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The BCEHP also thanks the members of the BCEHP Diagnostic Audiology Advisory Group (DAAG) for their hard work developing this document.

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Audiology Assessment Protocols

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101. **Assessment Personnel**

All assessments funded by the BCEHP will be conducted by BCEHP-registered audiologists, having received approved training in this Audiology Assessment Protocol. The rationale consists of several important points:

a. this protocol is technically demanding and contains elements that may be outside conventional experience of many paediatric audiologists;

b. specialized training is required to maximize understanding of, and to fulfill a highly specific standard of care with many mandatory elements;

c. for quality improvement, the obligatory performance review that is in a separately funded provincial program with defined deliverables, which requires full, explicit and proven exposure to the procedures required and their rationale.

Assessment funding is administered locally by five regional BCEHP co-ordinating agencies, according to locally negotiated contracts within the provincial funding guidelines and envelope. Procedures in compliance with this protocol will normally qualify for BCEHP funding, and will not concurrently be billed to MSP or any other funding source.

Audiologists outside the BCEHP may choose to adopt BCEHP procedures, but their activities do not qualify for BCEHP funding, because they are not registered as BCEHP providers and their activities are neither budgeted nor verifiable by the BCEHP. Accordingly, audiometry that is not provided by BCEHP audiologists is not a sufficient basis for BCEHP services.

All BCEHP-certified Audiologists must be certified by the College of Speech and Hearing Health Professionals of BC (CSHHPC).

102. **Test Environment**

Assessments, with the exception of Middle Ear Analysis (MEA), will be done in an audiometric environment that satisfies the current ANSI standards for manual, pure tone audiometry. Testing in any other environment will not qualify for BCEHP funding unless the environment has been specifically and previously approved by the BCEHP.

For Visual Reinforcement Audiometry (VRA), the room will be of sufficient size to accommodate the parent, infant and distracter comfortably and will be adequately ventilated. The room will contain minimal visual distractions to the infant. It is recommended that the room lights be provided with a dimmer switch, to allow for enhancement of the illuminated visual reinforcers.

For VRA, the presentation of stimuli and visual reinforcement are controlled from a second (observation) room. The test and observation rooms should be separated by a one-way window so that the infant is not distracted by the examiner, yet the examiner can clearly see the infant. Two-way communication must be available between the examiner and the distracter.
For alternative test environments to be considered acceptable, conventional pure tone threshold audiometry by air conduction, using a supra-aural (TDH) earphone, in at least five adult subjects with normal hearing should achieve reliable thresholds of 25 dB HL or better at 500 Hz through 4000 Hz, in the precise test situation being proposed. The environmental review must also include octave-band sound level measurements, and demonstrate sound levels at or better than those indicated below. Satisfactory test conditions may be achievable in a quiet, untreated room with little noise from traffic or air handling systems. If there is a problem, it is most likely to occur at 500 Hz. In Auditory Brainstem Response (ABR) and Otoacoustic Emissions (OAE) testing, well-fitted insert earphones can provide some protection against environmental noise, but the amount of protection is variable, small and not exactly known. Because the ABR is an averaged phenomenon, isolated transient sounds may not have a significant effect on the accuracy of threshold estimates. Furthermore, because the BCEHP protocol does not pursue ABR thresholds below 20 dB EHL, the likelihood of an environmental problem due to steady-state noise is lessened. However, OAE measurements are easily compromised by significant room noise, especially at frequencies below 2000 Hz. MEA measurements are not affected by moderate levels of room noise.

The safety and comfort of the infant are the paramount concern, and all reasonable steps will be taken to ensure them. The infant will be supervised closely throughout the testing, by an individual who is familiar with all pertinent safety procedures and who has adequate training in handling young infants. Local protocols must comply with all relevant local safety standards and with generally accepted standards of care.

In many test situations, it is feasible for a single audiologist with appropriate training to conduct tone pip ABR testing. Where feasible, it is recommended that the tester and instrumentation be inside the sound room, with the infant, who may be in a bassinet, crib or pram. This may reassure the parents, who may be reluctant to leave their child alone in what they may see as an intimidating test environment. It also facilitates the option of single-handed, unassisted testing.

The current ABR/OAE equipment (IHS Smart-EP) is laptop-based, and noise levels from that unit are not a significant concern. Printing of records (laser or inkjet), if necessary, should be done off-line, so it is not absolutely necessary to power up the printer during testing. Alternatively, the printer may be located outside the sound room, given adequate cable routing though the trap or connector panels.

Attendance of family members/caregivers during ABR testing is a matter of local preference, and at the discretion of the BCEHP audiologist. In specific situations, the presence of a family member or third party may be desirable for reasons unrelated to test quality: such as, to secure compliance or to manage perceived medico-legal risk. Family members may differ in their knowledge and skills related to infants' sleeping habits.

Having parent(s) in the test room, at least initially, can alleviate their anxiety. They can assist by trying to get their child to sleep. A practice of allowing a limited time for parents to encourage sleep and then leave the sound room is recommended. This general approach has been successful for many years in
several centres. Primary factors in the choice of approach are the audiologist’s sleep-promotion skills and the pressure of time in local scheduling practices.

ABR threshold testing must be conducted in an audiometric sound room that satisfies all pertinent and current ANSI criteria for manual, pure tone audiometry. It is strongly recommended that OAE testing also be conducted in such an environment. In special circumstances, exceptions may be made, subject to BCEHP review and acceptance of the proposed environment. In general, assessments in any test environment other than an audiometric sound room will not qualify for BCEHP funding unless BCEHP management approves the environment.

103. Test Equipment, Calibration and Supplies

VRA

VRA testing requires a clinical audiometer that meets the ANSI S3.6-1996 specifications. The audiometer will be capable of presenting pure tone and FM warbled-tone stimuli through insert earphones, supra-aural earphones, and a bone conduction oscillator. Warbled tones are the stimuli of choice for the BCEHP protocol.

The ambient noise in the test room must meet the ANSI S3.1-1999 criteria. Calibration of insert earphones, supra-aural earphones and bone vibrator must be carried out according to ANSI standards (ANSI S3.6-1996). This calibration is required to be done when the audiometer is installed (or moved), and then annually thereafter. BCEHP providers are responsible for keeping calibration records, for audit purposes, for a period of 3 years following the date of calibration.

A visual examination of the equipment and a listening check, at all frequencies being tested, will be carried out at least once per week.

ABR

The BCEHP provides all the instrumentation and operating supplies necessary to conduct ABR assessments according to this protocol.

Instrumentation will be calibrated and maintained according to BCEHP specifications. The manufacturer’s calibrations supplied with the BCEHP ABR instrumentation are not acceptable for BCEHP assessments and will be modified according to BCEHP specifications. See Appendix 3 – “ABR Technical Details”.

Many factors affect the proper calibration of stimuli for tone pip ABR testing of infants. Important variables include stimulus route and transducer, frequency, envelope, and repetition rate, and the definition of threshold. Provided that the key features of BCEHP test protocols match those of the protocols used in deriving the published data, the use of published, large-sample norms is generally superior to the development of local, small-sample norms.

The BCEHP is responsible for the determination and dissemination of reference settings for the calibration files that govern stimulus levels for ABR testing. BCEHP ABR systems are calibrated by designated specialists familiar with calibration of stimuli for electrophysiologic measures. All BCEHP tests will be
done using current BCEHP calibration and set-up files. The calibration data will be updated from time to time, as further information becomes available from published research or BCEHP clinical practice.

Because of the digital nature of modern ABR equipment, traditional calibration practices that were necessary for analogue instruments are moot. The main reasons for routine, full acoustical calibration is now mechanical change in the stimulus transducer or defects in leads and connections. Annual acoustical calibration is a formal BCEHP requirement. Calibration services will be arranged by the BCEHP, with reasonable notice to the assessment centres. Because transducer malfunction can occur at any time, additional, listening checks for transducer malfunction or problems in leads and connections will be done weekly or, if the test interval exceeds one week, just prior to testing. The individual BCEHP audiologist is responsible for routine listening checks. Busy clinics conducting several (4-5) ABR assessments each week will likely have to replace their air- and bone-conduction transducers every 2-3 years (and earlier if indicated by listening checks or annual calibration).

