

# Universal Newborn Hearing Screening and Early Intervention Programme

National Policy and Quality Standards

Diagnostic and amplification protocols

**October 2023**

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# Document scope

This document is an evidence based protocol which combines audiological research, clinical expertise and patient values and circumstances. This document details key procedural elements and technical specifications required for the provision of audiological assessment and amplification to babies and pre-school children. These babies and children have been identified through the Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP) or have been referred to Audiology due to incidental or discovered risk for permanent hearing loss.

This document is not a standalone document and is 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 15-22):

- Audiologist qualifications and competencies
- Audiology equipment and testing environment
- Providing timely audiological assessment
- Adherence to UNHSEIP audiology protocols
- Results of the 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 and amplification procedures in compliance with the requirements of this protocol.

Deviation from the protocols may be appropriate for individual babies and under special circumstances. The nature and rationale of any deviation from the protocols must be thoroughly 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.

# Foreword

The Universal Newborn Hearing Screening and Early Intervention Programme Diagnostic and Amplification Protocol has been developed through the work of a New Zealand technical working group formed to provide audiological advice and support to the Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP) in 2008. Additional advice was taken from the New Zealand Audiological Society (NZAS) Special Interest Group, and included recommendations from the New Zealand Universal Newborn Hearing Screening and Early Intervention Programme (UNHSEIP) Amplification Guidelines, September 2005.

Thank you to the Ontario Ministry of Children, Community and Social Services for permission to adopt and modify as required their Ontario Infant Hearing Program Protocol for Auditory Brainstem Response based Audiological Assessment (ABRA) Version 2018.02 and Provision of Amplification Version 2023.01 for use in New Zealand.

This document was updated in October 2023 and replaces previous versions. It is acknowledged that although this document provides an evidence-based protocol to inform best clinical practice at the time of publication, the technology and evidence base are continually evolving. Clinicians should continue to exercise professional judgement and clinical decision making that reflects the individual circumstances with the goal of placing whānau at the centre of the clinical decision making process.

# Abbreviations

ABR	auditory brainstem response
AC	air conduction
ANSD	auditory neuropathy spectrum disorder
AODC	advisor on deaf children
AR	acoustic reflex
BC	bone conduction
BOA	behavioural observation audiometry
BTE	behind the ear
CM	cochlear microphonic
CMV	cytomegalovirus
CPA	conditioned play audiometry
dB	decibels
DPOAE	distortion product otoacoustic emissions
DSL	Desired Sensation Level Method®
ECMO	Extracorporeal membrane oxygenation
EEG	electroencephalography
eHL	estimated hearing level
FM	frequency modulated
FRESH™	Frequency Specific Hearing Assessment noise
GA	general anaesthetic
HFV	high frequency ventilation
HL	hearing level
IEC	International Electrotechnical Commission
ISO	International Standards Organisation
MRI	magnetic resonance imaging

MRL	minimum response level
NBN	narrow band noise
NICU	neonatal intensive care unit
NSU	National Screening Unit
nV	nanovolts
NZAS	New Zealand Audiological Society
ORL	otorhinolaryngologist
PCHL	permanent congenital hearing loss
PEACH	Parents' Evaluation of Aural/oral performance of Children
PTA	pure tone audiometry
REAR	real-ear aided response
RECD	real-ear-to-coupler difference
RESR	real-ear saturation response
RM	remote microphone
RNL	residual noise level
SDT	speech detection threshold
SNHL	sensorineural hearing loss
SPANZ	speech perception assessments New Zealand
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) All procedures must be performed in sound treated rooms and with equipment that complies with IEC/ISO specification for diagnostic audiometric testing including sound field testing.
- b) Diagnostic ABRs and OAEs are typically carried out in a sound-treated booth. If this is not possible, the tests must be carried out in a quiet room with measured sound pressure levels not exceeding:
  - 22 dB SPL at 500 Hz
  - 30 dB SPL at 1 kHz
  - 35 dB SPL at 2 kHz
  - 43 dB SPL at 4 kHz.
- c) For ABR, electrical isolation is required.
- d) For all behavioural testing (BOA<sup>1</sup>/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 0 dB HL (with 5 dB maximum uncertainty) across the frequencies from 250 Hz–8 kHz. This is due to the need to perform accurate sound field and bone conduction testing with ears uncovered. For full details refer to the data for maximum permissible ambient sound pressure levels in one-third-octave bands for bone conduction audiometry (ISO 8253-1 2010).

<sup>1</sup> Behavioural Observational Audiometry (BOA) may be used to establish minimal response levels (not hearing thresholds) for infants/children who are developmentally unable to complete VRA or CPA. In most cases this is a tool used in exceptional circumstances for infants/children who have multisensory impairment and are medically unable to undergo a hearing assessment under general anaesthetic. A detailed assessment protocol is not provided in this document, however if Audiologists are performing this type of assessment it is recommended that they review the British Society of Audiology Practice Guidance BOA February 2019.

## 1.2 Audiology equipment requirements

As per **Standard 16**, providers of audiology services for babies referred from newborn hearing screening must ensure that the following equipment is utilised.

- A two channel auditory evoked potential system with supra-aural, insert and bone conduction transducers as approved by NZAS.
- Diagnostic distortion product otoacoustic emissions (DPOAE) equipment.
- Diagnostic immittance equipment with high frequency tympanometry and high frequency acoustic reflexes.
- A diagnostic audiometer capable of presenting pure tone, narrow band noise (or currently available alternatives such as FRESH noise™), FM warble-tone stimuli and monitored live voice through insert earphones, supra-aural earphones, sound-field speakers and bone vibrator.
- Sound room 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 as below:

- ABR Calibration values are calculated in NZ by the ISO registered calibration company. Care needs to be taken to ensure values are not inadvertently altered.
- Audiometers, ABR systems and loud speakers for sound field testing on a two-year cycle.
- Tympanometers are calibrated annually.

## 1.3 Role of Tele-Audiology

Tele-audiology refers to the implementation of audiological services via telehealth technologies. This is an area of development which has the potential to improve accessibility to audiology services for infants and children, particularly for families/whānau who live in remote or rural areas. Audiology services provided via tele-audiology must abide by current NZAS tele-audiology best practice guidelines.

## 1.4 Clinical records

General requirements for audiology data and record management are set out in **Standard 22**.

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

Records must identify:

- the child, tester, test date and location
- test parameters including transducer and coupling used for testing
- ABR waveforms, DPOAE graphical representations and data
- immittance graphical representation and data
- interpretation and contingent recommendations.

The baby's audiological record must include:

- Audiological case history
- details of the procedure used to calculate prescriptive targets (i.e., 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 summary of outcome measurement results
- a synopsis of recommendations and information provided to the family/whānau. 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 audiological assessment are:

- a) to determine the presence or absence of permanent congenital hearing loss (PCHL) for both ears.
- b) to complete diagnostic assessment by three months of age. This enables implementation of amplification and/or communication service options elected by the family/whānau, before six months of age.
- 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 (ANS) and retrocochlear disorders affecting the auditory pathways.

Whilst not the target population, children with mild or minimal hearing loss may be identified through UNHSEIP. 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. Children with mild or minimal hearing loss may be at risk of speech, language, social, emotional and/or educational difficulties, however not

every child will experience difficulties and it is not clear that providing hearing aid technology will be beneficial for every child (See 11.3 Acoustic Characteristics for further information). Audiologists should refer to the University of Western Ontario Version 2023.01: Protocol for the Provision of Amplification (Addendum 4) for a support guide to assist with hearing aid management decisions for a child with mild or minimal 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 pure tone 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

Some babies who pass the newborn hearing screening will be identified as having a risk factor for possible late onset or progressive hearing loss. For those babies hearing surveillance is required.

Paediatricians, special care nurses and midwives are responsible for identifying babies with conditions requiring hearing surveillance and they will complete a *UNHSEIP Risk Factors Requiring Hearing Surveillance* form. This form is given to the screeners who will send these referrals to audiology.

The surveillance criteria fall into three categories:

1. Risk factors requiring DPOAE 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, the audiologist will triage each referral on a case by case basis. In the future specific recommendations may be developed but are currently not available:

- Atresia (not screened, referred directly for audiology diagnostic assessment)
- Jaundice levels at or above where transfusion is recommended (babies >3mths old. Babies <3mths old should be re-screened once the jaundice has resolved)
- Head and brain trauma

3. Risk factors with specific pathways for audiological testing:

- Down syndrome
- Cleft palate
- Positive for Cytomegalovirus infection
- Meningitis (not screened, referred directly to Audiology)

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
Craniofacial anomalies			
Atresia	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
Cleft palate	Midwife, paediatrician Physical examination	Medical staff make referral/ communicate referral to screening staff via UNHSEIP risk factor form.	As per specific condition pathway see 3.3.1 for detail
<i>NB: Not requiring follow up: pits and tags, cleft lip without cleft palate.</i>			
Syndromes associated with hearing loss			

Down Syndrome	Midwife, paediatrician Physical examination, genetic testing, maternity records	Regardless of the outcome of screening the screener refers to Audiology for a diagnostic assessment UNHSEIP risk factor form completed.	As per specific condition pathway see 3.3.2 for detail
Other syndromes associated with hearing loss, including but not limited to: Pierre Robin, Sticklers, Goldenhar, CHARGE Waardenburg, Pendred, genetic mitochondrial disorder	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.	DPOAE testing at 18 months (see appendix 6)
Confirmed congenitally acquired infections			
Cytomegalovirus (CMV)	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 specific condition pathway see 3.3.4 for detail
Toxoplasmosis	Midwife, obstetrician (may identify in pregnancy), paediatrician Positive laboratory results for the mother and baby.	Medical/nursing/mid wifery staff make referral/ communicate referral to screening staff via UNHSEIP risk factor form.	DPOAE testing at 18 months (see appendix 6)
Rubella	Midwife, obstetrician (may identify in pregnancy), paediatrician Most women will be vaccinated – check serology antenatally.	Medical/nursing/mid wifery staff make referral/ communicate referral to screening staff via UNHSEIP risk factor form.	DPOAE testing at 18 months (see appendix 6)

	Laboratory results for the mother and baby.		
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## 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. Good communication mechanisms (e.g., between coordinator and paediatricians) are needed to ensure referral is made on receipt of results.

Condition requiring surveillance	Who/how identified	Referral	Audiological surveillance
NICU			
Ventilation > 5 days Continuous ventilation with: IPPV or HFV, Nitric oxide, ECMO Severe persistent pulmonary hypertension	Paediatrician/NICU nurse	NICU staff make referral/ communicate referral to screening staff via UNHSEIP risk factor form.	DPOAE testing at 18 months (see appendix 6)
<i>NB: No surveillance after CPAP use</i>			
Severe asphyxia Sarnat stage 2/3, cooled	Paediatrician/NICU nurse Clinical findings, investigations e.g., MRI, EEG	NICU staff make referral/ communicate referral to screening staff via UNHSEIP risk factor form.	DPOAE testing at 18 months (see appendix 6)
Brain haemorrhage Grade 4 + post haemorrhagic hydrocephalus	Paediatrician/ NICU nurse Clinical findings	NICU staff make referral/ communicate referral to screening staff via UNHSEIP risk factor form.	DPOAE testing at 18 months (see appendix 6)
Ototoxic medications 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.	DPOAE testing at 18 months (see appendix 6)



Other postnatal conditions			
Severe jaundice (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 rescreening by screener before discharge (if < 3months 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
Meningitis (viral/bacterial) and meningoencephalitis Confirmed or strongly suspected	Paediatrician /medical staff	Not screened, referred directly to audiology with completed UNHSEIP risk factor form 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 as soon as possible and no later than 7-10 days of the baby being well enough to be tested. Refer to 3.3.3 for additional detail
Head/brain trauma 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 must be referred to audiology urgently.

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 (2019) has lowered the timing of surveillance audiology assessment to 9 months of age, a change in the timing is not supported by local NZ data. 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 have all passed aABR newborn hearing screening. The approach for surveillance should be viewed as further screening rather than a full diagnostic assessment. In addition, regardless of previous hearing screening outcomes, all infants with or without risk factors for hearing loss will receive ongoing surveillance of hearing and communicative development through the well child programme.

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

- **DPOAE to achieve a four point DPgram**

A pass is achieved if DPOAEs are present in a minimum of four frequencies out of 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, and 6 kHz as per the DPOAE protocol in [Appendix 6](#).

- **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 an ipsilateral acoustic reflex using a BBN stimulus (up to maximum level of 90-95 dB HL) with a 226Hz probe tone must be performed.

If the child passes DPOAE testing, a significant cochlear hearing loss has been ruled out (at this time) and the child should be discharged from audiology. Hearing screens will continue as part of the Well Child Tamariki Ora programme.

