stimulus artifact. Together with DPOAE records, the evidence for AD must be evaluated. Absence of DPOAE does not rule out AD, whereas presence of DPOAE and absence of ABR or grossly elevated ABR thresholds does make AD a primary inference. If DPOAE are absent but the CM records suggest AD, that finding is less definitive and is considered to yield a presumptive inference.

With AD the click record may contain neurogenic activity, which may or may not be a recognisable ABR. Neurogenic activity does not invert, may not be present for both stimulus polarities, and increases in latency as stimulus level decreases.

### **2.36 Auditory Dys-synchrony Implications**

If definite or presumptive AD is the diagnostic inference, perceptual tone burst thresholds may be substantially better than ABR-based threshold estimates, and regular follow-up assessment is mandatory. The true threshold picture will usually emerge if and when behavioural testing becomes viable. If the DPOAE are not normal, a presumptive inference of AD may be clarified by family and whānau report of responsiveness and behavioural observation by the audiologist.

Intervention strategy is highly dependent on the individual case. Deferral of amplification pending a period of observation and a behavioural assessment is recommended. Cortical auditory evoked potential testing may be considered.

### **2.37 Auditory Dys-synchrony Report**

If AD is the definite or presumptive finding, the tone burst thresholds are not valid. Currently, they must be entered in the report as if they were valid, typically as reflecting non-response at the highest available stimulus levels, but must be qualified by an entry indicating definite or probable AD. Permanent congenital hearing loss must be reported as present.

### **2.38 Click ABR Thresholds**

Threshold seeking using click ABR is only done when the audiologist suspects AD or neurologic involvement affecting tone-ABR threshold validity. If a clear and replicable response to clicks is identifiable at 95 dB HL, the click-ABR threshold must be determined by bracketing. The response need not contain waves that are clearly identifiable as e.g., wave III, wave V, but there must be a replicable waveform in the range 2-20 ms to determine response presence. If a clear wave V is seen in response to clicks, in the absence of tone burst responses at maximum AC levels, a possible cause is that there is better hearing at some frequency not yet tested by tone bursts, in the range 0.5-8

kHz that may be excited by clicks. This might be explored by tone burst ABR measurements at the untested primary frequencies, at least in the range 1-4 kHz. Another possible cause of a wave V-V' to clicks but not to tone bursts is that there is severe cochlear impairment and insufficient synchronous excitation of primary neurons with a frequency-specific stimulus, whereas the click excites a broader region of the cochlear partition and with greater synchrony. In that situation, no tone burst response will be seen at any frequency, but the click threshold could be much lower. If this pattern of results is seen, the audiometric values reported should be based on the tone burst results, but the finding of a click response should be noted. A click response threshold should be determined by bracketing and noted as comment on the report.

### **2.39 *Estimated Hearing Levels (EHLs)***

ABR thresholds must be converted to estimates of the true perceptual threshold in dB HL by the application of the threshold adjustment factors listed in Appendix D. The resulting thresholds must be referred to as 'Estimated Hearing Level' (EHL) thresholds, with units 'dB EHL'. EHL values must be entered as thresholds in the UNHSEIP report.

## **3.0 DPOAE TESTING**

### **3.1 *DPOAE Protocol***

All DPOAE tests must be done in compliance with this protocol and using the technical parameters and interpretive criteria detailed in Appendix E.

DPOAE testing is mandatory for all ABR-based assessments and also for VRA-based or CPA-based assessments.

DPOAE levels and noise thresholds must be measured at nominal (F2) frequencies of 1.5, 2, 3 and 4 kHz. DPOAEs must be replicated if the stimulus level tracing is not flat or if the DPOAE/noise separation is less than 5 dB at any frequency. DPOAEs must be plotted for each ear with the replicates overlaid on a single plot. It is recommended that the left and right ear results be plotted side by side, wherever feasible. The hardcopy plots and numerical data listings must be retained on file.

### **3.2 *DPOAE Test procedure***

Test parameters for diagnostic DPOAE measurements are detailed in Appendix E. The UNHSEIP protocol includes replicated DPOAE measurements at nominal (F2) frequencies of approximately 1.5, 2, 3 and 4 kHz. The f2/f1 ratio is 1.2, with f1 and f2 levels of 65 and 55 dB SPL.

### **3.3 *DPOAE Interpretation***

The interpretation must take account of absolute DPOAE levels, absolute noise levels, DPOAE-noise level differences and differences among replicates. The primary rationale for DPOAE testing is to cross-check ABR threshold inferences and also to assess the potential for AD, for any threshold technique (ABR, VRA, CPA, conventional).

## **4.0 IMMITTANCE TESTING**

### **4.1 *Immittance Protocol***

Immittance testing is mandatory in all assessments. All immittance tests must be in compliance with this protocol and the technical parameters and interpretive criteria detailed in Appendix F.

### **4.2 *Tympanometry***

Tympanometry must be done with a 1 kHz probe tone for babies under six months corrected age and a 226 Hz probe tone for children aged 6 months or more. The tympanogram must be replicated immediately if the trace is noisy or if it is not clearly normal. A clean, obviously normal tympanogram need not be replicated. Tympanograms must be plotted and retained on file.

For babies below six months corrected age (1 kHz probe tone): the key abnormality criterion is a negative peak that occurs on a line drawn from the positive to negative tail of the tympanogram (see Baldwin, 2006).

For children of six months or more corrected age (226 Hz probe tone), the abnormality criterion is  $<0.2$  mmho or  $<-100$  daPa (Type C tymps are still abnormal even with a high compliance).

### **4.3 *Acoustic Reflexes***

Ipsilateral acoustic reflex measurements must be done with a 1 kHz probe tone for babies under six months corrected age and with a 226 Hz probe tone for children aged six months or more. The eliciting stimulus must be BBN for the babies under 1 month and a minimum of 1 kHz tone stimuli for children over 6 months. The goal is not to establish an accurate reflex threshold, but to demonstrate the clear presence or absence of reflexes at any safe stimulus level. The starting level must be 80 dB for BBN and 90 dB for tonal stimuli, with at least two replications at any level considered to be reflex-positive. Reflex records must be plotted and retained on file if they are ambiguous.

### **4.4 *Acoustic Reflex Interpretation***

Reflexes must be used as a cross-check whenever ABR threshold estimates are 70 dB EHL or greater, whenever AD is suspected, whenever tympanometry is abnormal, and whenever an air-bone gap greater than 10 dB is inferred from ABR thresholds.

## **5.0 VRA-BASED ASSESSMENT**

All Initial VRA-based assessments must include:

- ear-specific AC thresholds at 2 kHz, 500 Hz, and 4 kHz, plus 1 kHz if indicated by rules analogous to those specified previously for ABR-based assessments
- ear-specific speech detection thresholds obtained through monitored live voice testing
- BC thresholds at 2 kHz, 500 Hz and 4 kHz, if indicated by conventional criteria
- DPOAE levels and noise thresholds at nominal F2 values of 1.5, 2, 3 & 4 kHz
- immittance testing including tympanometry with a 226 Hz probe tone and ipsilateral acoustic reflexes at 1 kHz (2 kHz and 500 Hz reflexes may be obtained if the child is co-operative) with a 226 probe tone (if the baby is under 6 months of age 1 kHz probe tones should be used for tympanometry and reflex testing).

### **5.1 Tests & Protocol**

Where developmentally appropriate, visual reinforcement audiometry (VRA) must be used to obtain behavioural estimates of hearing sensitivity. All VRA testing must be conducted in accordance with the detailed procedures listed in this protocol. See the detailed specifications and rationale below and in Appendix G.

### **5.2 Target Population**

Candidates for VRA-based assessment include babies aged from about 6 to about 24 months corrected age who have been identified with PCHL by ABR-based assessment, or who fail routine follow up (by VRA), or who are referred to audiology due to risk factors such as postnatal infections, head trauma, etc.

### **5.3 Test Personnel**

Two testers are normally needed for VRA testing – the examiner and the distracter. The examiner must be an audiologist who has had VRA training. The distracter must be supervised by the examiner, and should preferably have appropriate training and experience. A parent or other family member may be used in this capacity, at the discretion of the audiologist. Where necessary and appropriate, an audiologist discretionally may conduct VRA testing alone, acting both as examiner and distracter.

### **5.4 Test Environment**

VRA testing must be done in an audiometric test room satisfying current IEC/ISO standards for maximum permissible ambient noise for audiometric test rooms. The room must accommodate the parent, baby and distracter comfortably and permit the loudspeaker to be at least one meter from the child's head. Stimuli and reinforcement are usually controlled from an adjacent area separated by a one-way window, in which case two-way communication

must be available to the examiner and distracter. In the test room, the baby and distracter must be seated appropriately and with access to an array of distraction items. Reinforcers must be located to the side of the child and at eye level.