104. ABR Noise Standards

Threshold ABRs are typically done in the sound booth but, when not possible, the ABRs should be done in a quiet room with measured octave band Sound Pressure Levels not exceeding those listed below:

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Sound Pressure Level (dB SPL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>22</td>
</tr>
<tr>
<td>1000</td>
<td>30</td>
</tr>
<tr>
<td>2000</td>
<td>35</td>
</tr>
<tr>
<td>4000</td>
<td>43</td>
</tr>
</tbody>
</table>

Octave band measurements: (see Appendix 3 – “ABR Technical Details”)

105. Additional Room Standards for ABR

- Electrical isolation is required – i.e. more than 25 ft away from an elevator shaft; more than 25 ft away from X-ray equipment & power doors.
- Other sources of electrical interference may exist, but cannot be predicted.
- Facility management and clinicians must be aware of possible sources of electrical interference and be prepared to relocate the ABR room if other measures to isolate are not successful.
- A dedicated circuit is not a requirement.
- Access to a sink/hand sanitizer for hand washing within close proximity to the testing room is a requirement.

106. Furnishings

- An upholstered recliner in which a parent can hold a sleeping infant for one to two hours.
- Alternate sleeping arrangement for baby (e.g. crib).
• A pillow in a plastic case with linens to allow greater comfort for parents when holding their infant.
• ABR equipment on a moveable cart/computer desk.
• A comfortable chair with wheels, for examining audiologist.

107. Other Required Equipment

• Otoacoustic emissions equipment (usually within same room).
• Acoustic immittance equipment with high frequency tympanometry and acoustic reflexes in close proximity.
• Sound suite for VRA and BOA assessment, as per typical set up: i.e. a minimum of 2 reinforcers, 2 sound field speakers, insert phones, and bone conductor, clinical audiometer with capability of testing 250 Hz through 8000 Hz to profound levels and meeting ANSI calibration specs, microphone, and CD input. The sound suite for behavioural assessment may not necessarily be at the same site or location as the ABR room, but must be available.
Data and documentation procedures as described below are mandatory. They will be examined for completion upon commencement of the quality assurance/auditing process. Additional, non-BCEHP, site-specific processes and requirements may also be in place.

201. Documentation in the patient/client chart:

The following items are required:

- acoustic immittance printouts (if acoustic immittance measures obtained)
- otoacoustic emissions printouts (if otoacoustic emission measures obtained)
- ABR printouts of all saved waveforms, as well as completed ABR recording sheet (if ABR measures obtained)
- audiologic assessment recording form (if behavioural measures obtained)
- documentation of the date, test(s) performed, final result for that assessment, recommendations made, and the audiologist who performed the testing should be present in the patient/client’s chart.

For any test performed where printouts are not on file, documentation of the reason that they are not present is required.

202. Reporting:

For each assessment, results of the assessment (even if incomplete) must be entered in the BEST data system as a single assessment. Results should be entered as completely as possible as allowed by the format of the BEST data system.

In addition to the BEST entry, there must be a summary clinical report in the patient/client chart, signed by the testing audiologist and with printed name, regardless of whether any external reporting is issued. A report sent externally (i.e., outside of the BCEHP) is highly recommended for all assessments.

203. Documentation and protocol for non-attendance and/or lost to follow-up:

Children who require further BCEHP services as per the screening and assessment protocols who repeatedly do not show for scheduled appointments without sufficient notice to the centre (as determined by the centre) or are lost to follow-up must be documented in the BCEHP database and the patient/client chart.

Protocol:

1. Three phone calls to the family to reschedule.
2. If the family repeatedly does not show for scheduled appointments/does not reply to voicemail messages, or there is no means of leaving a message after a 1 week period, a letter should be sent to the family with
information about what further testing is required and contact information for the ABR centre.

3. Allow 10 days for the family to respond to the letter.

4. If at that point, the family has not made contact, document in the BCEHP database that the child was lost to follow-up.

5. Send a letter to the child’s family physician or pediatrician.

6. A record must be kept in BEST of interaction with the family and information about the attempts made to make contact. It is recommended that a record of these interactions also be kept in the patient/client chart.

204. Adverse event recording:

An adverse event is defined as any unfavourable and unintended outcome associated with a (para)medical procedure, regardless of whether it is considered related to the (para)medical treatment or procedure, that occurs during the course of service delivery.

Site-specific procedures for documentation of such an event will be in place, and should be followed. Refer to the “CQI Process” document for additional information about reporting of adverse events.

205. Consent for release of information:

Should the assessment result in the generation of a report to be sent externally (i.e. outside of BCEHP and the ABR centre), consent for release of information should be signed by the child’s parent or guardian, and should be documented in the patient/client’s chart. Site-specific procedures and documents will be in place, and should be followed.

206. Standard Reporting for ABR results:

For an ABR assessment where a formal report is sent externally (i.e. outside of BCEHP and the ABR centre), ABR results must include at least 2 of the 3 following measures:

1. nHL data
2. current correction factors
3. dBEHL (dB Estimated Hearing Level) data

The report must include both numerical ABR data, as well as a prose summary of results with interpretation of those results.

207. Archiving/Back-up of electronic data:

Electronic data, such as that generated by OAE and ABR testing, should be regularly backed up to a password-protected removable media such as a USB flashdisk or a CD and stored securely within the clinic. An alternative would be to backup the data up to the facility’s secure network server. This backup procedure should be carried out at least every 6 months (or every 50 clients, whichever comes first). This is an interim process; a province-wide guideline is in development and should be available by December 2012.
DX 300: Target Hearing Loss

301. BCEHP target hearing loss:

The BCEHP target hearing loss includes any PCHL for which there is reasonable evidence that it will compromise auditory communication development and speech perception, in the absence of intervention. Most PCHL includes a loss of sensitivity to sound, as reflected in audiometric thresholds. The target includes pure tone threshold elevation to a level equivalent in an adult to 30 dB HL or greater at any frequency in the range 500 Hz to 4000 Hz.

Currently, there is no compelling scientific evidence that lesser severities of loss merit address by public health programming, but that issue is the subject of much current research. Globally, some programs limit their targets to hearing levels that are 40 dB HL or greater in the better ear. Hearing loss is considered permanent by the BCEHP if it is genuinely irreversible, or if it is likely to be sustained for more than one year. This includes all sensorineural loss and most conductive loss that has a structural cause, such as canal atresia or middle-ear malformation.

It is considered appropriate to include children with unilateral PCHL because they are at risk for bilateral PCHL, and increased disability should the normal ear acquire a conductive disorder, even if transient, and such children require specific strategies to enhance hearing and/or communication development. Please refer to the “BCEHP Hearing Equipment Policy” for BCEHP eligibility for amplification in cases of unilateral or minimal hearing losses.

The BCEHP target includes the cluster of disorders commonly termed auditory Neuropathy Spectrum Disorder (ANSD). ANSD is included in the target because it may be present in up to 10% of infants with sensorineural PCHL and because, even if there is negligible loss of hearing sensitivity, there is likely to be a significant disorder of speech perception. There is also a significant risk for progressive loss of sensitivity to sound over time.

Currently, transient hearing loss such as threshold elevations due to middle-ear infection are not targeted by BCEHP and are the domain of the well-established, universal medical care system in BC. The BCEHP is NOT an alternative system for audiometric services in the context of active medical or surgical management of hearing loss.

In practice, the effective target hearing loss severity and frequency range for a Universal Newborn Hearing Screening (UNHS) program is dictated by the operating characteristics of the screening tests used. Automated Auditory Brainstem Response (AABR) screening is currently done using clicks. The click level is selected by BCEHP management and currently is equivalent to 35 dBnHL in an adult ear. That level may ultimately prove to be too high, given the target hearing loss definition. There are at least three factors that influence the severity of hearing loss that will be detected by such a screen: first, the effective SPL of any given click stimulus is greater on average in the infant ear canal than in the adult ear canal, by an amount that depends on frequency of stimulus energy, anatomical characteristics of the individual child, and the age of the child;
second, the presence of a clear and reproducible ABR implies that the stimulus is substantially supra-threshold, probably by at least 10 dB with conventional AABR techniques at low stimulus levels; and third, the click ABR threshold will typically reflect most closely the best pure tone sensitivity in the frequency range 500-4000 Hz, so children with hearing losses at low or very high frequencies or at isolated, specific frequencies may be missed.

Similarly, OAE screening typically addresses frequencies of 1000 Hz or 2000 Hz and higher, so hearing losses at 1000 Hz and below will be missed. Current BCEHP settings for OAE screening are recording at 2000, 3000 and 4000 Hz, with a mandatory pass rule at all 3 frequencies. Lower frequencies are impractical because of ambient noise levels. Higher frequencies may be recorded for cochlear status monitoring purposes.
Assessments will comply with all current guidelines and protocols issued by the BCEHP and relevant clinical guidelines provided by the College of Speech and Hearing Health Professionals of BC (CSHHPCBC). Updates to this protocol will be issued as required, and the current protocol includes all updates distributed at least one month before the date of assessment.