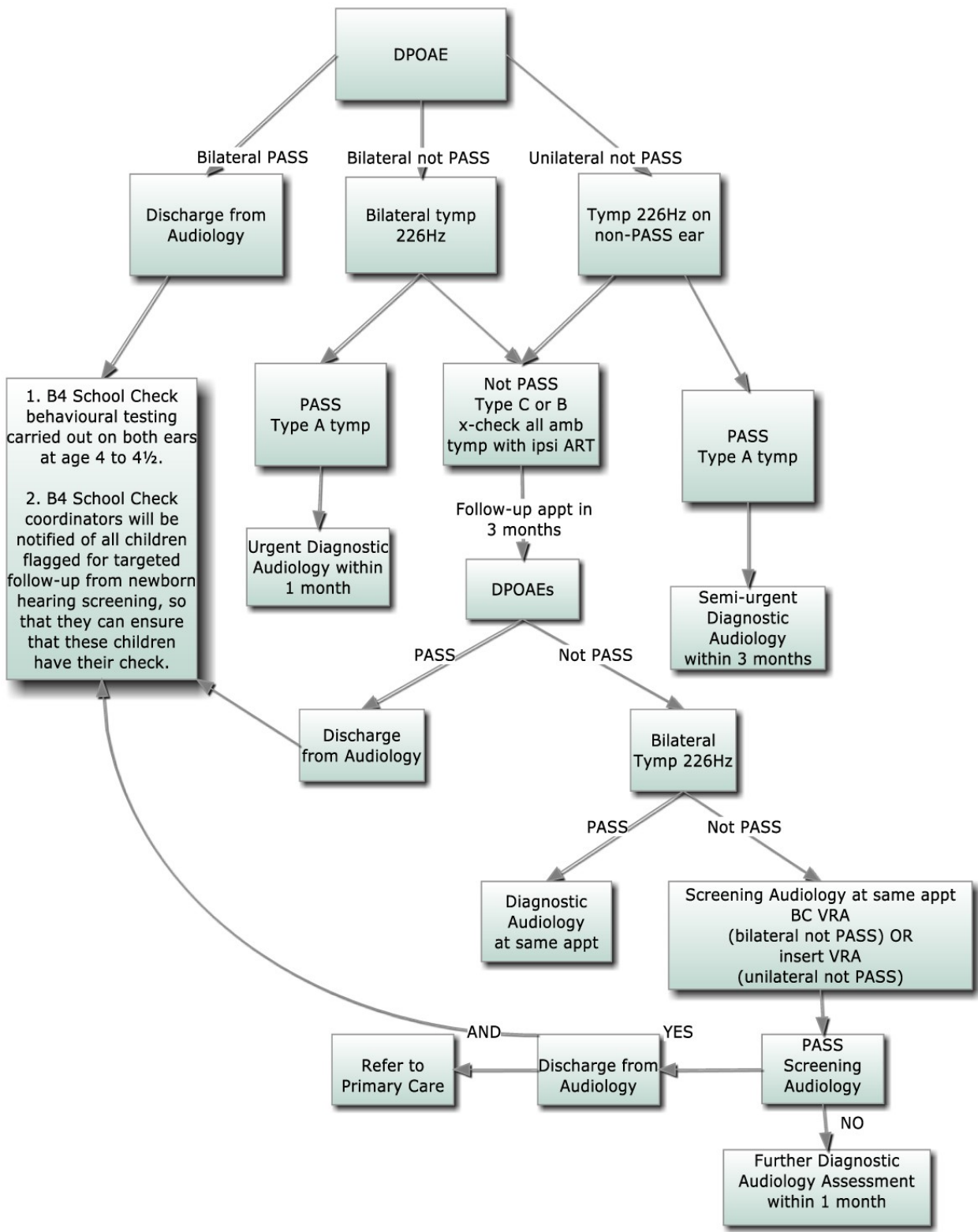
If the child does not pass DPOAE testing but passes immittance testing (type A tympanograms) then an urgent diagnostic audiology assessment must be booked within 1 month given the high suspicion of a significant permanent hearing loss.

If the child does not pass DPOAE and immittance testing (type B or C tympanogram), it is likely that they are experiencing middle ear pathology and therefore they should have another appointment for the same screening regime in three months' time, allowing time for resolution of the middle ear condition. 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 dB HL at 0.5, 2 and 4 kHz) must be achieved on BC VRA (or insert testing if suspicious of a unilateral hearing loss). If a pass is achieved, the child may be discharged from audiology. Importantly though, under these circumstances, the child should be referred to primary care (GP) for middle ear management or a referral to ORL, if consistent with local ORL referral guidelines.

If the child does not pass the screening VRA, they must have further audiology assessments to reach a definitive 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. The audiologist will 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 –**
    - Diagnostic ABR assessment prioritising BC testing for each ear. If time permits and feasible ABR AC testing with headphones.
    - Discussion of bone conduction hearing aid fitting on a soft-band after diagnostic ABR testing completed (bilateral fitting should be considered). Refer to Amplification protocol for details on fitting and evaluation.
  - **Unilateral –**
    - Diagnostic ABR assessment prioritising BC testing for the atretic ear.
    - Discussion of bone conduction hearing aid fitting on a soft-band after diagnostic ABR testing completed 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/whānau at frequent intervals.
- **Severe jaundice at or above the level requiring transfusion**
  - If <3mths old the baby must be rescreened by the screener when well and before discharge. If a pass result is obtained no further surveillance is required.
  - If > 3 months old the baby must be booked for an audiology assessment within four weeks after recovery from jaundice using the surveillance DPOAE protocol and high frequency acoustic reflex testing. If a pass result is obtained no further surveillance is required
- **Head and brain trauma**
  - Diagnostic Audiology assessment must be booked and completed 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

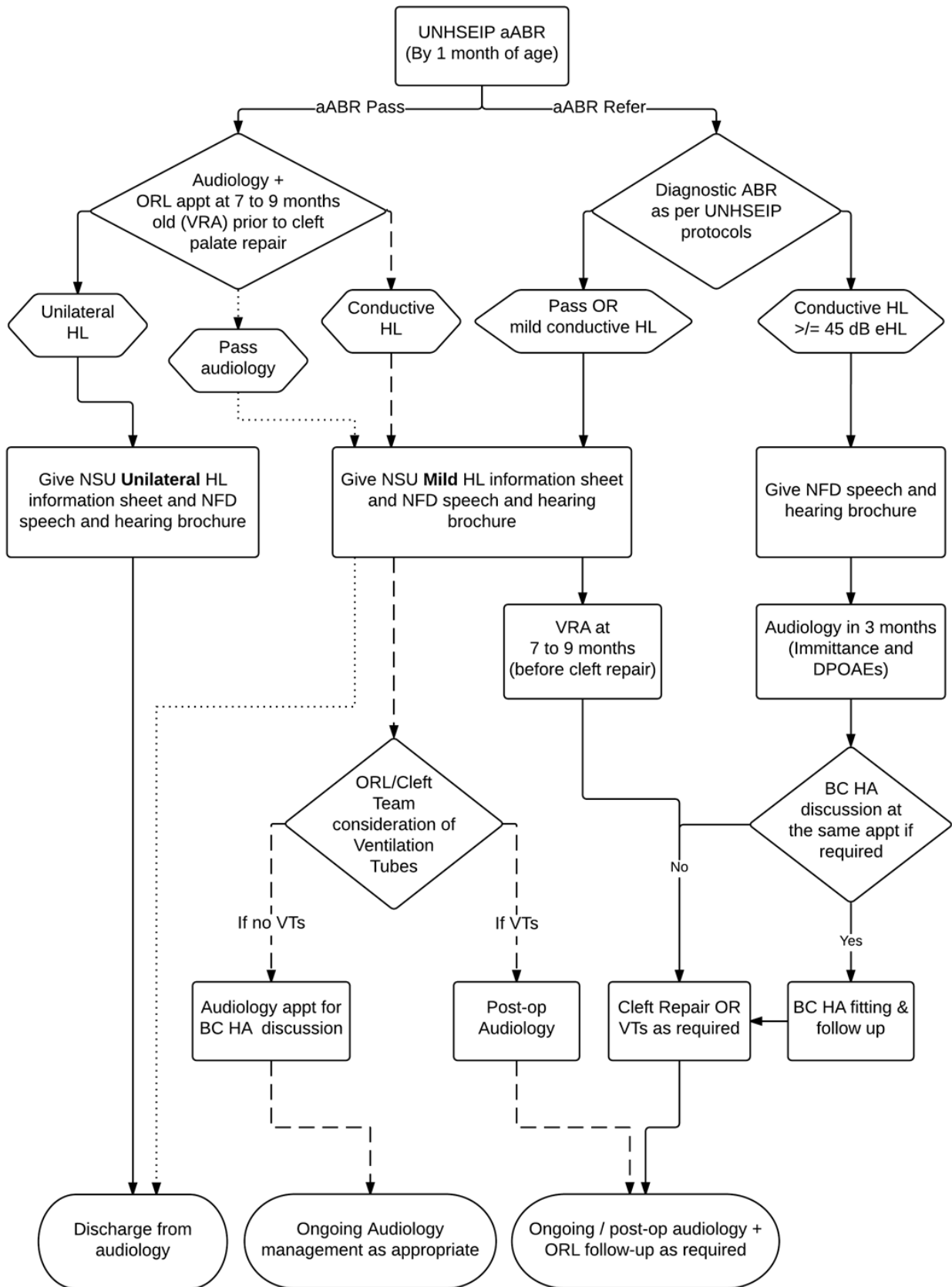
Babies identified as having a cleft palate require close audiological management to ensure appropriate access to sound and to optimise opportunities for speech and language development.

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 should be seen for at least one follow-up at 7–9 months old for potential detection of OME. An assessment at this age also allows the audiologist and ORL to understand the extent of any conductive hearing loss. 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 with the family/whānau 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 on a diagnostic ABR assessment as having a conductive hearing loss warranting intervention, 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/whānau. 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/whānau, 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/whānau are concerned about their baby/child's hearing. Parents should be given written information so they can observe their child's hearing and speech and language development over time (e.g. NSU mild hearing loss information sheet and Talking Matters "Talking over Time" 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**





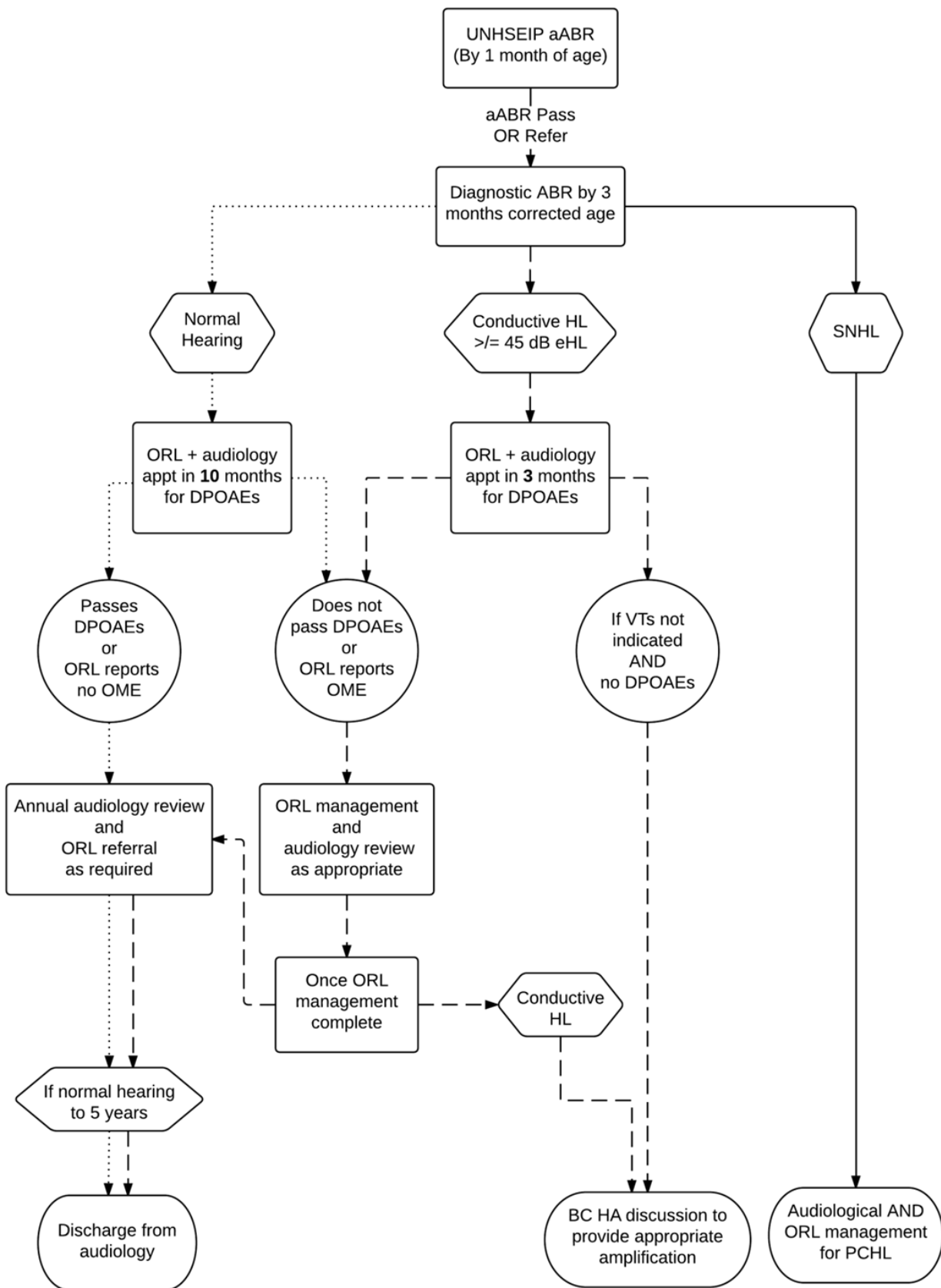
### 3.3.2 Audiological management of babies with Down syndrome

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 1 kHz, 2 kHz, and 4 kHz 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 will conduct joint review appointments when possible, this enables the current state of the baby/child's middle ear function and hearing to be assessed concurrently.
- A discussion regarding a bone conduction hearing aid is completed with family/whānau at the earliest opportunity as a management option for any significant conductive hearing loss. In some 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/whānau. 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/whānau 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/whānau are concerned about their baby/child's hearing. Give appropriate written information such as the NSU mild hearing loss information sheet and the Talking Matters "Talking over Time" brochure.

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



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

Babies who contract meningitis require urgent audiological assessment as there is a high risk of sensorineural hearing loss. Urgent assessment is required to identify severe/profound hearing loss, which may require cochlear implant(s) before any cochlear ossification takes place. All babies with confirmed or strongly suspected neonatal bacterial meningitis, viral meningitis or meningococcal septicaemia must be seen urgently by Audiology.

- Screening pathway – not screened, direct referral to audiology.
- 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 treating paediatrician. Protocols in NICU/SCBU need to be in place to ensure correct and timely referral from the paediatric wards or NICU/SCBU to audiology occurs. The baby must be referred to audiology urgently and seen ideally before discharge from the hospital. If this is not possible, an outpatient appointment should be scheduled within 7-10 days. 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. At any age, if ear-specific and frequency specific information cannot be obtained to exclude a significant hearing loss an urgent referral to ORL must be completed and a joint plan for future assessment (e.g. GA-ABR) should be made.