### **5.5 Instrumentation & Calibration**

VRA must be done using a clinical diagnostic audiometer that meets the current IEC/ISO specifications. The audiometer must be capable of presenting pure tone, NBN and FM warbled-tone stimuli through insert earphones, supra-aural earphones, loud speakers and a BC transducer.

In the absence of specific contraindications, insert earphones must be used for AC VRA. Tolerance of insert earphones by babies can usually be achieved, as has been proven unequivocally by Widen (2000).

TDH 49/MX41 supra-aural earphones must be used when insert phones are anatomically contraindicated. Careful attention to accurate placement is required to ensure appropriate stimulus levels and to avoid collapsing ear canals. Soft padding for the headband must be available.

A BC transducer satisfying current IEC/ISO standards is required. To establish BC thresholds requires accurate and stable placement of the transducer. If proper force and stability cannot be achieved and tolerated with the standard headband, an elastic Velcro headband may be required.

Calibration of insert earphones, supra-aural earphones, loud speakers and bone vibrator must be carried out according to current IEC/ISO standards. A visual check of the equipment and a listening check at all frequencies used must be carried out at least monthly.

### **5.6 Test Objectives**

Wherever feasible and appropriate, VRA must be used to obtain frequency-specific and ear-specific thresholds by air conduction and also by bone conduction, where the latter are indicated by conventional audiometric criteria.

### **5.7 Soundfield versus Ear-specific VRA**

VRA soundfield thresholds must not be considered as sufficient, either diagnostically or as a quantitative basis for optimal intervention. Such thresholds are acceptable only if there is clear documentation of a failed, substantial effort to obtain ear-specific thresholds. Soundfield measurements are discretionary for purposes other than threshold estimation, such as demonstration of non-responsiveness for families.

### **5.8 Selection and Order of Stimulus Frequencies**

AC testing must be done using pulsed NBN or FM-warbled tones of 1-2 s duration presented through insert earphones. Frequency selection is dictated by VRA assessment context (i.e. initial or follow-up testing).

VRA follow-up from ABR-based assessment must include 2 kHz, 500 Hz and 4kHz bilaterally, because of their fundamental importance, and to compare with the previous ABR results, assessing accuracy and possible progression. The importance of 1 kHz depends on results at 2 kHz and 500 Hz, as in ABR assessment.

In follow-up VRA after initial VRA, choice of frequencies is dictated by clinical need in relation to diagnosis, monitoring of progression, and amplification. On occasion, 3 kHz may also be required, especially given large differences between thresholds at 2 and 4 kHz. BC thresholds should be determined according to standard audiometric indications for differential diagnosis of loss type and loss components.

AC thresholds for speech (Speech Detection Threshold) should be determined for each ear. Monitored live voice speech stimuli should be used for the initial conditioning of the baby prior to frequency specific thresholds testing and may help to regain the baby's attention after several NBN/warble-tone frequencies.

### **5.9 Threshold Procedure**

The protocol for determining thresholds must be based on the procedure described by Gravel et al. (1994) and conducted as detailed in the technical summary in Appendix G.

### **5.10 Auditory Dys-synchrony Inference from VRA**

In the event of normal DPOAEs and reliable VRA thresholds of 55 dB HL or greater, AD is highly probable and a confirmatory ABR test with the click protocol for AD must be considered. Such a test is likely to require general anaesthetic/sedation.

### **5.11 Normal Hearing thresholds Determined by VRA**

The minimum test levels required to define normal hearing by VRA are 20 dB HL.

## **6.0 CONDITIONED PLAY AUDIOMETRY (CPA)**

All Initial CPA-based Assessments must include:

- ear-specific AC threshold estimates at 2 kHz, 500 Hz and 4 kHz, plus threshold estimation at 1 kHz, where indicated by rules analogous to those specified previously for ABR-based and VRA-based Assessments
- ear-specific BC threshold estimates at 2 kHz, 500 Hz and 4 kHz, where indicated by conventional audiometric criteria; plus threshold estimation at 1 kHz, where indicated by rules analogous to those specified previously for VRA-based Assessments
- DPOAE levels and noise thresholds at nominal F2 values of 1.5, 2, 3 & 4 kHz
- immittance testing including tympanometry and ipsilateral acoustic reflexes at 1 kHz, with a 226 Hz probe tone, if possible acoustic reflexes should also be obtained at 500Hz and 2 kHz.

### **6.1 Tests & Protocol**

Where developmentally appropriate, conditioned play audiometry (CPA) must be used to obtain behavioural estimates of hearing sensitivity.

CPA testing must be conducted in accordance with the procedures listed in this protocol. See the CPA specifications and rationale below.

### **6.2 Target Population**

Candidates for CPA can arise through: follow-up of children with PCHL identified from prior UNHSEIP assessment by ABR and/or VRA, failure at routine follow up of high-risk children, and referral to audiology of children newly identified as at risk for PCHL.

### **6.3 Test Personnel**

One examiner is normally needed for CPA testing. The examiner must be an audiologist who has had VRA training. Certain children who are difficult to test may require a second tester to complete the testing. The second tester or play partner must be supervised by the examiner. A parent or other family member may be used in this capacity, at the discretion of the audiologist.

### **6.4 Test Environment**

CPA testing must be done in an audiometric test room satisfying current IEC/ISO standards for maximum permissible ambient noise for audiometric test rooms. The room must be of sufficient size to accommodate the baby and play partner (if required) comfortably.

### **6.5 Instrumentation & Calibration**

CPA testing must be done using a clinical diagnostic audiometer that meets current IEC/ISO standards. The audiometer must be capable of presenting

pure tone, NBN and FM warbled-tone stimuli through insert earphones, supra-aural earphones, loud speaker or a BC transducer.

In the absence of specific contraindications, insert earphones must be used for AC CPA. TDH 49/MX41 supra-aural earphones must be used when insert phones are contraindicated anatomically. Careful attention to accurate placement is required to ensure appropriate stimulus levels and avoid collapsing ear canals. Soft padding for the headband must be available.

A BC transducer to current IEC/ISO specifications is required. Establishment of BC thresholds requires accurate and stable placement of the bone oscillator. If proper force and stability cannot be achieved with the standard headband, an elastic Velcro headband may be required.

Calibration of insert earphones, supra-aural earphones, loud speaker and the BC transducer must be carried out according to current IEC/ISO standards. A visual examination of the equipment and a listening check at all frequencies used must be carried out at least monthly.

## **6.6 Test Objectives**

Wherever feasible and appropriate, CPA must be used to obtain frequency-specific and ear-specific thresholds by air conduction, and also by bone conduction, where the latter are indicated by conventional audiometric criteria.

## **6.7 Soundfield CPA**

CPA soundfield thresholds must not be considered as a sufficient basis for optimal intervention. Such thresholds are acceptable only if there is documentation of a failed, substantial effort to obtain ear-specific thresholds. Soundfield measurements are discretionary for purposes other than threshold estimation, such as demonstration of non-responsiveness.

## **6.8 Selection and Order of Stimulus Frequencies**

AC testing must be done using pulsed pure tones, NBN, or FM-warbled tones of 1-2 s duration presented through insert earphones. Frequency selection is dictated by CPA assessment context.

Follow-up from ABR-based or VRA-based assessment must include 2 kHz, 500 Hz and 4 kHz bilaterally, because of their fundamental importance and to compare with the previous VRA results, with respect to accuracy and possible progression. The importance of 1 kHz depends on results at 2 kHz and 500 Hz, as in ABR and VRA assessment. In follow-up CPA, choice of frequencies is dictated by clinical need for diagnosis, monitoring of progression, and amplification. On occasion, 3 kHz may also be required, given large threshold differences between 2 kHz and 4 kHz. BC thresholds should be determined according to standard audiometric indications for differential diagnosis of loss type and loss components.

### **6.9 *Speech stimuli***

Speech audiometry using the Kendall Toy Test, or another closed-set task suitable for young children, is recommended. AC thresholds for Speech Detection (SDT) may be established at the discretion of the audiologist, if this does not compromise the goal of establishing frequency-specific thresholds.

### **6.10 *Threshold Determination***

The procedures recommended for threshold determination by CPA are closely analogous to those for VRA. The VRA worksheet and the methodology of stimulus control and response documentation may be followed closely, at the discretion of the audiologist.

### **6.11 *Test Procedure***

CPA test procedure must follow VRA test procedure as closely as possible, with due regard to the differences in subject age and behaviour, and in the reinforcement paradigms.

### **6.12 *Normal Hearing thresholds Determined by CPA***

The minimum test levels required to define normal hearing by CPA are 20 dB HL.

### **6.13 *AD Inference from CPA***

In the event of clear and normal DPOAE records in the presence of reliable CPA thresholds at 2 kHz of greater than 55 dB HL, AD is almost certain. A confirmatory ABR test including the click protocol for AD must be considered, if there is any question about the reliability of the CPA thresholds. Such a test may require general anaesthesia/sedation.