401. Deviations from Protocol

This protocol must be adhered to unless there is a clear contraindication in the individual case. Any deviation must be documented briefly with a note of the rationale. BCEHP reserves the right to review documentation and clinical records involving any departures from this protocol.

402. Medication Standards

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

403. History Taking

Obtaining a full case history is important for identifying those infants who are at risk for progressive hearing loss and, therefore, require ongoing audiological monitoring. In instances where PCHL is identified, it is an important source of information in investigating etiology.

At the time of screening, a case history is obtained to determine which infants carry risk factors for progressive loss and require follow-up audiology testing. However, not all risk factors may be evident at the time of screening. Therefore, a full case history including review of the risk factors in Appendix 9A: “Late Onset/Progressive Hearing Loss Risk Factors” and Appendix 9C: “Syndromes Commonly Associated with Hearing Loss in Children” should be obtained at the time of the first audiology assessment, with review of relevant factors at subsequent assessments.

Essential components of a case history include family history, perinatal history, maternal history, developmental history, otological history, previous screening/audiology results, current health of child, and parental concern. A sample, parent-friendly case history form is provided in Appendix 5: “History Form”. Included in the case history form are questions relating to what other agencies/professionals are involved in the child's health and development, for the purpose of reporting.

404. Types of Assessment

There are two basic types of assessment: ABR-based and behaviour-based. The latter may entail VRA or playaudiometry. ABR-based assessments are generally appropriate for infants under six months of age, or for older infants who, for reasons of development or co-morbidity, are deemed by the BCEHP audiologist to be unsuitable for behavioural audiometry. VRA-based assessment is usually
appropriate for infants over about six months of age. Play audiometry may be practical for children over about 24 months of age.

Each type of assessment may be of two sub-types: initial or follow-up. The procedural specifications in this protocol apply to both sub-types, but the selection of tests and the direction of testing effort in the context of follow-up are at the discretion of the audiologist. For initial assessments under the BCEHP, the full complement of tests is mandatory.

405. Assessment Components

Wherever feasible, the initial ABR-based assessment will include the following procedures, in BOTH ears regardless of screening outcome (i.e., test both ears even if only one ear referred on hearing screening).

- Tone pip ABR threshold estimation by air conduction (AC) at 2000 Hz and 500 Hz, and where specified by this protocol, 4000 Hz and 1000 Hz. Insert earphones will be used for all AC measurements, except where specifically contraindicated. Ipsilateral (“notched noise”) masking will not be applied.

- Tone pip ABR by bone conduction (BC) at the minimum “normal” levels, where specified by this protocol, at 2000 Hz and, where indicated and feasible, at 500 Hz. Actual BC thresholds (for 2000 Hz, and 500 Hz where specified) up to and including no response at BC maximum levels are required when a BC response is not present at the minimum normal level.

- In special circumstances, where specified by this protocol: high-intensity click-ABR sub-protocol for ANSD/neurologic disorder, including cochlear microphonic potentials and stimulus artifact analysis (i.e., clamped-tube).

- Cursory otoscopy.

- OAE amplitude and noise floor measurements at 2000 Hz through 4000 Hz.

- Middle-Ear Analysis, which will include admittance tympanometry using a probe frequency of 1000 Hz in infants under six months corrected age and 226 Hz in children aged six months or greater, and ipsilateral middle-ear muscle reflex testing using a broadband noise eliciting stimulus with a probe frequency of 1000 Hz.

406. Timing of Initial Assessments

Most initial assessments will be ABR-based and the candidates will be infants with refer results either from a two-stage AABR screening in neonates at risk for PCHL, or in the case of neonates not at risk, from an AOAE-AABR-two-stage screening sequence. Please see Appendix 9A: “Late Onset/Progressive Hearing Loss Risk Factors” and Appendix 9C: “Syndromes Commonly Associated with Hearing Loss in Children”.

Where not medically contra-indicated, initial assessments of infants referred from BCEHP screening will be targeted at a corrected age of 4-8 weeks (relative to a 40-week term).
This may cause an interval of one month or more between the screening Refer and the assessment, especially for premature infants discharged promptly from the NICU.

For Well Babies, who will have received a post-discharge AABR re-screen, the interval is typically less than two months. For NICU graduates after extended hospital stays, the initial assessment will be targeted within 4 weeks of discharge home, subject to appropriate health status. Infants meeting risk criteria as per Appendix 9A and 9C, who pass screening, will be scheduled for follow up, typically between ages 9 to 12 months.

Follow-up assessments in children with the target PCHL may be done by the behavioural assessment type deemed by the BCEHP audiologist to be appropriate.

For any infant with a meningitis risk indicator, the initial assessment is indicated as soon as possible after recovery, if there is a referral into BCEHP. BCEHP Screening prior to full assessment is not appropriate. Local special, non-BCEHP, fast-track protocols for follow up of meningitis may be in place. For the recommended BCEHP follow up schedule for meningitis please refer to Appendix 18.
501. **ABR and ASSR**

Objective, physiologic measures are necessary for the audiologic assessment for all younger infants (i.e., under six months of age) and some older infants. Tone pip ABR (AC and BC) is the method of choice for estimating the hearing thresholds in young infants and it is specifically recommended by the US Joint Committee on Infant Hearing (2007).

There is reasonable evidence from meta-analysis that, given appropriate test protocols, tone pip ABR thresholds by air conduction can predict conventional audiometric thresholds with reasonable accuracy (typically within about 10 dB) for a wide variety of hearing losses in adults and children (Stapells, 2000; 2011). Thus, in most cases, tone pip ABR provides threshold information sufficient to fully inform communication development options, including amplification. If proper ABR techniques are used, unless there are concerns about ABR reliability, it is inappropriate to defer initiation of communication development options, pending behavioural confirmation of threshold estimates.

Therefore, for BCEHP assessment, tone pip ABR is a required procedure for pure-tone threshold estimation in infants under six months of age. It is also strongly recommended for use in older children for whom VRA is deemed unfeasible or unreliable, or where VRA does not provide ear-specific and frequency-specific information to satisfy the audiometric objectives of the BCEHP. Testing under sedation may be necessary, especially in older infants.

ABR testing needs to be accurate. Errors in assessment can have serious consequences, and every possible effort must be made to avoid them. It is necessary to obtain and weigh all types of information that may assist valid and accurate assessment. Major errors have been reported in infant assessments, the most common source of which is related to incorrect judgements about ABR presence or absence, and especially to misinterpretation of ABR absence.

Accordingly, ABR threshold estimation methods must be of the highest possible quality: a multi-component approach to assessment is required, so that redundancy of information, such as an additional measure can provide cross-checks. Discrepancies among test results must be addressed by critical review of results and by further testing, wherever feasible.

Experience from the Ontario Infant Hearing Program (IHP) and, more recently, BC Children’s Hospital (BCCH), indicates that, in the presence of elevated AC tone pip ABR thresholds, the BC tone pip ABR (at the minimum BCEHP recommended stimulus) correctly indicates whether the elevation has a sensorineural component or is conductive in nature. In addition, BCCH research indicates an absent BC-ABR at the maximum BC level suggests the presence of a significant sensorineural component and an elevated BC-ABR threshold with a present response at an intensity above the minimum normal level suggests a sensorineural component in the mild/moderate range (Hatton, Janssen, & Stapells, 2012).
Currently, there is insufficient evidence to consider Auditory Steady-State Response (ASSR) as a standalone alternative to tone pip ABR. The popular viewpoint that ASSR provides more accurate threshold information for severe or profound hearing loss is considered to be unproven and potentially invalid. ASSR, however, may be used as the initial check of normal versus elevated air-conduction thresholds (Stapells, 2011). Currently, BCEHP has approved a trial of ASSR for this purpose at BCCH. Thus, instead of starting with air-conduction tone pip ABR 2000 Hz at 30dBnHL, BCCH currently starts with multiple-ASSR (AC, both ears, 4 frequencies, “normal intensities”) to check if any air-conduction thresholds are elevated. If any air-conduction ASSR results are elevated, testing is immediately switched to AC/BC tone-pip ABR. ASSR continues to be under active evidence review and experimental evaluation by University of British Columbia (UBC) researchers (e.g., Van Maanen & Stapells, 2010) as well as by others (see Stapells, 2011 for review). BCEHP will continue to review this evidence and introduce changes when/if appropriate. Assuming results are positive, as appropriate data are gathered worldwide, it is possible that ASSR-based protocols will be considered in future revisions of these BCEHP protocols. Currently, tone pip ABR must be used to estimate elevated behavioural thresholds.