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

The baby must 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.

The following tests are required:

- Diagnostic DPOAE
- High Frequency tympanometry
- High frequency acoustic reflex testing

Further urgent assessment using ABR must be arranged if robust responses are not obtained for DPOAE testing.

For babies who have not passed newborn hearing screening the ART is an important test to exclude ANSD.

If DPOAE testing indicates robust results and the infant has previously passed their newborn hearing screen then an ART is not mandatory.

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

The following tests are required:

- Diagnostic DPOAE
- High Frequency tympanometry
- High frequency acoustic reflex testing

Further urgent assessment using ABR (under general anaesthetic for older infants) must be arranged if robust responses are not obtained for DPOAE testing and ART testing.

If DPOAE testing indicates robust results and the infant has previously passed their newborn hearing screen then an ART is not mandatory.

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

The following tests are required:

- Diagnostic DPOAE
- Tympanometry
- Acoustic reflex testing

An urgent VRA assessment must be completed if robust DPOAE responses are not obtained. A significant hearing loss should be excluded.

If clear ear-specific and frequency-specific information cannot be obtained for whatever reason, an ABR under general anaesthetic should be considered.

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

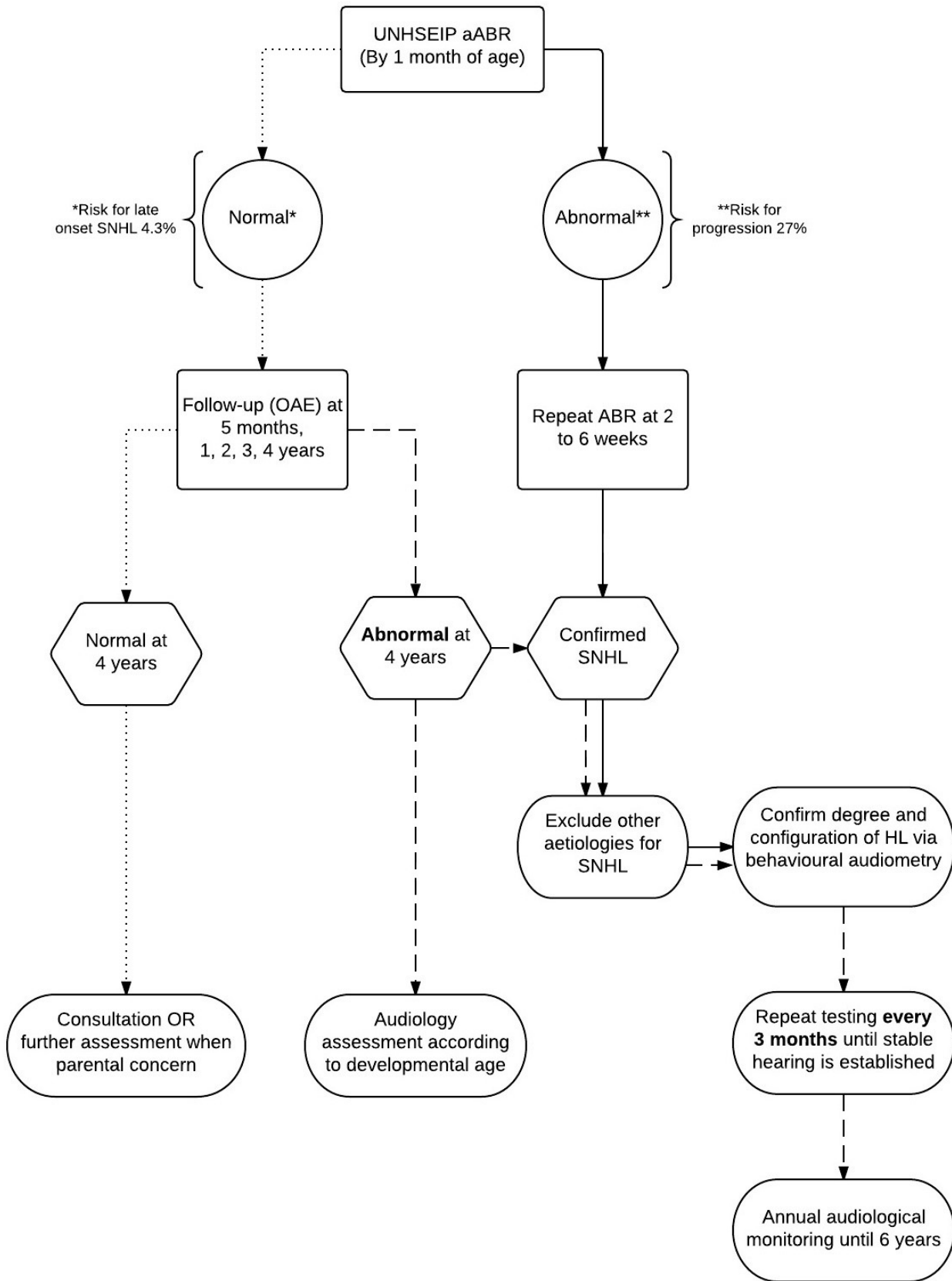
For all ages, if the hearing is found to be normal following meningitis further testing is not mandatory.

### **3.3.4 Audiological management of babies positive for cytomegalovirus (CMV) infection**

CMV infection is a leading cause of congenital infection and can cause unilateral or bilateral sensorineural hearing loss. Due to the risk of developing late onset sensorineural hearing loss, babies with confirmed cCMV require ongoing monitoring by Audiology to identify any change in hearing.

- Screening pathway – Screening completed and referral to audiology for early surveillance.
- The baby must have a confirmed CMV diagnosis (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. The timeframe for review depends on their hearing status.
- In some cases paediatricians may consider antiviral therapeutics for the treatment of babies positive for CMV infection. Given the current toxicity profile of the available therapeutics this treatment is limited to babies with symptomatic congenital CMV infection and needs to occur early on in the post-natal period. As part of the decision making process, paediatricians may request additional hearing assessments. It is recommended that upon request, additional diagnostic DPOAE assessment should be completed. If clear responses are not obtained then an urgent ABR assessment must be arranged.

**Figure 4: Audiological management of babies positive for CMV infection**



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** 20, 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 (ANSO) 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 audiologically and is elected by the family/whānau after review of the options and information, the process of amplification must be

undertaken in a timely manner. As per **Standard** 20, amplification should normally be provided within four weeks of diagnosis.

## 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 Pure Tone Audiometry (PTA). The choice of approach is at the discretion of the audiologist, taking into account 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 devices 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

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 should include ALL of the following.

- A complete description of the baby's audiological results for both ears. Threshold estimates for at least 500 and 2 kHz must be obtained in each ear prior to initiating the provision of amplification. It is expected the 4 kHz thresholds will be determined early on in the fitting process, and ideally at the initial diagnostic appointment.
- Accurate ear impression(s) for the purposes of fabricating an ear mould if fitting an air conduction hearing aid.
- A description of the acoustic characteristics of the baby's ear canal(s) in the form of a Real-Ear-to-Coupler Difference (RECD).
- 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 for speech at soft, conversational, and loud levels.
- DSL v5 target ear canal SPLs for defining the maximum saturation.



- Frequency Response of the hearing instrument.
- DSL v5 target ear canal SPLs for s defining the maximum power output of the hearing aid.
- Verification that the electroacoustic characteristics of the hearing instrument adequately match the auditory needs of the baby. For the target population, simulated measurements of the real-ear aided response (REAR) must be completed across test levels for speech and maximum output.
- Education and counselling sessions with the family/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, and appropriate aided speech perception testing).
- Appropriate follow-up schedule and adjustments to the amplification as required.

# Diagnostic protocol

## 5 ABR-based assessment

### 5.1 ABR calibration

Manufacturers' default calibrations are not acceptable. See appendix 3: ABR calibration for specific dB SPL to HL offset values.

ABR instrumentation must be calibrated and documented every two years. Listening checks for transducer malfunction or problems in leads and connections should 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, DPOAE testing, must be attempted first during natural sleep. Exceptions that may merit initial assessment under general anaesthetic/sedation include prior failure to obtain adequate results in natural sleep, and long-distance family/whānau travel to the assessment.

### 5.3 Baby pre-test state

For assessments in natural sleep, every reasonable effort should 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/whānau 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 (GA)/sedation

It is expected that as the first option all assessments should be completed in natural sleep. However, there may be rare occurrences when this is not possible and GA/sedatives may be required. 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.

### 5.5 ABR test environment/personnel

It is recommended that the tester and instrumentation be inside the test room. When instrumentation is inside the test room, 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 and based on the state of the baby.

## 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 should be taken to not disturb the baby and rouse them 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 should include all of the following procedures, in both ears, irrespective of whether the UNHSEIP screening referral was in one ear or both ears. For full details of mandatory and discretionary procedures see Appendix 4.

- 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. Contralateral 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.
- d) High-intensity click ABR including cochlear microphonic potentials and stimulus artifact analysis should be undertaken if indicated (see 5.35 for details), at 80 dB nHL if tone burst thresholds are normal or at a higher level (90 dB nHL) if tone burst thresholds are elevated.
- e) DPOAE amplitude and noise floor measurements at 1.5, 2, 3, 4 and 6 kHz (see Appendix 6 for test parameters).
- 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. For unilateral referrals the ear that referred on screening should be tested first. 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 or B-81) should 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 (see Appendix 4 for further detail).

## 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 k $\Omega$  for all electrodes, and impedance differences within each channel of less than 1 k $\Omega$ .

## 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 Appendix 4. Tone burst ABR threshold estimates must be obtained according to the following specifications, in each ear.

## 5.13 Determining a response

The primary method of determining the presence or absence of a response is by visual interpretation of the waveforms by the audiologist performing the assessment. This requires skilled judgement with appropriate specialised training, experience and individual skill. In addition, objective measurements, when available, can provide confidence in the interpretation and can aid in deciding when to stop averaging.

For some equipment, statistical measures of waveform quality which compares the response amplitude to the residual noise may be available, e.g. Fsp and Fmp. Essentially these measures relate to the chance of having a repeatable response in the measurement, and can be expressed as a response confidence. The Fsp and Fmp are most useful for supra-threshold measurements and get progressively less sensitive when detecting a response at threshold. These measures may also be misleading in the presence of artifact. For this reason, Audiologists need to use this information with caution and discretion, whilst utilising their clinical training and expertise to determine the presence or absence of a response. Use of residual noise measurements are encouraged if they are available your ABR system.

Important notes:

- Low values of Fsp or Fmp cannot be used to imply response absence
- High values of Fsp or Fmp should only be accepted if the waveforms appear to contain appropriate ABR features and is not just due to the presence of a reproducible artifact in the appropriate time window

Response detection judgements should be made for each waveform and categorised as Response Positive (RP), Threshold (TH), No Response (NR) or Inconclusive (INC). These decisions can be annotated on the waveforms or on an ABR summary sheet to support peer review.

## 5.14 Response definition

### Response Positive (RP)

For the RP decision, the replicated waveforms should be highly correlated and show the expected characteristics in terms of amplitude, latency and morphology. The response

amplitude should be at least three times the level of the background noise (i.e. SNR 3:1). For supra-threshold recordings, the RP decision may be made on the basis of a single average if the amplitude, latency and morphology of the waveform are appropriate and residual noise is typically 40 nV or below.

#### Response Positive

- Consistent waveform characteristics of amplitude, latency and morphology
- SNR 3:1
- Residual noise typically <40 nV

#### No Response (NR)

For NR, the waveforms must be appropriately flat, with no evidence of a response. For NR decision to be valid it must be true that if a response were present then it would have been recognised and so it is essential that the noise level is low. The average noise should be less than 25 nV. In some equipment an objective report of residual noise is not available and so the noise level can be estimated from the average difference between the repeated waveforms when superimposed. Replications of NR waveforms may not be required if the waveform is sufficiently flat and the residual noise level is low (i.e. <25 nV).

#### No Response

- Flat waveform
- Low residual noise typically <25 nV

#### Threshold (TH)

If there is a hearing loss, an ABR threshold (TH) is defined by RP pair of replications at some level, and replications of NR waveforms at the level below (i.e. typically 10 dB below that level). Note that replications of NR waveforms are not required if the waveform is sufficiently flat and the residual noise level is low (i.e. <25 nV). In addition, there should be RP at 10-20 dB above the threshold demonstrating growth of the response, if not at the maximum intensity level. If the RP pair of replications is at the minimal passing level then it is likely the true ABR threshold is below this. For the purpose of UNHSEIP reporting, this result can be recorded as threshold and recordings below this level are not required and should not be pursued.

#### Threshold

- RP waveform repeatable
- NR waveform(s) typically 10 dB below

- RP waveform typically 10-20 dB above showing expected latency and amplitude characteristics of a supra-threshold response

### Inconclusive (INC)

INC occurs when the waveforms have low response amplitude or there is high residual noise, meaning the criteria for RP or NR cannot be met. To try to resolve INC waveforms, it is important to first check the test conditions are correct (e.g. positioning of cables, electrode impedance etc.) and ensure that the baby is appropriately settled. Where there is some evidence of a response, completing further replications may help to resolve the result. Most ABR systems allow the performance of a “weighted addition” of waveforms. This will produce a summed waveform with a greater number of sweeps and should usually reduce the noise level. This summed waveform can then be examined to see if it meets the criteria for RP or NR.

#### Inconclusive

- Waveforms of low amplitude
- High residual noise
- Does not provide any clinical information

## 5.15 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.

## 5.16 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). RP must be confirmed in that average, in order to accept the threshold bracket as valid.

## 5.17 Number of sweeps and averages

Typically, each replication will have up to 2000 sweeps in each average, although averaging may either be stopped early if a decision is made based on the presence of RP or after more than 2000 sweeps if waveform noise levels are high. All averages must be terminated by the audiologist, with due regard to the current number of sweeps, and the appearance of the recording.