## **7.0 OVERALL INFERENCE AND CONTINGENT ACTIONS**

### **7.1 General Approach**

Overall audiologic inference must be based on integration and critical evaluation of all available findings, according to the principles outlined in this protocol.

### **7.2 Normal Hearing Definition**

A child must only be considered as audiometrically 'normal' if AC HLs or thresholds are estimated with confidence at 20 dB for all frequencies that are mandatory under this protocol and there is no audiometric indication of AD or any retrocochlear disorder.

### **7.3 Hearing Loss Present**

Hearing loss is present if any threshold in the range 500 Hz to 4 kHz is estimated with confidence to be greater than 35 dB EHL for 500 Hz and greater than 30 dB EHL for 1 kHz, 2 kHz and 4 kHz (or greater than 20 dB HL for behavioural methods) or if AD is strongly indicated.

### **7.4 Permanent Congenital Hearing Loss (PCHL) Present**

PCHL is present if any BC threshold is estimated with confidence to be greater than 30 dB EHL, or if any required AC threshold is estimated with confidence at 70 dB or greater, or if the presence of AD is strongly indicated.

### **7.5 Minor Conductive Hearing Loss**

Given minor elevation of ABR threshold at 500 Hz only, with no indication of PCHL, hearing loss must be reported as present, PCHL as absent, and the strong probability is a minor, transient middle-ear disorder. In that case, at the discretion of the audiologist the child may be discharged from audiology, with appropriate cautionary remarks to the family and whānau. Any further management should be provided within primary care, unless and until there is a determination of PCHL risk that warrants re-entry into further audiologic follow-up.

### **7.6 Substantial Conductive Hearing Loss**

Given a substantial conductive impairment and no indication of PCHL, then in the absence of obvious anatomic abnormality or symptoms of a middle ear disorder, consented referral to ORL is discretionary. An option is to consider the assessment provisional and incomplete and to retest after 12 weeks, with appropriate caution to families regarding self-referral to a GP if any concerns arise. The apparent conductive component may resolve spontaneously and more definitive audiometry will be obtained at retest. If such a course is elected, a finding on retest of sustained and substantial conductive component must result in a referral to ORL, if consented, and the child must be discharged from audiology, pending emergence of any information to indicate that the impairment is due to a structural cause.

### **7.7 *Mixed Hearing Loss***

If the assessment indicates a mixed conductive and sensory/neural impairment, or if there is any evidence (eg, the opinion of an ORL) that a purely conductive impairment is attributable to a structural disorder, then the audiological management should continue. Wherever feasible, the baby must receive a repeat assessment following active medical management of the condition (not including watchful waiting).

# **Amplification Protocol**

## **8.0 ASSESSMENT CONSIDERATIONS**

### **8.1 *Auditory Characteristics***

Auditory characteristics must be defined prior to providing amplification to babies. Threshold estimates for at least 500 and 2000 Hz must be obtained in each ear prior to initiating the provision of amplification. In some cases, obtaining additional diagnostic information may occur concurrently with beginning the trial of amplification. Threshold estimates at other frequencies (i.e. 1000 and 4000 Hz) are recommended, but are not required for beginning the provision of amplification. It is expected the 4000 Hz thresholds will be determined early on in the fitting process, and ideally at the initial diagnostic appointment. Strategies for determining hearing thresholds will vary depending on the age of the baby.

### **8.2 *Consultation by an Otolaryngologist or Paediatrician***

Babies identified with a permanent congenital hearing loss must be referred immediately to an otolaryngologist (or paediatrician, depending on local referral pathways) for the aetiologic investigation of the permanent congenital hearing loss. This referral has the main goal of providing a broad review of the child's health status in light of the hearing impairment, and may include radiologic, serologic, and ophthalmologic tests, as well as genetic review and other cross-referrals.

### **8.3 *Acoustic Characteristics***

The Real-Ear-to-Coupler Difference (RECD) measurement procedure was developed to determine an individualised acoustic transform for use with the Desired Sensation Level (DSL®) Method (Moodie et al., 1994; Seewald, 1995; Scollie et al., 2005). The individual's RECD is used to obtain SPL thresholds, generate the appropriate gain and output response for a hearing instrument, and has been shown to be highly repeatable and valid (Munro & Hatton, 2000; Sinclair et al., 1996; Seewald et al., 1999). Therefore, it is a required element in the amplification process for babies.

### **8.4 *RECD Measurement***

Wherever feasible, audiologists must measure the individual baby's RECD as part of the amplification process. RECD measurement procedures are outlined in Appendix L. RECD measurements should be obtained from each baby using SpeechMap DSL in the real ear hearing aid test system following the procedure described by Moodie et al (1994). RECD values, tester, coupling type (earmould, foam tip, immittance tip), ear and test date must be documented and retained on file.

### **8.5 Age-appropriate Predicted RECD Values**

In the event that the individual RECD measurement cannot be obtained, age-related predicted values must be applied. If individual RECD measurement is only achieved for one ear, it is preferable to use these values for the opposite ear, rather than using the age-related predicted values. A description of the use of these values within applications of DSL v5 is located in Appendix M. If predicted values are used, they must be specified (i.e. age, coupling type), documented, and retained on file. The current values are derived from data collected from babies and children of varying ages and are provided for foam tip and earmould coupling (Bagatto et al, 2002).

## **9.0 PRESCRIPTION OF AMPLIFICATION**

### **9.1 *Ear Impressions***

Ear impressions must be obtained from each ear for fabrication of personal earmoulds (see Appendix N) as per the earmould prescription. The prescription must include length of canal and helix, material (silicone, etc.), tubing type, shell style, vent (if possible) and options.

The baby's earmoulds should be made of a soft material for comfort, safety and retention. Also, softer material reduces the possibility of acoustic feedback from the hearing instrument. The advantages and disadvantages of various earmould materials should be weighed for each individual baby (See Appendix N for details). The need for frequent replacement of earmoulds to prevent acoustic feedback should be explained to the family and whānau. Open fit hearing aids are not recommended for babies due to retention issues, and lack of robustness of the thin tube.

### **9.2 *Non-electroacoustic Characteristics***

The audiologists must consider non-electroacoustic characteristics of the prescribed hearing aid. The style of the hearing aid, monaural vs binaural fitting, deactivation of certain advanced features, FM system compatibility, and tamper resistant battery doors are important considerations when providing hearing aids to babies and young children. It is expected that the fitting would be usually be binaural, behind-the-ear hearing aids. Body worn hearing aids may be considered for some children with poor head control, multiple disabilities and severe-profound hearing loss, where acoustic feedback is potentially problematic.

### **9.3 *Electroacoustic Characteristics***

The use of a systematic, objective approach to electroacoustic selection that incorporates age-dependent variables into the computations for selecting a hearing instrument is required. The formula that must be used to develop the appropriate electroacoustic characteristics for each baby is the Desired Sensation Level (DSL) Method® v5 (Scollie, et al. 2005) included within the real ear measurement system. This version of the DSL Method provides targets that vary depending on the type of fitting. Specifically, targets for babies and children (i.e. congenital hearing loss) and for adults (i.e. acquired hearing loss) are now available. This change was implemented due to the numerous studies that have demonstrated adult-child differences in performance ceilings, loudness ratings, and preferences by listening level (see review in Scollie et al, 2005). Audiologists must use the DSL v5 'Child' targets within the real ear measurement system. The real ear measurement system must have a speech stimulus or a temporally and spectrally speech-like stimulus. Coupler targets for the amplified long term average speech spectrum and MPO across frequency for each ear requiring amplification must be documented. A description of this process can be found in Appendix O.

#### **9.4 Device Selection**

Once the non-electroacoustic and electroacoustic characteristics of the potential hearing instrument have been identified, the audiologist must select a hearing instrument that will meet the criteria. Earmoulds and hearing instruments must be ordered, with a request for paediatric filtered tonehooks. A bone anchored hearing aid (BAHA) coupled to a soft band is the preferred treatment for hearing loss resulting from bilateral atresia. A phase-cancelling feedback manager is essential for all paediatric fittings. Advanced features that should be available for all paediatric hearing aids are data logging, speech enhancement, noise reduction and automatic adaptive directional microphones.

#### **9.5 Other Assistive Technology**

Some babies may be candidates for assistive listening technologies and devices other than personally-worn hearing instruments. If the audiologist determines that the baby is a candidate for other assistive technology, such as a FM system, the audiologist must explain the option to the family and whānau and facilitate careful consideration and informed choice. If the device option is elected by the family and whānau, the audiologist must provide the appropriate prescription to the parents, and/or facilitate access to service provision, as soon as is appropriate.

