

# **Universal Newborn Hearing Screening and Early Intervention Programme**

## **National Policy and Quality Standards**

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Diagnostic and amplification  
protocols

January 2016

National Screening Unit

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# Document scope

This document details key procedural elements and technical specifications required for the provision of audiologic assessment and amplification to babies and pre-school children identified through the Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP).

It forms part of the UNHSEIP National Policy and Quality Standards and must be used by audiologists providing UNHSEIP services in conjunction with the principal document, which includes requirements in relation to the following areas (Standards 16–24):

- Audiologist qualifications and competency
- Audiology equipment and environment
- Providing timely audiology assessment
- Adherence to UNHSEIP audiology protocols
- Results of audiology assessment
- Initiation of early intervention services
- Audiology follow-up
- Audiology data and clinical record management.

The UNHSEIP National Policy and Quality Standards principal document is available at [www.nsu.govt.nz](http://www.nsu.govt.nz)

All audiologists must practise diagnostic procedures in compliance with the requirements of this protocol.

Departures from the protocols may be appropriate for 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 these protocols.

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# Acknowledgements

This document is based on the work of a technical working group that was formed to provide audiological advice and support to the Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP).

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The technical working group would like to thank the Ontario Ministry of Health for permission to adopt and modify as required their Ontario Infant Hearing Program Audiologic Assessment Protocol Version 3.1, January 2008 and Provision of Amplification Version 3.1, October 2007 for use here in New Zealand.

The Ontario documents were developed and based on:

- a workshop in December 2000 involving 20 invited Ontario audiologists, many of whom have experience with electrophysiological 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 centres.

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.

This document was updated in January 2016.

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# Abbreviations

ABR	auditory brainstem response
AC	air conduction
ANSD	auditory neuropathy spectrum disorder
AODC	advisor 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
HL	hearing level
IEC	International Electrotechnical Commission
ISO	International Standards Organisation
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



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# Programme overview

## 1 Audiology equipment and record requirements for UNHSEIP

### 1.1 Audiology room requirements

- a. Diagnostic ABRs and OAEs are typically carried out in a soundbooth. If this is not possible, the tests must be carried out in a quiet room with measured sound levels not exceeding:
  - 22 dBSPL at 500 Hz
  - 30 dBSPL at 1000Hz
  - 35 dBSPL at 2000 Hz
  - 43 dBSPL at 4000 Hz.
- b. For ABR, electrical isolation is required.
- c. For all behavioural testing (BOA/VRA/CPA) where a diagnostic assessment is to be performed, the ambient noise in the test room must not exceed the standard for testing sound field or bone conduction thresholds down to 5 dB HL (with 5 dB maximum uncertainty) across the frequencies from 500–6000 Hz (ISO 8253-1 2010). This is due to the need to perform accurate sound field and bone conduction testing with ears uncovered.

### 1.2 Audiology equipment requirements

As per Standard 17, providers of audiology services for babies referred from newborn hearing screening must ensure that the following is provided.

- Two channel auditory evoked potential system with supra-aural, insert and bone conduction transducers.
- Diagnostic distortion product otoacoustic emissions (DPOAE) equipment.
- Diagnostic immittance equipment with high frequency tympanometry and acoustic reflexes.
- A diagnostic audiometer capable of presenting pure tone, narrow band noise, FM warbled-tone stimuli and monitored live voice through insert earphones, supra-aural earphones, sound field speakers and bone vibrator.
- Sound suite for VRA/BOA assessment with a minimum of two visual reinforcers (mechanical or video), talk back microphone, one sound field speaker, insert earphones, supra-aural earphones and bone conductor, diagnostic audiometer with capability of testing 250 Hz through 8000 Hz, to profound levels. VRA performed with hand puppets is not a suitable technique.
- A real ear measurement system capable of measuring RECDs with an approved test stimulus.
- A computer with DSL v5 installed with NOAH or similar interface.

Instruments must be calibrated regularly:

- audiometers, ABR systems and loud speakers for sound field testing on a two-year cycle.
- tympanometers are calibrated annually.

## **1.3 Clinical records**

General requirements for audiology data and record management are set out in Standard 24.

Audiology records must be full and complete for all appointments, including all amplification information and process, and sufficient to facilitate consultation, clinical review and case conferencing.

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.

The baby's audiological record should include:

- details of the procedure used to calculate prescriptive targets (ie, measured RECD values, DSL targets)
- a summary of the prescribed amplification including the settings of the device, make and model
- ear mould specifications
- a record of the real ear measurement results
- 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 (eg, with the use of questionnaires such as LittleEars® and/or PEACH).

The audiologist must record and keep a report of all amplification information. If completion of the provision of amplification requires further appointments, the report may be deferred to follow the ensuing appointment. This information will be subject to periodic audit.

## **2 Assessment**

### **2.1 Assessment goals**

The main goals of audiologic assessment are:

- a. to determine the presence or absence of permanent congenital hearing loss
- b. 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
- c. 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
- d. to provide an ongoing, sufficient audiometric basis for follow-up services, for children identified with permanent congenital hearing loss.

## 2.2 Assessment objectives

The specific objectives of audiological 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.

## 2.3 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. 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 neuropathy spectrum disorder (ANSD) and retrocochlear disorders affecting the auditory pathways.

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.

## 2.4 Types of assessment

Assessments are ABR-based, OAE-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.

# 3 Hearing surveillance criteria and pathway

There were significant changes in the UNHSEIP protocol in 2015 that reduced the number of risk factors that require ongoing surveillance. The term ‘targeted follow-up’ was replaced with ‘hearing surveillance’. It is important to note that paediatricians, special care nurses and midwives are responsible for identifying babies with conditions requiring hearing surveillance. Under the new system, for babies with risk factors, they will need to complete a *UNHSEIP Risk Factors Requiring Hearing Surveillance* form to give to screeners who will send these referrals to audiology. In the future, the Maternity Clinical Information System, Newborn Clinical Information System and Newborn Hearing Information Management System, once fully implemented, will facilitate identification and referral of these babies and simplify this process.

The new surveillance criteria fall into three categories:

- 1 Risk factors requiring OAE testing at 18 months:
  - **Continuous ventilation > 5 days:** IPPV or HFV, nitric oxide, ECMO, severe persistent pulmonary hypertension, excludes CPAP
  - **Severe asphyxia:** Sarnat stage 2/3, cooled
  - **Brain haemorrhage:** Grade 4 +post haemorrhagic hydrocephalus
  - **Ototoxic medications** at above therapeutic levels: confirmed by blood test

- **Other syndromes associated with hearing loss including but not limited to: Pierre Robin, Sticklers, Goldenhar, CHARGE, Waardenburg, Pendred**
  - **Toxoplasmosis**
  - **Rubella**
- 2 Risk factors for conditions that are low incidence and will require audiological care, audiologist to triage each referral on a case by case basis. In the future specific recommendations may be developed but are not available at present:
- **Atresia**
  - **Jaundice levels at or above where transfusion is recommended**
  - **Head and brain trauma**
- 3 Risk factors with specific pathways for audiological testing:
- **Down syndrome**
  - **Cleft palate**
  - **Cytomegalovirus**
  - **Meningitis**

These specific recommendations were introduced reflecting their differing risks of late onset or progressive loss. Table 1 lists further details of the conditions, some additional notes regarding the screening process and the criteria and method of referral.

**Table 1: UNHSEIP hearing surveillance criteria and pathways summary**

Condition requiring surveillance	Who/how identified	Referral	Audiological surveillance
<b>Craniofacial anomalies</b>			
<b>Atresia</b>	Midwife, paediatrician Physical examination	Not screened, referred directly to audiology via UNHSEIP risk factor form.	Standard audiological clinical practice.  Audiological assessment as clinically appropriate for individual circumstances
<b>Cleft palate</b>	Midwife, paediatrician Physical examination	Medical staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	As per NZAS protocols for cleft palate.
<i>NB: Not requiring follow up: pits and tags, cleft lip without cleft palate.</i>			
<b>Syndromes associated with hearing loss</b>			
<b>Down</b>	Midwife, paediatrician Physical examination, genetic testing, maternity records	If baby passes screening, screener offers early referral to audiology. UNHSEIP risk factor form completed.	As per NZAS protocol for Down syndrome.

Condition requiring surveillance	Who/how identified	Referral	Audiological surveillance
<b>Other syndromes associated with hearing loss</b> , including but not limited to: <ul style="list-style-type: none"> <li>Pierre Robin, Sticklers, Goldenhar, CHARGE, Waardenburg, Pendred</li> </ul>	Paediatrician Physical examination, bloods Some syndromes associated with hearing loss are not evident in postnatal period. Baby is usually on the ward. Often syndromes associated with hearing loss are not recognised until some days after birth.	It is very likely these babies will refer from screening. Where babies pass screening, medical/nursing/midwifery staff are responsible for referral/communicating referral to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months
<b>Confirmed congenitally acquired infections</b>			
<b>Cytomegalovirus (CMV)</b>	Midwife, obstetrician (may identify in pregnancy), paediatrician Positive laboratory results – urine CMV of baby.	Medical/nursing midwifery staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	As per NZAS protocol for CMV
<b>Toxoplasmosis</b>	Midwife, obstetrician (may identify in pregnancy), paediatrician Positive laboratory results for the mother and baby.	Medical/nursing/midwifery staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months
<b>Rubella</b>	Midwife, obstetrician (may identify in pregnancy), paediatrician Most women will be vaccinated – check serology antenatally. Laboratory results for the mother and baby.	Medical/nursing/midwifery staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months

#### Notes

- Infections must be confirmed. At time of screening baby, test results may not be received and screeners may not be aware of the condition. Prior to implementation of MCIS and NHSIS good communication mechanisms (eg, between coordinator and paediatricians) are needed to ensure referral is made on receipt of results.
- Information on infections in the antenatal period may also be entered into MCIS.

Condition requiring surveillance	Who/how identified	Referral	Audiological surveillance
<b>NICU</b>			
<b>Ventilation &gt; 5 days</b> Continuous ventilation with: <ul style="list-style-type: none"> <li>IPPV or HFV, Nitric oxide, ECMO Severe persistent pulmonary hypertension</li> </ul>	Paediatrician/NICU nurse	NICU staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months
<i>NB: No surveillance after CPAP use</i>			
<b>Severe asphyxia</b> Sarnat stage 2/3, cooled	Paediatrician/NICU nurse Clinical findings, investigations eg, MRI, EEG	NICU staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months
<b>Brain haemorrhage</b> Grade 4 + post haemorrhagic hydrocephalus	Paediatrician/ NICU nurse Clinical findings	NICU staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months

Condition requiring surveillance	Who/how identified	Referral	Audiological surveillance
<b>Ototoxic medications</b> at above therapeutic levels	Paediatrician/ NICU nurse Paediatrician discretion – levels monitored after third course, refer only if outside of therapeutic range	NICU staff make referral/ communicate to screening staff via UNHSEIP risk factor form.	OAE testing at 18 months
<b>Other postnatal conditions</b>			
<b>Severe jaundice</b> (at or above exchange transfusion level)	Paediatrician/medical/nursing staff Low risk of kernicterus – depends on a range of factors including clinical condition of baby, gestational age etc	Once jaundice resolves, referral by medical/nursing/midwifery staff to screening team for <b>rescreening by screener</b> before discharge (if < 3 months old), via UNHSEIP risk factor form. Discharge with a pass result.  If > 3 months old, refer to audiology/communicate referral to screening staff	Hearing assessment needs to be carried out within four weeks of the child being well enough to be tested.
<b>Meningitis and meningoencephalitis</b> Confirmed or strongly suspected	Paediatrician /medical staff	Referred as soon as recovered. Urgent assessment is required to identify severe/profound hearing loss before any cochlear ossification takes place. Medical/nursing staff make referral/communicate referral to screening staff via UNHSEIP risk factor form.	Hearing assessment needs to be carried out within four weeks of the child being well enough to be tested.
<b>Head/brain trauma</b> Especially basal skull/ temporal bone fracture	Paediatrician /medical staff Clinical exam, investigations	Direct referral as soon as recovered.	Hearing assessment needs to be carried out within four weeks of the child being well enough to be tested.

#### Risk factors occurring later *NB: not part of the UNHSEIP*

The UNHSEIP hearing surveillance policy is primarily concerned with conditions occurring prior to or during the first month of life. There are a small number of medical conditions occurring later, such as temporal bone fracture and meningitis, which can cause sensorineural hearing loss. These children should be referred to audiology within four weeks of the child being well enough to be tested.

Speech and language delay is sometimes caused by hearing loss. If a health or education professional or the child's caregiver has concerns about an infant's hearing or development of speech and language, this should always be taken seriously, and the child should be referred to audiology.

## 3.1 Hearing surveillance at 18 months

Risk factors requiring audiological assessment when the baby is around 18 months are listed below. Babies are to be seen according to the test protocol as detailed in Figure 1. This is the minimum test protocol and in some cases clinical judgement will dictate that further audiology assessments are required beyond 18 months.

- **Continuous ventilation > 5 days:** IPPV or HFV, nitric oxide, ECMO, severe persistent pulmonary hypertension, excludes CPAP.
- **Severe asphyxia:** Sarnat stage 2/3, cooled.
- **Brain haemorrhage:** Grade 4+ post haemorrhagic hydrocephalus.
- **Ototoxic medications** at above therapeutic levels: confirmed by blood test.

- **Other syndromes associated with hearing loss including but not limited to:** Pierre Robin, Sticklers, Goldenhar, CHARGE, Waardenburg, Pendred.
- **Toxoplasmosis**
- **Rubella**

**Note: Timing of hearing surveillance criteria**

While the Joint Committee on Infant Hearing recommendation is for at least one audiology assessment between 24 and 30 months of age, in practical terms, children of this age can be difficult to assess as they are developmentally too advanced for visual reinforcement audiology but not yet able to undertake a play audiometry assessment. Overseas research has indicated that the majority of progressive hearing loss is picked by the time the child is 18 months old. Hence in New Zealand it is recommended that all referrals for surveillance are seen by their local audiology department at approximately 18 months of age (corrected).

In regard to the audiology approach to testing babies referred for surveillance, it is important to remember that this group all passed aABR newborn hearing screening. The approach for surveillance should be viewed as further screening rather than a full diagnostic assessment.

The audiology approach for surveillance is OAE-based testing. The audiology screening regime for surveillance testing consists of the following:

- **DPOAE to achieve a three-point DPgram**  
A pass is achieved if DPOAEs are present in three frequencies out of 1.5 kHz, 2 kHz, 3 kHz and 4 kHz as per the DPOAE protocol in Appendix 5.
- **Tympanometry with a 226 Hz probe tone if a PASS is not obtained on DPOAEs**  
If tympanometry is ambiguous and it is difficult to distinguish between a type B and a shallow type A tympanogram, then ipsilateral acoustic reflexes at 1 kHz with a 226 probe tone must be done (2 kHz and 500 Hz reflexes may be obtained if the child is cooperative).