## 5.18 50 Hz artifact and notch filtering

Records must be inspected carefully for 50 Hz artifact. 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 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.

## 5.19 Amplifier gain and artifact rejection

Amplifier gain traditionally needs to be high to optimise the recording due to the small amplitude of the ABR response (typically set at 100,000). Some equipment have alternative options using sophisticated signal processing to optimise the recording. In addition a mechanism should be employed to exclude significant artifact which will negatively impact on the quality of the recording. Different equipment will have different systems to exclude or minimise artifact. For example, in some equipment weighted averaging (e.g. Bayesian or Kalman) is available. These tools assess the amount of noise within a recording epoch and more weight is given to low noise epochs and conversely less weight is given to noisy epochs in the overall average. For successful ABR assessments the baby needs to be relaxed and sleeping. The artifact rejection strategy is used to ensure that data are only collected when conditions are favourable. If the background activity (typically myogenic noise) is high for periods of time then it is best to pause until the activity reduces.

## 5.20 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 responses down to pass levels. Ascent by 10 dB must be avoided unless there is a 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 the routine use of an input–output function curve to threshold estimation. The smaller the number of levels used for a given threshold estimation, the more efficient is the test. For BC testing, if there is a clear response at pass levels, testing at suprathreshold levels is not required.



## 5.21 Efficient test strategy

The optimal test strategy requires adaptive switching between test ears, switching between stimulus delivery methods (AC and BC) and switching of stimulus frequencies. Insert earphones should be placed in both ears prior to the start of testing as switching between ears is required.

Initial ABR assessment aims to answer the following three questions in each ear, in order of priority:

1. Is the target hearing loss present?
  - a. Is an ear's AC threshold elevated?
  - b. Is the other ear's AC threshold elevated?
2. If elevated, what is the nature of the hearing loss?
  - a. Is the elevation conductive or is there a sensorineural component?
3. If hearing loss is present, what are the specific AC (and BC) thresholds across a range of frequencies

## 5.22 Stimulus sequence 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.

## 5.23 Air conduction at 2 kHz

In the absence of prior assessment results, testing must begin with 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 in section 5.18.

## 5.24 Air conduction at 500 Hz

AC at a minimum of 35 dB eHL at 500 Hz must be done. Testing at 500 Hz is a mandatory component of initial assessment if AC is obtained at minimal level (30dB eHL) at 2 kHz. When testing at 2 kHz has indicated a conductive hearing loss it is preferable to test 500Hz BC prior to 500Hz AC. If 500Hz BC has been obtained down to minimal levels (30dB eHL) and a temporary conductive hearing loss is the most likely diagnostic outcome, then 500Hz AC is not required.

## 5.25 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 an elevated threshold at 2 kHz, the likelihood of an elevated threshold 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. 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.

## 5.26 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.

## 5.27 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  $>40$  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 down to the minimal level (30dB eHL) and the baby is still in a good state, an alternative recommended strategy is to immediately test 500 Hz BC.

## 5.28 Bone conduction at 4 kHz

BC at a minimum of 30 dB eHL at 4 kHz is recommended, where time permits, but is not mandatory if BC at 2 kHz has been obtained. If the only AC abnormality is at 4 kHz then BC at 4 kHz must be done. Testing should start at 30 dB eHL if there is no response by AC at  $\geq 40$ dB eHL.

## 5.29 Bone conduction stimulus artifact

At 500 Hz, at the highest stimulus levels (typically 50 dB eHL) 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.

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

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

## **5.31 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.

## **5.32 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 65-70 dB SPL masking noise should provide adequate masking; additional masking noise is not recommended because of the risk of cross over and central masking.

## **5.33 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/whānau.

## **5.34 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.

### **5.35 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.

### **5.36 Auditory neuropathy spectrum disorder / retro-cochlear lesion click ABR sub-protocol**

If there is an absent, delayed or abnormal wave V at  $\geq 80$  dB eHL at any frequency measured in any ear, then an AC click ABR test must be done at 90 dB nHL 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. There are two aspects of diagnostic inference that may be clarified by the use of click stimuli: retro-cochlear pathology and ANSD. If there is any repeatable deflection in the first 5 ms of any such average, the click records should 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 90 dB nHL recordings.

### **5.37 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 neural response, 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.

### **5.38 Auditory neuropathy spectrum disorder implications**

If definite or presumptive ANSD is the diagnostic inference, behavioural hearing thresholds may be substantially better than ABR-based threshold estimates. Regular follow-up is mandatory and should include an assessment of the child's responsiveness from the family/whānau, completion of auditory developmental questionnaires (e.g. LittleEARS®) and behavioural observation by the audiologist and AODC.

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 if behavioural assessment is inconsistent or not possible.

### **5.39 Auditory neuropathy spectrum disorder report**

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

### **5.40 Click ABR**

Click stimuli should only be used when testing at high levels for a diagnosis of ANSD.

### **5.41 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 5**. 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 levels and noise thresholds must be measured at nominal (F2) frequencies of 1.5, 2, 3, 4 and 6 kHz. DPOAEs should 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 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 6**. The UNHSEIP protocol includes replicated DPOAE measurements at nominal (F2) frequencies

of approximately 1.5, 2, 3, 4 and 6 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, PTA).

# 7 Immittance testing

## 7.1 Immittance protocol

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 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 retained on file if they are ambiguous.

## 7.4 Acoustic reflex interpretation

Reflexes should be used as a cross-check when:

- ABR threshold estimates are 70 dB eHL or greater
- ANSD is suspected
- tympanometry is abnormal and/or ambiguous

- an air-bone gap greater than 10 dB is inferred from ABR thresholds.

## 8 VRA-based assessment

All initial VRA-based assessments should include the following.

- Otoscopy
- Ear-specific AC thresholds at 2 kHz, 500 Hz, and 4 kHz, plus 1 kHz if indicated by rules analogous to those specified previously for ABR-based assessments.
- Ear-specific speech detection thresholds obtained through monitored live voice testing.
- BC thresholds at 2 kHz, 500 Hz and 4 kHz, if indicated by conventional criteria.
- DPOAE levels and noise thresholds at nominal F2 values of 1.5, 2, 3, 4 and 6 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 nine months of age 1 kHz probe tones should be used for tympanometry and reflex testing).
- If tests were attempted but not able to be completed this should be documented clearly.

### 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 as:

- Having PCHL by ABR-based assessment
- Have failed routine follow-up
- Who are referred to audiology due to risk factors such as postnatal infections, head trauma, etc.,
- Due to concern regarding hearing or speech and language development

### **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 have appropriate training and experience. A parent or other family/whānau 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 sound pressure levels in one-third-octave bands for bone conduction audiometry 250 Hz-8 kHz (ISO 8253-1 2010). The room should 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 by use of a dimmed light in the control room or a one way window. Two-way communication should be available to the examiner and distracter via a headset or other communication device. In the test room, the baby and distracter should be seated appropriately and with access to an array of distraction items. Reinforcers, such as video or puppet display box 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 (or currently available alternatives such as FRESH noise™) and FM warble-tone stimuli through insert earphones, supra-aural earphones, loud speakers and a BC transducer.

Transducers satisfying current IEC/ISO standards are 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 BC transducer 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 by bone conduction, where the latter are indicated by conventional audiometric criteria.

## 8.7 Sound field 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 should be obtained. This should include DPOAE testing and immittance testing. If the infant has previously passed their newborn hearing screen and there are no newly identified risk factors for ANSD then an ART is not mandatory.

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.

For infants with permanent hearing loss 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). For infants who have been fitted with hearing aids their well-fitting (minimally vented) personal earmoulds should be used for separate ear VRA testing (see appendix 12 for coupling detail).

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 should be available.

## 8.8 Selection and order of stimulus frequencies

AC testing must be done using pulsed NBN (or currently available alternatives such as FRESH noise™) or FM warble-tones of 1–2 s duration presented through insert earphones. Frequency selection is dictated by VRA assessment context (i.e., initial or follow-up testing).

VRA follow-up from ABR-based assessment must include 2 kHz, 500 Hz and 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 appointments 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. 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/FM 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 neuropathy spectrum disorder inference from VRA**

In the event of robust DPOAEs and reliable elevated VRA thresholds, ANSD is highly probable and a confirmatory ABR test with the click protocol for ANSD should 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 should include the following.

- Otoscopy
- Ear-specific AC threshold estimates at 2 kHz, 500 Hz and 4 kHz, plus threshold estimation at 1 kHz, where indicated by rules analogous to those specified previously for ABR-based and VRA-based assessments. Ear-specific BC threshold estimates at 2 kHz, 500 Hz and 4 kHz, where indicated by conventional audiometric criteria; plus threshold estimation at 1 kHz, where indicated by rules analogous to those specified previously for VRA-based assessments.
- DPOAE levels and noise thresholds at nominal F2 values of 1.5, 2, 3, 4 and 6 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 testing include:

- 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
- Children newly identified as at risk for PCHL who are new referrals to Audiology.

## 9.3 Test personnel

One examiner is normally needed for CPA testing. The examiner must be an audiologist who has had CPA training. Some 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/whānau 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 sound pressure levels in one-third-octave bands for bone conduction audiometry 250 Hz-8 kHz (ISO 8253-1 2010). 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 (or currently available alternatives such as FRESH noise™) and FM warble-tone stimuli through insert earphones, supra-aural earphones, loud speaker or a BC transducer.

The use of insert earphones is encouraged as they reduce the need for masking in certain circumstances and may be more comfortable for the child. For children fitted with hearing aids, insert earphones with a foam tip or well-fitting (minimally vented) personal earmould should be used for separate ear testing. If supra-aural earphones are used careful attention to accurate placement is required to ensure appropriate stimulus levels and avoid collapsing ear canals. Soft padding for the headband must be available.

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

Calibration of insert earphones, supra-aural earphones, loud speaker and the BC transducer must be carried out according to current IEC/ISO standards. A visual examination of the equipment and a listening check at all frequencies used should 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 currently available alternatives such as FRESH noise™) or FM warble-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.

## 9.11 Test procedure

CPA test procedure should 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 warble-tones, NBN (or currently available alternatives such as FRESH noise™) 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 for 500 Hz-4 kHz.

## 9.13 ANSD inference from CPA

In the event of robust DPOAEs and reliable elevated CPA thresholds, 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.

# 10 Integration of audiology results

## 10.1 General approach

Overall audiologic inference should 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 should only be considered as audiometrically 'normal' if AC hearing levels or thresholds are measured with confidence at 20 dB HL based on behavioural audiometry mandatory frequencies under this protocol, and there is no indication of ANSD or any retrocochlear disorder. Note that under the current protocol, 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)

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

## 10.5 Mild conductive hearing loss

Mild elevation of ABR air conduction thresholds, with no indication of PCHL, hearing loss must be reported as present, PCHL as absent, and the strong probability is a 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/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 audiological follow-up.

## 10.6 Moderate conductive hearing loss

Given a moderate conductive impairment and no indication of PCHL, then in the absence of obvious anatomic abnormality, a review after 12 weeks for DPOAE and immittance testing should be arranged. If on retest sustained conductive impairment is present, then the baby may be referred to ORL, if consistent with local ORL referral guidelines. If a referral is not made a second Audiology review should be arranged for a VRA assessment to obtain further definitive audiometry prior to re-consideration of a referral to ORL.

## 10.7 Mixed hearing loss

If the assessment indicates a mixed conductive and sensorineural impairment, or if there is any evidence (e.g., the opinion of an ORL) that a purely conductive impairment is

attributable to a structural disorder, then the audiological management should continue. Wherever feasible, the baby must receive a repeat assessment following active medical management of the condition (not including watchful waiting).

# Amplification Protocol

## 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 2 kHz must be obtained in each ear prior to initiating the provision of amplification. In some cases, obtaining additional diagnostic information may occur concurrently with beginning the trial of amplification. Threshold estimates at other frequencies (i.e., 1 kHz and 4 kHz) are recommended, but are not required for beginning the provision of amplification. It is expected the 4 kHz 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** 20, babies identified with a permanent congenital hearing loss must be referred immediately to an otolaryngologist (or paediatrician, depending on local referral pathways) for the aetiological 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.



When comparing audiometric thresholds for the same infant over time, it is important to take into account the changes in the individual ear-canal acoustics. By applying the RECD measurement to an infant's hearing thresholds the real-ear SPL can be compared over time. If ear canal acoustics are not considered when making comparisons as the child grows, what appears to be a change in hearing threshold sensitivity may be a result of changes in ear canal acoustics due to ear growth. See appendix 13 for further information.

Measuring and applying the individual RECD to the dB HL thresholds can aid in the decision making for amplification options for infants with mild hearing loss. When using insert earphones for hearing assessments of infants, the effective sound level in the ear canal is typically higher than the sound level in the 2-cm<sup>3</sup> coupler, on which the dial reading for the audiometric equipment is calibrated. The result of the higher effective sound level in the infant's ear canal can give the clinical impression of better thresholds when referenced to dB HL. Infants who appear to have a mild hearing loss on the dB HL audiogram may actually have poorer hearing thresholds when the influence of the ear canal acoustics is taken into consideration (McCreery et al 2020).

## 11.4 RECD measurement

Wherever feasible, audiologists must measure the individual baby's RECD as part of the amplification process. For the most accurate fitting, the RECD should be measured using the individual baby's well fitted unvented earmould (see appendix 12 for details). RECD measurement procedures are outlined in **Appendix 13**. 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.

## 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 (assuming equivalent middle ear status), 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 13**. If predicted values are used, they must be specified (i.e., age, coupling type), documented, and retained on file. The current values are derived from data collected from babies and children of varying ages and are provided for foam tip and 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 16**) as per the ear mould prescription. The prescription should 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/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, activation of advanced features, remote microphone (RM) system compatibility, rechargeable options and tamper resistant battery doors are important considerations when providing hearing aids to babies and young children. It is expected that the fitting would usually be binaural, behind-the-ear hearing aids.