## **10.0 VERIFICATION OF AMPLIFICATION**

### ***10.1 RECD Values***

The acoustic properties of the baby's personal earmould must be taken into account through the use of RECD measurements or age-appropriate predicted values. Whenever a new earmould is obtained, a new RECD measurement must be collected and applied in the calculation of prescriptive targets. Thus, the prescriptive targets must be updated with the new RECD measurement when a new earmould is obtained. The verification procedures described in this document must be carried out every time the prescriptive targets have been updated, due to new threshold or RECD information being obtained.

### ***10.2 Hearing Aid Listening Check***

A biological listening check should be performed on all hearing aids as part of the initial hearing aid fitting to subjectively evaluate sound quality and physical function of components.

### ***10.3 Electroacoustic Verification***

The prescribed hearing instrument must be adjusted to approximate the target electroacoustic values for gain and maximum output that were specified according to the section of this document dealing with prescription. All verification curves, in SPL, and final hearing instrument settings must be documented and dated for each ear requiring amplification. Ideally, real ear measurements of gain and maximum output values should be performed on each ear (i.e., the RECD may have already been measured in the pre-selection phase) and the hearing instrument adjusted to provide the best match to targets. With babies, it is difficult to obtain valid and reliable measures of real-ear hearing instrument performance using this method. Therefore, predicting the real-ear performance of the hearing instrument using the baby's RECD is the preferred method for babies. Where possible, individual RECDs should be measured. This approach is fully implemented through the use of DSL in the real ear measurement system. For a detailed description of this procedure see Appendix P. One major advantage of this approach is that shaping the electroacoustic response of the hearing instrument can be performed in a highly controlled hearing instrument test box environment. Additionally, the baby does not need to be present for fine tuning adjustments made at this stage. It is, however, important for the audiologist to check for feedback from the instrument once it has been placed on the baby's ear. The feedback manager application should be implemented at every fitting appointment.

### ***10.4 Application of Advanced Technologies***

DSL targets are computed with the goal of listening to speech in quiet listening environments. As such, it is recommended that the prescribed hearing instruments be worn with this goal in mind. However, if technology that aims to improve the signal-to-noise ratio (i.e. directional microphones) is available, it should not be activated when verifying the hearing instrument for

quiet listening environments. In addition, if these technologies are activated in the instrument, it is recommended that they not be used on a full-time basis until sufficient evidence exists regarding their impact on prelinguistically hearing impaired babies. Thus, multiple memories may be considered (i.e. quiet and noise programs) at the discretion of the audiologist and should be considered on an individual basis.

Automatic feedback suppression technologies should be employed if feedback is noted when the hearing instrument has been placed on the baby's ear following verification. Every attempt to reduce feedback (i.e. good earmould fit, use of lubricant) should be attempted prior to applying feedback suppression strategies. If applied, verification of the instrument must be conducted following application of these technologies. The application of feedback reduction should be reassessed whenever new earmoulds are obtained, and the feedback suppression technology should be deactivated when not required.

### ***10.5 Simulated Real-Ear Measurements***

With babies, it is difficult to obtain valid and reliable measures of real-ear hearing instrument performance using real-ear measurement procedures. Therefore, predicting the real-ear performance of the hearing instrument using the baby's RECD is the preferred method for babies and young children. Simulated measurements of the real-ear aided response (REAR) and real-ear saturation response (RESR) must be conducted for each ear requiring amplification through the use of simulated real ear measures.

### ***10.6 Verification Stimuli***

Verification of hearing instrument performance at various input levels (i.e. soft, average, and loud speech) must be conducted to determine audibility and compression characteristics of the instrument. Verification of speech targets must be completed using stimuli approximating speech as closely as possible. The real ear measurement system contains stimuli that meet these requirements. Maximum output characteristics for most hearing instruments must be verified using narrowband stimuli. For aids that use multichannel broadband output limiting, use a loud speech stimulus (80 dB SPL) and ensure the peaks of speech fall at or below the Upper Limits of Comfort (Scollie and Seewald, 2000).

## **11.0 INFORMATION AND INSTRUCTION**

### ***11.1 Orientation***

The dispensing and fitting of an instrument must include explanations of use, care and maintenance of the devices provided in an understandable way and preferably supplemented by appropriate printed materials. Babies are unable to report if their hearing instruments are malfunctioning, so family and whānau vigilance is required and a kit is usually helpful. Supportive information and instruction for the family and whānau must be given at the time of the first fitting of the hearing instrument, and at follow-up visits.

### ***11.2 Information***

In any communication with family and whānau, the principles of the UNHSEIP should be reflected. Only evidence-based information should be imparted. Anecdotal information and personal opinions are not considered appropriate content for communication with parents. Service providers are encouraged to impart unbiased information in their area of expertise. Interdisciplinary referrals should be made when appropriate as questions arise which are outside of the audiologists scope of practice such as prognosis, or medical issues.

### ***11.3 Family and Whānau Support***

Despite their decision to proceed with amplification, family and whānau may continue to need various supports to help them through the process of acceptance and adaptation. Family and whānau support is available through the local AODC. A combination of timely and relevant information from the audiologist, and family and whānau support from the AODC is the desired minimum.

## **12.0 OUTCOME EVALUATION**

### ***12.1 Follow-up Schedule***

Follow up to the initial hearing instrument fitting should be on a regular schedule, with accommodation for individual needs. The audiologist should see the baby and family and whānau for a minimum number of 2 follow up visits within the first two months after fitting of amplification. A minimum schedule of follow-up visits thereafter should include visits every three months up to two years of age, every six months until age five and annually thereafter. This follow-up schedule is typical but may vary from baby to baby. For babies identified as having a progressive or fluctuating hearing loss, auditory dys-synchrony or multiple disabilities a more intensive schedule may be required. The schedule should be re-assessed on an ongoing, individual basis, with appropriate documentation.

### ***12.2 Follow-up Visits***

At each follow-up visit, an incremental history must be obtained from the family and whānau. Use, care and maintenance of the hearing instruments should be discussed as parents' questions arise, or as new information is required. Otoscopy and immittance testing must be done at every visit. Assessment of hearing levels (typically behaviour-based) will normally be done according to the minimum schedule above. Earmoulds must be assessed for appropriate fit and new earmoulds obtained when required. An RECD should be re-measured and documented to account for growth and development, as well as if the earmould has changed or if there has been a change in middle ear status. Subsequent adjustments should be made to the hearing instruments if RECD values or hearing levels have changed, or new earmoulds have been fitted.

### ***12.3 Outcome Measures***

Validation of the fitting must be done using a combination of questionnaires (ASC-R, PEACH), behavioural reports from the family and whānau and age appropriate aided speech perception testing (see Appendix H). Cortical evoked response testing should be considered for children diagnosed with auditory dys-synchrony or where auditory behaviour is uncertain. The purpose of validation is to ensure that the hearing aids are providing access to conversational speech (65 dB SPL/50-55 dBA/45 dB HL).

### ***12.4 Progress with Amplification***

If outcome measures and/or reports from other members of the early intervention team indicate unsatisfactory progress with amplification then other approaches such as cochlear implants or manual communication systems should be discussed with the family and whānau in consultation with the AODC. Referrals to appropriate agencies should be made as soon as possible.

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## Appendix B: UNHSEIP Instrumentation and Calibration

ABR CALIBRATION file offsets for UNHSEIP are nominal 0 dB HL at dial 0 dB

These values are numbers specified by the UNHSEIP in the SETUP/TRANSDUCER CALIBRATION files that are intended to produce appropriate stimulus levels, such that dial values approximate dB HL values. The numbers are NOT actual values of dB SPL ppe; the current values are internal offsets that yield actual SPLs or force levels in dB ppe at UNHSEIP nominal 0 dB HL.

	<b>Transducer &amp; calibration</b>	<b>Click</b>	<b>500 Hz</b>	<b>1 kHz</b>	<b>2 kHz</b>	<b>4 kHz</b>
Air conduction	ER3A insert earphone in 2 cc coupler	35.0	23.0	25.0	21.0	26.0
Air conduction	TDH 39 supra aural headphone in a 6cc coupler	35.0	25.0	23.0	26.0	29.0
Bone conduction	B71 calibrated on an artificial mastoid with a reference level of 1 $\mu$ N		62.5		64.0	

## Appendix C: ABR Technical Parameters

### Electrode sites

- Noninverting: High midline forehead, referenced to
- Inverting Channel 1: Right mastoid
- Inverting Channel 2: Left mastoid
- Common: Lateral forehead > 3cm from Noninverting

### Channels

- Air Conduction: View Ipsi or Both, Plot Ipsi
- Bone Conduction: View & plot Ipsi AND Contra

### Filters

- High-pass ('Low')            Tone burst thresholds 30 Hz  
   All click recordings 100 Hz
- Low-pass ('High')            Tone burst thresholds 3000 Hz  
   All click recordings 3000 Hz
- Notch filter Off, subject to 50 Hz considerations (see protocol text)

### Artifact reject

- On, 20-25 $\mu$ V

### Amplifier gain

- 100,000

### Averaging

- 2000-4000 accepted sweeps per average, 2 or 3 averages per condition, subject to RNL considerations in protocol text

### Epoch length

- Approx 20 ms, plus a pre-stimulus baseline

### Analysis offset

- Zero, or as required to avoid large BC artifact

### Residual noise level

- 25 nanovolts

### Stimuli

- **Tone bursts**
  - Linear ramp (Trapezoidal envelope), 2-1-2 cycle rise/plateau/fall times
  - Alternating polarity
  - Repetition rate 39.1/s
- **Clicks**
  - 100  $\mu$ s
  - Polarity as specified (separate recordings of both polarities)
  - Repetition rate 17.1/s

**Masking**

- Ipsilateral: None
- Contralateral: discretionary as described in protocol text.