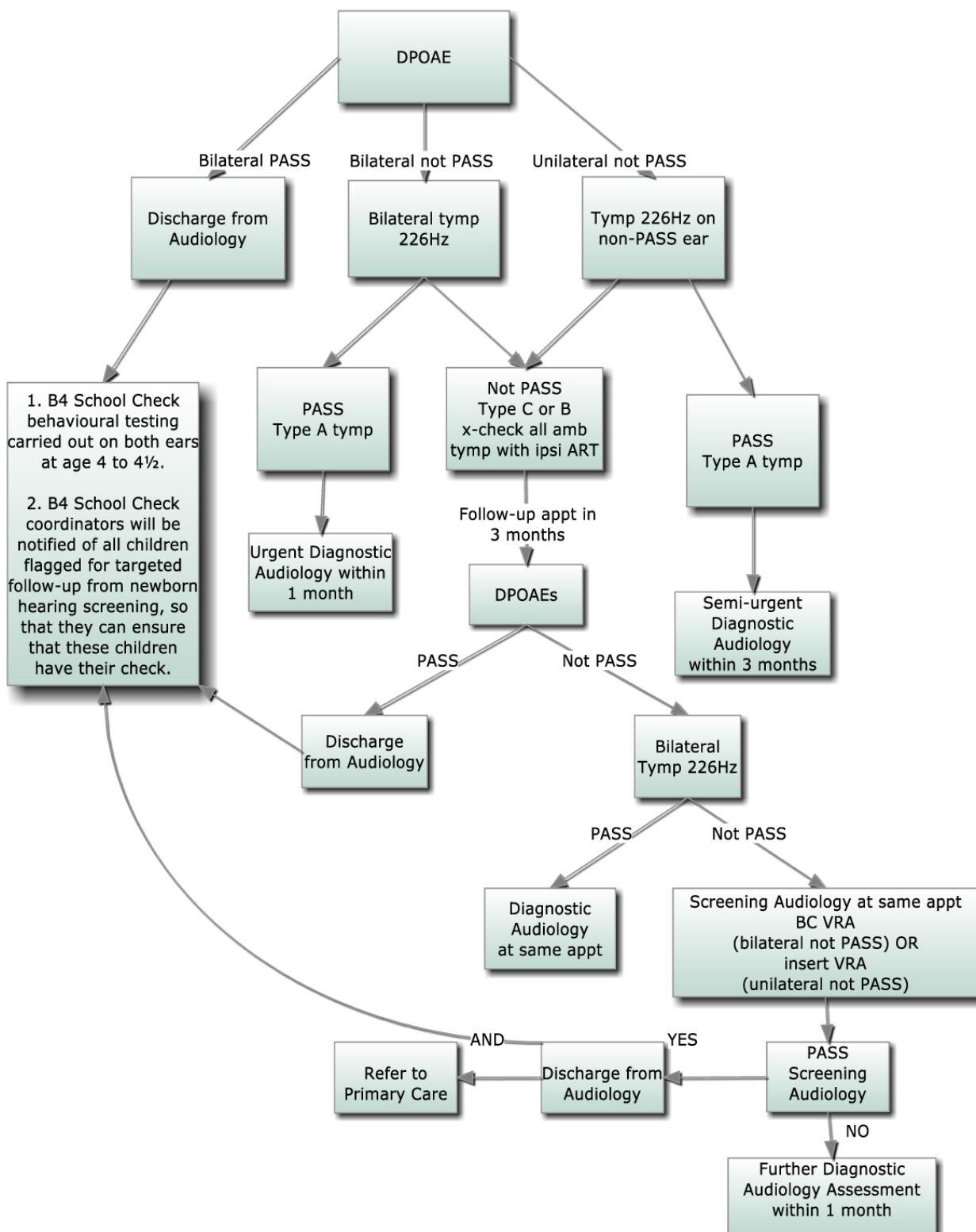
If the child passes DPOAE, a significant sensorineural hearing loss has been ruled out (at this time) and the child should be discharged from audiology. Their next hearing check will be behaviour testing of both ears as part of the B4 School Check at around the age of four years.

If the child does not pass DPOAE and immittance testing, they should have another appointment for the same screening regime in three months' time. However, this time if the child does not pass, the audiologist must move on to BC VRA. This means that a 'VRA appointment' should be scheduled, even though the full amount of time will not be needed if the child passes on DPOAE testing.

Screening audiology consisting of a three frequency pass (20 dBHL at 0.5, 2 and 4 kHz) must be achieved on BC VRA (or insert testing if suspicious of a unilateral hearing loss) and if it is, the child should be discharged from audiology. Importantly though, under these circumstances, the child must be referred to primary care (GP) for middle ear management.

If the child does not pass the screening VRA, they should have further audiology assessments to reach a diagnosis.

**Figure 1: Audiology approach to surveillance criteria and pathway from newborn hearing screening**





### 3.2 Risk factors for conditions requiring audiological testing and potential ongoing monitoring

These conditions will be low incidence and will require review by the service in terms of best practice audiological care, and the audiologist to triage each referral on a case by case basis. In the future specific recommendations may be developed but are not available at present.

- **Atresia**
  - **Bilateral** – fit bone conduction hearing aid on soft-band after diagnostic ABR testing completed (bilateral fitting should be considered), monitor progress with aid as per usual infant hearing aid criteria.
  - **Unilateral** – fit bone conduction hearing aid on soft-band after diagnostic ABR if parents/caregiver wishes. If not fitted then immittance testing/OAEs six months post ABR appointment and then annual review. Hearing aid options to be discussed with family at frequent intervals.
- **Severe jaundice at or above the level requiring transfusion**
  - Hearing test within four weeks after recovery from jaundice.
- **Head and brain trauma**
  - Hearing test within four weeks of recovery from injury.

### 3.3 Specific assessment pathways for listed conditions

#### 3.3.1 Audiological management of babies with cleft palate

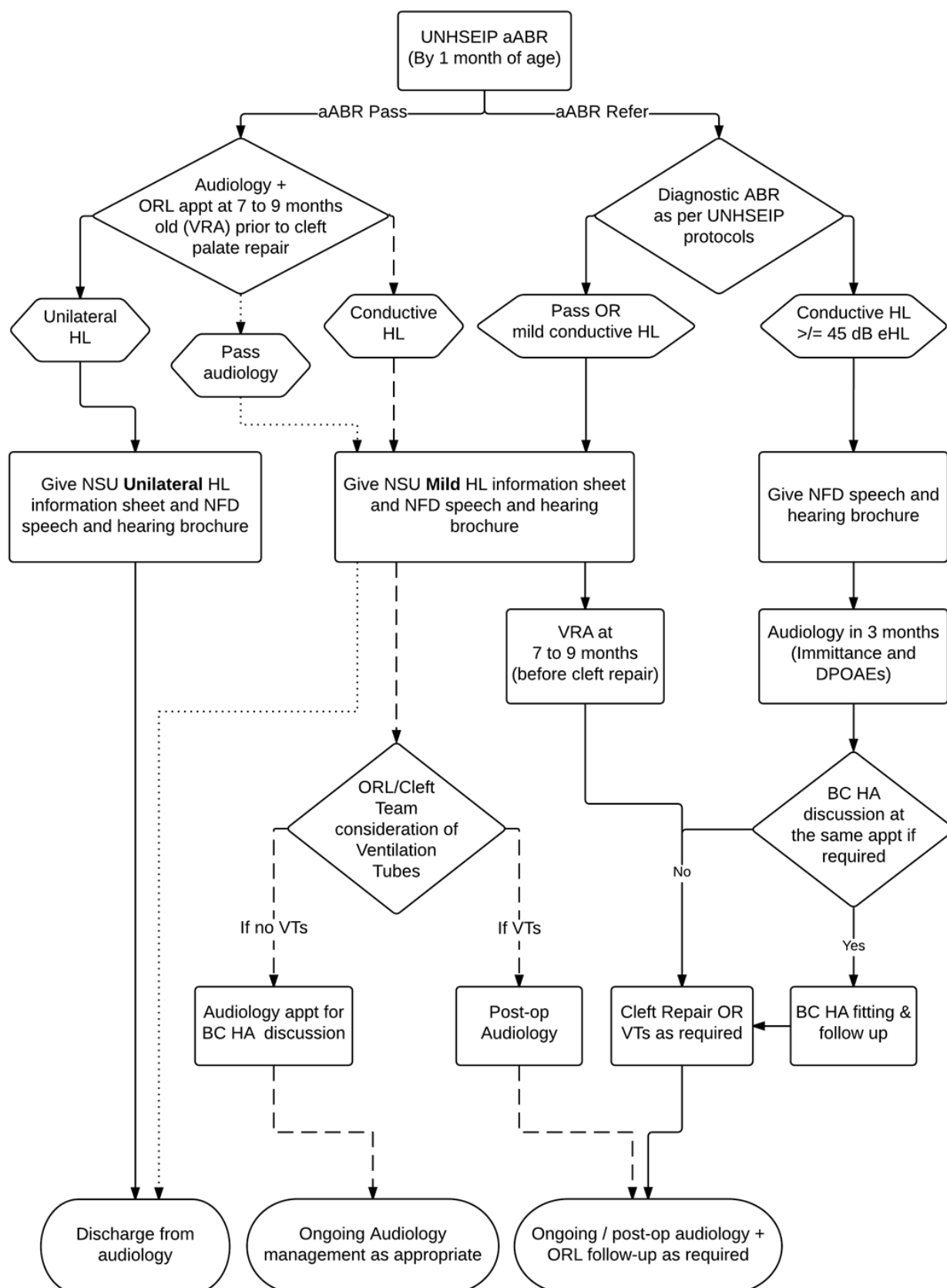
Babies identified as having a cleft palate require close audiological management to ensure appropriate access to sound and to optimise opportunities for speech and language development.

The key features of the audiological management pathway are as follows.

- Babies born with a cleft palate are likely to develop otitis media with effusion that may have a significant impact on their hearing and so even if they have passed hearing screening as a newborn should be seen for follow-up at 7–9 months old. An assessment at this age also allows the audiologist and ORL to understand the extent of any conductive hearing loss and this information will aid in the decision as to whether or not the infant will need ventilation tubes in conjunction with their palate repair.
- The timing of the cleft palate repair surgery may vary for different babies and across cleft palate programmes, and this may vary the timing of the discussion regarding a bone conduction hearing aid for those babies that have passed their initial hearing screening. In principle it is important to consider the degree of any conductive hearing loss and the length of time the baby may have the conductive hearing loss to provide timely management options.
- For babies that have been identified as having a conductive hearing loss warranting intervention on diagnostic ABR assessment, a discussion regarding a bone conduction hearing aid is completed early on in the audiological management pathway. In these cases it is important that amplification options are discussed with the family. Conventional BTE hearing aids are not appropriate in these children at a young age due to the possible fluctuating nature of the conductive hearing loss component.
- At all appointments with the family, regardless of the test outcome, discussion should cover good communication strategies, ways to enhance the listening development, how to recognise signs that the hearing may have changed and what to do if the family are concerned about their baby/child's hearing. Give the NSU mild hearing loss information sheet and NFD speech and hearing milestones brochure.

- Note that there will be local variation throughout the country dependent on the configuration of the cleft palate teams and ORL service. It is important that the audiologist liaise closely with both their local ORL service and regional cleft palate teams to provide the most appropriate audiological management for these babies.

**Figure 2: Audiological management of babies with cleft palate**



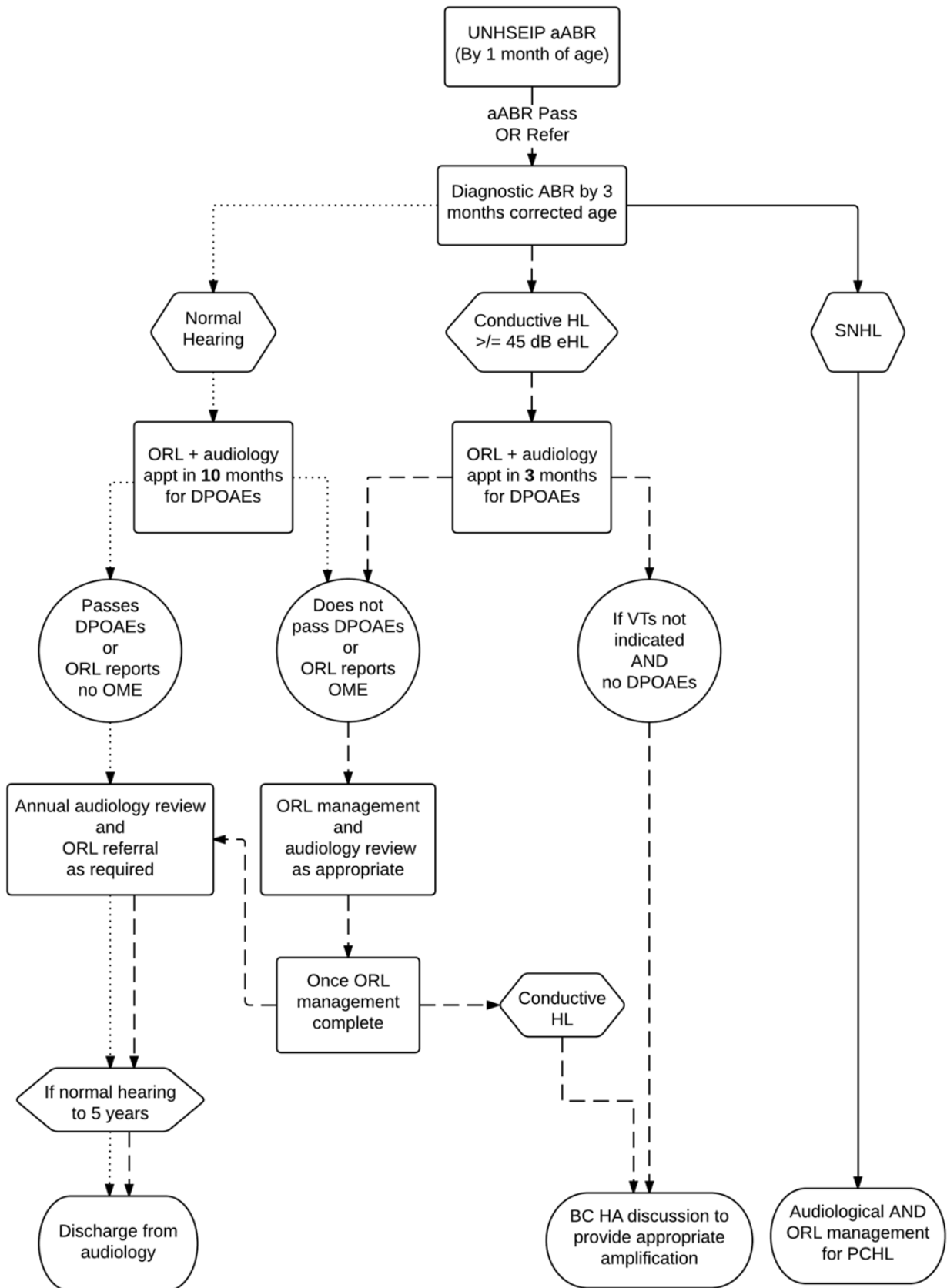
### **3.3.2 Audiological management of babies with Down syndrome**

Babies identified as having Down syndrome require close audiological management to ensure appropriate access to sound and to optimise opportunities for speech and language development.

The key features of the audiological management pathway are as follows.

- If possible, a diagnostic ABR with 20 dB eHL as the lowest level tested to for 1000, 2000, and 4000 Hz and 25 dB eHL for 500 Hz should be performed for all babies identified as having Down syndrome. The current UNHSEIP ABR diagnostic protocol does not exclude a mild hearing loss. For babies with Down syndrome even a mild degree of hearing impairment may have a significant impact on their ability to develop speech and language. In addition, many infants with Down syndrome take longer to reliably perform behavioural audiological assessment; if a normal ABR is obtained as a newborn then the primary aim of audiological review is the effective identification and management of any significant conductive hearing loss associated with middle ear dysfunction.
- Audiology and ORL joint review appointments enables the current state of the baby/child's middle ear function and hearing to be assessed at the same time.
- A discussion regarding a bone conduction hearing aid is completed early on in the management of any significant conductive hearing loss. In many cases due to the size of the baby/child's ear canal or parental choice it will not be possible to proceed with ventilation tube insertion. In these cases it is important that amplification options are discussed with the family. Conventional BTE hearing aids are not appropriate in this patient at a young age due to the often fluctuating nature of the conductive hearing loss component and small ear canal size.
- At all appointments with the family regardless of the test outcome discussion should cover good communication strategies, ways to enhance the listening development, how to recognise signs that the hearing may have changed and what to do if the family are concerned about their baby/child's hearing. Give the NSU mild hearing loss information sheet and NFD speech and hearing milestones brochure if appropriate.