## 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 (i.e., congenital hearing loss) and for adults (i.e., acquired hearing loss) are available. This version was implemented due to 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 17.**

When prescribing amplification for an infant, the selection of electroacoustic characteristics shall include the following:

1. Sufficient gain, level-dependent processing, and frequency shaping to allow the hearing aid to be adjusted to a child's individualized DSL v5 prescription using the procedures described in this document.
2. The hearing aid(s) selected shall avoid unnecessary distortion.
3. The hearing aid(s) selected shall provide electroacoustic flexibility to accommodate anticipated changes in ear canal growth, changes in hearing threshold level, anticipated needs for advanced signal processing and coupling to external sound sources.

## **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 devices. Identifying challenging listening situations through outcome measures or family/whānau report is essential when considering providing assistive listening technology such as a remote microphone system to infants and children. If recommended the audiologist must explain the option to the family/whānau and facilitate careful consideration and informed choice. If the device option is elected by the family/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 should be collected and applied in the calculation of prescriptive targets. Thus, the prescriptive targets should 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 dB SPL, and final hearing instrument settings must be documented and dated for each ear requiring amplification. Ideally, real ear measurements of gain and maximum output values should be performed on each ear (i.e., the RECD may have already been measured in the pre-selection phase) and the hearing instrument adjusted to provide the best match to targets. With babies, it is difficult to obtain valid and reliable measures of real-ear hearing instrument performance using this method. Therefore, predicting the real-ear performance of the hearing instrument using the baby's RECD is the preferred method for babies. Where possible, individual RECDs should be measured. This approach is fully implemented through the use of DSL in the real ear measurement system. For a detailed description of this procedure see [Appendix 17](#).

A 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. As a result, 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. Automatic feedback suppression technologies should be employed if feedback is noted. Every attempt to reduce feedback (i.e., 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 activation of automatic feedback suppression to ensure there is no detrimental impact on high frequency gain. 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.

## 13.4 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.

## 13.5 Application of advanced technologies

DSL targets are computed with the goal of listening to speech in quiet listening environments. As such, it is recommended that the prescribed hearing instruments be worn with this goal in mind. However, if technology that aims to improve the signal-to-noise ratio (i.e., directional microphones) is available, it should be de-activated when verifying the hearing instrument for quiet listening environments.

Advanced signal processing, such as automatic noise reduction, automatic program switching, and frequency lowering processors are continuously evolving. As new technologies and new evidence emerges, Audiologists are encouraged to use technologies that meet the listening needs of their patients. General information regarding these technologies have been included in this protocol. When considering the implementation of these advanced technologies Audiologists should refer to the University of Western Ontario Version 2023.01: Protocol for the Provision of Amplification (Addendum 2, Addendum 3, Addendum 6) for evidence review and specific protocols for verification.

### Frequency Lowering Technology

Frequency lowering is defined as high-pitched sounds that have been processed to be presented at a lower pitch. If the original frequency is not audible, then frequency lowering may present the sound at a pitch where the listener has (a) better hearing thresholds; (b) more hearing aid gain and output; or (c) both. These effects may allow benefit for high-frequency sound detection or recognition. Therefore, frequency lowering can be considered as a means to provide access to high-frequency speech sounds, when these cannot be provided via conventional amplification. The impact of activating frequency lowering technology should be carefully validated clinically (e.g. using age appropriate aided speech testing) and the child's speech and language development and auditory function should be closely monitored over time. Particularly in cases of steeply sloping

hearing loss it is important to consider whether a cochlear implant may provide improved audibility. If frequency lowering is needed to provide high frequency speech sound detection then a referral for a cochlear implant assessment is warranted.

### Noise Management

The rationale for providing noise management in hearing aids is to reduce the discomfort and interference caused by noise for a child who uses hearing aid(s).

Currently, hearing aids offer three main options for managing listening in noise.

1. Directional microphone systems use more than one microphone to reduce the amplification of sounds coming from non-frontal locations.
2. Adaptive noise reduction (ANR) involves digital signal processing to identify and minimize unwanted noise in the hearing aid's output.
3. Frequency-gain shaping is the adjustment of the amount of amplification provided across the frequency and input range.

Activation of noise management features is recommended on a case by case basis and at the Audiologist's discretion. Indicators of need for noise management include: (1) the child is regularly in noisy situations; (2) the child or caregiver reports limited hearing aid use attributable to noisy or loud environment limitations; (3) the child or caregiver reports loudness discomfort in any situation; (4) the caregiver observes poor speech understanding in noise. In all cases the implementation of a noise management strategy should be coupled with counselling of caregivers on ways to maximise benefits in everyday situations.

Automatic switching between alternate programs within the hearing aid is also a common feature in modern hearing aids. These hearing aids monitor the ongoing acoustic environment, classify it by acoustic features, and switch to the program that is associated with that environment. Although little research is available on the use of these features in infants and young children, manual switching is not feasible in this population. Trials of automatic programme switching is recommended as part of a monitored noise management strategy. Using this feature gives the Audiologist flexibility in establishing a noise management strategy across multiple programmes. For example, full time directional microphone use is generally not recommended. However, children as young as 11 months have been shown to orient to the talker of interest in everyday life and so would likely benefit from directional microphone systems when they look at the talker close to them in a noisy environment (Ching et al, 2009). The net effect of automatic switching will be beneficial if the hearing aid chooses directional mode more often when speech is coming from the front than when it is coming from the back.

## 13.6 Verification stimuli

Verification of hearing instrument performance at various input levels in the range of 55 to 75 (i.e., soft, average, and loud speech) must be conducted to determine audibility and compression characteristics of the instrument. Verification of speech targets must be completed using pre-recorded, calibrated speech test stimuli. Maximum output characteristics for hearing instruments must be verified using narrowband stimuli at high intensity level (85 to 90 dB SPL).

# 14 Information and instruction

## 14.1 Orientation

As per **Standard** 21, 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/whānau vigilance is required and a care kit is usually helpful. Supportive information and instruction for the family/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/whānau support

Despite their decision to proceed with amplification, family/whānau may continue to need various supports to help them through the process of understanding and adaptation. Family/whānau support is available through the local AODC. A combination of timely and relevant information from the audiologist, and family/whānau support from the AODC is the desired minimum. Family/whānau can also benefit from connecting with parent support groups such as Deaf Children New Zealand | Tamariki Turi o Aotearoa.

# 15 Outcome evaluation

## 15.1 Follow-up schedule

As per **Standard 21**, 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/whānau for a minimum one follow up visit within the first two months after fitting of amplification. A typical schedule of follow-up visits thereafter should include visits every three months for the first year, about every six months for the second year, and annually thereafter. This follow-up schedule is typical but may vary from baby to baby and may consist of different modalities e.g. tele-audiology appointments. For babies identified as having a progressive or fluctuating hearing loss, ANSD 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/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 should be completed at every visit. Assessment of hearing levels (typically behaviour-based) will normally be completed according to the typical 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. Data-logging information should be recorded and discussed with the family/whānau with a plan to increase hearing aid wear time as necessary with appropriate counselling and support. Audiologists should seek support for other professionals for example AODC, Kaitakawaenga.

Subsequent adjustments should be made to the hearing aids as needed and an evaluation of the need for additional technologies (e.g., remote microphones, noise reduction, frequency lowering) shall be conducted through counselling and outcome measures.

## 15.3 Outcome measures

Validation of the fitting must be done using a combination of questionnaires (LittleEARS®, PEACH), behavioural reports from the family/ whānau and age appropriate aided speech perception testing (see **Appendix 15**). Cortical auditory evoked potential testing should be considered for children diagnosed with ANSD and for children who are unable to complete behavioural assessment. The purpose of validation is to ensure that the hearing aids are



enabling children to participate fully in all aspects of communication. Hence validation should demonstrate that the child can hear across the frequency range, hear soft and conversational speech and hear speech in noisy environments.

## **15.4 Progress with amplification**

As per **Standard 21**, 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/whānau in consultation with the AODC. Referrals to appropriate agencies should be made as soon as possible.

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# Appendix 3: ABR calibration

Calibration data and coupler details of the approved ABR systems that are in current use in NZ can be found in the NZAS document: ABR protocol settings for current approved systems.

All equipment must be calibrated using these settings. Manufacturer's default calibration values must not be used.

# Appendix 4: ABR technical parameters

The following general parameters should be utilised on all ABR equipment used for infant diagnostic testing. There will be differences between approved ABR test equipment for specific test parameters such as artifact rejection, amplifier gain, and statistical confidence measures. All device parameters for specific ABR equipment must be configured exactly as specified in the NZAS document: ABR protocol settings for current approved systems.

## 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 rejection

- Set to maximum of +/-10  $\mu$ V
- Alternatively an appropriate signal processing algorithm can be used to reduce the impact of electrical and myogenic artifact on the EEG average

## Amplifier gain

- Typically 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.

## Statistical confidence measures

- Different systems use a range of statistical confidence indicators. Consult the manufacturer’s manual to ensure these measures are enabled and set appropriately for newborn ABR threshold measurement.

## 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 µs

- Polarity as specified (separate recordings of both polarities)
- Repetition rate 17.1/s

## ANSD protocol

- Record separate polarity recordings at 80 dB nHL if normal hearing or at 90dB nHL 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

## Mandatory and discretionary procedures for determining hearing status

- This section contains a summary of important test components for the initial ABR assessment. The tests are grouped according to hearing type and as procedures that must always be done (mandatory), procedures that may be done under certain circumstances (additional mandatory) and those that may be done if the ABR audiologist chooses (discretionary).

## Normal Hearing

Mandatory Procedures	AC at 2 kHz (response at 30 dB eHL) both ears, 500 Hz (response at 35 dB eHL) both ears, AC at 4 kHz (response at 30 dB eHL)
Additional mandatory based on initial test outcome	DPOAE measurement if AC testing at 4 kHz is incomplete
Discretionary Procedures (these are recommended if time permits as they are helpful as a cross check)	Tympanometry using a 1 kHz probe tone

## Presumed temporary conductive hearing loss

Mandatory Procedures	<p>Elevated AC showing a threshold at 2 kHz &gt; 40 dB eHL (or 500 Hz &gt;40 dB eHL, if it is the only AC elevated level) with pass BC (response at 30 dB eHL) at the corresponding frequency</p> <p>Note that 500 Hz BC is only required if 500 Hz AC is the only AC elevated level</p> <p>Tympanometry using a 1 kHz probe tone</p>
Discretionary Procedures	<p>BC testing at 500 Hz and 4 kHz at the pass intensity (30 dB eHL)</p> <p>10 dB final threshold bracketing for AC at 2 kHz, 500 Hz, and 4 kHz</p> <p>DPOAE measurement</p>

## Microtia/Atresia: for ear(s) where insert earphone/probe placement is not possible

Mandatory Procedures	BC testing at 2 kHz and 500 Hz at the pass intensity (30 dB eHL)
Discretionary Procedures	<p>BC testing at 4 kHz at the pass intensity (30 dB eHL)</p> <p>AC at 2 kHz (headphone) with a 10 dB final threshold bracketing</p>

## Permanent hearing loss (includes sensorineural, mixed and permanent conductive)

Mandatory Procedures	<p>AC at 2 kHz and 500 Hz with a 10 dB final threshold bracketing</p> <p>BC at 2 kHz if AC 2 kHz threshold is elevated; 10 dB threshold bracketing when BC shows NR at the minimal stimulus intensity (30 dB eHL)</p> <p>Tympanometry using a 1 kHz probe tone</p> <p>DPOAE measurement</p>
Additional mandatory based on initial test outcome	BC at 500 Hz if AC 500 Hz threshold is elevated; 10 dB threshold bracketing when BC shows NR at the minimal stimulus intensity (30 dB eHL)

	<p>BC at 4 kHz if AC 4 kHz threshold is elevated; 10 dB threshold bracketing when BC shows NR at the minimal stimulus intensity (30 dB eHL)</p> <p>AC at 1 kHz (10 dB bracketing if elevated) if the difference in dB eHL between AC at 2 kHz and AC at 500 Hz exceeds 30 dB</p> <p>AC using a high intensity click stimulus if AC at 2 kHz has a delayed, abnormal or absent wave V <math>\geq</math> 80 dB eHL</p> <p>Ipsilateral acoustic reflexes (BBN stimulus). This measurement has some value as a crosscheck to ABR thresholds and when a significant conductive component is demonstrated in the presence of a type A/peaked tympanogram</p> <p>If unilateral/asymmetric hearing loss, a 2-channel AC recording must be obtained to allow comparison of ipsilateral and contralateral traces in order to determine responding ear. An audiologists should switch to a 2-channel AC viewing when responses in one ear are at pass intensity and the other ear thresholds are <math>\geq</math> 60 dB eHL, or thresholds are elevated in both ears with at least a 40 dB threshold difference between ears</p> <p>Use of contralateral masking. If AC/BC 2 channel ipsi/contra asymmetries are unclear or abnormal, application of contralateral masking may be necessary to determine the responding ear</p>
Discretionary Procedures	If AC thresholds are greater than 70 dB eHL, 5 dB AC threshold bracketing may be pursued, but only after all mandatory measurements are completed

## ANSD

In addition to the requirements specified for permanent hearing loss (above) if AC at 2 kHz has a delayed, abnormal or absent wave V $\geq$ 80 dB eHL the assessment for ANSD should be initiated prior to further toneburst testing	
Mandatory Procedures	Slow rate (17.1/s), separate recordings of rarefaction and condensation at 90 dB nHL (at least 2 replications for each polarity) for assessment of cochlear microphonic potentials (CM), cochlear summing potentials (SP) and neural

	<p>components (ABR waves 1 to V presence, morphology, latency and amplitude)</p> <p>No stimulus recordings to either rarefaction or condensation by clamping insert earphone tubing</p> <p>Determination of ANSD requires low-noise recordings, as responses with low peak-to-peak amplitudes are often assessed.</p>
Additional mandatory based on initial test outcome	<p>For unilateral hearing loss, a 2-channel recording is required. Masking may also be necessary</p>
Discretionary Procedures	<p>Acoustic reflex measurements as these have some value as a cross check when ABRs are absent at high stimulus levels. The presence of a reflex is not consistent with a diagnosis of both ANSD and profound cochlear hearing loss</p>

### 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. Set up of the room can be flexible, based on the needs of the baby and the Audiologist.