**Calibration offsets**

- see Appendix B for CALIBRATION file entries.

## Appendix D: Minimum Required Levels and EHL Adjustments

UNHSEIP Minimum Required Levels and ABR threshold adjustment factors for Estimated Hearing Level (EHL) derivation (Stapells, 2002):

Frequency (Hz)	Air Conduction				Bone Conduction	
	500	1k	2k	4k	500	2k
Minimum Level (dB Dial)	40	35	30	25	35	35
Adjustment (dB)	-5	-5	0	+5	-5	-5
Estimated Level (dB EHL)	35	30	30	30	30	30

The UNHSEIP minimum levels are now set at dial values that correspond to 35 dB EHL after adjustment, for 500 Hz, and 30 dB EHL for 2 kHz, 1kHz and 4 kHz. These levels are consistent with a target impairment equivalent to 40 dB EHL or greater for 500 Hz, and 35 dB EHL at any frequency in the set [1, 2, 4 kHz]. UNHSEIP calibrations result in dial values being similar to dB HL on the basis of the best available published normative data. For bone conduction, norms for dB HL and for ABR-behavioural threshold relationships are not considered by UNHSEIP to be well-established.

These adjustment factors may occasionally yield small, negative air-bone gaps. Such a finding is expected, given that the adjustments are based on group mean normative data.

### Adjustment of Intensity for Age

It is recommended that a 5 dB correction factor is used for babies aged 3 months corrected age or less, i.e., assume stimulus level is 5 dB louder in the ears of young babies  $\leq$  3 months old due to their small earcanals. For example, 20 dB HL on the ABR equipment dial is equivalent to 25 dB HL for all stimulus frequencies and the click stimulus, for babies 3 months or younger.

### Example

	500 Hz	1kHz	2kHz	4kHz	Units
ABR threshold	50	50	50	50	dB HL (dial)
Add 5 dB only for babies $\leq$ 3 months	55	55	55	55	dB HL
<b>Correction factor to be subtracted*</b>	5	5	0	-5	dB
Estimated HL (HL)	50	50	55	60	dB EHL

*\*Subtract these values from air conduction ABR threshold in dB nHL to obtain EHL*

**Passing levels for babies  $\leq$  3 months**

	500 Hz	1kHz	2kHz	4kHz	Units
ABR threshold (dial setting)	35	30	25	20	dB HL (dial)
Add 5 dB only for babies $\leq$ 3 months	40	35	30	25	dB HL
Correction factor to be <b>subtracted</b>	5	5	0	-5	<i>dB</i>
Estimated HL (HL)	35	30	30	30	dB EHL

**Passing levels for babies  $>$  3 months**

	500 Hz	1kHz	2kHz	4kHz	Units
ABR threshold (dial setting)	40	35	30	25	dB HL
Correction factor to be <b>subtracted</b>	5	5	0	-5	<i>dB</i>
Estimated HL (HL)	35	30	30	30	dB EHL

## Appendix E: DPOAE Technical Summary

Nominal F2 frequencies: 1.5,2,3,4 kHz

F1 & F2 levels: 65 and 55 dB SPL

DPOAE tests should be replicated and the consistency of the two sets of values should be considered (along with absolute SPL and SNR) in the overall judgment as to whether OAEs are present and within normal limits, depressed or absent. A reasonable consistency criterion is no greater than 5 dB difference. A reasonable minimum SNR criterion is 8 dB to be confident in DPOAE presence at individual frequencies. Several adjacent frequencies that achieve at least 5 dB SNR are also acceptable evidence.

Replicated tests must be integrated so that a single plot/printout shows double curves for each type of measure, preferably with left and right test plots side by side and two sets of data listed below. Reproducibility cannot be assessed easily with replicates plotted separately. Ears may be plotted discretely on separate pages, but an integrated plot with the two ears side by side is preferable.

<b>Criterion</b>	<b>Recommendation</b>	<b>Comments</b>
SNR	At least 6 dB	
Absolute response amplitude	-5 dB or better	
Repeat testing if SNR at any frequency is less than 6 dB	Amplitudes should agree within 5 dB	
Recommended frequencies	1.5, 2, 3, 4 kHz	Include 6 and 8 kHz if time and test conditions permit this

## Appendix F: Immittance Testing Technical Summary

### Tympanometry

The UNHSEIP protocol is based on the criteria specified in Baldwin, 2006. For babies under six months corrected age tympanometry must be done using a high (1 kHz) probe tone frequency, with repetition as necessary and feasible, to improve reliability.

Procedure for high frequency tympanogram:

- record tympanogram with 1 kHz probe tone using a +200 to -600 daPa pressure range, without baseline correction
- print tympanogram
- draw a baseline between +200 and -200 daPa and apply the criteria listed in the table below:

	<b>Pass</b>	<b>Refer</b>
Recommended NZ classification	Type A	Type B
(2006) descriptor	Positive	Negative
Classification method	A positive peak falls above the line.	The peak falls below the line. If the peak is indeterminate classify as a Negative (Type B)

Note: Admittance change without development of a genuine peak is abnormal regardless of change size.

For babies six months and over corrected age:

- tympanometry must be done using a 226 Hz probe frequency, with repetition as necessary and feasible, to improve reliability
- the key abnormality criterion is peak admittance < 0.2 mmho.

### Acoustic Reflexes

For babies under 6 months corrected age, acoustic reflexes must be elicited with a BBN stimulus and measured ipsilaterally, using a 1 kHz probe tone frequency.

For babies over 6 months corrected age, acoustic reflexes must be elicited with a 1 kHz stimulus and measured ipsilaterally, using a 226Hz probe tone frequency (500Hz and 2kHz acoustic reflexes may be elicited if the baby is cooperative).

Stimulus level must start at 85 dB and increase in 5 dB steps. Reflex presence is defined by a clear, negative deflection, repeatable at any stimulus level.

## **Appendix G: VRA Technical Summary - Adapted from Gravel et al. (1994)**

Testing should begin with insert earphones in place in both ears. The ear closest to the loudspeaker should be tested first as this should elicit a spontaneous head-turn.

Testing should be done first with Monitored Live Voice (MLV) delivered through the audiometer to obtain an SDT in each ear. Live speech is the stimulus most preferred by babies. After this is established switch to pure tones. For pure tone testing test 500 Hz first because babies prefer low frequency stimuli.

Because babies are not good at localizing sound, only one loudspeaker and puppets on the same side should be used. The purpose of the test is to demonstrate a head-turn that is time-locked to the stimulus, not to demonstrate localisation.

Typically developing babies will generally spontaneously head-turn to the sound and this is visually reinforced.

Hand puppets should not be used, as the tester cannot directly see the child's face. At least one audiologist must be present, but the role of the distractor may be filled by others such as an audiometrist, AODC or parent if required.

Hand puppets were used previously because a range of automated toy reinforcers were generally not available; hand puppets are not used in most other countries (some centres in Australia do but require two audiologists).

Nominal Frequencies: 2 kHz, 500 Hz and 4 kHz. The importance of 1 kHz depends on results at 2 kHz and 500 Hz, as in ABR assessment.

Stimulus: Pulsed, NBN of duration 1-2 seconds or pulsed warble tones. Vary inter-stimulus interval (ISI); longer ISI initially if random head-turns are frequent.

Monitored live voice to obtain speech detection threshold (SDT).

BEGIN with 500 Hz NBN in insert phone (or best frequency in better ear, if known).

30 dB HL - if baby turns naturally, reinforce

2 correct consecutive responses - go to TEST PROTOCOL.

30 dB HL - no head-turn go to 50 dB HL

50 dB HL - if head-turn, reinforce

2 consecutive responses - go to TEST PROTOCOL

if no head-turn - go to 70 dB HL CONDITIONING TRIALS

## **Conditioning Trials**

70 dB HL paired with reinforcement - 2 times

70 dB HL "probe" - if head-turn - reinforce  
2 consecutive head-turns prior to reinforcement - go to TEST PROTOCOL  
if no head-turn on probe - do listening check of earphone.  
If okay - go to:

90 dB HL paired with reinforcement, 2 times  
90 dB HL "probe" - if head-turn, reinforce

2 consecutive responses - go to TEST PROTOCOL  
If no turn on probe - hearing problem or conditioning problem?