**Figure 3: Audiological management of babies with Down syndrome**



### **3.3.3 Audiological management of babies with meningitis**

- Screening pathway – direct referral to audiology.
- Confirmed or strongly suspected neonatal bacterial meningitis, viral meningitis or meningococcal septicaemia.
- Referral is the responsibility of the medical team caring for the child. Screening teams should treat these babies as a direct refer to audiology and enter them into the database as such.
- Responsible for identifying child and referral to audiology – medical team.
- Responsible for arranging appointment and follow-up – audiology.

### **Guidelines for audiological follow-up of babies diagnosed with meningitis**

#### ***General information***

The responsibility for ensuring referral for hearing testing in this group of babies resides with the responsible paediatrician. Protocols need to be in place to ensure referral from the paediatric wards or NICU/SCBU to audiology. Hearing assessment needs to be carried out within four weeks of the child being well enough to be tested. Urgent assessment is required to identify severe/profound hearing loss, which may require cochlear implant(s) before any cochlear ossification takes place. The timing of tests needs to be practical and flexible. The aim should be to determine ear-specific and frequency-specific auditory thresholds as soon as possible, to identify hearing loss of any degree or configuration. Children can also have complex developmental problems following meningitis.

#### ***Under 12 weeks corrected age***

The baby should be referred for assessment irrespective of whether or not they have been screened and irrespective of the screen result as they are very high risk for having a hearing loss. Testing would normally be by ABR under natural sleep, using standard protocols in Appendix F. Additionally, a diagnostic OAE test should be performed. If the baby does not sleep, a diagnostic DPOAE test must be performed combined with immittance testing. Further assessment (ABR and/or DPOAEs) should be arranged.

#### ***Between 12 weeks and six months corrected age***

Options should be discussed by the audiologist with parents and include one or more of: ABR under natural sleep (especially if the baby is still quite young); diagnostic DPOAE test; ABR under general anaesthetic (for older infants, if there is considerable parental/professional concern or if it has not been possible to obtain a reliable test); waiting until behavioural testing around six months (if the baby is close to this age), bearing in mind the importance of urgent assessment as discussed above.

#### ***Over six months corrected age***

The baby should be referred to audiology on discharge from hospital and seen within four weeks. Testing would normally be by VRA using ear-specific and frequency specific stimuli. A significant hearing loss should be excluded. If ear and frequency-specific information cannot be obtained for whatever reason, an ABR under general anaesthetic should be considered.

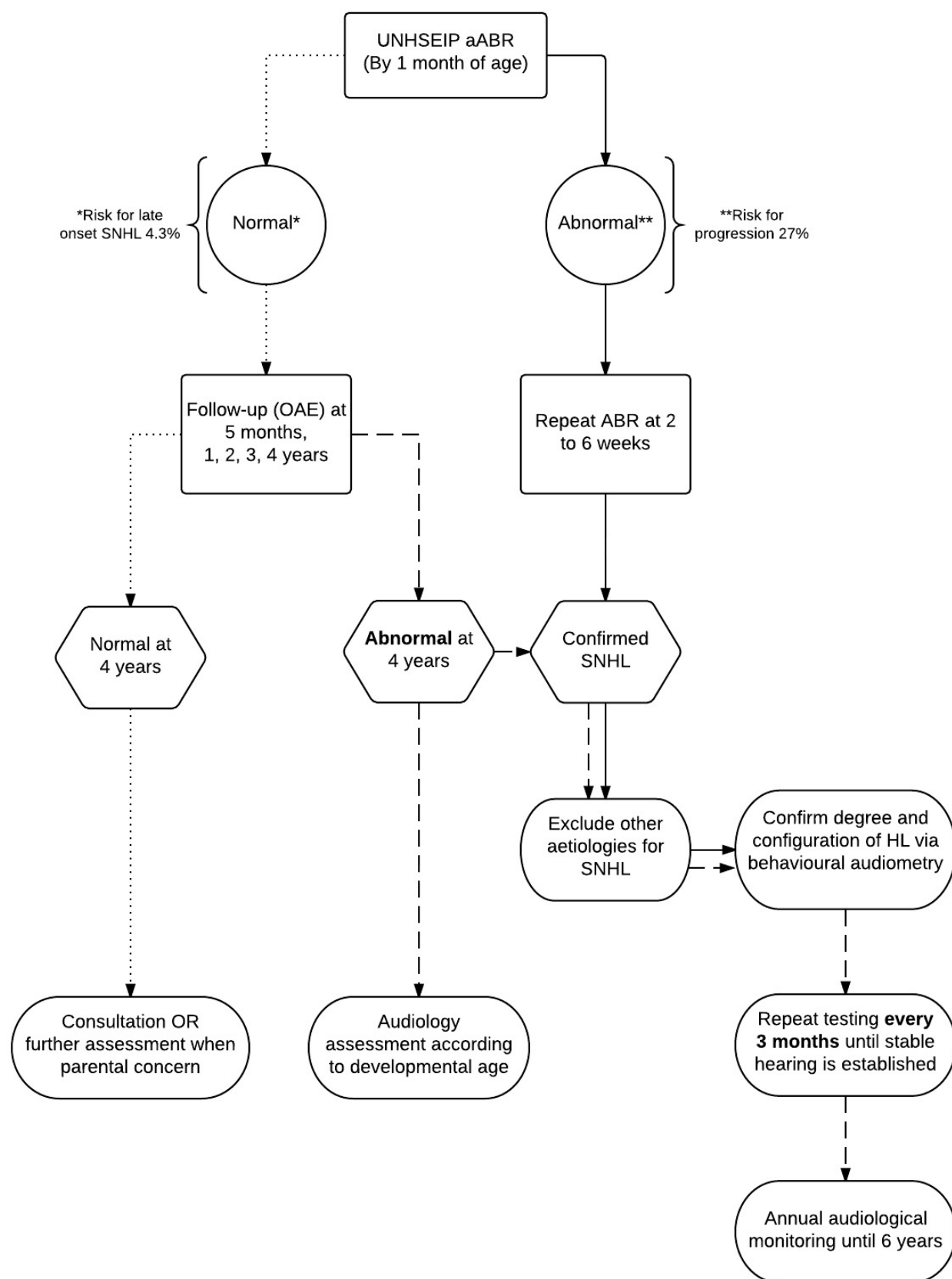
### ***Further follow-up***

For all ages, there appears to be no good evidence supporting the need for further follow-up if the hearing is found to be satisfactory following meningitis, therefore further testing is not mandatory. However this is a matter for local policy.

### **3.3.4 Audiological management of babies with cytomegalovirus (CMV)**

- Screening pathway – direct referral to audiology.
- Confirmed CMV in infant (mother's status does not have any impact).
- Responsible for identifying child and referral to audiology – medical team.
- Responsible for arranging appointment and follow-up – audiology.
- All infants with confirmed CMV need to have their hearing tested at certain intervals, which depends on their hearing status.

**Figure 4: Audiological management of babies with CMV**



Source: Foulon I (2014).

## **4 Amplification**

### **4.1 Amplification goals**

The main goals of amplification are to:

- a. provide an amplified speech signal that is consistently audible across input levels
- b. avoid distortion of varying inputs at prescribed settings for the user
- c. ensure the signal is amplifying sounds in as broad a frequency range as possible
- d. 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.

### **4.2 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 and Moeller 1998).

As per Standard 21, amplification should normally be provided within four weeks of diagnosis.

### **4.3 Target impairments for amplification**

The nominal target PCHL for consideration of amplification 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. 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 neuropathy spectrum disorder (ANS) and retrocochlear disorders affecting the auditory pathways.

### **4.4 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.

### **4.5 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.



## 4.6 Calibration

Real ear systems should be calibrated at least once a week using the system's inbuilt calibration procedure.

## 4.7 Otoscopy and 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.

## 4.8 Amplification components

Wherever feasible, provision of amplification must include (at least) ALL of the following.

- A complete description of the baby's audiological results for both ears.
- A description of the acoustic characteristics of the baby's ear canal(s) in the form of a Real-Ear-to-Coupler Difference (RECD).
- Accurate ear impression(s) for the purposes of fabricating an ear mould.
- An assessment of the non-electroacoustic needs of the baby.
- Electroacoustic analysis of prescribed hearing instruments (ANSI test).
- DSL v5 target ear canal sound pressure levels (SPL) for the amplified long-term average speech spectrum.
- DSL v5 target ear canal SPLs for defining the maximum saturation.
- Response of the hearing instrument.
- DSL v5 target ear canal SPLs for soft and loud speech.
- Verification that the electroacoustic characteristics of the hearing instrument adequately match the auditory needs of the baby.
- Simulated measurements of the real-ear aided response (REAR) and the real-ear saturation response (RESR).
- Education and counselling sessions with the family and whānau when the hearing instrument is first fitted and at subsequent follow-up visits as needed.
- An evaluation of the outcome of the intervention (using the LittleEARS® and PEACH as specified in the UWO PedAMP protocol).
- Appropriate follow-up schedule and adjustments to the amplification as required.

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# Diagnostic protocol

## 5 ABR-based assessment

### 5.1 ABR calibration

ABR calibration values (dB SPL to HL offset) are specified in Appendix 4. Manufacturers' default calibrations are not acceptable.

ABR instrumentation must be calibrated electro-acoustically every two years. 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.

### 5.2 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.

### 5.3 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.

### 5.4 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.

### 5.5 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.

### 5.6 Order of tests

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

## 5.7 Otoscopy and cerumen/debris

Cursory otoscopy should be conducted at the start of any assessment if possible. 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. Care must be taken to not disturb the baby and rouse it from sleeping. At times it may be appropriate to replace otoscopy with careful observation of the opened ear canal.

## 5.8 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.

- a. Cursory otoscopy or observation of the opened ear canal.
- b. 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 unless a significant asymmetry is diagnosed.
- c. 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, 4 kHz and 1 kHz. Calibration values for 4 kHz and 1 kHz became available from January 2015.
- d. 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.
- e. DPOAE amplitude and noise floor measurements at 1.5, 2, 3 and 4 kHz.
- f. Immittance testing, which must include tympanometry and ipsilateral acoustic reflex testing. The probe tone frequency must be 1 kHz for babies under nine months corrected age and using a broad band noise stimulus for reflex testing. For children aged nine 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 results are obtained for both ears. If the baby wakes before the second ear is tested, an additional ABR appointment should be scheduled where possible, however if the ABR is incomplete but results of DPOAE and immittance testing (high frequency tympanogram + acoustic reflex threshold) are consistent with a pass result then the baby can be discharged.

## **5.9 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. Bone conduction (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.

## **5.10 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 3 kilohms for all electrodes, and impedance differences within each channel of less than 1 kilohm.

## **5.11 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.

## **5.12 Tone burst ABR measurement parameters**

All ABR testing must be conducted using the technical parameters detailed in Appendix3. Tone burst ABR threshold estimates must be obtained according to the following specifications, in each ear.

## **5.13 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 (ie, replications typically 10 dB below threshold level, except if threshold is > 70 dBHL, where a final step size of 5 dB may be employed). Replications of 'no response' waveforms may not be required if waveforms contain minimal noise and are very clear, typically a SNR of 3:1 is required to demonstrate a response is present in the waveform.

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 early if a decision is made upon the presence of a clear response or after more than 2000 trials if waveform noise levels are high. If two clear replications are obtained at the minimum passing level, it is required that the presence of a response is confirmed by doing one average at a higher intensity (typically 20 dB louder) that demonstrates characteristics of growth of an evoked potential response such as increased amplitude and decreased latency.

If there is a hearing loss, an ABR threshold is defined by a response-positive pair of replications at some level, a negative response 10 dB below that level (with a replication if required) and a positive response 10 dB above that level demonstrating growth of the response if not at the maximum intensity level.

A response-negative decision may be made if a single average is subjectively flat.

A response-positive decision may be made on the basis of a single average if the location and shape of the waveform are appropriate.

The maximum number of sweeps should be set to nominally 4000. All averages must be terminated by the audiologist, with due regard to the current number of sweeps, and the appearance of the records.

## **5.14 ABR threshold definition and 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 may 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 of clearly identifiable waveforms that demonstrate appropriate latency and amplitudes characteristics of evoked potentials.

## **5.15 Confirmation of threshold upper bracket response**

In the event that there is 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.

## **5.16 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 (i.e. no audible sound). 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.

## **5.17 High noise recordings and 50 Hz artifact**

In the event that there is evidence of a large problem with electrical noise in the recordings the averaging strategy must revert to replicated averages of at least 2000–4000 sweeps. If noisy recordings are a frequent problem, the test environment, instrumentation, electrodes and cables should be evaluated and electrode application procedures should be reviewed. It may be necessary to abandon the recording session rather than reach an erroneous conclusion about elevated thresholds.

## **5.18 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  $\mu\text{V}$ , or less. Gain must not be decreased if the EEG noise level increases during the test. Artifact rejection must not be disabled.

## **5.19 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.

## **5.20 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.

## **5.21 Air conduction at 2 kHz**

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

## **5.22 Air conduction at 500 Hz**

AC at a minimum of 35 dB eHL at 500 Hz, with threshold bracketing if no response, must be done. Testing at 500 Hz is a mandatory component of initial assessment.

## **5.23 Bone conduction at 2 kHz**

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

## **5.24 Bone conduction at 500 Hz**

BC at a minimum of 30 dB eHL 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 eHL. 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. If BC at 2 kHz has been obtained and it is within normal limits and the baby is still in a good state an alternative recommended strategy is to immediately test 500 Hz BC prior to switching to 500 Hz AC as this may establish that there is no PCHI present in this ear.

## **5.25 Bone conduction at other frequencies**

In addition to 500 Hz and 2 kHz, BC testing can be done at 1 kHz and 4 kHz. Calibration values for these frequencies are available from January 2015.

## **5.26 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 minimise BC stimulus artifact must be used. The maximum BC level is discretionary in the presence of large, irreducible artifact. Careful placement of the bone vibrator on the high mastoid with a low placement of the electrode can help reduce the size of the stimulus artifact. The use of 'blocked points', which is available in some commercial evoked potential systems, can assist in dealing with excessive stimulus artifact.

## **5.27 Bone conduction two-channel recording**

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

## **5.28 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.

## **5.29 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 60-65 dB masking noise should provide adequate masking; additional masking noise is not recommended because of the risk of cross over and central masking.

## **5.30 Air conduction at 4 kHz**

AC at a minimum of 30 dB eHL 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. However, it is recommended that testing at 4 kHz occurs routinely as this enables a baseline high frequency result that can be referred to if a later hearing loss identified.

## **5.31 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.

### **5.32 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.

### **5.33 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.

### **5.34 Auditory neuropathy spectrum disorder / retro-cochlear 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 1000 sweeps per average with a low noise level of noise in the waveforms. 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: retro-cochlear pathology, ANSD, 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 clamped or detached from the transducer and positioned as far as possible from it; this procedure is to differentiate cochlear microphonic from stimulus artifact. The insert and transducer must not be moved from their positions for the previous 95 dB recordings.