502. Natural Sleep

ABR testing will be attempted first – and where feasible, OAE testing after ABR – during natural sleep, unless testing under sedation is specifically indicated. Exceptions that may merit initial assessment under sedation include prior failure by a BCEHP audiologist to obtain adequate results in natural sleep, and long-distance family travel to the assessment.

503. Infant Pre-Test State

For assessments in natural sleep, every reasonable effort will be made to ensure that the infant arrives for testing in an appropriate state. It is recommended that the infant be tired (but not overtired) and hungry on arrival. From a risk management standpoint, families who drive to assessments will be STRONGLY encouraged to be accompanied by a third party who will manage the infant. The potential futility of attempting assessment in an inappropriately prepared infant will be stressed.

The infant’s behavioural state upon arrival for assessment is important for successful testing in natural sleep. The family should be made fully aware of the importance of appropriate preparation for testing, and should be given detailed instructions on what and what not to do. Written instructions and telephone confirmation are recommended (see Appendix 6: “ABR Test Instructions for Parents”). The importance of preparation increases with age, due to a decrease in the amount of the infant’s daytime sleep. Wherever possible, the infant should arrive at the test tired and hungry. It is normally appropriate to deny sleep and food for at least an hour before testing, where not medically contraindicated. If the child is being brought to the test by car, it is important that every reasonable effort be made (consistent with safety) to keep the child awake on the journey. Because of the soporific effect of car journeys on infants, another person in addition to the driver is usually necessary.
Upon arrival at the assessment, it is recommended that cursory otoscopy be done, the electrodes be attached and then the infant be fed, before attempting to induce sleep. MEA testing may be practical shortly after feeding. OAE testing may be attempted before the ABR, at the audiologist’s discretion; however, more typically, test priority indicates beginning first with tone pip ABR (see below).

### 504. Order of Tests

Except for the initial otoscopy, the order of procedures is discretionary. The order of testing should proceed on the basis of the principle of obtaining the most important/most useful (for determining hearing levels, management and parental information purposes) information first, the next most important next, etc. The sequence-of-testing within a procedure (e.g., within ABR assessment) should follow the same underlying principle; thus, most infants would undergo the same sequence. See below for discussion of options and rationale.

ABR testing is the core of the assessment for young infants, but OAE and MEA components are also mandatory if ABR results indicate hearing loss; thus, the first strategic question relates to test order. This is a matter for local discretion, and the best order may vary across infants. As indicated above, a general principle is that one should first obtain results that provide the most important information.

Points in favour of OAE testing first, if behavioural conditions permit, are that it may be difficult to obtain a successful OAE test after the child has woken up from the ABR; that having the OAE result immediately informs the tester about possible ANSD, should an absent or abnormal ABR be seen, and this may alter the ABR testing; the OAE attempt may remove canal debris and/or improve canal patency.

It can also be argued that MEA results can inform the ABR test as well as improve canal status. However, there are a number of counter arguments that favour starting with ABR:

- **ABR is the core procedure**, and since doing these other tests up front may irritate the child or consume valuable sleep time, ABR success may be compromised. This may be a more significant issue for older infants or those who are inherently irritable or disinclined to sleep.
- **OAE and MEA tests do not provide threshold information**, and, in many cases, OAE and/or MEA are non-contributory; whereas, **reliable ABR results are always contributory**. For example, the presence of a flat tympanogram and/or absent OAE cannot indicate the presence of a clinically significant hearing loss, as both may occur with only a 5-dB conductive loss. In contrast, an absent ABR at 30dBnHL indicates a threshold elevation. Only when MEA or OAE results are present and normal, do they provide information. Even when normal, interpretation difficulties with MEA and OAE results can occur due to immaturity or the presence of ANSD. Presence or absence of ABR at minimum levels is always informative.

From the above discussion, two conclusions can be reached: (i) if an infant is sleepy or already sleeping, testing should begin with tone pip ABR, and (ii) if the infant is clearly awake, which test to begin with is up to local discretion, although beginning with tone pip ABR is usually preferred.
505. Sedation

Assessments under sedation will comply with generally accepted standards of care and all local risk management protocols. The BCEHP strongly recommends written, informed consent, medical referral and specification of sedative and dosage, administration by medical/nursing staff, appropriate supervision of the child post-medication, and adequate access to emergency services.

Extensive experience from Ontario and from British Columbia indicates that under about 5 months of age, tone pip ABR testing can almost always be done satisfactorily with the baby in natural sleep. For example, in over 20 years of experience with tone pip ABR in infants at Toronto’s Mount Sinai Hospital, with over 10,000 infant ABR assessments, the rate of sedation requirement is less than 2%. Appropriate training, test protocols and infant management methods are necessary and sufficient. Appropriate and effective instruction to families about pre-test preparation is crucial. Family members routinely underestimate their babies’ inclinations to sleep and adopt inappropriate strategies if involved in the test. Routinely resorting to sedation or general anaesthesia in infants under six months’ corrected age is not recommended, and is largely unnecessary given adequate skills at sleep induction.

Testing under sedation may be necessary in infants for whom acceptable behaviour and EEG conditions cannot otherwise be obtained. Usually, at least one attempt to test in natural sleep would have failed before resorting to sedation. It is reasonable to consider fairly routine use of sedation in children older than 5-6 months or for children who have to travel long distances for assessment, because it is especially important to have a reasonable assurance of success. BCCH routinely uses sedation in infants older than 6 months of age.

The audiologist determines that sedation is indicated on audiometric grounds; whereas, the family, in consultation with the audiologist and appropriate physicians and nurses determines whether sedation will actually occur. The infant’s paediatrician or family physician would normally be involved, as he or she may have unique knowledge of contraindications or risk indicators in the client’s history. Where specific centres have established high-quality protocols, they should take precedence. Documented, informed consent would normally be required.

If sedation is indicated, and the parent consents, a physician should prescribe the sedative agent (usually oral chloral hydrate). Appropriate risk management procedures to guard against rare, adverse events such as respiratory depression should be in place. While there is wide variation in practices for sedation, the BCEHP strongly recommends a conservative standard of care. Testing under sedation should normally be done under medical order and, preferably, with medical or nursing supervision of the infant from the time of administration through to the end of the indicated recovery period. Immediate access to respiratory support and emergency services is appropriate, but local safety protocols are the determining factor of what is required in a given test setting.

In a few infants, especially those with neurological and/or behavioural disorders, the response to sedation may be paradoxical activation. This has been addressed in various ways: by increasing the dosage of the sedative, by using alternative medications, or by resorting to light, general anaesthesia. The
indications for these procedures are a matter for local risk management protocols and standards of care.

Whereas testing under sedation is generally easier than under natural sleep, not all BCEHP audiologists will have access to the required medical coverage. The decision whether or not to accommodate testing under sedation rests with the individual audiologist. Where necessary, cross-referral to another BCEHP audiologist who has a sedation practice may occur.

506. Otoscopy & Cerumen/Debris

Detailed otoscopy and TM visualization can be difficult in the young infant and are, therefore, the domain of the experienced physician, but it is recommended that the audiologist conduct at least a cursory otoscopic examination at the outset of the assessment. Its main purpose is to detect foreign bodies, canal occlusion and any physical condition of the ear that indicates referral to a physician under standard red flags.

The ear canals of young infants frequently contain varying amounts of debris and/or cerumen. Hearing testing remains viable unless the canal is completely occluded acoustically, but total acoustical occlusion is difficult to determine visually. If the canal appears totally occluded, which is infrequent, or if there is a foreign body or evidence of acute infection, then referral for management by an experienced physician is mandatory.

In the absence of a red flag condition, the decision to undertake testing with insert phones, when there is partial occlusion by debris or cerumen, is at the discretion of the audiologist. If the results of such testing are not normal, removal and replacement of the ear tip often gives improved results and may remove significant debris or cerumen. Supra-aural earphones are an option, with the caveats noted below. Bone-conduction testing is an option, but a return visit for AC testing would be required after cerumen removal in both cases.

If the behavioural state of the infant is appropriate, initial MEA and/or OAE testing may improve canal status for ABR testing, by inflating a collapsed canal or by partial removal of occluding material when the ear tip is withdrawn.