## 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. If BC results are abnormal, the Audiologist should ensure it is not due to incorrect BC technique (i.e., incorrect positioning, insufficient force application).

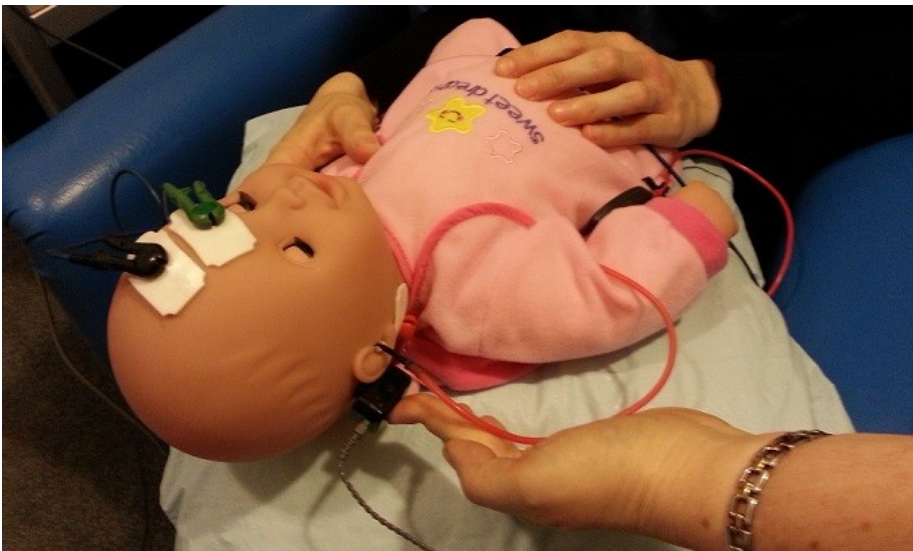
There is no evidence at this time of an occlusion effect with infant evoked recordings so it is not necessary to remove insert foam from ear canal or be worried about BC touching the pinna.



Supero-posterior  
position

## 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 and maximum stimulus levels and eHL adjustments

## Minimum Stimulus Levels

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

Frequency (Hz)	Air conduction				Bone conduction			
	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.

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, i.e., 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
<b>ABR threshold</b>	50	50	50	50	dB HL (dial)
<b>Add 5 dB only for babies ≤ 3 months</b>	55	55	55	55	dB HL
<b>Correction factor to be subtracted*</b>	5	5	0	0	dB
<b>Estimated HL (HL)</b>	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 ≤ 3 months**

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

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

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

## Maximum Stimulus Levels

Absolute maximum stimulus levels for tonebursts are determined by the upper limit of the transducer. Maximum stimulus values are typically from 95-105 dB nHL

	Air conduction			
Frequency (Hz)	500	1k	2k	4k
Maximum level (dB nHL)	105	105	100	95
Adjustment (dB)	-5	-5	0	0
Estimated level (dB eHL)	100	100	100	95

	Air conduction			
Frequency (Hz)	500	1k	2k	4k
Maximum level (dB nHL)	105	105	100	95
Add 5 dB only for babies ≤ 3 months	+5	+5	+5	+5
Adjustment (dB)	-5	-5	0	0
Estimated level (dB eHL)	105	105	105	100

# Appendix 6: DPOAE

## technical summary

Nominal F2 frequencies: 1.5, 2, 3, 4, 6 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.

Criterion	Recommendation	Comments
SNR	At least 6 dB	Or 5 dB if adjacent to a frequency that passes by 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	
Required frequencies	1.5, 2, 3, 4, 6 kHz	

# 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
- 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.

For babies under nine months corrected age:

- The goal is not to establish an accurate reflex threshold, but to demonstrate the clear presence or absence of reflexes at a safe stimulus level.
- Acoustic reflexes must be elicited with a BBN stimulus at 85 dB HL and measured ipsilaterally, using a 1 kHz probe tone frequency, with at least two replications to be considered present. Reflex records should be plotted and retained on file if they are ambiguous. Testing above 85 dB HL is not required as the majority babies will have present acoustic reflex thresholds for a BBN stimulus at or below 85 dB HL. The absence of an acoustic reflex at this level indicates abnormality.

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. The starting level should be 80 dB HL with at least two replications at any level to be considered present. Where the baby is active it is reasonable to obtain a clear repeatable response at a single level of 90 dB HL rather than undertake a threshold seeking procedure. For older infants and children it can be useful to obtain acoustic reflex thresholds at 500Hz and 2kHz (if the child is cooperative) to provide an additional cross check to the frequency specific threshold, particularly if there is any change in hearing over time.
- 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 (90-95 dB HL) to confirm the absence of the reflex and therefore increase the certainty of correctly identifying the tympanogram.



# 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 the child has a patent ventilation tube or a perforated tympanic membrane and the goal of the hearing assessment is only to measure hearing thresholds, then supra-aural headphones may be used. For infants who have been fitted with hearing aids their well-fitting (minimally vented) personal earmoulds should be used for separate ear VRA testing. For further information on coupling the insert phone to the earmould see Appendix 12. Even if the child has a patent ventilation tube or perforated tympanic membrane the use of insert earphones coupled to the child's personal earmould is still the recommended option. This is because the RECD measure satisfactorily accounts for the effect of a patent ventilation tube or TM perforation on ear canal acoustics and prescribed output.

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 the infant has previously passed their newborn hearing screen and there are no newly identified risk factors for ANSD then an AR is not mandatory.

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 reinforcers 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.

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 (or currently available alternatives such as FRESH noise™) of duration 1–2 seconds or FM 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 dB HL, 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 pulsed NBN (or currently available alternatives such as FRESH noise™).

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 (e.g., FM 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: 2 kHz and 4 kHz , 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 dB HL if 2 head turns obtained begin frequency specific testing.

If there is no spontaneous head turn, increase in 20dB steps until 70 dB HL. 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 pulsed NBN (or currently available alternatives such as FRESH noise™) 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 (e.g., FM 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: 2 kHz and 4 kHz 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.

1 kHz 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.

2 kHz and 4 kHz – proceed as above for 500 Hz.

1 kHz 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.

Place BC transducer on mastoid of ear with better AC threshold.

Note: placing the BC transducer 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 BC transducer on the mastoid with the worse AC threshold should apply.

Start with intensity at or below air-conduction threshold and test down to 20 dB HL.

Use same test protocol to find threshold.

# Appendix 9: Conditioned play audiometry

1. Test procedure is similar to that used for adult pure-tone audiometry but needs to establish thresholds **quickly** given the limited attention span in young children.
2. Frequency order: 2 kHz, 500 Hz, 4 kHz, and 1 kHz 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 1 kHz before 4 kHz 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 2 kHz 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 2 kHz and 500 Hz in the other ear, then test 4 kHz (and 1 kHz as required). However, this should only be attempted if you have no reason to suspect that one ear is worse than the other (i.e., 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 at ~ 70 dB HL if available (if a significant loss is expected such as with atresia/glue ear conditioning via bone conduction can be attempted). For infants who have been fitted with hearing aids their well-fitting (minimally vented) personal earmoulds should be used for separate ear testing and can be used in the conditioning sequence. For some children it is important to include non-verbal instruction and model the desired behaviour yourself (i.e., 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 the test sequence.
4. Start testing at 2 kHz 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 by 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 HL). Test down to 20 or 10 dB HL dependent on the child's attention.
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>2</sup>

1. The KTT can be presented as monitored live voice or using the SPANZ recording via the audiometer. For live voice testing, 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. When presenting via the audiometer the level of the calibration signal is adjusted on the VU meter. The following presentation dial readings can be used to be equivalent to 40 dBA (passing level for normal hearing).

Inserts	27.5 dB HL
Supra aural headphones	20 dB HL
Loud speaker	25.5 dB HL

For practicality in a clinic setting it would be appropriate to round these values down to the nearest 5 dB.

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 distracter items as practice items at normal voice level. Use the phrase 'Show me the \_\_\_\_\_' or 'Point to the \_\_\_\_\_'.
4. Lower your voice or reduce the audiometer level to the passing level (see commentary below) and ask the child to point to each test item, being sure to randomise the order

<sup>2</sup> Antognelli 1986.

of the test items. Start the first item at a minimal intensity level first, if the item is not identified by the child at that level, continue to raise your voice or audiometer presentation level 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 level 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 at which the child accurately discriminated 90% or 100% of the test items.

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, e.g., 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?'
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 distracter 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 distracter 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 passing level 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 dB HL. Antognelli comments that as a 'rule of thumb' the maximum score should be 15–20 dB above the pure tone average (*i.e., if the pure tone average was 50dB HL 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 dB HL. 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 Instrumentation

- Clinics providing a habilitation service must have access to hearing aid programming software, real-ear and hearing aid test systems that provide specific functions that support the entirety of hearing aid evaluations and verification procedures described in this protocol.

## 1. Desired Sensation Level (DSL) V5.0 prescriptive targets

The hearing aid test system should provide DSL targets for every frequency at which audiometric data has been entered. Preferably, the system should also interpolate for targets in between frequencies at which audiometric data has been entered.

## 2. Fitting Parameters

### a) Age

The real-ear system must allow entry of age or birth-date of the patient, or read this information in from NOAH or other similar database

### b) Client Type

The real-ear and hearing aid test system must allow the choice of whether the DSL prescription is based on paediatric hearing loss or hearing loss acquired in adulthood.

### c) Circuit Type

The real-ear and hearing aid test system must define whether the targets are displayed for linear or wide dynamic range compression. Alternatively, if only one circuit type is used, the targets must be displayed for wide dynamic range compression.

### d) Prescription Type

The DSL Method v5.0 calculates different prescriptions for use in quiet or in noise environments. This variable creates two different prescriptions: the DSL-noise prescription uses less gain and output. It is recommended that the real-ear hearing aid test system provides the DSL Quiet and Noise environment listening targets.

### e) Transducer Type

The real-ear and hearing aid test system must allow the choice of the transducer used for audiometry from the following list:

- 1) insert earphone + foam tip,

- 2) insert earphone + custom earmould,
- 3) TDH phone,
- 4) Sound field, with specification of azimuth of 0, 45, or 90 degrees
- 5) frequency specific ABR in eHL is preferred. If nHL only is supported, it must allow programme-specific corrections to convert nHL to eHL.
- 6) Correction factors for transducer mismatches between those used in audiometry and RECD measures are incorporated into software algorithms when calculating gain targets.

### 3. Data Entry and Data Display

#### a) Acoustic Transforms

The real-ear and hearing aid test system must prompt to either enter values for, or measure directly the following transforms: RECD and REUG. For REUG measurements, the measurement azimuth (0, 45, 90 degrees) must be specified. For RECD measurements, the coupling type (foam tip, earmould) and coupler type (HA-1, HA-2 or HA-4) must be specified. If this is not available the DSL age-predicted values should be used. The real-ear and hearing aid test system must display onscreen the chosen RECD measurement option (from the list of 4 above).

#### b) Audiometric Data

The real-ear and hearing aid test system must allow the entry of frequency-specific measures of the patient's air conduction thresholds and bone conduction thresholds for each aided ear.

#### c) Verification Displays

The real-ear and hearing aid test system must support hearing aid verification either when the hearing aid is coupled to the ear, or when the hearing aid is attached to a coupler. The system should provide appropriate corrections when coupler-based verification is used (accounting for both microphone location effects and the RECD). Testing with calibrated running speech must be provided in both the 2cc coupler and REAR displays, with analysis of the hearing aid in 1/3 octave bands both for percentile analysis and for the long term average speech spectrum. Running speech test signals may include the ISTS signal or any signal that provides equivalent test results. The speech test signals should be equivalent in spectral and dynamic range properties to the ISTS.

#### d) SPL-ogram

The real-ear and hearing aid test system must display and label either the REAR90/OSPL-90 and/or the predicted or measured UCL values onscreen. The system must display and label the patient's hearing thresholds, converted to SPL

using the DSL transforms. These variables should be displayed together with the DSL targets and hearing aid verification curves. An analysis of the Speech Intelligibility Index (SII) should be displayed for each verification curve performed with running speech.

e) Evaluations of accessories and signal processing

The system should provide support for assessment of external microphone systems (e.g., Remote microphone systems and similar) as well as assessment of noise reduction, frequency lowering, noise floor, and any other hearing aid signal processing required by this protocol.

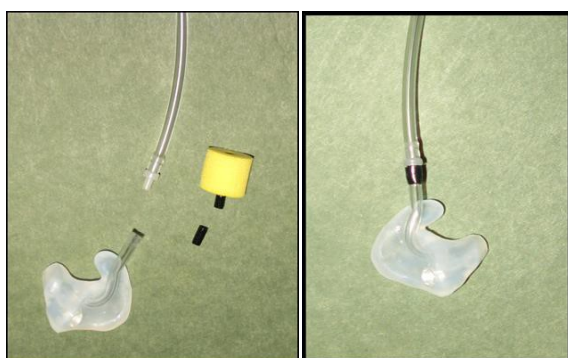
# Appendix 11: Estimated hearing levels (eHLs) and hearing aid fitting

Toneburst ABR thresholds in dB nHL are not directly equivalent to perceptual thresholds in dB HL, and both dB nHL and dB HL 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 and, 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 v5.0 in the real-ear hearing aid test system as well as the hearing aid programming software. Choosing eHL indicates that the ABR thresholds have been corrected as per described above (see Appendix 5) and no further correction will be applied by the system. The eHL option is often found in the “Transducer” section of the system when DSL v5.0 Child Targets are chosen.