### **5.35 Diagnosing auditory neuropathy spectrum disorder**

The high-intensity click records must be assessed for presence of cochlear microphonic (CM) and stimulus artifact. Together with DPOAE records, the evidence for ANSD must be evaluated. Absence of DPOAE does not rule out ANSD, whereas presence of DPOAE and absence of ABR or grossly elevated ABR thresholds does make ANSD a primary inference.

With ANSD 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.



### **5.36 Auditory neuropathy spectrum disorder implications**

If definite or presumptive ANSD 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 DPOAEs are not normal, a presumptive inference of ANSD 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.

### **5.37 Auditory neuropathy spectrum disorder report**

If ANSD 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 ANSD. Permanent congenital hearing loss must be reported as present.

### **5.38 Click ABR thresholds**

Threshold seeking using click ABR is not recommended as results are unreliable and of little value. Click stimuli should only be used at high levels for diagnosis of ANSD; threshold-seeking using clicks is not part of the New Zealand paediatric protocols.

### **5.39 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 4. 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.

## **6 DPOAE testing**

### **6.1 DPOAE protocol**

All DPOAE tests must be done in compliance with this protocol and using the technical parameters and interpretive criteria detailed in Appendix 6.

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.

## **6.2 DPOAE test procedure**

Test parameters for diagnostic DPOAE measurements are detailed in Appendix 5. 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.

## **6.3 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 ANSD, for any threshold technique (ABR, VRA, CPA, conventional).

# **7 Immittance testing**

## **7.1 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 7.

## **7.2 Tympanometry**

Tympanometry must be done with a 1 kHz probe tone for babies under nine months corrected age and a 226 Hz probe tone for children aged nine 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 (nine months and over) or printed (under nine months) and retained on file.

## **7.3 Acoustic reflexes**

Ipsilateral acoustic reflex measurements must be done with a 1 kHz probe tone for babies under nine months corrected age and with a 226 Hz probe tone for children aged nine months or more. The eliciting stimulus must be BBN for the babies under nine months and a minimum of 1 kHz tone stimuli for children over nine 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. Reflex records must be plotted or printed and retained on file if they are ambiguous.

## **7.4 Acoustic reflex interpretation**

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

## **7.5 Acoustic reflex interpretation**

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

## 8 VRA-based assessment

All initial VRA-based assessments must include the following.

- 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 and 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 cooperative) with a 226 probe tone (if the baby is under six months of age 1 kHz probe tones should be used for tympanometry and reflex testing).

### 8.1 Tests and 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 8.

### 8.2 Target population

Candidates for VRA-based assessment include babies aged from about six to about 30 months corrected age who have been identified with PCHL by ABR-based assessment, or who fail routine follow-up, or who are referred to audiology due to risk factors such as postnatal infections, head trauma, etc.

### 8.3 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.

### 8.4 Test environment

VRA testing must be done in an audiometric test room satisfying current 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 metre 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.

## **8.5 Instrumentation and 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 et al (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.

## **8.6 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.

## **8.7 Soundfield versus ear-specific VRA**

Testing may be conducted in the sound field or by using insert phones for separate ear testing. If sound field results are obtained that indicate normal hearing then separate ear information must be obtained from DPOAE testing indicating good hearing in each ear and immittance testing including reflex testing needs to be conducted in each ear to ensure ANSD can be excluded. If sound field results indicate a hearing loss then further behavioural testing needs to be scheduled in order to establish separate ear threshold results. If a hearing loss is diagnosed every attempt to obtain separate ear results must be made prior to the fitting of any hearing aids. This may require an ABR test under general anaesthetic to establish separate ear results.

## **8.8 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 (ie, initial or follow-up testing).

VRA follow-up from ABR-based assessment must include 2 kHz, 500 Hz and 4 kHz 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.

## **8.9 Threshold procedure**

The protocol for determining thresholds must be based on the procedure described by Gravel (1994) and Gravel et al (1999) and conducted as detailed in the technical summary in Appendix 8.

## **8.10 Auditory dys-synchrony inference from VRA**

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

## **8.11 Normal hearing thresholds determined by VRA**

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

# **9 Conditioned play audiometry (CPA)**

All initial CPA-based assessments must include the following.

- 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 and 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 500 Hz and 2 kHz.

## **9.1 Tests and 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. Detailed instructions are in Appendix 9.

## **9.2 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.

## **9.3 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.

## **9.4 Test environment**

CPA testing must be done in an audiometric test room satisfying current 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.

## **9.5 Instrumentation and 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.

The choice of earphones is at the discretion of the audiologist for AC CPA. It is common practice to use TDH 49/MX41 supra-aural earphones. 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. Use of insert earphones is encouraged as they reduce the need for masking in certain circumstances and may be comfortable for the child.

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.

## **9.6 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.

## **9.7 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.

## **9.8 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 or supra aural 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.

## **9.9 Speech stimuli**

Speech audiometry using the Kendall Toy Test, or another closed-set task suitable for young children, is recommended. Detailed instructions for the Kendall Toy Test are in Appendix 9. 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.

## **9.10 Threshold determination**

The procedures recommended for threshold determination by CPA are closely analogous to those for VRA however, a smaller down 10 dB up 5 dB threshold determination procedure may be used if the child is cooperative. The VRA worksheet and the methodology of stimulus control and response documentation may be followed closely, at the discretion of the audiologist.

## **9.11 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. Acceptable stimuli are steady or pulsed FM modulated (warble tones), narrow band noises or pure tones.

## **9.12 Normal hearing thresholds determined by CPA**

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

## **9.13 ANSD 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, ANSD is almost certain. A confirmatory ABR test including the click protocol for ANSD must be considered, if there is any question about the reliability of the CPA thresholds. Such a test may require general anaesthesia/sedation.

# 10 Overall inference and contingent actions

## 10.1 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.

## 10.2 Normal hearing definition

A child must only be considered as audiometrically 'normal' if AC HLs or thresholds are estimated with confidence at 20 dB HL based on behavioural audiometry for all frequencies that are mandatory under this protocol and there is no audiometric indication of ANSD or any retrocochlear disorder. Note that ABR-based audiometry does not rule out the possibility of slight hearing loss.

## 10.3 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 ANSD is strongly indicated.

## 10.4 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 (in the absence of BC testing), or if the presence of ANSD is strongly indicated.

## 10.5 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.

## 10.6 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.



## **10.7 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).

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# Amplification protocol

## 11 Assessment considerations

### 11.1 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 (ie, 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.

### 11.2 Consultation by an otolaryngologist or paediatrician

As per Standard 21, 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.

### 11.3 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 and Hatton 2000, Sinclair et al 1996, Seewald et al 1999). Therefore, it is a required element in the amplification process for babies.

### 11.4 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 14. 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 (foam tip or earmould) ear and test date must be documented and retained on file. The coupling type should be the same for hearing threshold measurement and RECD measurement.

## **11.5 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 14. If predicted values are used, they must be specified (ie, 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 ear mould coupling (Bagatto et al 2002).

# **12 Prescription of amplification**

## **12.1 Ear impressions**

Ear impressions must be obtained from each ear for fabrication of personal ear moulds (see Appendix 15) as per the ear mould 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 ear moulds 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 ear mould materials should be weighed for each individual baby (see Appendix 16 for details). The need for frequent replacement of ear moulds 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.

## **12.2 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.

## **12.3 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 (ie, congenital hearing loss) and for adults (ie, 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 18.

## **12.4 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. Ear moulds and hearing instruments must be ordered, with a request for paediatric filtered tonehooks. A bone anchored hearing aid 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.

## **12.5 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.

# **13 Verification of amplification**

## **13.1 RECD values**

The acoustic properties of the baby's personal ear mould must be taken into account through the use of RECD measurements or age-appropriate predicted values. Whenever a new ear mould 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 ear mould 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.

## **13.2 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.

## **13.3 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 (ie, 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 17. 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.

### **13.4 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 (ie, 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 pre-linguistically hearing impaired babies. Thus, multiple memories may be considered (ie, 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 (ie, good ear mould 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 ear moulds are obtained, and the feedback suppression technology should be deactivated when not required.

### **13.5 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.

### **13.6 Verification stimuli**

Verification of hearing instrument performance at various input levels (ie, 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 et al 2000).

# **14 Information and instruction**

## **14.1 Orientation**

As per Standard 22, 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.

## **14.2 Information**

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 that are outside of the audiologists scope of practice such as prognosis, or medical issues.

## **14.3 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.

# **15 Outcome evaluation**

## **15.1 Follow-up schedule**

As per Standard 23, 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 two 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 neuropathy spectrum disorder or multiple disabilities a more intensive schedule may be required. The schedule should be re-assessed on an on-going, individual basis, with appropriate documentation.

## **15.2 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. Ear moulds must be assessed for appropriate fit and new ear moulds obtained when required. An RECD should be re-measured and documented to account for growth and development, as well as if the ear mould 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 ear moulds have been fitted.

### **15.3 Outcome measures**

Validation of the fitting must be done using a combination of questionnaires (LittleEARS®, PEACH), behavioural reports from the family and whānau and age appropriate aided speech perception testing (see Appendix 10). Cortical evoked response testing should be considered for children diagnosed with ANSD 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).

### **15.4 Progress with amplification**

As per Standard 23, 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 1: References

- Antognelli T. 1986. The Kendall Toy Test Revisited: The Development of an Australian Version. Conference presentation, VII National Conference of the Audiology Society of Australia.
- Bagatto MP, Moodie S, Scollie S, et al. 2005. Clinical protocols for hearing instrument fitting in the Desired Sensation Level method. *Trends in Amplification* 9(4): 199–226.
- Bagatto MP, Scollie SD, Seewald RC, et al. 2002. Real-ear-to-coupler difference predictions as a function of age for two coupling procedures. *Journal of the American Academy of Audiology* 13(8): 407–15.
- Bagatto MP, Seewald RC, Scollie SD, et al. 2006. Evaluation of a probe-tube insertion technique for measuring the real-ear-to-coupler difference (RECD) in young infants. *Journal of the American Academy of Audiology* 17(8): 573–81.
- Carney A, Moeller MP. 1998. Treatment efficacy: hearing loss in children. *Journal of Speech, Language and Hearing Research* 41: S61–S84.
- Elfenbein JL. 2000. Batteries required: instructing families/caregivers on the use of hearing instruments. In RC Seewald (ed). *A Sound Foundation Through Early Amplification: Proceedings of an International Conference* (pp 141–9 Table 1).
- Feigin JA, Kopun JG, Stelmachowicz PG, et al. 1989. Probe-tube microphone measures of ear canal sound pressure levels in infants and children. *Ear and Hearing* 10(4): 254–8.
- Foulon I. 2014. Characteristics of hearing loss and proposal for follow up in children with congenital cytomegalovirus infection. URL: <http://cmv.usu.edu/Uploads/pdfs/291InaFoulon.pdf> (accessed May 2014).
- Gravel JS. 1994. Auditory assessment of infants. *Seminars in Hearing* 15(2): 100–13.
- Gravel J, Fausel N, Liskow C, et al. 1999. Children's speech recognition in noise using omnidirectional and dual-microphone hearing aid technology. *Ear and Hearing* 20(1): 1–11.
- Hoffmann A, Deuster D, Rosslau K, et al. 2013. Feasibility of 1000 Hz tympanometry in infants: Tympanometric trace classification and choice of probe tone in relation to age. *International Journal of Pediatric Otorhinolaryngology* 77: 1198–203.
- ISO 8253-1. 2010. Acoustics — Audiometric test methods — Part 1: Basic pure-tone air and bone conduction threshold audiometry. International Standards Organisation.
- Kei J, Allison-Levick J, Dockray J, et al. 2003. High-frequency (1000 Hz) tympanometry in normal neonates. *Journal of the American Academy of Audiology* 14: 20–8.
- Moodie KS, Seewald R, Sinclair S. 1994. Procedure for predicting real ear hearing aid performance in young children. *American Journal of Audiology* 3: 23–31.
- Munro KJ, Hatton N. 2000. Customized acoustic transform functions and their accuracy at predicting real-ear hearing aid performance. *Ear and Hearing* 21(1): 59–69.
- Scollie SD, Seewald RC, Cornelisse LC, et al. 2005. The Desired Sensation Level multistage input/output algorithm. *Trends in Amplification* 9(4): 159–97.
- Scollie SD, Seewald RC, Moodie KS, et al. 2000. Preferred listening levels of children who use hearing aids: Comparison to prescriptive targets. *Journal of the American Academy of Audiology* 11(4): 230–8.



- Seewald RC. 1995. The Desired Sensation Level (DSL) Method for hearing aid fitting in infants and children. *Phonak Focus* 20: 1–19.
- Seewald RC, Moodie KS, Sinclair ST, et al. 1999. Predictive validity of a procedure for paediatric hearing instrument fitting. *American Journal of Audiology* 8: 1–10.
- Seewald RC, Scollie SD. 1999. Infants are not average adults: Implications for audiometric testing. *The Hearing Journal* 52(10): 64–72.
- Sinclair ST, Beauchaine KL, Moodie KS, et al. 1996. Repeatability of a real-ear-to-coupler-difference measurement as a function of age. *American Journal of Audiology* 5: 52–6.
- Stapells DR. 2002. The tone evoked ABR: why it's the measure of choice for young infants. *The Hearing Journal* 55(11): 14–18.
- Widen JE, Folsom RC, Cone-Wesson B, et al. 2000. Identification of neonatal hearing impairment: hearing status at 8 to 12 months corrected age using a visual reinforcement audiometry protocol. *Ear & Hearing* 21(5): 471–87.
- Yang EY, Rupert AL, Moushegian G. 1987. A developmental study of bone conduction auditory brain stem response in infants. *Ear & Hearing* 8(4): 244–51.