- Change stimulus frequency?
- Change stimulus type (e.g. speech)?
- Change ear?
- Change stimulus modality (bone-conductor held in hand)?
- Try soundfield?

TEST PROTOCOL - after 2 consecutive head-turns prior to reinforcement  
Down 20 dB, up 10 dB for threshold search

Test down to 20 dB HL (2 responses out of 3 presentations) OR  
Test down to lowest level at which 2 responses out of 3 presentations are  
obtained.

2nd frequency: 2000 Hz in same ear, begin at level of previous response if 2  
consecutive responses, continue threshold search if no response, increase  
intensity until response obtained 2 times continue threshold search

## **Second Ear**

500 Hz at 30 dB HL - if head-turn (either side), reinforce on side of turn  
proceed with threshold search. If no head-turn - increase intensity until  
response obtained 2 times continue threshold search.

2000 Hz - proceed as above for 500 Hz 3rd and 4th frequencies (3000/4000  
Hz and 1000 Hz) - as for 1st and 2nd frequencies, in each ear. Deviations  
from this order may be made if the baby begins to habituate - change stimuli,  
or re-condition at a level responded to previously.

## **Bone-conduction**

For at least one frequency where AC threshold is >30 dB HL bilaterally.  
Vibrator on mastoid of ear with better AC threshold.  
Start with intensity at or below air-conduction threshold.  
Use same test protocol to find threshold.

## Appendix H: Verification and Validation Tools

All procedures should be performed in sound treated rooms and with equipment that comply with IEC/ISO specification for diagnostic audiometric testing including sound field testing. Clinics providing a habilitation service should have:

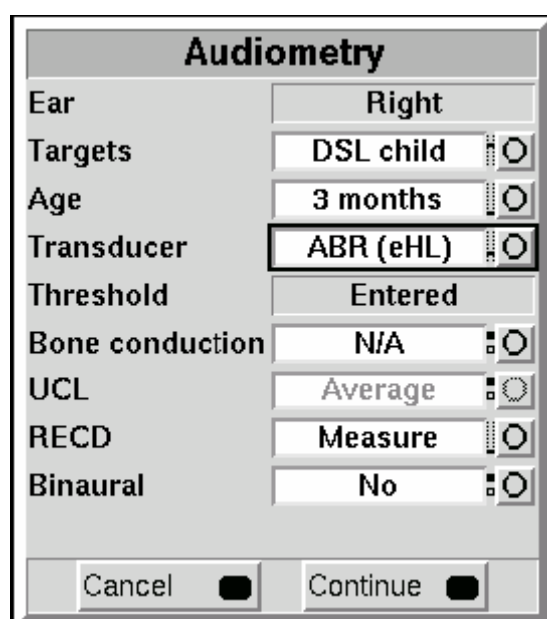
- A real ear measurement system that
  - has a speech stimulus or a temporally and spectrally speech-like stimulus (eg Audioscan RM500SL or Verifit)
  - incorporates DSL v5 prescriptive targets
  - allows simulated real ear measures
- Hearing instrument programming module
- Outcome evaluation tools
  - Questionnaires:
    - Auditory Skills Checklist – Revised (ASC-R, see NSU UNHSEIP website)
    - Parents' Evaluation Of Aural/Oral Performance Of Children (PEACH, see National Acoustic Laboratories website)
  - Aided speech perception tests (at least one test must be used):
    - 0-3 years:
      - Monitored live voice speech detection via audiometer
      - Macquarie Pediatric Sentence Identification Test (MPSI) in quiet
      - Kendall Toy Test monitored live voice via audiometer
      - VRASPAC  
([http://www.slhs.sdsu.edu/aboothro/V.I.P.Spac/VIPspac\\_manual.pdf](http://www.slhs.sdsu.edu/aboothro/V.I.P.Spac/VIPspac_manual.pdf))
    - 3-6 years:
      - Monitored live voice speech detection via audiometer
      - Macquarie Pediatric Sentence Identification Test (MPSI) in quiet
      - Kendall Toy Test monitored live voice via audiometer
      - PLAYSPAC  
([http://www.slhs.sdsu.edu/aboothro/V.I.P.Spac/VIPspac\\_manual.pdf](http://www.slhs.sdsu.edu/aboothro/V.I.P.Spac/VIPspac_manual.pdf))
      - NUChips
      - Hearing in noise test – children (HINT-C)
      - CVC words
      - Lexical neighborhood test (LNT).

## Appendix I: Estimated Hearing Levels (EHLs) and Hearing Aid Fitting

Toneburst ABR thresholds in dBnHL are not directly equivalent to perceptual thresholds in dBHL, and both dBnHL and dBHL are defined with reference to adult norms. ABR thresholds are converted to bias-free estimates of true perceptual threshold in dB HL by applying adjustment factors based on empirical, longitudinal validation studies. This correction is applied by the audiologist following completion of the protocol. The resulting thresholds must be referred to as 'Estimated Hearing Level' (EHL) thresholds, with units dB EHL. EHL values are entered as thresholds in the report and data forms.

For the purposes of calculating the hearing aid prescription, the audiologist must use the EHL values directly in applications of DSL v5. In the Real ear measurement system, the audiologist must follow these steps:

1. Enter Speechmap from the Tests menu.
2. Select Audiometry and set Target to **DSL Child** and Age to correspond to the baby's age in months.
3. In the Transducer section, select **ABR (eHL)**. This indicates that the ABR thresholds have been corrected as described above and no further correction will be applied by the system.



The screenshot shows a software window titled "Audiometry" with the following settings:

Ear	Right
Targets	DSL child
Age	3 months
Transducer	ABR (eHL)
Threshold	Entered
Bone conduction	N/A
UCL	Average
RECD	Measure
Binaural	No

At the bottom of the window are two buttons: "Cancel" and "Continue".

## Appendix J: Coupling Insert Earphones to Personal Earmoulds

During follow-up appointments, the audiologist may conduct VRA or CPA using insert earphones. If the child has personal earmoulds, the insert earphones should be coupled to them for an accurate assessment of hearing thresholds in both ears. For a more stable connection, a suggested modification is described below. It should be noted that the RECD should be measured with the child's personal earmoulds if the hearing thresholds are measured with this coupling method. Any changes to the child's auditory thresholds and RECD values should be applied to the hearing instrument prescription as needed.

Description of coupling the insert earphone to the earmould:

1. Trim approximately 5mm of tubing from a standard foam eartip, as shown in Figure 1.
2. Insert the trimmed tubing into the tubing of the earmould. Be sure the tubing of the earmould has been trimmed for use with the hearing instrument.
3. Insert the tip of the insert earphone transducer into the other end of the trimmed foam tip tubing, as shown in Figure 2.



Figure 1

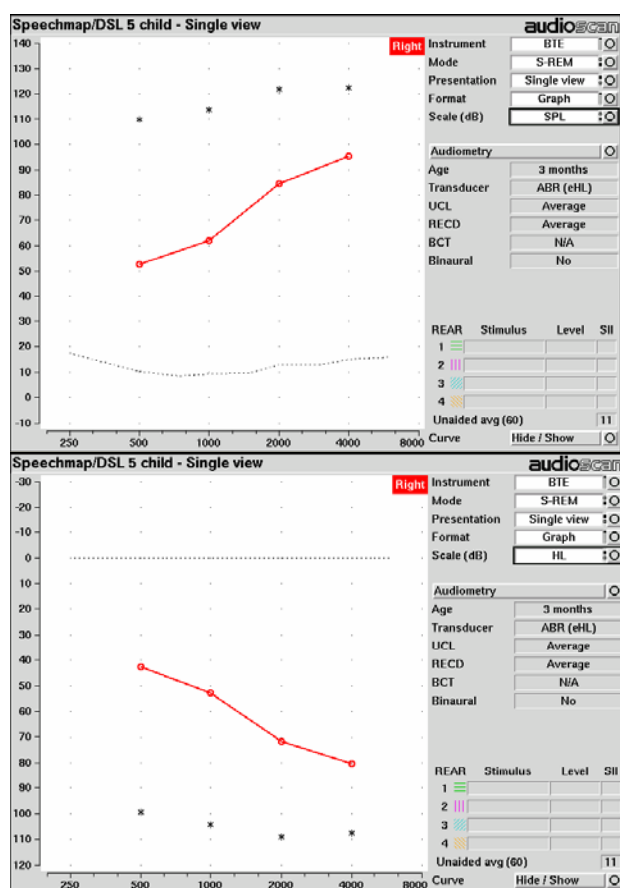


Figure 2

## Appendix K: Comparing Audiograms for the Same Baby over Time

When comparing audiometric thresholds for the same baby over time, it is important to take into account the changes in individual ear-canal acoustics. If ear canal acoustics are not considered, what appears to be a change in hearing threshold sensitivity may be a result of changes in ear canal acoustics due to ear growth. It is possible to apply RECD measurements to the hearing thresholds in EHL or HL for a more accurate representation in real-ear SPL or HLp. HLp represents an HL audiogram that has been corrected for ear canal acoustics (Bagatto et al, 2002; Feigin et al, 1989; Seewald & Scollie, 1999). When working in an SPLogram format on the Audioscan RM500SL or Verifit, the entered hearing thresholds will be converted to real-ear SPL.