# Appendix 12: Insert earphone coupling for RECD measures

During follow-up appointments, the audiologist may conduct VRA or CPA using insert earphones. If the child has personal earmoulds, the insert earphones should be coupled to them. This improves retention in the child's ear and improves accuracy with the hearing aid fitting compared to an assessment using a foam tip. The earmould tubing should have been trimmed for use with the hearing aid prior to testing. For a more stable connection a small section (5mm maximum) of the tubing from a standard foam ear tip can be used as shown below.



It should be noted that for the most accurate hearing aid fitting the RECD should also be measured using the same earmould. In everyday clinical practice this is not always possible and different combinations of audiometry coupling and RECD coupling may occur. In these circumstances modern verification systems will apply a correction factor. The table below shows a basic hierarchy of recommended verification configurations which may occur in clinical practice. For detailed information on how this hierarchy was determined and the potential errors at different steps of the verification process please see Moodie et al. 2016.

**Table 6: Optimal verification coupling for BTE hearing aids**

	Coupler verification		On-ear verification	
	Audiometry Coupling	RECD measured with	Audiometry Coupling	RECD measured with
More accurate 	Earmould	Earmould	Earmould	Earmould
			Foam Tip	Foam Tip
	Foam tip	Earmould	Foam Tip	None
	Foam tip	Foam tip		
Less accurate	Foam tip	None		

(Adapted from Moodie et al 2016).

# Appendix 13: RECD

## measurement procedure

Wherever feasible, Audiologists should measure the individual infant's RECD as part of the amplification process following the procedure described by Moodie et al (1994) and Moodie et al (2016). RECD values, tester, coupling type (earmould/foam tip), coupler type (HA-1, HA-2, HA-4), ear and test date should be documented and retained on file. Note that some modern verification systems have transitioned to the use of a 0.4cc (HA-4) coupler for the measurement of a wideband RECD up to 12,500 Hz. Hence it is necessary to indicate which coupler type was used to measure the RECD.

### Measurement Procedure

The HA-2 or HA-4 coupler is connected to the coupler microphone of the unit and a transducer is connected to the other end of the coupler. A pink noise stimulus generated by the probe microphone system is delivered into the coupler and the coupler response is measured by the microphone. Once the coupler measurement has been obtained, a foam ear tip or personal earmould is coupled to the transducer and inserted into the infant's ear along with the probe tube.

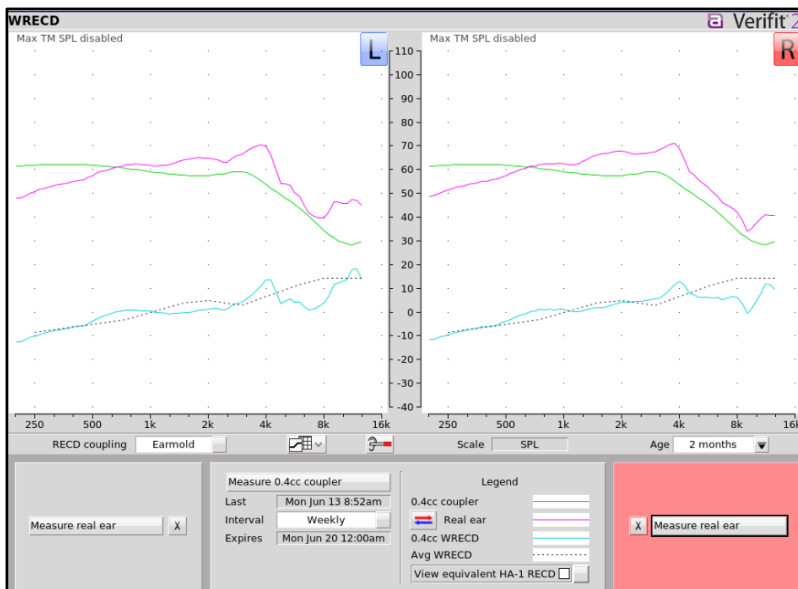
Consistent probe tube placement or prevention of venting can be difficult to obtain during RECD measurement in infants. It may be helpful to attach the probe tube to the earmould or insert foam tip (i.e., moisture guard or soft surgical tape) for very small ear canals. This technique is helpful in coordinating insertion and ensuring a constant depth placement. The same stimulus is presented via the probe microphone system and insert earphone/custom earmould coupling, and the real-ear response is measured. The difference between the real-ear response and the coupler response is obtained. This difference is the individual transfer function designated as the RECD and will be applied throughout several stages of the amplification.

To compare audiograms for the same child over time you need to document the HL thresholds which have the RECDs accounted for. In the verification system you may need to select a different view format (e.g. Table rather than graph) and keep these on file.

### 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:





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 RECD values. 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 asleep 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.

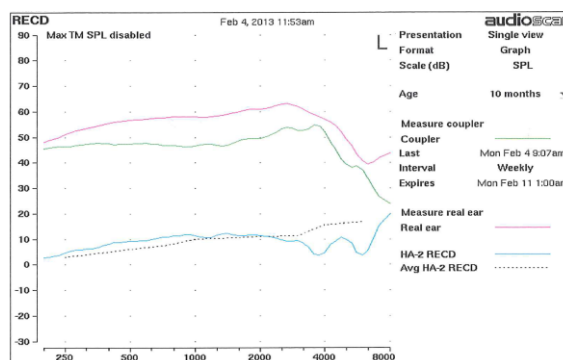
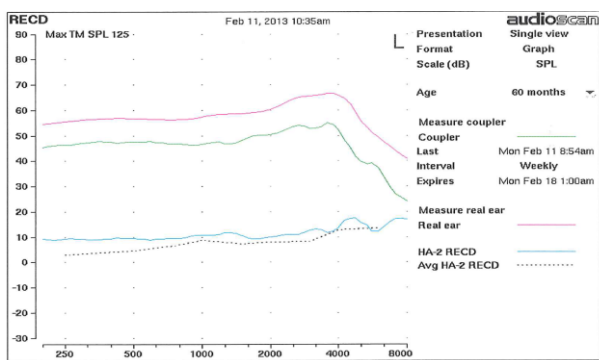
## 2 Lubricate

Apply ear mould lubricant (e.g., 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 (e.g., Otoease, Otoferm, 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 ventilation tube is in place or there is a perforation in the child's eardrum.

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

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

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

## **Summary**

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

# Appendix 14: Applying age-appropriate predicted RECD values

Every effort should be made to obtain an individual's RECD measurement. However, in some circumstances if this cannot be obtained, age-related predicted values can be applied. The predicted values used should be specified (i.e. age, audiometry coupling type), documented and retained on file. It is important to remember that age-appropriate group average values may differ significantly from individual real-ear SPL values and also do not reflect any acoustic changes related to middle ear disorders.

# Appendix 15: Validation tools

Validation of the hearing aid fitting is an ongoing process. A combination of objective and subjective measures should be used to reflect real world performance. Information collected throughout the validation process should be used to inform further management. This is particularly important when the integration of test results suggests an area of unexpected difficulty. In such cases, a clear management plan should be determined which may include such options as additional technology, a change of technology and/or an auditory skills programme. Objective measures, such as speech perception tests provide information about how a child is using hearing to perceive spoken language. Subjective questionnaires completed by family/whānau and teachers are used to assess the child's auditory function over time and to understand the child's performance across a range of listening environments. Validation of the hearing aid fitting should include tools to assess and identify situations where there is the potential to increase hearing aid use.

## Questionnaires:

The University of Western Ontario Paediatric Audiological Monitoring Protocol (UWO PedAMP, Bagatto et al., 2011) was developed to allow monitoring of hearing aid details and hearing abilities of children aged 0-6 years. The following questionnaires are included in the UWO PedAMP, and are internationally recognised, and should be completed as part of the hearing aid validation process and results discussed with the whānau (see <https://www.dslio.com> for printable documents and administration guidelines)

- 1) LittlEARS® Auditory Questionnaire
- 2) Parents' Evaluation of Aural/Oral Performance in Children (PEACH)
- 3) Infant Hearing Program Amplification Benefit Questionnaire

## Aided speech perception tests:

### Test conditions:

To reflect the child's needs in everyday listening situations aided speech perception testing should assess how well the child hears conversational speech, soft speech and speech in the presence of competing noise. Testing should be completed via the audiometer for the following stimulus presentation conditions:

- 1) Normal conversational level at 45-50 dB HL

- 2) Soft conversational level at 35-40 dB HL
- 3) Normal conversational level in noise (+5 SNR using multi-talker speech babble noise)

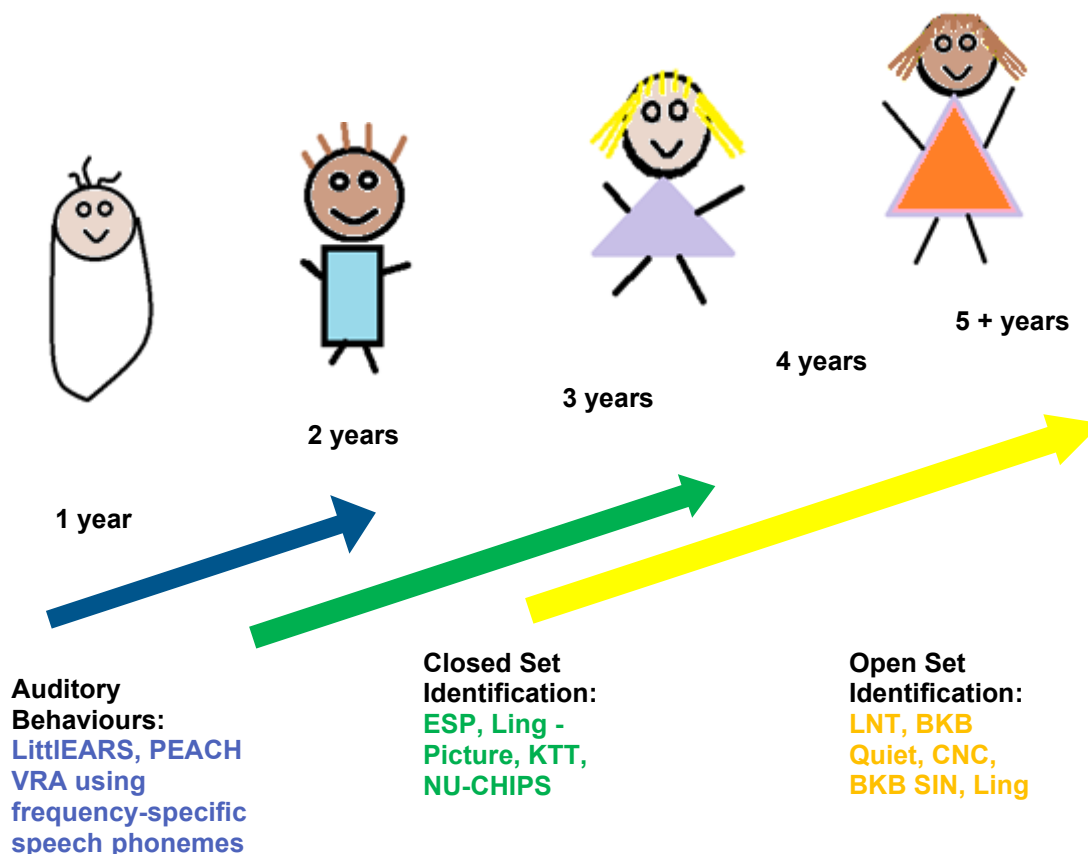
Testing should be completed in a binaural aided condition, unless there is a significant difference in the hearing threshold levels between ears in which case monaural testing is essential.

Test materials:

It is recommended that recorded speech materials are used for all testing to maintain consistency of speaker level, accent and intonation and to enable direct comparison across test sessions. However, if required for very young children or for children with reduced cognitive function, an alternative task is to revert to using a monitored live voice via the audiometer.

Test materials should be chosen based on the child's developmental age, cognitive function and language abilities. As the child's development continues and their language abilities mature it is expected that more complex tasks will be performed and the child's progress over time can be assessed (see Hierarchy of speech testing below).

**Figure 5: Hierarchy of speech testing**



For the assessment to be valid for our New Zealand English speaking paediatric population the content of the speech material should reflect the features of New Zealand English (NZE). The Speech Perception Assessment New Zealand updated compilation (SPANZ II) is available to NZ Audiologists. SPANZ II contains recorded speech materials for 15 speech audiometry assessments. The speech material has been modified and adapted for use with NZ children and has been re-recorded by two native NZE speakers. The SPANZ II technical instructions and score sheets are available via the NZAS website. In addition, many children fitted with hearing aids are raised within Te Reo Māori immersion environments and taught at Kōhanga Reo and Kura throughout NZ. For children to be assessed in their own language there is a need for recorded speech materials to be available in Te Reo Māori. This is an area of much-needed development and appropriate speech materials may be available in the future.

### Test Performance

The main goal of amplification is to maximise functional auditory capacity to enable the child to fully participate in every aspect of communication that occurs in their daily lives.

To ensure audibility of the average speech spectrum including soft phonemes in speech, measured speech detection thresholds using the frequency specific speech phonemes should be in the range of 20-25 dB HL. Results consistently poorer than this should prompt review of management. In particular, detection thresholds for the high frequency speech phonemes of  $\geq 35$  dB HL despite an optimised hearing aid fitting would warrant consideration of cochlear implant assessment referral. As part of this process it is important to consider the degree of hearing loss, the child's speech and language development, additional aided audibility measures (Aided SII) and the local cochlear implant programme referral criteria.

For aided speech perception testing a score of greater than 75-80% correct suggests that the child is performing at a level approaching ceiling effect for the specific test (Uhler et al., 2017). This would indicate good performance for the specific speech test condition. If a score of 75-80% correct is achieved then the next step is to proceed to the next hierarchical level of difficulty. For example, performing the same test at a soft speech level, or in competing noise (+5 dB SNR), or move to a more complex test e.g. from a closed set to an open set task. On the contrary, a score of 25% or lower suggests that a simpler task is necessary (Uhler et al., 2017).