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# Appendix 2: Bibliography

- ANSI. 1996. American National Standard Specification for Audiometers (ANSI S3.6–1996). New York, American National Standard Institute.
- Baldwin M. 2006. Choice of probe tone and classification of trace patterns in tympanometry undertaken in early infancy. *International Journal of Audiology* 45: 417–27.
- Bess FH, Dodd-Murphy J, Parker RA. 1998. Children with minimal sensorineural hearing loss: prevalence, educational performance, and functional status. *Ear and Hearing* 19(5): 339–54.
- Bess FH, Tharpe AM. 1984. Unilateral hearing impairment in children. *Paediatrics* 74(2): 206–16.
- Brown DK, Tobolski C, Shaw G, Dort J. 2000. Towards determining distortion product otoacoustic emission protocols for newborn hearing screening. *Journal of Speech–Language Pathology and Audiology* 24: 68–73.
- Cone-Wesson B, Ramirez G. 1997. Hearing sensitivity in newborns estimated from ABRs to bone-conducted sounds. *Journal of the American Academy of Audiology* 8(5): 299–307.
- Cone-Wesson B, Vohr BR, Sininger YS, et al. 2000. Identification of neonatal hearing impairment: infants with hearing loss. *Ear & Hearing* 21(5): 488–507.
- Crandell CC. 1993. Speech recognition in noise by children with minimal degrees of sensorineural hearing loss. *Ear and Hearing* 14(3): 210–16.
- CWGCH. 2005. *Early Hearing and Communication Development*. Canadian Working Group on Childhood Hearing (CWGCH) resource document. Ottawa: Minister of Public Works and Government Services Canada.
- Gorga MP, Neely S, Ohlrich B, et al. 1997. From laboratory to clinic: a large-scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. *Ear & Hearing* 18(6): 440–55.
- Government of Ontario. 1991. Audiology and Speech-Language Pathology Act. URL: [www.elaws.gov.on.ca/DBLaws/Statutes/English/91a19\\_e.htm](http://www.elaws.gov.on.ca/DBLaws/Statutes/English/91a19_e.htm) (accessed 14 May 2007.)
- Gravel JS. 2002. Potential pitfalls in the audiological assessment of infants and young children. In Seewald RC and Gravel JS (eds). *A Sound Foundation through Early Amplification 2001: Proceedings of the Second International Conference*. Phonak AG, 85–101.
- Hattori H. 1993. Ear dominance for nonsense-syllable recognition ability in sensorineural hearing-impaired children: monaural versus binaural amplification. *Journal of the American Academy of Audiology* 4(5): 319–30.
- Hawkins DB, Yacullo WS. 1984. Signal-to-noise ratio advantage of binaural hearing aids and directional microphones under different levels of reverberation. *Journal of Speech and Hearing Disorders* 49(3): 278–86.
- Hodgetts WE, Scollie SD, Swain R. 2006. Effects of applied contact force and volume control setting on output force levels of the BAHAs Softband. *International Journal of Audiology* 45(5): 301–8.
- Hunter LL, Margolis RH. 1992. Multifrequency tympanometry – current clinical application. *American Journal of Audiology* July, 33–43.
- JCIH. 2000. Joint Committee on Infant Hearing – Year 2000 Position Statement. Principles and Guidelines for Early Hearing Detection and Intervention Programs. URL: [www.jcih.org](http://www.jcih.org)

- JCIH. 2007. Joint Committee on Infant Hearing – Year 2007 Position Statement. Principles and Guidelines for Early Hearing Detection and Intervention Programs. *Pediatrics* 120(4): 898–921.
- Jenstad L, Pumford J, Seewald R, et al. 2000. Comparison of linear gain and WDRC hearing aid circuits II: Aided loudness measures. *Ear and Hearing* 21(1): 32–4.
- Jenstad L, Seewald R, Cornelisse L, et al. 1999. Comparison of linear gain and WDRC hearing aid circuits I: Aided speech perception measures. *Ear and Hearing* 20(2): 117–26.
- Kruger B. 1987. An update on the external ear resonances in infants and young children. *Ear & Hearing* 8(6): 333–6.
- Margolis RH, Bass-Ringdahl S, Hanks W, et al. 2003. Tympanometry in newborn infants – 1 kHz norms. *Journal of the American Academy of Audiology* 14(7): 386–95.
- McMillan PM, Bennett M, Marchant C, et al. 1985. Ipsilateral and contralateral acoustic reflexes in neonates. *Ear & Hearing* 6(6): 320–4.
- Moeller MP, Donaghy KF, Beauchaine KL, et al. 1996. Longitudinal study of FM system use in nonacademic settings: effects on language development. *Ear and Hearing* 17(1): 28–41.
- Nozza RJ. 2002. Developmental psychoacoustics: science to practice. In Seewald RC and Gravel JS (eds). *A Sound Foundation through Early Amplification 2001: Proceedings of the Second International Conference*. Phonak AG, 37–46.
- Palmu A, Puhakka H, Huhtala H, et al. 2001. Normative values for tympanometry in 7- and 24-month old children. *International Journal of Audiology* 40: 178–84.
- Palmu A, Tapani Rahko T. 2003. Normative values for tympanometry in 4–5 year old children. *International Journal of Audiology* 42: 327–30.
- Parry G, Hacking C, Bamford J, et al. 2003. Minimal response levels for visual reinforcement audiometry in infants. *International Journal of Audiology* 42: 413–17.
- Ricketts T, Tharpe AM. 2004. Potential for directivity-based benefit in actual classroom environments, pp 143–53. In R Seewald and J Bamford (eds). *A Sound Foundation Through Early Amplification: Proceedings from an International Conference*. Phonak AG: Chicago, IL.
- Scollie SD, Seewald RC, Cornelisse LC, et al. 1998. Validity and repeatability of level-independent HL to SPL transforms. *Ear and Hearing* 19: 407–13.
- Sininger YS, Abdala C, Cone-Wesson B. 1997. Auditory sensitivity of the human neonate as measured by the auditory brainstem response. *Hearing Research* 104: 27–38.
- Small SA, Hatton JL, Stapells DR. 2007. Effects of bone oscillator coupling method, placement and occlusion on bone-conduction auditory steady-state responses in infants. *Ear & Hearing* 28(1): 83–98.
- Stapells DR. 2000a. Frequency-specific evoked potential audiometry in infants. In RC Seewald (ed). *A Sound Foundation through Early Amplification*. Phonak AG 13–32.
- Stapells DR. 2000b. Threshold estimation by the tone-evoked auditory brainstem response: a literature meta-analysis. *Journal of Speech–Language Pathology and Audiology* 24: 74–83.
- Stapells DR, Oates P. 1997. Estimation of the pure-tone audiogram by the auditory brainstem response: A review. *Audiology and Neuro-Otology* 2: 257–80.
- Stapells DR. HAPLAB website: [audiospeech.ubc.ca/haplab/ThreshABR.html](http://audiospeech.ubc.ca/haplab/ThreshABR.html)
- Stuart A, Durieux-Smith A, Stenstrom R. 1990. Critical differences in aided sound field thresholds in children. *Journal of Speech and Hearing Research* 33(9): 612–5.

Wake M, Hughes EK, Poulakis Z, et al. 2004. Outcomes of children with mild-profound congenital hearing loss at 7 to 8 years: A population study. *Ear and Hearing* 25(1): 1–8.

Yang EY, Stuart A. 2000. The contribution of the auditory brainstem responses to bone-conducted stimuli in newborn hearing screening. *Journal of Speech-Language Pathology and Audiology* 24: 84–91.

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# **Appendix 3: UNHSEIP instrumentation and calibration**

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

Calibration values are calculated in NZ by the ISO registered calibration company. Care needs to be taken to ensure values are not inadvertently altered.

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# Appendix 4: ABR technical parameters

## Electrode sites

- Non-inverting (positive) : high midline forehead, referenced to:
  - inverting (negative) channel 1: left mastoid
  - inverting (negative) channel 2: right mastoid
- Common (ground): low forehead >3 cm from non-inverting or offset to side if insufficient space under the non-inverting electrode

## Channels

- Air conduction: view Ipsi or both, plot Ipsi
- Bone conduction: view and 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, minimum of two averages at the threshold intensity, subject to the amount of noise present in the waveforms. Less than 2000 sweeps may be accepted if there is a large amplitude low noise response identified.

## Epoch length

- Tone burst
  - Approximately 20 ms for 1, 2 and 4 kHz
  - Approximately 30 ms for 500 Hz

- Click
  - Approximately 12–15 ms plus a 1 ms pre-stimulus baseline

### **Analysis offset or use of blocked points**

- Zero, or as required to avoid large BC artifact dependent upon the frequency of the stimulus

Frequency	Stimulus duration
500 Hz	10 ms
1 kHz	5 ms
2 kHz	2.5 ms
4 kHz	1.25 ms

### **Stimuli**

- Tone bursts
  - Linear ramp (trapezoidal envelope), 2-1-2 cycle rise/plateau/fall times
  - Alternating polarity
  - Repetition rate 39.1/s, slightly slower rate may be required for 500 Hz
- Clicks
  - 100  $\mu$ s
  - Polarity as specified (separate recordings of both polarities)
  - Repetition rate 17.1/s

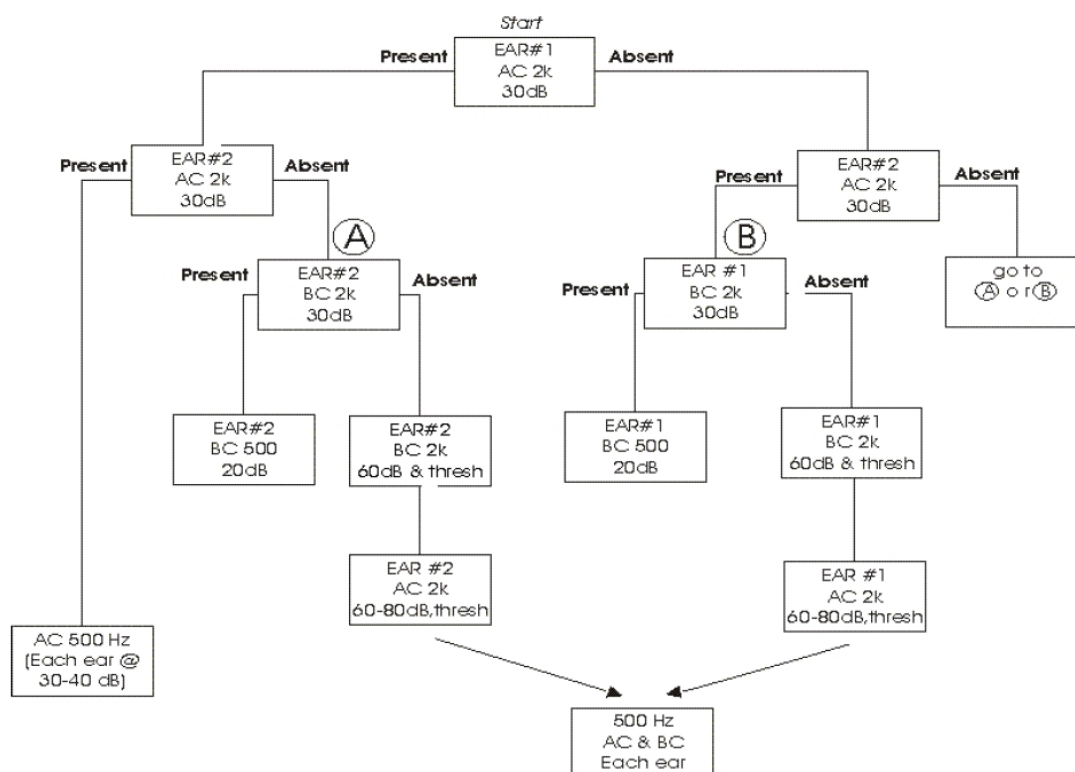
### **ANSD protocol**

- Record separate polarity recordings at 80 dB HL if normal hearing or at maximum levels if a hearing loss has been diagnosed. Repeat if possible.
- Record a ‘no sound’ trial at the same intensity as above, but ensure sound is not delivered to the ear by either clamping the sound tube or taking the insert out of the ear. It is extremely important to not disturb the position of the insert transducer or electrode leads at this point. This run should demonstrate the presence of the stimulus artefact and the absence of any response from the patient.
- Display the separate polarity recordings in a manner that enhances the cochlear microphonic responses.
- Display the added and subtracted waveforms and the ‘no sound’ trial waveforms.

### **Masking**

- Ipsilateral: none
- Contralateral: discretionary as described in protocol text

**Figure 5: Tone-ABR test sequence (partial)**



### ABR test sequences

1. Normal
2. Conductive
3. Sensorineural

### Sequence for normal ABR bilateral refer

1. 2000 Hz at 30 dBnHL each ear
2. 500 Hz at 35 dBnHL each ear
3. 4000 Hz at 30 dBnHL each ear

### Sequence for normal ABR unilateral refer

1. 2000 Hz at 30 dBnHL referred ear
2. 500 Hz at 35 dBnHL referred ear
3. 4000 Hz at 30 dBnHL referred ear
4. 2000 Hz at 30 dBnHL passed ear
5. 500 Hz at 35 dBnHL passed ear
6. 4000 Hz at 30 dBnHL passed ear



## **Sequence for conductive HL**

### **Sequence for bilateral refer**

1. 2000 Hz AC threshold established \*
2. 2000 Hz BC at 35 dBnHL each ear where 2000 AC elevated
3. Present bilaterally
4. 500 Hz BC at 35 dBnHL
5. Present bilaterally
6. (NB: can do 500 BC after step 2 instead)
7. 500 Hz AC threshold established
8. 1000 and 4000 Hz AC can be deferred if fluctuating middle ear involvement suspected

### **Sequence for unilateral refer**

1. 2000 Hz AC threshold established in referred ear
2. 2000 Hz BC at 35 dBnHL in referred ear where 2000 AC elevated
3. 500 Hz BC at 35 dBnHL
5. 500 Hz AC threshold established
6. 1000 and 4000 Hz AC can be deferred if fluctuating middle ear involvement suspected
7. Test passed ear

\* Do 2k BC prior to 2k AC in the second ear if first ear 2k AC is elevated.

## **Sequence for sensorineural HL**

### **Sequence for bilateral refer**

1. 2000 Hz AC threshold in 1st ear  
Threshold identified or absent
2. 2000 Hz BC threshold in 1st ear  
Threshold identified or absent
3. 2000 Hz AC threshold in 2nd ear  
Threshold identified or absent
4. 2000 Hz BC threshold in 2nd ear  
Threshold identified or absent
5. 500 Hz AC threshold 1st ear  
Threshold identified or absent
6. 500 Hz BC threshold in 1st ear  
Threshold identified or absent
7. 500 Hz AC threshold 2nd ear  
Threshold identified or absent
8. 500 Hz BC threshold in 2nd ear  
Threshold identified or absent
9. 4000 Hz AC threshold both ears
10. 1000 Hz AC threshold both ears if difference between 500 and 2000 Hz is > 20 dB

### **Sequence for unilateral refer**

1. 2000 Hz AC threshold in referred ear  
Threshold identified or absent
2. 2000 Hz BC threshold in referred ear  
Threshold identified or absent
3. 500 Hz AC threshold referred ear  
Threshold identified or absent
4. 500 Hz BC threshold in referred ear  
Threshold identified or absent
5. 4000 Hz AC threshold referred ear
6. 1000 Hz AC threshold if difference between 500 and 2000 Hz is  $> 20$  dB
7. Test passed ear

### **Illustration of ideal room setup for ABR testing**

Arrange the patient chair and desk to ensure that BC testing can be carried out by the audiologist with one hand while controlling the ABR computer with the other.



### **Illustration of electrode positions**

Ensure there is maximum separation between the electrode leads and insert transducers to reduce the occurrence of the electrical stimulus artifact created by the transducers being picked up by the electrode leads. This can cause a large artifact being displayed in the early part of the response waveform. The non-inverting (negative) electrodes should always be placed below the ear to allow space for the bone conductor if required.



### **Illustration of alternative electrode placement for common electrode**

If there is insufficient space to place the ground electrode under the non-inverting (negative) electrode, offset it to the side of the forehead.

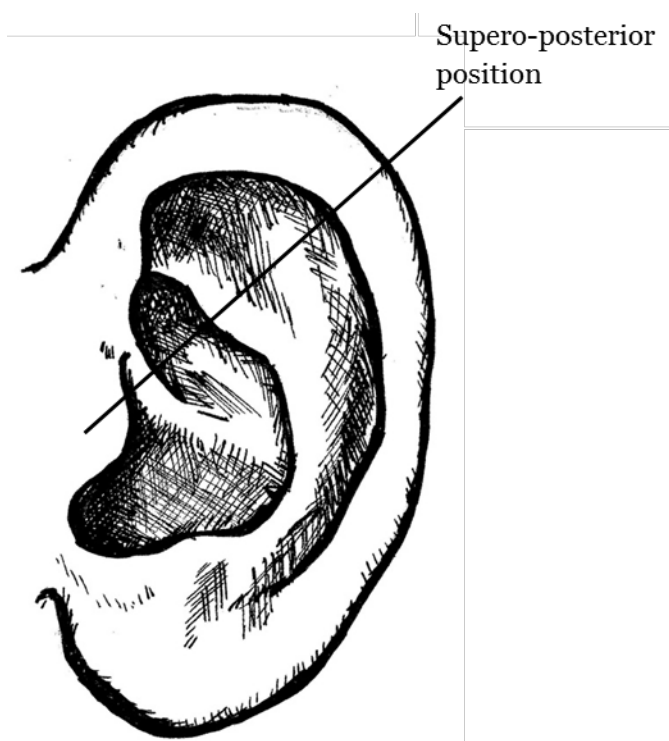


### **Illustration of bone conductor (BC) placement position**

The bone conductor should be held by one finger in the supero-posterior position as illustrated below, close to the pinna.