To obtain HL thresholds that have RECDs accounted for (i.e. HLp), select **Scale** on the Speechmap screen and choose **HL**. To obtain the numerical HLp values, choose **Table** in the *Format* section.



## Appendix L: RECD Measurement Procedure

### Audioscan RM500SL and Verifit

**System Setup** (assuming the system is on and both microphones are calibrated)

1. Select <TESTS> from the main menu.
2. In the test selection menu select <SPEECHMAP> and set the following menus:
  - Instrument: BTE
  - Mode: S-REM
  - Presentation: User preference
  - Format: User preference
  - Scale (dB): SPL
3. Select <AUDIOMETRY> and set the following menus:
  - Target: DSL Child
  - Age: Choose age in months
  - Transducer: insert + foam (for foam, immittance or OAE tip)
    - OR
    - insert + earmould
    - OR
    - ABR (eHL)
  - BONE CONDUCTION: User discretion
  - UCL: Average
  - RECD: Measure
  - BINAURAL: No
4. Press <CONTINUE> and follow prompt to enter audiometry. Press <CONTINUE>.

### Coupler Measure

1. Carefully plug the coupler microphone into the test box and the RE-770 transducer into the front of the system.
2. Screw the HA-2 coupler onto the coupler microphone.
3. Couple the tip of the RE-770 transducer to the tubing of the HA-2 coupler.
4. Press <CONTINUE> to introduce the stimulus.
5. Press <CONTINUE> again to store the coupler measure. (TIP: once you have done this, it will be saved for up to one week. It saves time to do this in the morning right after calibrating the two microphones, so that it is completed when the baby arrives.)

### Real-ear Measure

1. Perform an otoscopic examination on the baby.
2. Ensure the real-ear module is plugged into to the front of the system and that it corresponds to the ear that is activated on the screen.
3. Place the probe microphone module over the baby's ear and adjust for length.

4. To ensure the probe tube is positioned correctly, couple a probe tube alongside the eartip or earmould using plastic film or soft surgical tape. Ensure the tube extends approximately 2 to 4mm beyond the sound bore (see Figure 4).
5. Connect the RE-770 transducer to the tube/tip combination and insert the unit into the baby's ear. If you do not wish to couple the probe tube to the tip, inserting the probe microphone approximately 11 mm from the opening of the ear canal will provide appropriate insertion depth for young babies (Bagatto et al, 2006).
6. Insert the tube/tip combination into the baby's ear canal and press <CONTINUE> to introduce the signal.
7. You will see four curves on the screen:
  - a. Top curve: real-ear response
  - b. 2nd curve: coupler response
  - c. 3rd curve: difference between a and b (this is the RECD)
  - d. 4th curve: a dashed line that represents an average RECD for comparison
8. The RECD will be saved in the system until you make another measurement.
9. Press <PRINT SCREEN> to print the curves. In the Format section, select Table to view and print the RECD values at each frequency. This is required for the child's chart.



Figure 4

### **RECD Tips and Guidelines** (Adapted from Bagatto, 2001)

Obtaining an accurate RECD measurement starts with learning what a typical RECD looks like. Typically, RECD values measured 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 babies and small children, the size of the ear canal is much smaller than adults, therefore, the values will be larger. In other words, smaller volume, greater SPL, and thus greater 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 a baby while the parent/caregiver cradles him/her or while the baby is still sedated from the ABR. The following are some hints that will help you obtain an accurate RECD measurement.

### **1) Proper Probe Tube Placement**

For babies, mark the probe tube approximately 11 mm from the medial tip. The mark should stop at the opening of the ear canal. Coupling the probe tube to the earmould or tip is also an appropriate strategy. For children, 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 baby's earmould.

Always use otoscopy before placing anything in the child'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 earmould 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 earmould 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**

When the probe tube is in place, insert a foam tip or earmould carefully without altering the position of the tube. When inserting the earmould or foam tip into the ear canal, stabilize the probe tube at the intertragal notch with your little finger. Use the thumb and index finger of the same hand to insert the mold/tip. Stabilize your hand against the baby'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 a baby 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 are situated in your child’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**

*Earmould 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**

*Earmould Measurement:* The probe tube may be causing some of the low frequency sound to escape from around the earmould. Also, the earmould 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 earmould lubricant (e.g. Otoease, Otoferm, etc.) on the foam tip or earmould to create a better seal around the ear canal. Plug the medial side of the earmould 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**

*Earmould or Foam Tip Measurement*

The child 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 child’s eardrum.

*d) Increased positive values in the low and mid frequency region*

**Possible Cause:**

The child 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). When a child 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 child 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 child's hearing instrument.

## Appendix M: Applying Age-Appropriate Predicted RECD Values

The most recent version of the DSL Method (eg, DSL v5) contains age-appropriate predicted RECD values for use with babies and young children when the RECD measurement cannot be obtained. These values differ from previous versions of DSL (eg, DSL v4.1) in that they provide values for more discrete age ranges and different coupling methods (Bagatto et al, 2005; 2006). A description of how to access these values and apply them to the hearing aid fitting process is described below.

**System Setup** (assuming the system is on and both microphones are calibrated)

1. Select <TESTS> from the main menu.
2. In the test selection menu select <SPEECHMAP> and set the following menus:
  - Instrument: BTE
  - Mode: S-REM
  - Presentation: User preference
  - Format: User preference
  - Scale (dB): SPL
3. Select <AUDIOMETRY> and set the following menus:
  - Target: DSL Child
  - Age: Choose age in months
  - Transducer: insert + foam (for foam, immittance or OAE tip)
    - OR
    - insert + earmould
    - OR
    - ABR (eHL)
  - BONE CONDUCTION: User discretion
  - UCL: Average
  - RECD: Average
  - BINAURAL: No
4. Press <CONTINUE> and follow prompt to enter audiometry. Press <CONTINUE>.

# APPENDIX N: Procedure for Obtaining an Earmould Impression

## Recommended Materials

- silicone-based earmould impression material
- 2 measuring scoops
- impression syringe – paediatric tip
- oto-blocks
- earlight
- otoscope with paediatric specula
- mixing spatula
- non-stick mixing pad
- non-latex plastic gloves

## Procedure

1. Instruct parent re: positioning, and child control
2. Wear a clean pair of non-latex plastic gloves throughout the entire procedure (or follow your clinic's specified infection control guidelines).
3. Perform an otoscopic examination to ensure that there are no conditions that would preclude taking an earmould impression (e.g. discharge from the ear, excessive cerumen). Make an estimate of ear canal size and length.
4. Measure and mark earlight using the following general guidelines: <6 months – mark earlight for approximately 10 mm from ear canal entrance >6 months – mark earlight for 10-15 mm from ear canal entrance, depending on ear size and age.

Note: If the baby is premature, has Down's syndrome, low birth weight, etc., insertion depth may need to be reduced.

5. Using the earlight, insert the oto-block gently into the ear canal so that the marked position on the earlight is at the ear canal entrance (see #3 above). Examine the depth and position of the oto-block with the otoscope. When satisfied with the placement, wrap the string from the block over and around the baby's ear.
6. Measure the appropriate amount of earmould impression material as indicated on the container. Mix the material together as directed. Place the material in the syringe and insert the plunger forcing the material down the syringe.
7. Place the tip of the syringe down the ear canal as close to the otoblock as possible. Do not pull on the child's ear, as this will change the shape of the ear canal.
8. Depress the plunger slowly and move the syringe out as the canal fills. Keep the tip of the syringe in the impression material at all times. Once the canal is full, move out into the concha, filling in as much as possible without removing the syringe from the impression material. Next, fill in the

- helix area and then the rest of the concha. Gently press on the tragus to ensure that this area is not overfilled.
9. Employ techniques to encourage jaw movement while filling the canal e.g. sucking or other mouth movement. Movement need not continue throughout the hardening process.
  10. Allow the impression material to harden; approximately 5 to 10 minutes. If you push your fingernail on the material without leaving an indentation, then the material is set.
  11. To remove the impression, pull gently on the pinna to loosen the impression in the baby's ear. Then, carefully peel out the concha portion without bending the canal; at the same time remove the helix portion. When the concha portion is about a third of the way out, gently rotate the impression forward (towards the child's nose) and remove the canal portion of the impression.
  12. Perform an otoscopic inspection of the ear canal to ensure removal of the oto-block and earmould material, and to evaluate the status of the ear canal.
  13. Inspect the impression for quality and completeness
  14. Mark the canal for appropriate length.