507. ABR Stimulus Transducers

ABR measurements by air-conduction (AC) will be done using insert earphones, except where specifically contraindicated (e.g., ear-canal atresia), in which case supra-aural earphones (TDH/MX41) will be used. Bone-conduction (BC) ABR testing will be done with careful placement supero-posterior to the canal opening of the individual test ear. The BC transducer will be secured firmly in place, either by a custom Velcro band or by hand-holding by an individual specifically trained in this procedure (Small, Hatton & Stapells, 2007). Application force measurements are not required. All BCEHP ABR sites will be equipped with insert and supra-aural earphones and B-71 bone transducer.

Pediatric-sized foam ear tips, often cut down in thickness (not in length) to size for a young infant, are preferred over supra-aural headphones. Insert phones have several advantages over supra-aural earphones, including reduced stimulus artifact, decreased background noise, less acoustic cross-over, decreased likelihood of collapsed canals, and increased comfort. Under typical
situations, an infant undergoing ABR assessment will have insert earphones inserted into both ear canals simultaneously. Experience has shown that this is possible for most (80-90%) infants; a parent may hold the infant during testing or the infant may lie supine. This allows efficient switching between ears. Use of impedance probe-tip adaptors often does not allow for insert phones to be inserted in both ears, and they are very prone to falling out. Thus, under typical situations, impedance probe-tip adaptors should not be used.

Supra-aural earphones (TDH/MX type) are more bulky, are more restrictive in terms of infant position, and require more skill and attention to maintain proper placement. Conducting the test and applying a supra-aural earphone without assistance may be difficult for the audiologist; whereas, a single tester can usually implement the test with insert earphones. It is not recommended that family members hold supra-aural earphones.

Supra-aural earphones must be used when insert phones are contraindicated, such as when the ear canals are very small or highly stenotic, or when the infant does not tolerate an insert earphone. Careful attention to accurate, axial placement of a TDH earphone and avoidance of canal collapse by excessive pressure, are especially important to ensure appropriate stimulus levels.

Tone pip ABR measures by bone conduction (BC) are required to indicate presence of conductive and sensorineural hearing loss, and possibly to quantify these components. In contrast to adult testing, in the infant, intra-cranial transmission losses are sufficiently large that each ear MUST be tested individually, that is, it should not be assumed that a given mastoid placement stimulates both cochleae equally.

Accurate BC ABR tests require proper placement (supero-posterior to the meatal opening) and stable retention of the transducer, with adequate contact force (at least 400 grams). To achieve proper force and stability of the bone oscillator, the BCEHP audiologist may either use a band of elastic fabric with Velcro attachments or, with training, use hand-holding.

Velcro bands are simple to construct. The width of material should be sufficient to envelop the transducer and hold it securely in place. The reported need for quantitative measurements to ensure adequate application force is questionable. At present, application force measurements are NOT required, provided that the band is applied correctly and with moderate tension. Bands are available commercially for about $30: for example, “Design Veronique Universal Facial Band # 210”, from Nightingale Medical Supplies Ltd. (previously Keir/Pike Surgical), Vancouver, B.C. A disadvantage of the Velcro band is that placing it may awaken the infant.

Alternatively, the bone-conduction transducer may be hand-held firmly in place by an individual specifically trained in this procedure. Recent research at UBC (Small, Hatton & Stapells, 2007) as well as clinical experience has demonstrated that handholding, under controlled conditions, allows quick and effective screening of BC-ABR at minimum test level. Moreover, experience has shown that this method is less likely to awaken the infant compared to the elastic band. Provided the audiologist is seated comfortably next to the infant being tested, he/she performing the assessment can often hand-hold the transducer while testing. However, when BC-ABR results are complicated and/or the setup does
not allow this, either another individual trained in hand-holding or the use of the elastic headband will be required. It is not recommended that the transducer be held by an untrained individual. See Appendix 2 “BC Hand-held Transducer Instructions” for training recommendations.

The BCEHP audiologist must use his/her discretion as to which method – the Velcro band or hand-holding – is the most appropriate method for a given infant.

The metal bone-conductor band used in behavioural testing should not be used for BC-ABR testing as it is uncomfortable, easily slips off during testing, and does not provide sufficient or calibrated application force for young infants.

Insert earphones do not need to be removed for BC-ABR testing in infants aged 12 months or less. The occlusion effect is not present at 2000 Hz in adults. Recent research at UBC indicates that there is no occlusion effect: (i) at 2000 or 4000 Hz in young or older infants (Small, Hatton & Stapells, 2007; Small & Hu, 2011), and (ii) at 500 or 1000 Hz in young infants aged 12 months or less (Small, Hatton & Stapells, 2007; Small & Hu, 2011). In these infants, the insert earphones thus need not be removed during BC-ABR testing. However, there is a small occlusion effect at 500 and 1000 Hz in older infants (>12 mos), thus to be conservative, insert earphones should be removed if testing these frequencies in these older infants (Small & Hu, 2011).

508. Electrodes and Impedances

ABR recording electrodes will 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 will be made to obtain impedances of less than 3 kOhms for all electrodes, and impedance differences within each channel of less than 1 kOhm.

Use of four recording electrodes is required by the BCEHP. Site preparation using a mild abrasive is recommended. Excessive abrasion must be avoided. The non-inverting electrode is placed on the high forehead as close as possible to the hairline, and at or close to the midline. Inverting electrodes are placed on each mastoid area (as low as possible on the mastoid bone to reduce contamination by the post-auricular muscle response; also to be farther away from the bone-conduction transducer to reduce stimulus artifact), which allows two differential recording channels: forehead to L mastoid, and forehead to R mastoid. The common electrode is placed elsewhere on the forehead (e.g., lateral forehead), not within about 3 cm of the non-inverting electrode. Electrode wires should be led away from where the transducers (air or bone, but especially bone) are to be placed; electrode wires should be kept close together, short, and preferably braided to decrease 60-Hz artifact.

Use of a neck (C7 spinal) position for the inverting electrode is NOT appropriate. While such an electrode may yield larger ABR Wave V amplitudes, there is increased noise to offset that benefit, as well as loss of ipsilateral/contralateral waveform cues to stimulus laterality that are crucial for BC ABR.

Electrode impedances can have significant effects on EEG quality and, therefore, on successful testing. The impedance does not affect the ABR itself, but the larger the impedance, the larger the amount of pickup of external
electromagnetic interference and of artifacts from movement of the electrode leads. Every reasonable effort will be made to obtain impedances of less than 3 kOhms for all electrodes. Even more important is the symmetry of the two electrodes’ impedances for each differential pair. These should be as similar as is possible with reasonable effort. A difference of not more than 1 kOhm is a desirable target.

The effect of large impedance differences is to degrade the common-mode rejection ratio (CMRR) of the preamplifier, that is, to reduce its ability to block EEG noise components that are common to both electrode sites in a differential pair. The amount of reduction in CMRR increases almost proportionally with the impedance difference. The effect can be to have difficulty achieving a satisfactorily low level of EEG noise for ABR recording, despite the fact that the child appears quiet. Careful attention to electrode impedance asymmetry is required.

Given reasonable efforts to achieve satisfactorily low and symmetrical impedances, testing may proceed despite less than ideal conditions. The audiologist should document the impedance values and be alert to the possible need for larger averages and more frequent replication of records, should EEG conditions require it.

### 509. Recording Channels

For AC measurements, the channel ipsilateral to the stimulated ear will be evaluated and plotted. For BC measurements, two-channel recording is mandatory, and both ipsilateral and contralateral channels will be evaluated and plotted.

The four recording electrodes allow two EEG amplification channels, ipsilateral and contralateral to the stimulated ear. For AC stimuli, only ipsilateral EEG recordings are normally obtained, as the contralateral channel has limited value. However, it is sometimes helpful to record both ipsilateral and contralateral channels for AC stimuli to (i) help identify errors of stimulated ear selection, and (ii) to view ipsilateral/contralateral response asymmetries (see below) when a significant interaural threshold asymmetry is suspected.

When stimulating by bone conduction, the two EEG channels are necessary in order to resolve the responding cochlea; overall, ABR waveform morphology is better, with wave V earlier and generally larger in the channel ipsilateral to the responding cochlea. This approach avoids several practical difficulties and unsolved questions related to contralateral masking of BC ABRs in infants.

### 510. Tone pip ABR Measurement Parameters

All ABR testing will be conducted using the technical parameters detailed in Appendix 3: “ABR Technical Details”. Tone pip ABR threshold estimates will be obtained according to the specifications below, in each ear.