Hold the BC in place with one finger in the high mastoid (supero-posterior) position close to the pinna so the maximum force is applied to the head of the baby and not absorbed by the fingers of the audiologist.

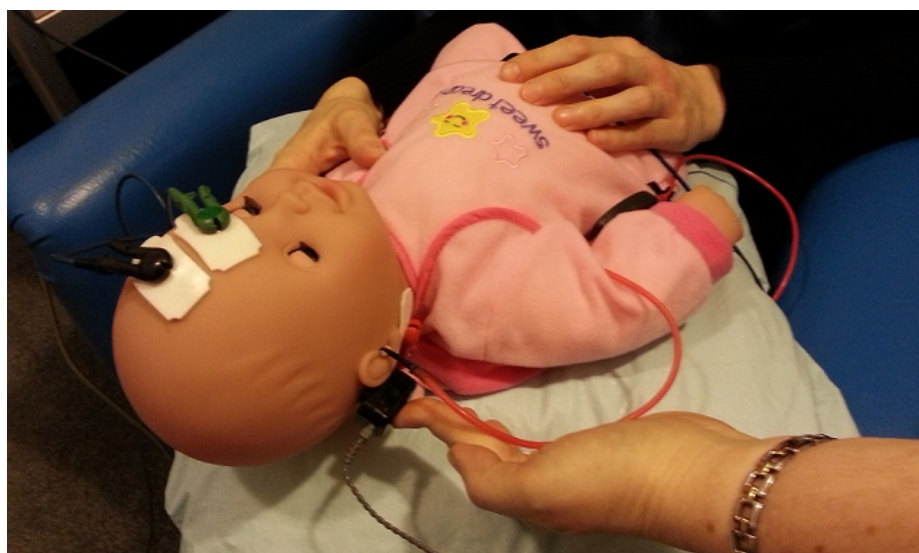
There is no evidence at this time of an occlusion effect with infant evoked recordings so it is not necessary to remove insert foam from ear canal or be worried about BC touching the pinna.





### **Illustration of bone conductor (BC) placement using a single finger**

Note the low placement of the inverting (negative) electrode to allow room for the BC and the separation of the BC lead from the electrode lead. If necessary twist the electrode lead away from the BC to avoid electrical artefact. The audiologist rather than a carer should hold the BC this to maintain consistent placement.



# Appendix 5: Minimum required levels and EHL adjustments

**Table 2: UNHSEIP minimum required levels and ABR threshold adjustment factors for Estimated Hearing Level (eHL) derivation**

	Air conduction				Bone conduction			
Frequency (Hz)	500	1k	2k	4k	500	1k	2k	4k
Minimum level (dB dial)	40	35	30	30	35	35	35	35
Adjustment (dB)	-5	-5	0	0	-5	-5	-5	-5
Estimated level (dB eHL)	35	30	30	30	30	30	30	30

Source: Stapells 2002, Kim & Kelly 2015

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, 1 kHz 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 three months corrected age or less, ie, assume stimulus level is 5 dB louder in the ears of young babies  $\leq 3$  months old due to their small ear canals. 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 three months or younger.

**Table 3: Adjustment of intensity for age example**

	500 Hz	1 kHz	2 kHz	4 kHz	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	0	dB
Estimated HL (HL)	50	50	55	55	dB eHL

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

**Table 4: Passing levels for babies  $\leq$  3 months**

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

**Table 5: Passing levels for babies  $>$  3 months**

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

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# Appendix 6: DPOAE technical summary

Nominal F2 frequencies: 1.5, 2, 3, 4 kHz  
F1 and F2 levels: 65 and 55 dB SPL

DPOAE tests should be replicated if the results of the first sweep are of low amplitude and have a limited number of points that meet the pass criteria. 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 6 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 discretionally on separate pages, but an integrated plot with the two ears side by side is preferable.

Criterion	Recommendation	Comments
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 7: Immittance testing technical summary

## Tympanometry

The UNHSEIP protocol is based on the adaption of the classification system of Kei et al (2003), described in Hoffmann et al (2013), which differentiates between peaked (normal) and flat (abnormal) curves. For babies under nine months corrected age tympanometry must be done using a high (1 kHz) probe tone frequency, with repetition as necessary and feasible, to improve reliability. It is recommended to continue to use high frequency tympanometry up to nine months of age and for older infants with craniofacial abnormalities and small ear canals (Hoffmann et al 2013).

Procedure for **high frequency** tympanogram for babies aged less than nine months:

- record tympanogram with 1 kHz probe tone using a +200 to -600 daPa pressure range, without baseline correction
- print tympanogram
- interpret the tympanogram using the following criteria:

Peaked	Flat	Indeterminate
single-peaked tympanogram	flat sloping tympanogram (no peak)	other shaped tympanograms
double-peaked tympanogram		

For babies at and above nine months corrected age tympanometry must be done using a 226 Hz probe frequency, with repetition as necessary and feasible, to improve reliability:

- $\geq 9$  months of age and  $< 12$  months of age:
  - the key abnormality criteria are peak admittance (Y)  $< 0.2$  mmho or tympanometric width (TW)  $> 235$  daPa or peak pressure  $< -100$  daPa.
- $\geq 12$  months of age up to school age:
  - the key abnormality criteria are peak admittance (Y)  $< 0.3$  mmho or tympanometric width (TW)  $> 200$  daPa or peak pressure  $< -100$  daPa.

## Acoustic reflexes

Reflex presence is defined by a clear, repeatable deflection, at any stimulus level. Note that it is a normal variation of high frequency reflex testing that reflexes may be recorded with a positive deflection.

- Babies under nine months corrected age: Acoustic reflexes must be elicited with a BBN stimulus and measured ipsilaterally, using a 1 kHz probe tone frequency. The starting level must be 80 dB for BBN with at least two replications at any level to be considered present. Reflex records must be plotted and retained on file if they are ambiguous.
- Babies at or over nine months corrected age: Where the primary purpose of reflex testing is for cross checking frequency specific threshold results, reflexes are usually elicited with a 1 kHz stimulus and measured ipsilaterally, using a 226 Hz probe tone frequency (500 Hz and 2 kHz acoustic reflexes may be elicited if the baby is cooperative). The starting level must be 90 dB with at least two replications at any level to be considered present.

However, in cases where the primary purpose of reflex testing is to confirm the presence or absence of middle ear effusion it is good practice to use a BBN stimulus and increase it to maximum level (95 dB HL) to confirm the absence of the reflex and therefore increase the certainty of correctly identifying the tympanogram.

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# Appendix 8: VRA technical summary

Adapted from Gravel (1994) and Gravel et al (1999).

Testing may be conducted in the sound field or by using insert phones for separate ear testing. If sound field results are obtained that indicate normal hearing then separate ear information must be obtained from DPOAE testing indicating good hearing in each ear and immittance testing including reflex testing needs to be conducted in each ear to ensure ANSD can be excluded. If sound field results indicate a hearing loss then further behavioural testing needs to be scheduled in order to establish separate ear threshold results. If a hearing loss is diagnosed every attempt to obtain separate ear results must be made prior to the fitting of any hearing aids. This may require an ABR test under general anaesthetic to establish separate ear results.

Testing should be done first with Monitored Live Voice (MLV) delivered through the audiometer to obtain a speech detection threshold (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 localising 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 and use a voting system and masking for the distractor to remove bias).

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.

## **Sound field protocol**

### *Monitored live voice testing*

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

- Begin at 30 dB HL – if baby turns naturally, reinforce.
- Repeat and if 2nd head turn occurs at this level – reinforce.
- Test to 20 dBHL, if two head turns are obtained begin frequency specific testing.

If there is no spontaneous head turn, increase speech level in 20dB steps until 70 dB. If head turn has still not occurred, go to CONDITIONING PROTOCOL to obtain a head turn and threshold seek this response.

### *Frequency specific testing*

Begin with 500 Hz NBN.

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.

Two consecutive head turns prior to reinforcement – go to TEST PROTOCOL.

90 dB HL (if speaker can present the sound without distortion otherwise 80 dB HL) paired with reinforcement, 2 times.

90 dB HL 'probe' – if head turn, reinforce.

Two consecutive responses – go to TEST PROTOCOL.

If no turn on probe – hearing problem or conditioning problem?

- Change stimulus modality (bone-conductor at vibrotactile level on the mastoid or held in hand)?
- Change stimulus frequency?
- Change stimulus type (eg, warble tones, filtered environmental sounds)?

## **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 two responses out of three presentations are obtained.

2nd and 3rd frequencies: 2000 and 4000 Hz , begin at 30 dB HL , if response obtained, continue threshold search, if no response, increase intensity until response obtained two times, continue threshold search.

### **Insert earphone protocol**

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

### **Monitored live voice testing**

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

Begin at 30 dB HL – if baby turns naturally, reinforce.

Repeat and if 2nd head turn occurs reinforce.

Test to 20 dBHL if 2 head turns obtained begin frequency specific testing.

If there is no spontaneous head turn, increase in 20dB steps until 70 dB. If head turn has still not occurred go to CONDITIONING PROTOCOL to obtain a head turn and threshold seek this response.

### **Frequency specific testing**

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.

Two consecutive head turns prior to reinforcement – go to TEST PROTOCOL.

If no head turn on probe – do listening check of earphone.

If OK – go to:

- 90 dB HL paired with reinforcement, 2 times
- 90 dB HL 'probe' – if head turn, reinforce.

Two consecutive responses – go to TEST PROTOCOL.

If no turn on probe – hearing problem or conditioning problem?

- Change stimulus frequency?
- Change stimulus type (eg, warble tones, filtered environmental sounds)?
- Change ear?
- Change stimulus modality (bone-conductor at vibrotactile levels on the mastoid or 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 and 3rd frequency: 2000 and 4000 Hz in same ear, begin at 30 dB HL if 1 response obtained, continue threshold search, if no response, increase intensity until response obtained 2 times continue threshold search.

1000 Hz as required depending upon shape of audiogram.

### **Second ear**

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

2000 Hz and 4000Hz – proceed as above for 500 Hz.

1000 Hz as required depending upon shape of audiogram.

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 greater than 20 dB HL bilaterally.

Vibrator on mastoid of ear with better AC threshold.

Note: placing the vibrator on the mastoid with the better AC threshold is appropriate for young infants under 1 year of age where there is still significant inter-aural attenuation for bone conduction present, The estimated inter-aural attenuation in the 1-year old is between 15 to 25 dB (Yang et al 1987). In older children and for play audiometry the normal practice of placing the vibrator on the mastoid with the worse AC threshold should apply.

Start with intensity at or below air-conduction threshold.

Use same test protocol to find threshold.

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# Appendix 9: Conditioned play audiometry

1. Test procedure is similar to that used for adult pure-tone audiometry but needs to establish thresholds **quickly**.
2. Frequency order: 2000, 500, 4000, and 1000 Hz if required. The importance of 1 kHz depends on results at 2 kHz and 500 Hz, as in ABR assessment. (You may choose to test 1000 Hz before 4000 Hz in cases where a U-shaped hearing loss is suspected.) If you think you are going to lose a child's attention, test at least 2000 and 500 Hz before switching ears.

NOTE: a recommended protocol is to test 2 kHz and 500 Hz in one ear then swap ears and test 2kHz and 500 Hz in the other ear, then test 4 kHz (and 1 kHz as required). However, this should only be attempted as long as you have no reason to suspect that one ear is worse than the other (ie, a Type B in one ear or suspected unilateral loss). In such cases, you should complete testing in the non-symptomatic ear first before swapping ears.

3. Condition the child using a 2 kHz signal (unless earlier results indicate a more appropriate frequency) presented using supra-aural headphones on the table with test signal at ~ 110 dB HL or via a loudspeaker if available (if a significant loss is expected such as with atresia/glue ear conditioning via bone conduction can be attempted). For some children it is important to include non-verbal instruction and model the desired behaviour yourself (ie, hold a peg to your ear and place it in a board at the presentation of the tone). Obtain clear behavioural responses to a few stimuli before proceeding to placing supra-aural headphones or insert phones on the child.
4. Start testing at 2000 Hz at 30 dB HL and obtain a repeat. If a clear response is obtained go to 20 dB HL and obtain a repeat. For each subsequent frequency, begin with obtaining one response at 30 dB HL, since the child should understand the task by now, then test down to 20 dB HL and obtain a repeat at each frequency.  
  
Note: If no initial response is obtained at 30 dB HL increase in 20 dB steps until a response is obtained (you must repeat this response for the first frequency tested) and then begin threshold seeking.
5. If child won't accept supra-aural headphones or insert phones (or a hand held headphone ensuring that adequate force is used) test via a loudspeaker if available so that you have at least better-ear information. Test down to 20 dB HL when testing via a loudspeaker. Remember that you can always try headphones again later when the child is more relaxed.
6. Change games if the child starts to lose interest in the task or starts to respond unreliably.
7. Test bone conduction where necessary (if AC threshold >20 dB). Test down to 10 dB HL.

8. Mask where necessary and the child is still attending well. Use the Step Method, as this is quickest and simplest for the child. Usually if you don't make a fuss about the masking noise children will happily ignore it.

### **Kendall toy test<sup>1</sup>**

1. Place the SLM close to the child's head, with the distance between the tester and the child equal to the distance between the tester and the microphone. The SLM should be on 'fast' mode using the dBA scale.
2. Either:  
  
Take toys out of box one at a time and ask the child what each is called. If the child won't name the toy, don't waste too much time waiting for the child to respond, name it for them, spread the toys on the table.  
  
Or  
  
Place the laminated card on the table and ask the child what each picture is called, don't waste too much time waiting for the child to respond, name it for them.
3. Ascertain if the child can perform the task by using 2 or 3 of the 5 distractor items as practice items at normal voice level (55–60 dBA). Use the phrase 'Show me the \_\_\_\_\_', or 'Point to the \_\_\_\_\_'.
4. Lower voice to 40 dBA (see commentary below) and ask child point to each test item, being sure to randomise the order of the test items. Start the first item at a minimal intensity level (40 dBA) first, if the item is not identified by the child at that level, continue to raise your voice in 10 dB increments until the item is correctly identified. Continue until a minimal response level is obtained for each of the 10 test items. If it is apparent after several test items have been used that a raised voice above 40dBA is required to correctly identify the items, then that level may be used for the remaining items. Record the level for the KTT as being the level in dBA at which the child accurately discriminated 90% or 100% of the test items. This may be summarised across a 10 dB range, eg, 40–50 dBA.

### **Notes:**

1. Do not proceed with the administration of the test if you do not feel the child recognises all the test items.
2. Be quick – children will lose interest rapidly if you spend too much time recording responses between items.
3. Give plenty of reinforcement.
4. Be positive if child makes a mistake, eg, don't say 'No, that's not the car', say 'Yes, that's the bath, and here's the car'. Continue to raise your voice to the level where the child can correctly identify the toy.
5. Control child's behaviour so that you can be sure that errors are due to the child not hearing rather than a lack of cooperation or poor attention.
6. If the child is looking for one you may ask 'Which picture/toy are you looking for?'

<sup>1</sup> Antognelli 1986.



7. Ensure that the ambient room noise is low enough prior to presenting *each* test item, so you are able to accurately record your voice levels. In a well sound-treated room most of the ambient noise will originate from the child and/or other individuals in the room, so make sure they are still and not shuffling around or vocalising.