### **Earmould Material and Style**

Although earmould labs have a variety of brand names for their products, two main choices of pliable earmould material should be considered for children: PVC (vinyl) or Silicone.

For very young children (<12 months), the size of the ear canal may limit the diameter of the sound bore and how completely the earmould can be tubed. If the earmould material is too pliable, a small ear canal could constrict or close off the un-tubed portion of the sound bore. Silicone materials do not accept glue and usually require the use of a tube lock or tubing retention ring to hold tubing in place. This can distort the shape of the earmould in small ear canals, causing irritation or even feedback. PVC (vinyl) material accepts tubing glue and is somewhat stiffer in shape than silicone; therefore it is preferable for children under 6 months of age, or for children with unusually small ear canals. Earmould venting should be considered with caution. The primary fitting problem with babies and young children is feedback. A vented earmould can be an additional source of feedback. The size of a baby's ear canal will often limit the ability to add a vent. If venting is possible, it is diagonal, rather than parallel venting and tubing retention again will be affected. Shell-style earmoulds are the standard style recommended for children, because of retention and feedback-prevention. Helix locks may improve earmould retention, but parents should be carefully instructed on inserting them correctly to prevent irritation or feedback from a helix lock that is not placed properly.

## Appendix O: Deriving 2cc Targets for Purposes of Selecting a Hearing Instrument

Much of the work in DSL v5 has been aimed at preserving most of the prescriptive characteristics for babies and children applied in previous versions of the DSL Method (ie, v4.1). However, there have been some target modifications that audiologists can apply at their discretion. A detailed description of these changes can be found in Scollie et al, 2005. A Conductive Correction is available to compensate for mixed and conductive losses. This can be applied at the discretion of the audiologist by choosing it in the Bone Conduction menu described below. A binaural correction is available, however, it is recommended that audiologists do not apply this correction for their children fitted with binaural amplification. The literature is not conclusive whether a gain reduction is required for binaural fittings in children. Therefore, this item needs further investigation and future revision.

A description of deriving 2cc targets for selecting a hearing instrument using DSL v5 within the real ear measurement system is described below.

**System Setup** (assuming the system is on and both microphones are calibrated)

1. Select <TESTS> from the main menu.
2. In the test selection menu select <SPEECHMAP> and set the following menus:
  - Instrument: BTE
  - Mode: S-REM
  - Presentation: User preference
  - Format: 2cc Targets
  - Scale (dB): SPL
3. Select <AUDIOMETRY> and set the following menus:
  - Target: DSL Child
  - Age: Choose age in months
  - Transducer: insert + foam (for foam, immittance or OAE tip)
    - OR
    - insert + earmould
    - OR
    - ABR (eHL)
  - BONE CONDUCTION: User discretion
  - UCL: Average
  - RECD: Measured or Average or Enter
  - BINAURAL: No
4. Press <CONTINUE> and follow prompt to enter audiometry. Press <CONTINUE>.
5. Print out, or write down the Full On Gain (FOG), User Gain and Maximum Power Output (MPO) targets.
6. Using manufacturer's specification books, Noah Modules or real measures on consignment hearing instruments, select a hearing instrument that can provide this amount of gain, slope, and output limiting.

## Appendix P: Electroacoustic Verification

1. Follow steps 1 through 4 in Appendix O.
2. Place selected hearing instrument in the test box coupled to the HA-2 coupler.
3. In the REAR 1 section of Speechmap, choose the <Speech-std(1)> or <Speech-std(2)> stimulus type. Select a level of 70 dB SPL to verify average speech targets. NOTE: the DSL targets will not appear on the screen until a stimulus has been selected.
4. Adjust the instrument to the average speech targets (+) for 70 dB SPL.
5. Press <CONTINUE> to store the curve. This curve will be saved as REAR 1.
6. In the REAR 2 section, choose the <MPO> stimulus. Adjust the instrument so it approximates the small (+) targets and does not exceed the (\*) targets. Press <CONTINUE> to store the curve.

NOTE: The ULC target (\*) is intended to be matched by fully saturated hearing aid responses, therefore a slightly lower target may be more appropriate for use with the MPO test signal. For this reason, the target input/output function within DSL v5 can be used to compute a level-dependent target for either 85 dB SPL (in the real ear) or 90 dB SPL (in the coupler, using simulated real ear measurement). This new target will be somewhat lower than ULC for most hearing losses.

7. In the REAR 3 section, choose the <Speech-std(1)> or <Speech-std(2)> stimulus type. Select a level of 55 dB SPL to verify soft speech targets and a level of 75 dB SPL to verify loud speech targets.
8. Adjust the instrument to the soft and loud targets and press <CONTINUE> to store the curve.
- 9.

NOTE: Do not compromise your fit to targets for average speech or MPO to obtain a better match for soft and loud. A close match to average conversational speech and maximum output targets of the hearing instrument are to be given priority when verifying hearing instruments for babies and young children.

10. Repeat the verification procedure for average and MPO if you made adjustments in Step 8.
11. Save the final settings to the hearing instrument and print out the verification data from the Audioscan and Noah module for the child's chart.

## **Appendix Q: Protocol for Fitting FM Systems**

### **Goal for Fitting FM Systems**

The goal is to maintain approximately 10 dB difference between the FM and environmental microphone (EM) signals when both are activated simultaneously. The extent to which this goal can be achieved will be affected by the degree of hearing loss, maximum output of the system, hearing instrument processing and AGC in the microphone (transmitter).

### **General Steps for Fitting FMs**

Always make measurements in output

1. Confirm that the hearing aid is set for optimal audibility and maximum output for the individual.
2. Connect instrument to FM and turn on. Run instrument again to ensure instrument still functions with this setup. Run MPO first and then speech.
3. Place FM microphone in test box and evaluate with a 65 dB SPL speech input.
4. If the difference between the hearing aid response and the FM response is greater than  $\pm 2$  dB, adjust the FM setting appropriately and re-evaluate.
5. Evaluate the system using an 85 dB SPL speech signal into the FM. The FM response should be at least 5 dB higher, on average, than the hearing aid.
6. Perform a listening check with simultaneous inputs to the FM and the hearing aid microphone. Adjust the relationship as needed.

## **Appendix R: Instruction and Information**

### **Orientation Checklist**

Below is a suggested Orientation Checklist or a set of discussion topics for audiologists and families and whānau. Audiologists and dispensers must ensure that all of the following are covered in discussion and related questions are answered.

- Amplification and the speech signal, e.g. explanation of aided audibility and its implications for speech and language development
- Impact of noise and distance
- Coping with noise and distance (e.g. at home, in the car)
- Equipment needed to care for hearing instruments
- Techniques for cleaning earmoulds and hearing instruments
- Procedures for battery checks and insertion
- Procedures for listening checks of hearing instruments
- Putting hearing instruments on the child and securing them – retention and loss-prevention
- Setting user controls
- Incorporating use of hearing instruments into the child's routine
- Plans for documenting experiences with hearing instruments – hearing instrument diaries could be provided or recommended
- Safety issues (e.g. swallowing of hearing aid or battery)
- Understanding and combating feedback
- Protecting the hearing instruments from potential hazards (e.g. moisture, pets)
- Troubleshooting techniques
- Warranty and insurance information
- Plans for repair of malfunctioning hearing instruments
- Discussion of earmould life expectancy and hearing instrument life expectancy
- Plans for follow-up contact between the family and whānau and audiologist
- Options to be used at a later date (e.g. T-coil)

Adapted from: Elfenbein, Jill L. 2000. Batteries Required: Instructing Families/caregivers on the Use of Hearing Instruments. In R.C. Seewald, (ed.), A Sound Foundation Through Early Amplification: Proceedings of an International Conference (pp.141-149 Table 1).

### **Paediatric Considerations**

The unique needs of the baby must be considered when selecting non-acoustic features of the hearing instruments. Tamper resistant battery doors should be implemented, because hearing instrument batteries are toxic if ingested. Applying a volume control cover or lock will ensure that the baby is wearing the hearing instruments at the prescribed volume setting at all times.

Paediatric earhooks should also be utilized as a loss retention device as well as for filtering for appropriate acoustic outcomes. Non-acoustic features of hearing instruments should ideally be selected as part of the amplification prescription, but may be discussed between the prescriber and dispenser prior to ordering and fitting the devices.

### **Care and Maintenance “Kit”**

- Dry Aid Kit for removing moisture from the hearing instrument and earmould.
- Stethoscope for daily listening check.
- Battery tester.
- Earmould Blower for removing moisture and debris.
- Hearing instrument ‘Clips’ or Huggie Aids to prevent loss and protect from damage.

Care and maintenance kits are available upon request from the hearing instrument manufacturers for paediatric fittings. In addition to the above list, manufacturers’ kits may also include:

- other cleaning tools
- informational brochures, videos, books, stickers
- carrying case.