Specific, mandatory recording parameters for the various components of ABR testing are given in Appendix 3. The bandwidth must be appropriate relative to the frequency spectrum of the ABR waveforms of interest. Optimal high-pass cut-off frequencies for ABR threshold estimation are lower than that typically used for otoneurological ABR testing. The analysis window must be long enough to
encompass the target response, so it must be greater for near-threshold recording, especially for 500 Hz stimuli. For threshold estimation the stimulus repetition rate should also be as fast as possible, given a required analysis window length, because Wave V is relatively unaffected by high repetition rates, which yield more averaging per unit test time.

The required values for the ABR test components are set up in parameter ("setup") files that will be supplied to audiologists conducting BCEHP assessments. These files will be updated from time to time, as the need for enhancements to the test protocols is determined. Because all BCEHP assessments must be conducted under standard parameter conditions, local changes to test parameters are not permitted for BCEHP assessments. Audiologists are at liberty to use any parameters they see fit for non-BCEHP measurements, provided that those parameters are set up in non-BCEHP parameter files. Caution is required because the number of protocol files distributed by the BCEHP may increase over time, and distributed parameter files will overwrite local files.

The technical parameters in Appendix 3 are tightly coupled to BCEHP calibration values and to threshold norms derived by critical review and meta-analysis of published data. Because the parameter selections are strictly based on high-quality evidence, they may differ from popular recommendations. An example of this is the use of alternating tone pip polarity. Recent claims in the literature against the use of alternating tone pip polarity are unsubstantiated; indeed, the bulk of the literature supports alternating polarity.

Although the frequency-specificity of tone pip ABR threshold estimates may be improved slightly by an ipsilateral masking method such as notch-noise masking, the likelihood of clinically significant errors in threshold estimation, if such masking is not used, is small. It is also possible that response depression due to physiologic masking spread (both basal and apical) may occur at high stimulus levels. While the judicious use of such masking may improve results in a few cases, there are additional concerns regarding technical aspects, test complexity and consistency across British Columbia. Therefore, the use of ipsilateral notched masking noise is not recommended within the BCEHP protocol.

511. Averaging & ABR Detection

Except in special circumstances (see below), determination of response, which is present in the BCEHP protocol, requires visual observation of the replicability of waveforms by the BCEHP audiologist performing the assessment. Any threshold or minimum response level determination requires replication of responses at the threshold level and replications of “No Response” waveforms at the level below any elevated threshold (i.e., replications typically 10 dB below threshold level, except if the threshold is greater than 70dBNHL, where a final step size of 5 dB may be employed). Typically, each replication will have at least 2000 trials in each average, although averaging may be stopped early if waveform residual noise levels (see below) reach criterion levels and the waveforms are visually quiet (i.e., flat).

Although visual observation of replicability of waveforms remains the primary BCEHP method of determining response presence or absence, online measures
of residual noise (RN) and signal-to-noise ratio (SNR) supplement visual interpretation and are mandatory in specific circumstances.

BC EHP use of RN and SNR measures to supplement visual observation:

- **Determination of No Response (NR):** The overall average of all replications must show an RN of less than or equal to 0.08µV. In addition to this requirement, the average waveform must be visually quiet/flat when displayed using an appropriate scale. If the waveforms do not satisfy both of these criteria, a determination of Could Not Evaluate (CNE) must be made.

- **Determination of Response Present:** An overall SNR for the averaged waveform of all replications of 1.0 or greater likely indicates a response present. However, determination of response present requires visual replicability and sometimes a clearly replicable response shows an SNR of less than 1.0. See below.

- **When to stop averaging for a single replication:** RN or SNR criteria may be used to determine whether or not to stop averaging before 2000 trials are reached.
  - Averaging responses reduces the RN value by the square root of the number of trials averaged. Thus, if the RN of a single replication is 0.11µV or less, then averaging two or more of these replications will usually result in an overall averaged RN value of 0.08µV or less. Thus, averaging could be stopped at RN equals 0.11µV for an individual replication. However, a minimum of 1000 trials must always be obtained for each waveform.
  - Similarly, if SNR is 1.0 or greater, averaging may be stopped and a second (or third) replication initiated (keeping in mind the minimum of 1000 trials per waveform).

- **Visual versus Online measures:** Visual observation of replicated waveforms takes priority over online measures, with the one exception that one must have an RN of the overall average waveform of .08 µV or less to conclude “No Response”.

**Visual Observation of Waveforms**

Accurate and reliable judgement of response presence or absence and waveform noise is the key to ABR threshold estimation. For a useful discussion of good practices and sources of error, see Stapells (2011).

**EEG Conditions:** The ability to judge when EEG conditions are acceptable is extremely important in ABR threshold estimation – far more important than it is in otoneurological ABR measurements. In threshold work, there is a natural tendency to attempt to make response detection judgements and derive threshold estimates even under adverse EEG conditions. This must be resisted. For tone pip ABR threshold testing, EEG conditions MUST be satisfactory, or the results will be incorrect, and a significant clinical interpretive error may follow. BCEHP clinicians should observe the ongoing EEG regularly during testing. It is far better to suspend judgement than to make such an error. If the cause of the adverse EEG conditions cannot be rectified, then the ABR test should be aborted.
and rescheduled with appropriate attention to the causes of the poor EEG conditions. It may be necessary to resort to testing under sedation, in these circumstances.

Online measures of waveform residual noise remove some of the past subjectivity in judgements regarding EEG quality; nevertheless, there remains an important subjective aspect in judging EEG quality and response reliability. Moreover, determination of response presence/absence continues to require subjective, albeit skilled, judgement, which is a matter of training, experience and individual skill.

**Number of Sweeps Averaged:** Response detection judgements depend on appropriate averaging strategies, effective methods of interpreting averages, and the ability to decide whether the EEG conditions permit useful decision-making. In the past, a set number of sweeps per replication was required (typically 2000 sweeps) regardless of whether or not the results were quiet or noisy. However, modern techniques of recording and analysis, in particular measures of waveform residual noise and signal-to-noise ratio (SNR), allow for more flexibility in averaging stopping rules (i.e., how many trials should be averaged). As noted above, the **online measure of waveform residual noise (RN) and signal-to-noise ratio (SNR)** on the BCEHP ABR equipment (IHS Smart-EP) helps us to determine when enough trials/replications have been obtained, especially if no clear response is present.

Stopping rules for averaging: although continuation of averaging until waveform residual noise reaches criterion levels would seem to be a good strategy whether the response is deemed present or absent, this is not an efficient strategy. Often, a large and clear Wave V, for example, may be seen well before noise criterion is reached. Thus, the requirement to reach noise criterion applies only to determination of “no response”. Determination of the presence of responses, and the number of trials/replications required to make this determination must be made by the BCEHP audiologist. However, the residual noise level can aid in determining when a response is likely significantly greater (i.e., 3.2 - 4x) than the noise and, thus, when averaging may be stopped and a second (or third) replication initiated.

The routine use of larger numbers of sweeps, more than about 4,000 per replication, is discouraged because it is inefficient, due to the law of diminishing returns within averaging. For example, to double the response to noise ratio in an average of 4,000 sweeps would take 16,000 sweeps. Additionally, in order to decrease the likelihood of erroneously accepting a non-response as “Present”, averages of fewer than 1000 trials are strongly discouraged. Furthermore, in the interest of averaging efficiency, averages of greater than 10,000 trials (across all replications) are also discouraged.

**Number of Replications:** A minimum of two replications (usually with about 2000 accepted sweeps each) for any given stimulus condition is required. In cases of any uncertainty, further replication is strongly recommended (Stapells, 2011).

The use of more than four or five replications for a given stimulus condition should not be routine. It would be unusual if more than four or five replications are required often over many infants, and is likely indicative of a problem. In general, rather than doing more replications (assuming these have met RN noise
criteria), it is more effective to increase the stimulus level, where feasible, given persistent uncertainty about the response. However, in select circumstances, if there is no response or a very small response, more replications may be required to either meet the RN and “visually quiet” criterion for no response determination or to verify the presence of a very small response.

Replication of waveforms is not required under the following special circumstances:

- the waveform is well below the threshold, is below the 0.08µV noise criterion, is flat, and shows no suggestion of expected waveform: this may then be determined as “No Response,” provided it is not at the level bracketing threshold (i.e., not at level immediately below threshold);

- the waveform above the threshold shows a clear response, provided the response is typical/expected for the condition and has a peak-to-peak amplitude that is at least two times (2x) the residual noise (RN) amplitude, and/or the IHS Smart-EP (SN) measure is at least 1.0. Importantly, this non-replicated response must not be at the threshold, as BCEHP protocols require that any threshold determination involve demonstration of visual replication of waveforms.