For scores between 26% - 79% re-test is recommended at the next follow-up appointment. The test result must be integrated with other information such as hearing level, speech audibility, experience with amplification (including of daily use) and listening environment to understand what the result may indicate for the child in real world settings and to inform future management.

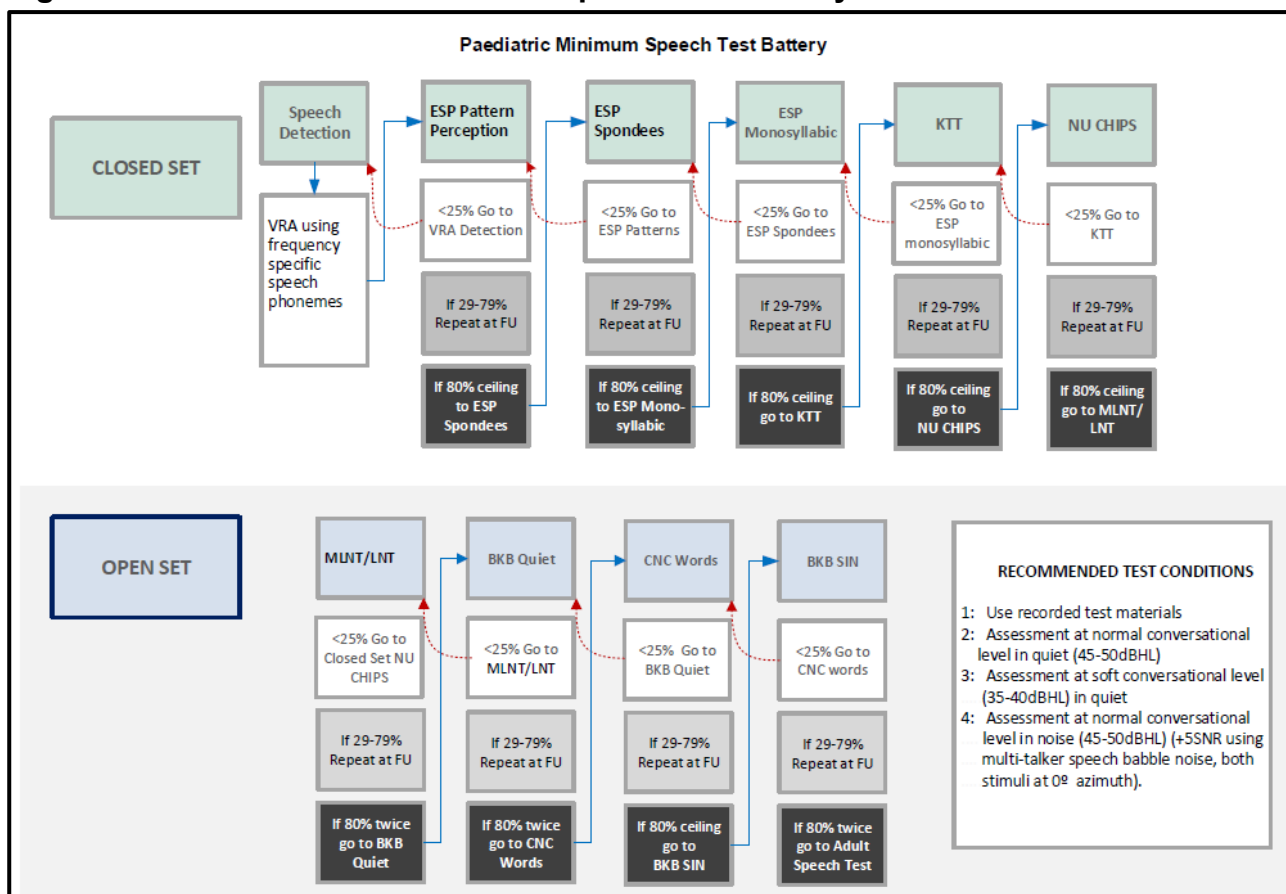
## Recommended minimum aided speech test battery

Adapted from Uhler et al 2017

It is recommended that multiple tests or conditions are completed at each follow-up appointment or over time. The test battery includes testing at two levels for speech in quiet (45-50 dB HL conversational speech and 35-40 dB HL soft speech) and conversational level in the presence of background noise (+5 SNR, using multi-talker speech babble noise both stimuli at 0° azimuth). If the child cannot perform the task at SNR +5 dB then testing should be completed at SNR + 10 dB. This will provide valuable information regarding the child's likely performance in classroom listening environments and may support the need for additional technology such as remote microphone systems.

The flow chart below illustrates the recommended sequence of the minimum speech test battery. This includes a stopping criterion for tests (<25%), continuation of testing (25-79%), and ceiling scores (≥80%). Once audibility is confirmed using speech detection a child may start at any stage within the minimum aided speech test battery depending on their language level and experience with amplification.

**Figure 6: Paediatric minimum aided Speech test battery**



In addition to the minimum aided speech test battery there may be situations when additional tests are completed. For example, the University of Western Ontario (UWO) Plurals Test is a measure of speech perception ability specific to English language



plurality. The UWO Plurals test can be used to evaluate hearing aid performance related to changes in high-frequency speech perception across hearing aid conditions or over time and may be particularly useful when assessing children with high frequency hearing loss. Additionally, the Ling Test can be useful to assess discrimination between different speech sounds spanning the main speech frequency range.

## **Aided Cortical Evoked Potential Testing**

The successful implementation of universal newborn hearing screening has significantly reduced the age at which hearing aids are first fitted for children with hearing loss. An infant's hearing aid prescription is based on estimated hearing thresholds determined from the frequency-specific ABR measurement which is typically completed before the child is 3mths old. Behavioural assessment using VRA is most reliable from around 7mths of age, and it may take multiple test sessions to obtain a complete frequency-specific and ear-specific audiogram. Also, children with additional disabilities may not be able to complete a reliable VRA assessment until a much older age. Hence there is a period of time between the hearing aid fitting and the complete VRA assessment for which the hearing aid evaluation is predominantly based on parental report and observation. The need to identify procedures that can confirm the audibility of speech and the appropriateness of the hearing aid prescription objectively has led to the use of aided cortical auditory evoked potential (CAEP) testing in some countries. In NZ, aided CAEP testing is available in some centres and is primarily used when unaided/aided VRA assessment has been inconclusive. Further work is required to develop an appropriately trained workforce with specific CAEP competency and infrastructure to ensure access to this type of assessment throughout NZ. This section provides general information on considerations for aided CAEP testing.

The morphology of the prominent peaks in a CAEP response varies considerably with age and large changes take place from infancy until late teens. Before interpreting CAEP results the age of the child must be taken into account.

For infants a test environment appropriate for VRA assessment is suitable for aided CAEP testing (Munro et al., 2020).

CAEP testing is undertaken when the child is awake and settled and hence test outcomes depend upon the state of the child.

Typically speech or speech-like stimuli with low, medium and high frequency emphasis are presented at supra-threshold levels. Responses are more robust to mid-frequency stimuli and hence it is recommended that testing starts with this stimulus. The presence of a clear response to specific supra threshold speech stimuli provides reassurance that the infant has access to speech with their current technology. However, the absence of a response does not directly indicate that the sound is inaudible. Research indicates that, for current test parameters, children vary in the sensation level required to evoke a robust cortical response (Chang et al., 2012, Glista et al., 2012).

For infants with SNHL, responses may be absent depending on the test stimuli used, test parameters, the infant state and the expertise of the assessing audiologist. As with all paediatric assessments it is essential to consider the test results not in isolation but in conjunction with information collected from complementary evaluation tools.

# 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 (e.g., discharge from the ear, excessive cerumen). Make an estimate of ear canal size and length.
4. Measure and mark earlight using the following general guidelines: <6 months – mark earlight for approximately 10 mm from ear canal entrance >6 months – mark earlight for 10–15 mm from ear canal entrance, depending on ear size and age.

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

5. Using the earlight, insert the otoblock gently into the ear canal so that the marked position on the earlight is at the ear canal entrance (see #4 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, e.g., sucking or other mouth movement. Movement need not continue throughout the hardening process.
10. Allow the impression material to harden; approximately 5 to 10 minutes. If you push your fingernail on the material without leaving an indentation, then the material is set.
11. To remove the impression, pull gently on the pinna to loosen the impression in the baby's ear. Then, carefully peel out the concha portion without bending the canal; at the same time remove the helix portion. When the concha portion is about a third of the way out, gently rotate the impression forward (towards the child's nose) and remove the canal portion of the impression.
12. Perform an otoscopic inspection of the ear canal to ensure removal of the oto-block and 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. Care is needed to ensure that venting does not compromise audibility or accuracy of the hearing aid fitting. It is not possible to accurately verify the effects of significant venting until the child is able to perform on-ear verification measurements. In addition, the RECD measurement and the insert to earmould RECD correction assumes an unvented earmould. 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.

# Appendix 17:

## Electoacoustic verification

1. Place selected hearing aid in the test box coupled to the HA-2 or HA-4 coupler.
2. In the simulated (test box) real-ear section of the system, choose a calibrated speech stimulus. Select a level of 65 dB SPL and measure a simulated real-ear aided response.
3. Adjust the aid to provide a close match (within +/- 5dB) to the average speech targets for 65 dB SPL and store the curve.
4. Choose a high-level (85 – 90 dB SPL) narrowband stimulus and adjust the hearing aid so it approximates the DSL v5.0 MPO targets and does not exceed the UCL targets. Store the curve.
5. Choose the same standard speech stimulus as in Step 2 above. Select a level of 55 dB SPL to verify soft speech targets and a level of 75 dB SPL to verify loud speech targets.
6. Adjust the hearing aid to the soft and loud targets and store the curves.

### NOTE:

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

7. Repeat the verification procedure for average and MPO if you made adjustments in Step 6.
8. Repeat steps 1 through 7 with the other hearing aid for binaural hearing aid fittings.
9. Save the final settings to the hearing aid(s) and record the verification data from the real-ear and hearing aid test system and the hearing aid fitting software for the patient's chart.

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

# Appendix 18: Protocol for fitting RM systems

The protocol for fitting RM 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 (updated April 2011)

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/RM systems is the verification of the HA settings to ensure full audibility of self and other students. All further measurements comparing RM and HA responses will be completed using the 2 cc coupler.

3. Evaluate EHA65<sub>SPL</sub> **without** the RM receiver attached.
4. Attach RM receiver to HA and set RM Receiver to manufacturer's DEFAULT setting. RM transmitter should be turned ON and set to MUTE.
5. Evaluate EHA/RM65<sub>SPL</sub> and compare to results of EHA65 to determine if there are impedance or program changes to the HA response with an RM receiver attached.
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 RM transmitter (HA microphone is still active, so the test room should be quiet). Put RM transmitter/microphone in test box and set to OMNI MICROPHONE position. Evaluate RM response with 65 dB SPL input to the RM microphone (ERM/HA65<sub>SPL</sub>).
7. Subtract HA (EHA/RM65<sub>SPL</sub>) from RM (ERM/HA65<sub>SPL</sub>) at the following three frequencies: 750 Hz, 1 kHz and 2 kHz. Calculate a three-frequency average of the differences. If the average difference is  $\leq \pm 2$  dB, do not change the RM setting. If the difference is  $> \pm 2$ , change the RM setting as appropriate and re-evaluate ERM/HA65<sub>SPL</sub> to confirm transparency. For example, if the RM average is 4 dB lower

than the HA average, the RM setting should be increased by 4 dB and the average differences recalculated.

8. Perform a listening check with simultaneous inputs to RM and HA to judge overall signal quality and the relationship of the RM level to the hearing aid microphone.
9. For further assessment of appropriateness of RM 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** RM level
  - if validation results indicate difficulty hearing others – **decrease** RM level
  - if validation results indicate distortion of main talker’s voice or annoying increase in background noise when that person stops talking – **decrease** RM level
  - if validation results indicate difficulty hearing talker wearing the RM microphone – **increase** RM level.



# Appendix 19: 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, i.e., 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.

Standardized skull simulators if available (with an abutment input) can be used to characterise the output of bone conduction hearing aid devices.

## **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. If the ABR was completed to BC pass levels and it is strongly suspected that the hearing loss is conductive in nature, then BC thresholds should be set to 20 dB HL in the manufacturer's software to ensure speech audibility.
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. In some cases where it becomes necessary to obtain an objective measure of amplification benefit, aided and unaided cortical auditory evoked potential testing using filtered speech phonemes could be used.

Validation of the bone conduction fitting should be obtained through the use of the LittEARS® auditory questionnaire (Coninx et al 2003) or the PEACH questionnaire (Ching et al 2000/2005) and age appropriate speech perception testing.

### **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, i.e., 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 programming 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 of 20-25 dB HL 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 materials, (see Appendix 15: Validation tools) 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 Auditory Evoked Potential (CAEP) testing 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.

# Appendix 20: Instruction and information

## Orientation checklist

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

- Amplification and the speech signal, e.g., explanation of aided audibility and its implications for speech and language development.
- Impact of noise and distance.
- Coping with noise and distance (e.g., at home, in the car).
- Incorporating use of hearing instruments into the child's everyday routines.
- Importance of consistent hearing aid use and wear time goals appropriate for the age of child.
- Explanation of data collection systems within the hearing aids and how the information can assist in establishing consistent hearing aid use
- 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.
- Plans for documenting experiences with hearing instruments – hearing instrument diaries could be provided or recommended.
- Safety issues (e.g., swallowing of hearing aid or battery).
- Understanding the common causes of acoustic feedback and when this may occur.
- Protecting the hearing instruments from potential hazards (e.g., moisture, pets).
- Troubleshooting techniques.
- Warranty and insurance information.
- Plans for repair of malfunctioning hearing instruments.

- Discussion of ear mould life expectancy and hearing instrument life expectancy.
- Plans for follow-up contact between the family/whānau and audiologist.
- Options to be used at a later date (e.g., Remote microphone system).

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 tone hooks 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 by the Audiologist as part of the amplification prescription.

## **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.