### **Commentary**

There is no formal manual available for this test, the New Zealand presentation method is believed to have evolved from the Australian version of the Kendall Toy Test Revisited (Antognelli 1986). The Australian test consisted of a set of five vowel pairs with a set of five distractor items that are used as familiarisation items for the test and were also to be used as foils to replace a matched vowel if the child was unfamiliar with one of the test items. The use of the distractor item as a foil is not thought to be common practice in New Zealand.

After the familiarisation phase of the test is completed the carrier phrase need not be at 35 dBA but no visual cues are permitted, in New Zealand the common practice is for the presenter to cover their mouth. It was acceptable to return to a raised level to regain the attention of the child if it was thought they had lost attention. A pass in the test that was interpreted as demonstrating normal hearing was  $\geq 90\%$  correct at 35 dBA. This would mean at least nine out of the ten items had to be correctly identified. Normal hearing was defined as thresholds less than or equal to 15 dBHL. Antognelli comments that as a 'rule of thumb' the maximum score should be 15–20 dB above the pure tone average (*ie, if the pure tone average was 50dbHL then the KTT score of 90% or more correct should be obtained at a presentation level of 60–65 dBA*).

The Australian version does not describe in detail the technique to get a percentage correct score at elevated levels and there is a wide variety of techniques used in New Zealand to achieve this. However the original test did indicate administration of the test until a passing result of 9 or 10 correct items was achieved at one level.

There is no New Zealand normative data for this test and the passing level of 35 dBA from the Antognelli (1989) paper was established with a pure tone average of thresholds no greater than 15 dBHL. With the current practice of a screening level of 20 dB HL for pure tone thresholds it is recommended that the pass level for KTT be adjusted to 40 dBA.

A recent variant of the test is to administer it as a picture pointing task with images of the test and distractor items on a laminated card. This was developed to encourage use of the test as frequently the real items are misplaced or lost from the set and it takes slightly less time to administer. As there is no normative data for either version it is presumed there will be no differences in the possible scores obtained as long as the correct familiarisation technique is used before proceeding with administering the test. Clearly further work is required to establish New Zealand normative data for this test.

---

# Appendix 10: 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 the following.

- 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:
  - **Recommended questionnaires:**
    - Parents' Evaluation of Aural/Oral Performance of Children (PEACH, see National Acoustic Laboratories website) LittleEARS® Auditory Questionnaire for 0-23 month olds [see [http://dsl.io.com/docs/Bagatto\\_IHCON\\_2010.pdf](http://dsl.io.com/docs/Bagatto_IHCON_2010.pdf) and [www.phonak.com](http://www.phonak.com) for recent Ontario normative study]
  - 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
      - VRA with calibrated frequency specific speech phonemes
    - 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
      - NUChips
      - Hearing in noise test – children (HINT-C)
      - CVC words.

# Appendix 11: 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". It contains several input fields and buttons. The "Ear" field is set to "Right". The "Targets" field is set to "DSL child". The "Age" field is set to "3 months". The "Transducer" field is set to "ABR (eHL)". The "Threshold" field is set to "Entered". The "Bone conduction" field is set to "N/A". The "UCL" field is set to "Average". The "RECD" field is set to "Measure". The "Binaural" field is set to "No". At the bottom, there are two buttons: "Cancel" and "Continue".

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

---

# Appendix 12: Insert earphone coupling for RECD measures

During follow-up appointments, the audiologist may conduct VRA or CPA using insert earphones. The coupling type (foam tip or personal earmould) should be the same for hearing threshold measurement and RECD measurement, ie, if an insert earphone is used for the measurement of HTL for ABR, VRA or CPA then an insert earphone must be used for the RECD measurement. If the individual's earmould is used in the measurement of HTL then the individual's earmould must be used in the measurement of the RECD.

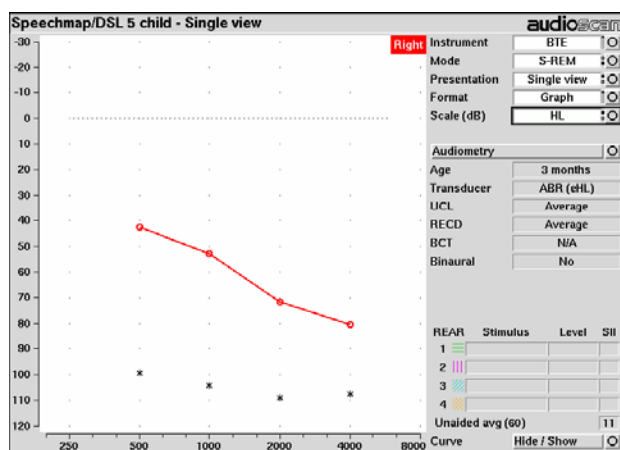
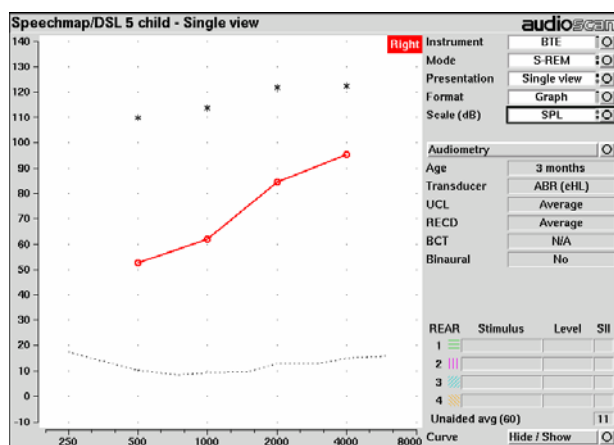
For more information on the detail of performing these measures refer to the following links:

- [www.audioscan.com/expert-insight-implications-ansi-recd](http://www.audioscan.com/expert-insight-implications-ansi-recd)
- [www.audioscan.com/Docs/vflmanual.pdf](http://www.audioscan.com/Docs/vflmanual.pdf)

# Appendix 13: 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 and 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 (ie, HLp), select **Scale** on the Speechmap screen and choose **HL**. To obtain the numerical HLp values, choose **Table** in the *Format* section.



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# Appendix 14: RECD measurement procedure

**Audioscan RM500SL and Verifit.** Note the procedure below is based on software version 3.12.9  
System set-up (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 (HA-2)  
Mode: Test box  
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)  
OR  
insert + ear mould  
OR  
ABR (eHL)  
Bone conduction: User discretion  
UCL: Average  
RECD: Measure  
RECD coupling: Foam tip or Earmould  
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 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. Position the probe tube alongside the ear tip or earmould so that the tube extends approximately 2 to 4 mm beyond the sound bore.
5. Connect the RE-770 transducer to the tube/tip or earmould combination and insert the unit into the baby's ear. If you do not wish to couple the probe tube to the tip or earmould, 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 or earmould 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.

## **RECD tips and guidelines (adapted from Bagatto et al 2005)**

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 ear mould 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 ear mould.

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**

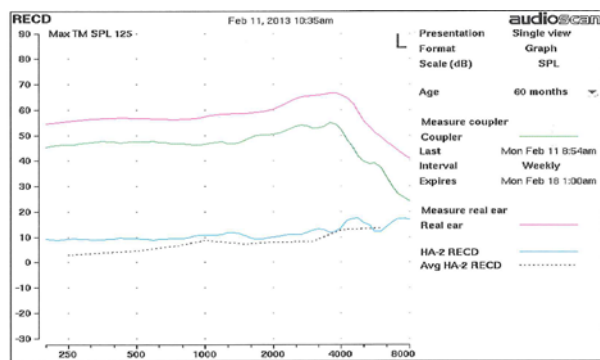
Apply ear mould lubricant (eg, Otoease, Otoform, etc) to the portion of the tube that will be inserted into the ear canal. Be careful not to go right to the end, as the lubricant may plug the tube. The lubricant will help keep the probe tube resting on the floor of the ear canal. In addition, applying some lubricant to the foam tip or ear mould 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**

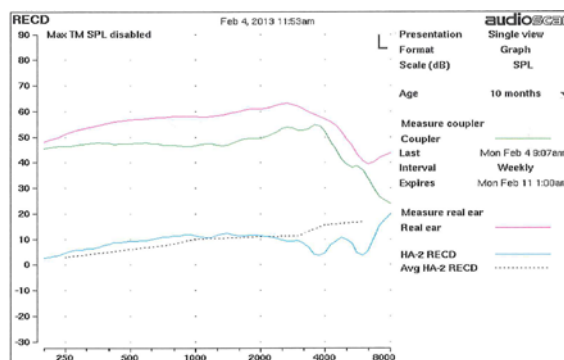
When the probe tube is in place, insert a foam tip or ear mould carefully without altering the position of the tube. When inserting the ear mould or foam tip into the ear canal, stabilise the probe tube at the intertragal notch with your little finger. Use the thumb and index finger of the same hand to insert the mould/tip. Stabilise your hand against the baby's cheek and/or head when inserting the tube or insert/mould, 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.



a) RECD measured with an insert earphone



b) RECD measured with an earmould



## 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 3 kHz**

Possible cause: Ear mould 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 re-measure.

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

Possible cause: Ear mould measurement: The probe tube may be causing some of the low frequency sound to escape from around the ear mould. Also, the ear mould 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 ear mould lubricant (eg, Otoease, Otoform, etc) on the foam tip or ear mould to create a better seal around the ear canal. Plug the medial side of the ear mould 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: Ear mould 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.

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# Appendix 15: 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 set-up** (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: Test box 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, tip)  
OR  
insert + ear mould  
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 16: Procedure for obtaining an ear mould impression

## Recommended materials

- Silicone-based ear mould 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 ear mould impression (eg, 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 otoblock 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 ear mould 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, eg, 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 ear mould 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.

### **Ear mould material and style**

Although ear mould labs have a variety of brand names for their products, two main choices of pliable ear mould 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 ear mould can be tubed. If the ear mould 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 ear mould 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 six months of age, or for children with unusually small ear canals. Ear mould venting should be considered with caution. The primary fitting problem with babies and young children is feedback. A vented ear mould 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 ear moulds are the standard style recommended for children, because of retention and feedback-prevention. Helix locks may improve ear mould 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.

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# Appendix 17: Deriving 2 cc 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 set-up** (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 + ear mould  
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.

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# Appendix 18: Electroacoustic verification

1. Follow steps 1 through 4 in Appendix 16.
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 65 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 65 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.

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.
9. Repeat the verification procedure for average and MPO if you made adjustments in Step 8.
10. 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.



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# Appendix 19: Protocol for fitting FM systems

The protocol for fitting FM Systems will be the AAA Clinical Practice Guidelines: Remote Microphone Hearing Assistance Technologies for Children and Youth Birth–21 Years, Supplement A. 4.22.08  
([www.audiology.org/resources/documentlibrary/Documents/HATSup042208.pdf](http://www.audiology.org/resources/documentlibrary/Documents/HATSup042208.pdf)).

The following instructions are taken from the above guidelines. Detailed instructions on electroacoustic and behavioural verification are in the document.

## SA1.6 Electroacoustic verification steps

1. Verification can be completed with **any** hearing aid test system that has speech-like or calibrated speech signals. When a calibrated speech input signal is **not** available, turn OFF automatic feedback control and/or noise reduction (if possible).
2. HA is verified for optimal audibility and maximum output for the individual user, using real-ear measures or 2cc coupler plus individually measured RECDs (Real-Ear-to-Coupler Differences).  
  
NOTE: The only real-ear measurement that is recommended for integrated ear-level HA/FM systems is the verification of the HA settings to ensure full audibility of self and other students. All further measurements comparing FM and HA responses will be completed using the 2 cc coupler.
3. Evaluate EHA65<sub>SPL</sub> **without** the FM receiver attached.
4. Attach FM receiver to HA and set FM Receiver to manufacturer's DEFAULT setting. FM transmitter should be turned ON and set to MUTE.
5. Evaluate EHA/FM65<sub>SPL</sub> and compare to results of EHA65 to determine if there are impedance or program changes to the HA response with an FM receiver attached. Record on worksheet. (For further discussion of possible impedance or programming effects, see Platz 2004.)
6. With HA still attached to the 2 cc coupler and test microphone, place the HA outside of the test box, at least 30 cm away from the FM transmitter (HA microphone is still active, so the test room should be quiet). Put FM transmitter/microphone in test box and set to OMNI MICROPHONE position. Evaluate FM response with 65 dB SPL input to the FM microphone (EFM/HA65<sub>SPL</sub>). Record on worksheet.
7. Subtract HA (EHA/FM65<sub>SPL</sub>) from FM (EFM/HA65<sub>SPL</sub>) at the following three frequencies: 750, 1000 and 2000 Hz. Calculate a three-frequency average of the differences. If the average difference is  $\leq \pm 2$  dB, do not change the FM setting. If the difference is  $> \pm 2$ , change the FM setting as appropriate and re-evaluate EFM/HA65<sub>SPL</sub> to confirm transparency. For example, if the FM average is 4 dB lower than the HA average, the FM setting should be increased by 4 dB and the average differences recalculated.

8. Perform a listening check with simultaneous inputs to FM and HA to judge overall signal quality and the relationship of the FM level to the hearing aid microphone.
9. For further assessment of appropriateness of FM fitting, proceed with validation procedures in Section 8 of the HAT guidelines (p 14) and make adjustments in setting as needed. For example:
  - if validation results indicate difficulty hearing self – **decrease** FM level
  - if validation results indicate difficulty hearing others – **decrease** FM level
  - if validation results indicate distortion of main talker's voice or annoying increase in background noise when that person stops talking – **decrease** FM level
  - if validation results indicate difficulty hearing talker wearing the FM microphone – **increase** FM level.

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# Appendix 20: Bone conduction hearing aids

Bone conduction hearing aids should be considered as an appropriate amplification option when in accordance of diagnostic testing there is either:

1. Permanent conductive hearing loss such as in association with microtia, atresia or any syndrome with known permanent conductive HL, ie, Treacher Collins or Goldenhar Syndrome.
2. Long-term temporary conductive hearing loss with thresholds  $\geq 45$  dB eHL in association with middle ear effusion where surgical remediation may be contraindicated.
3. Significant mixed hearing losses where the conductive component forms the majority of the hearing loss, with air conduction thresholds being at such levels that fitting standard BTE aids would be technically difficult and bone conduction thresholds fall within the range of power bone conduction devices  $\leq 50$  dB eHL.

As there is no electro-acoustic verification clinically available for bone conduction hearing aid fitting it is only possible to assess the fitting using aided behavioural measures and validating the fitting using questionnaires (Hodgetts, 2014).

## **Bone conduction fitting in infants who are unable to participate in behavioural testing**

1. Bone conduction thresholds from the diagnostic ABR should be entered into the manufacturer's software.
2. Approximately 10–15 dB gain is attenuated across the skin when fitting on a soft band (Hodgetts 2006), it therefore maybe necessary to increase overall loudness within this range to provide appropriate amplification.
3. The soft band should sit firmly but not tight.
4. If there is feedback with a well fitted band then the feedback manager should be run in the manufacturer's software whilst the aid is in situ on the patient.
5. For infants and children who have not yet developed sufficient head control the bone conduction device will mostly be worn on the forehead and will be likely to be moved around to varying positions in daily life. If this is the case in the software the microphone mode should be selected as omni.
6. When fitting infants under six months of age who have a permanent conductive HL or who have significant conductive component that in discussion with ORL will likely be long term (greater than 12 months) it would be recommended that at the discretion of the audiologist, a Bone Anchored Hearing Aid Device (BAHAD) on a soft band should be considered for ease of use and in the case of permanent conductive HL for eventual implantation.
7. In some cases where it becomes necessary to obtain an objective measure of amplification benefit, aided and unaided cortical evoked responses using filtered speech phonemes could be used.