To reiterate: a single replication will NOT be used in the final bracketing of the estimated ABR threshold. The ABR threshold is defined by a response-positive pair of replications at some level, and a response negative pair of replications at 10 dB, or in some cases 5 dB, below that level.

Response Interpretation: The interpretation of replicated waveforms itself relies on four main cues: the occurrence of a response-like waveform at a grossly reasonable latency, the prominence of that feature relative to the fluctuations in the remainder of the average (a sort of signal-to-noise ratio), the reproducibility of the feature across averages (a better measure of signal-to-noise ratio), and, with online measures of waveform residual noise, comparison of the peak-to-peak amplitude of the supposed response to the residual noise level (e.g., wave V-V’ peak-to-peak amplitude should be 2 times the size of the I.H.S. residual noise measure). During averaging, observation of a relative lack of change in the supposed response compared to decreasing noisiness of the overall waveform is also suggestive of a true response.

The morphology of the ABR to tone pips is very different from that seen in otoneurological ABR testing with click stimuli. The waveform changes are most marked near threshold. Typically, the earlier waves of the ABR are absent, and the response is a slow and late V-V’ negative-going transition. There may be no Wave V at all, but only a negative V’ peak. There may also be a positive-going deflection following V’, at the end of the analysis interval. The tone pip response at 2000 Hz usually shows a V Wave that is more clearly defined and sharper than at 500 Hz, and the 4000 Hz response can be quite similar to conventional click responses. In a normal ABR, earlier waveforms (e.g. Wave I, III) may be seen at BCEHP minimum response levels.

In general, the putative response should be larger than any other physiologic fluctuation in the average. It should also demonstrate marked similarity across averages, and the level of similarity in the putative response region should be
greater than elsewhere in the averages. Typically, for a response to be present, its peak-to-peak amplitude should be 3-4 times the average difference between replications in the 5-10-ms window around the response. Alternatively, it should be 2 times the estimate of the residual noise level provided online by the I.H.S. equipment. Furthermore, if a response is genuine, it will tend to remain relatively constant over the course of averaging. For this reason, very close monitoring of the increasing clarity of the putative response is necessary. Waveforms that develop suddenly at any point during the course of averaging should be regarded with suspicion. In contrast, genuine responses can be rapidly obscured by small numbers of high-noise sweeps; this may happen frequently if the gain is insufficient relative to the artifact reject level.

With regard to latency, in the assessment context, the range of possible latency is so broad that using specific targets for latency is unhelpful (i.e., we do not determine “normality” of response latency for tone pip ABR).

**ABR threshold:** The ABR threshold is defined as the lowest level giving replicated response-positive records, either at the BCEHP minimum required level or with replicated response-negative records at a level not more than 10 dB lower than the elevated threshold. If such a procedure yields an ABR threshold of greater than 70 dBnHL, use of a 5 dB final step is recommended (but not required), because increased precision may be clinically useful with limited residual dynamic range of hearing.

### 512. 60-Hz Artifact

Any ABR record may be contaminated by non-physiologic artifact, notably 60-Hz interference or radio-frequency (high frequency) interference that is partially phase-locked. This is more likely to occur with the lower high-pass cut-off frequencies used in tone pip ABR threshold measurement and sometimes interferes with response detectability. Given no adverse changes in the test environment (such as power cable routing or proximity), by far the most common cause of child-specific 60-Hz artifact is asymmetry of electrode impedances. Artifact management strategies are detailed in the protocol support text. Clamped-tube control recordings (insert earphone tube clamped) may be definitive in this context, to confirm 60-Hz artifact presence. Note: clamped-tube/no-sound control recordings cannot be used to determine the presence/absence of a response. In other words, clamped-tube only allows you to determine the presence of stimulus-locked non-physiologic artifact. Additionally, comparison of recordings with and without use of a 60-Hz notch filter will help confirm 60-Hz artifact presence versus a physiological response. This notch filter, however, must not be used for threshold determination. If a 60-Hz artifact is present, efforts must be made to reduce electrode impedance asymmetries as well as to reduce the source of the artifact (e.g., dimmer switches, fluorescent lights); 60-Hz artifact can often be unlocked from the averaging by slight changes in the repetition rate (e.g., 39.1/s vs 38.9/s) and analysis sweep time. If large, irreducible 60 Hz artifact is present, records are not interpretable for the presence or absence of a response. Consultation with BCEHP is recommended if artifact problems are persistent.

Electromagnetic artifact at 60-Hz is radiated from all power line sources that are not encased in a grounded metal enclosure, such as a metal conduit. The
amount of radiation depends on conductor geometry and current flow. The subject acts as an antenna and picks up small potentials induced by radiation from AC sources. The electrode leads also act as an antenna, and the induced potential in them will depend on their proximity to the source, their geometry – especially the subtended loop area – and their impedance. The amount of induced potential is directly proportional to the electrode impedance.

The amount of artifact picked up by a differential electrode pair especially depends on the impedance difference between the two electrodes and the subject’s scalp. The amplifier’s ability to reject induced voltages at the two electrodes (Common-Mode Rejection Ratio, CMRR) is drastically reduced by even minor asymmetries of impedance.

Power line artifact is manifested in the EEG record to an extent that depends on all these factors, as well as the recording bandwidth. Extension of the high-pass (low filter) filter cut-off to below 60-Hz will increase artifact dramatically, relative to typical recording bandwidths for otoneurological ABR (100 Hz). Current high-pass cut-offs for tone pip ABR are set at 30 Hz, in order to register the low-frequency components of the ABR, especially for 500-Hz stimuli at near-threshold levels.

There are two manoeuvres that will affect 60-Hz pickup in an average: one is the use of a notch filter designed to reject 60 Hz signal components; the other is the repetition rate of the averaging. Notch filters may cause dramatic waveform distortion; their use is not currently recommended in BCEHP recordings, although they are useful for confirming presence of 60-Hz artifact. An important parameter is that of the repetition rate of averaging which is generally selected such that 60-Hz tends to cancel out during the course of the average; for example, averaging at 60/s stimulus rate would result in phase-locking of 60-Hz and would be disastrous, as would averaging at 30/s. Averaging at other rates leads to a variable amount of 60-Hz suppression. One manoeuvre that may help reduce or eliminate 60-Hz artifact is to make a very small adjustment in the stimulus rate.

60-Hz pickup varies dramatically from subject to subject, and, provided that sources have been minimized, the most important factors are absolute and differential electrode impedance. 60-Hz manifests as a slow distortion of the trace, such that one approximately sinusoidal waveform is seen in about 17 ms of the window. The distortion may or may not be similar in its timing, across successive averages. Such distortion is a particular problem for 500-Hz ABR measurements, because of the low-frequency aspect of the responses to low-frequency stimuli.

At present, major 60-Hz interference renders ABR averages essentially uninterpretable. Tube-clamped (no-stimulus) control recordings (insert earphone tube clamped) may be definitive to confirm 60-Hz artifact presence in this context. Note: tube-clamped/no-sound control recordings cannot be used to determine presence/absence of a response. Comparison of recordings with and without use of a 60-Hz notch filter will help confirm 60-Hz artifact presence versus a physiologic response. In the event that such interference is only seen on one side, asymmetry of impedances for the high-artifact side is the probable cause.
BCEHP and Ontario are investigating last-resort strategies to deal with intractable 60-Hz artifact, but the current remedies are based on minimization of sources, pickup from electrode leads, and impedance adjustments. The danger in adopting band-aid solutions, such as changes in bandwidth or use of notch filters, is that the effects on the accuracy of ABR threshold estimates of using those remedies is currently unknown.

513. **Amplifier Gain & Artifact Rejection**

Amplifier gain will be set by the BCEHP. Gain (sensitivity) will not be changed if the EEG noise level increases/decreases during the test. Artifact rejection will never be disabled.

Amplifier gain must be set to a minimum of 100,000. A general recommendation is that the gain should be such that about 5-10% of sweeps are routinely rejected when the EEG is quiet. Operation in a manner in which the quiet EEG occupies only a small proportion of the amplitude range within the rejection limits is highly undesirable, because it results in negligible protection against substantial artifacts.