Validation of the bone conduction fitting should be obtained through the use of the LittlEARS® auditory questionnaire (Coninx et al 2003) or the PEACH questionnaire (Ching et al 2000/2005).

## **Bone conduction fitting in infants and children who are able to participate in behavioural testing**

1. Bone conduction thresholds for each ear should be obtained entered into the manufacturer's software.
2. If available, in situ audiometry should be obtained for the device(s) using the manufacturer's software with how the patient is going to wear the device, ie, soft band, hard band or abutment. If the device is being used for clinic preoperative trial then a hard band and power device are required as the gain from a transcutaneous device can be attenuated by the skin by up to 15 dB across different frequencies (Hodgetts 2006).
3. If no in situ audiometry is available in the device, initially program with the default settings with view to increasing device gain dependent upon functional gain and speech testing results.
4. If the patient has an abutment all software programing and measures should be referenced to the performance of the device on the abutment.
5. Visual reinforcement audiometry, play audiometry or pure tone audiometry using filtered speech phoneme stimuli should be used to obtain thresholds or 20 dBHL responses in the sound field as a measure of device performance. For unilateral fittings, the non-test ear will need to be appropriately masked.
6. Unaided and aided speech scores in quiet should be obtained using an age appropriate speech test, such as monitored live voice, Kendall Toy Test or CVC words in order to obtain a measure of device performance. For unilateral fittings, the non-test ear will need to be appropriately masked.
7. If aided speech phoneme thresholds and speech scores are not within the expected range of performance then the gain of the device should be increased in 6 dB steps until appropriate performance is achieved. The feedback manager may need to be run particularly if the device is on a soft band and there is the possibility of variation in firmness in how the band is fitted.
8. If there is a query regarding the reliability of the behavioural results then objective testing using aided and unaided Cortical Evoked Potentials to filtered speech phonemes could be considered.
9. For an in clinic trial of a unilateral BC fitting for either conductive HL or SSD speech in noise testing should be performed in order to demonstrate the lifting of the head shadow effect and to assess what benefit the aid will provide in noisy environments.
10. For older children and in particular for unilateral fittings speech in noise testing should be performed to assess aided benefit. Younger children can be assessed using the Bamford Kowal Bench Speech in Noise [BKB-SIN™ (child). Children from 10 years of age and onwards can be assessed using The Quick Speech in Noise [QuickSIN™ (adult)].
11. BC hearing aid fittings should be validated using the LittlEARS® (Coninx et al 2003) or PEACH (Ching et al 2000/2005), Speech, Spatial and Qualities of Hearing Scale 6 or 12 (SSQ6 or 12) (Noble et al 2005), Glasgow Benefit Inventory (GBI) (Robinson et al 1996), or Bern Benefit in Single-Sided Deafness (BBSSD) (Kompis et al 2011) questionnaire as judged appropriate by the audiologist.

## Speech in noise testing for bilateral BAHA

For teenagers and adults, the recommended speech in noise test is the QuickSIN™ as the language level is equivalent to high school requirements. For younger children the BKB-SIN™ is recommended as these tests provide an efficient and reliable measure of obtaining an SNR loss score.

### The QuickSIN™

The QuickSIN™ (Etymotic Research 2001), is an adaptive method of obtaining an SNR as the level of the sentences is fixed and the noise level varies. A list of six sentences with five key words per sentence is presented in four talker babble noise. Sentences are presented at pre-recorded signal to noise ratios that decrease in 5 dB steps, from 25 (very easy) to 0 (extremely) difficult. The SNRs are 25, 20, 15, 10, 5 and 0 dB.

For bilateral hearing aid fittings, speech and noise are presented through the same speaker. Speech and noise are on the same channel on the CD. The recommended configuration is that the person is placed facing the speaker so speech and noise are delivered at 0 degrees azimuth (see Figure 1).

1. Present at comfortably loud level 55–70 dBHL.
2. Instruct patient to repeat back the sentences spoken by the female talker.
3. Score the five key words in each sentence, one point per word. CD can be paused.
4. Add number of correct words, total for six sentences.
5.  $\text{SNR LOSS} = 25.5 - \text{total correct}$ .
6. Use the Quick SIN™ table to interpret the score: normal, mild impairment, moderate, severe.
7. Compare aided and unaided scores.

Speech in noise testing can be used in counselling and justification of the need to provide assistive technology such as a Remote Microphone Hearing Aid / FM system.

### BKB-SIN™

The BKB-SIN™ (Etymotic Research (2003) is also an adaptive speech in noise test that obtains an SNR-50 loss measure (signal to noise ratio for 50% correct. The level of the sentence is fixed and the noise level varies with automatic SNRs for each sentence at: +21, +18, +15, +12, +9, +6, +3 and 0 dB. There are 10 sentences in each list and two sets of lists are paired with each pair needing to be administered and scores averaged for valid scoring. Four key words are scored in the first sentence of each list pair and the remainder sentences have three. Three list pairs are recommended to achieve reliability if testing younger children or CI candidates. Results are compared to aged normative data to obtain the SNR-50.

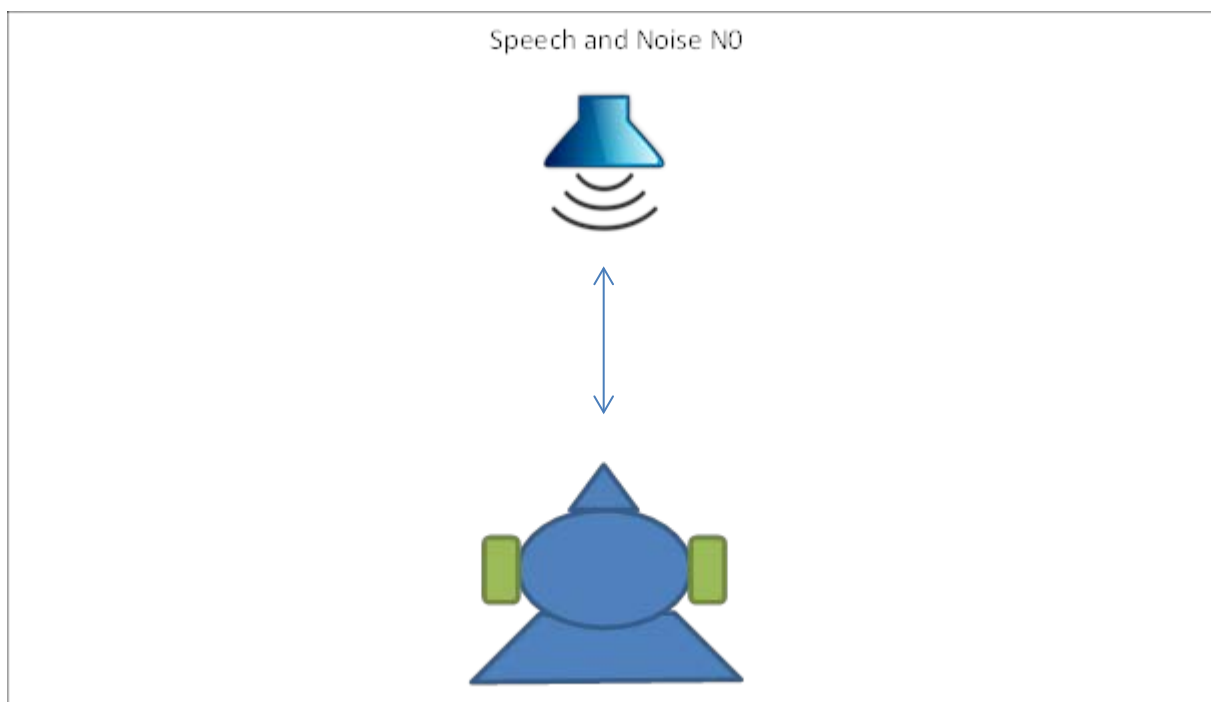
For bilateral hearing aid fittings, speech and noise are presented through the same speaker. Speech and noise are on the same channel on the CD. The recommended configuration is that the person is placed facing the speaker so speech and noise are delivered at 0 degrees azimuth (see Figure 7).

1. Present at comfortably loud level 55–70 dBHL.
2. Instruct patient to repeat back the sentences spoken by the male talker.
3. Score the 4–3 key words in each sentence, one point per word. CD can be paused.
4. Add number of correct words, total for 10 sentences.

5. SNR-50 = 23.5 – total correct
6. Present the second list in the pair.
7. Average the SNR-50 scores. When administering more than one list pair, average all the list pair SNR-50 scores.
8. Use the BKB-SIN™ age related norms table to interpret the score and determine SNR loss: normal, mild impairment, moderate, severe.
9. Compare unaided and aided scores.

Speech in noise testing can be used in counselling and justification of the need to provide assistive technology such as a Remote Microphone Hearing Aid / FM system.

**Figure 6: Configuration for speech in noise testing using one speaker for bilateral hearing loss**



Testing speech in noise for a bilateral bone conduction fitting, it is recommended that the speech and noise signal is presented through the one speaker at 0 degrees.

### **Unilateral BAHAD speech in noise testing**

Speech in noise testing is particularly important in unilateral BC fittings in order to provide validation of benefit. The results from speech in noise testing from unilateral fittings will assist in choosing the correct technology for each individual's needs. It will also assist in counselling about which listening situations will and will not provide improvement, helping to establish realistic expectations.

Unilateral clinical testing of an implantable device should always be undertaken using the hard test-band.

### Recommended two speaker configuration for unilateral speech in noise testing

The recommended clinical speaker configuration for speech in noise testing of unilateral hearing losses is a **TWO** speaker set up, with the speech signal presented through one speaker and the noise through the second. This separation of the two signals provides the most rigorous listening condition from which the benefit of unilateral aiding can be assessed. The speech is presented to the non-hearing side (test ear), at 90 degrees azimuth and the noise to the hearing side (non-test ear) at 270 degrees azimuth (see Figure 8).

**Figure 7: Recommended configuration for speech in noise testing using two speakers for unilateral hearing loss**



The recommended configuration for testing speech in noise with unilateral hearing loss requires two speakers. The speaker presenting the speech is on the side that has the hearing loss (test ear) and the speaker presenting the noise signal is on the side that has normal hearing (non-test ear). The speaker presenting the speech to the test ear is at either 90° or 270° azimuth.

Both the BKB-SIN™ and QuickSIN™ have a number of lists, where the speech is recorded on one channel of the CD and four talker babble noise on the other. This enables either the testing of directional microphones or unilateral hearing aid benefit. The BKB-SIN™ test has lists where the SNR levels are adjusted automatically but they have to be manually adjusted for the QuickSIN™ test:

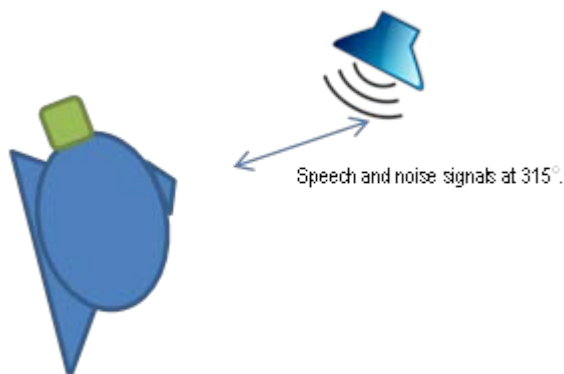
1. Present at comfortably loud level 55–70 dBHL.
2. Keep the sentence level fixed at the chosen presentation level and start with the easiest SNR from the test used in the automatic set up, ie, +25 for QuickSIN™ and +21 for BKB SIN™.
  - a. QuickSIN™ – Use tracks 24–35, adjust the SNRs per sentence by adjusting the noise level as stipulated.
  - b. BKB-SIN™ – Use tracks 3–20 for automatic SNR adjustment.
3. Instruct patient to repeat back the sentences spoken by the talker.
4. Score and calculate the SNR loss as per each test's instructions.
5. Interpret the SNR loss as per each test's instructions.
6. Compare aided and unaided scores.

### One speaker configuration for unilateral speech in noise testing

Speaker configurations for speech testing may vary widely across many clinics and not all will have a two speaker setup to enable the separation of the speech and noise signals required for testing unilateral hearing aid fittings. If this is the case the degree of benefit indicated by the SNR score in comparing the aided and unaided conditions will vary significantly.

If it has not been possible to upgrade to a two speaker configuration, then it is possible in extenuating circumstances to use one speaker. Both speech and noise signals are presented through the one speaker. It is important to place the individual at 315 degrees azimuth, so that the test ear with the aid is directed towards the speaker (see Figure 9).

**Figure 8: Configuration for speech in noise testing using one speaker for unilateral hearing loss**



Speech and noise signals are presented at 315° azimuth for unilateral BAHA testing through one speaker if two speaker configuration is not available. The BAHA processor should be on the ipsilateral side facing the speaker, so the ear with the hearing loss is closest to the speaker, not at 45° azimuth facing away from the speaker. As there is only one speaker presenting both signals, the instructions for bilateral speech in noise testing apply.

## References

- Ching, Hill, Psarros. 2000/2005. *Strategies for Evaluation of Hearing Aid Fitting for Children*. Paper presented at the International Hearing Aid Research Conference, 23 August, Lake Tahoe, USA ([www.nal.gov.au](http://www.nal.gov.au)).
- Coninx F, Weichbold V, Tsiakpini L. 2003. LittleEARS® Auditory Questionnaire, MED-EL.
- Etymotic Research. 2001. QuickSIN™ Speech-in-Noise Test, Version 1.3. (Compact Disk) User Manual, 61 Martin Lane, Elk Grove Village, IL 60007.
- Etymotic Research. 2003. BKB-SIN Speech in Noise Test, User Manual, 61 Martin Lane, Elk Grove Village, IL 60007.
- Hodgetts W. 2014. Prescription and verification of bone anchored devices. Presentation at the *Oticon Medical Scientific Meeting*, 28 January, Copenhagen, Denmark.
- Hodgetts W, Scollie S, Swain R. 2006. Effects of applied contact force and volume control setting on output force levels of the BAHA softband. *International Journal of Audiology* 45: 301–8.
- House Ear Institute. 1979. *Using the HINT Test on Compact Disk*. Starkey Laboratories Inc.
- Kompis M, Pfiffner F, Krebs M. 2011. Factors influencing the decision for Baha in unilateral deafness: the Bern benefit in single-sided deafness questionnaire. *Adv Otorhinolaryngol* 71: 103–11.
- Noble W, Jensen NS, Naylor G, et al. 2013. A short form of the speech, spatial and qualities of hearing scale suitable for clinical use: The SSQ12. *International Journal of Audiology* 52(6): 409–12.
- Robinson K, Gatehouse S, Browning G. 1996. Measuring patient benefit from otorhinolaryngological surgery and therapy. *Annals of Otology Rhinology Laryngology* 113(12): 415–22.





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# Appendix 21: 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, eg, explanation of aided audibility and its implications for speech and language development.
- Impact of noise and distance.
- Coping with noise and distance (eg, at home, in the car).
- Equipment needed to care for hearing instruments.
- Techniques for cleaning ear moulds 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 (eg, swallowing of hearing aid or battery).
- Understanding and combating feedback.
- Protecting the hearing instruments from potential hazards (eg, moisture, pets).
- Troubleshooting techniques.
- Warranty and insurance information.
- Plans for repair of malfunctioning hearing instruments.
- Discussion of ear mould 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 (eg, T-coil).

Adapted from Elfenbein 2000.

## **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 utilised 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 ear mould.
- Stethoscope for daily listening check.
- Battery tester.
- Ear mould 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.