Any infant may manifest high-amplitude myogenic bursts during a period of otherwise quiet EEG. Artifact reject systems, even if set as just indicated, do not provide complete protection against such bursts, which may rapidly distort an otherwise clean average. Such bursts are preceded and followed by a few sweeps of high-amplitude activity that may not reach artifact rejection levels. Careful and continuous monitoring of the ongoing EEG is essential through averaging; EEG amplitude increase should trigger immediate interruption of the averaging, which should then be resumed after a quiet EEG is re-established.

Should the infant’s EEG deteriorate substantially during the test, the amplifier gain should NOT be reduced, because that will simply admit more noise into the average. The reason for increase in myogenic noise levels must be dealt with at the source. Actions include quieting the child, checking electrode impedances, or simply waiting for the child to settle. It is strongly emphasized that if none of these actions is successful, the ABR test must be terminated, because useful ABR threshold estimates simply cannot be obtained in the presence of active EEG. **No result at all is preferable to an incorrect interpretation based on noisy and unreplicable averages.**

Under no circumstances should the artifact reject be disabled in order to permit averaging under poor EEG conditions.

Infants may manifest EEGs with high myogenic levels even if they appear to be resting quietly or sleeping. It is the EEG activity that determines whether it is worthwhile to commence or continue averaging, not the child’s overt behaviour.

514. **Strategy of Stimulus Frequency & Route, and Ear**

Strategy is multi-factorial and in part discretionary, subject to the specifications below. The special importance of results at 2000 Hz is emphasized, and testing normally begins at this frequency. See the support text for a discussion of key considerations.
The frequencies at which tone pip ABR testing by AC will be done, at a minimum, include 500 Hz and 2000 Hz. These frequencies are important generally, and with particular regard to prescription of amplification.

If there is severe or profound loss at 2000 Hz, 500 Hz is a key measure of residual low-frequency hearing. If reliable thresholds have been obtained at 500 and 2000 Hz, the clinical utility of measurements at 1000 Hz depends on the difference between 500 Hz and 2000 Hz thresholds. If the threshold difference in dBnHL values is 20 dB or less, subsequent clinical interpolation of the 1000 Hz threshold as the average value will rarely be seriously in error; however, such interpolation should NOT be entered as an actual test finding. If the difference in dBnHL thresholds at 500 Hz and 2000 Hz is greater than 20, then threshold measurement at 1000 Hz is mandatory, with the exception of a finding of a substantial conductive component at 500 Hz. In that case, AC thresholds may change with time or after medical management, so a detailed audiogram is not justified.

In cases of responses at normal levels at 500 Hz and 2000 Hz, there should be a determined effort to obtained results at 4000 Hz. Although the 4000 Hz threshold carries only limited information for immediate management, it may be a risk indicator for progressive, high-frequency hearing loss and indicate a need for careful monitoring. If 500 Hz or 2000 Hz are elevated, 4000 Hz testing is mandatory.

This assessment protocol takes into account the epidemiologic and clinical characteristics of the presenting population. For example, data from screening programs suggest that the majority of infants who have referred from AABR screening will be determined at the assessment not to have the target PCHL. This is commonly due to a middle-ear disorder that has resolved since the screening referral, or to intrinsic screening errors. At the assessment, other infants are likely to have minor, conductive losses, possibly overlaid on the target PCHL. Accordingly, the protocol is structured to be efficient in such circumstances.

A general theme underlying the clinical strategies identified here is to constantly review the specific clinical information that is most important at any point throughout the course of a clinical assessment, and to implement the precise procedural step that will yield that information in a valid, accurate and efficient manner. This principle applies to the strategic selection and sequencing of stimulus frequencies and routes, as well as to the detailed tactics of level selection within individual frequencies and routes of stimulation.

In general, testing for most infants seen for BCEHP ABR Assessment aims to answer the following three questions, in order of priority:
1. Is an ear’s AC threshold elevated? Is the other ear’s AC threshold elevated?
2. If elevated, is the elevation conductive in nature or is there a sensorineural component?
3. If elevated, what are the specific AC (and BC) thresholds?
The first question is answered by testing each ear at the minimum level. It would not routinely involve a threshold search. If the baby wakes up at the end of this, the BCEHP clinician is still able to state whether one or both ears’ thresholds are elevated.

The second question is answered by BC testing of the ear(s) with AC elevation(s) at the minimum BC level. If the infant wakes up at the end of this stage, the BCEHP clinician is able to state that the elevation in AC threshold is conductive in nature or has a sensorineural, and thus PCHL, component. As the majority of BCEHP infants with elevated AC thresholds will turn out to have conductive losses, this procedure will most often quickly identify an infant’s elevation as conductive in nature, providing important information for subsequent management and for the parents.

The third question is answered by detailed determination of AC (and BC) thresholds. AC (and BC at 2000 Hz and 500 Hz where specified in protocol) thresholds for each required frequency are required for fitting of amplification (if chosen by the family). The above does not indicate the priority sequence of testing for stimulus frequencies. In general, greatest priority is given to 2000 Hz, and results for this frequency are normally obtained first. 500 Hz is usually next in priority, with 4000 Hz and, if required, 1000 Hz following. Prior information, history (e.g., ototoxic medications) and actual results obtained during the assessment may alter the relative priority of frequencies, but the above sequence should be appropriate for most infants requiring BCEHP ABR assessment.

Many infants presenting for assessment will have normal or near-normal hearing. The initial key question is whether the target hearing loss is present. The minimum required levels for definition of normal hearing in the BCEHP context are listed in Section 900 of this Protocol. In the absence of prior audiometric data, testing should start at 2000 Hz because it is clinically the most important single frequency. The choice of which ear to test initially should match the ear that “referred” AABR screening, as this would provide information regarding the ear of concern to parents and decrease worry. However, testing of both ears is required, and testing is considered incomplete until both ears done (i.e., a second appointment required). If the referral indicates bilateral difficulties, choose the ear of convenience. Use the AC route first, because it is overall hearing sensitivity that is important initially.

If the starting ear gives a clear and reproducible 2000 Hz AC response at the minimum required level, the key question now is whether the other ear is normal at 2000 Hz. Such ear switching requires an infant have insert earphones inserted into both ear canals simultaneously.

If no response is obtained for the initial 2000 Hz condition, then the strategic question is to what accuracy should the 2000 Hz threshold be resolved before changing frequency, or whether to determine the nature (conductive vs. sensorineural) of the elevation by changing the route of stimulation to bone conduction. Previously, common practice has been to determine the 2000 Hz AC threshold, before changing the frequency or route. However, if the elevation then proves to be conductive in nature, the specific level of the threshold is of little use, as it is usually a moving target (changing day to day). Appropriate management of the hearing loss and providing information to parents is important
and depends upon knowing the nature of the loss. Hence, bone-conduction testing likely becomes a higher priority than determining the air-conduction threshold.

In the past, many clinicians have been reluctant to move quickly to BC testing; fearing that placement of the BC transducer may arouse the child. The result has been the common practice of completing at least the 2000 Hz and 500 Hz thresholds before switching to BC. Unfortunately, in many cases this results in test sessions ending (when infants awaken) without any idea whether the loss is conductive or sensorineural in nature. However, clinical experience indicates that hand holding the BC transducer by an individual trained in the procedure allows for a quick, and relatively non-disruptive, check of bone-conduction hearing. Thus, in most cases, BCEHP protocol requires switching to BC early in the test sequence.

A number of other test sequences may be employed by clinicians which, in some circumstances, may be appropriate. For example, some clinicians switch ears and determine the 2000 Hz and 500 Hz AC thresholds bilaterally, before going to BC. Alternatively, some clinicians, upon finding a hearing loss in the initial ear, especially at 2000 Hz, emphasize definitive measurement of one ear by both AC and BC, before changing ears. However, the above test sequences do not reflect BCEHP protocol and should not be routine. For most infants, a priority of testing based on the three questions (elucidated in the box above) will result in the most efficient test sequence, proving which information is required in the next steps and for the parents. Recent research at BC Children’s Hospital indicates that considerable information can be obtained using the BCEHP protocol test sequence (Janssen, Usher, & Stapells, 2010).

There are many combinations of possible response outcomes, and many factors that will influence the precise choice of next stimulus condition in the individual case. These are at the discretion of the BCEHP audiologist, who is in a position to weigh all the factors. Usually, efficient strategies targeting key clinical information tend to involve more switching of ears and changing routes of stimulation. Clinical experience and judgment are required here, but it is stressed that previous “conventional” tactics may be inefficient, and practices that may be necessary in older infants may be inappropriate in infants under three months. Infants under about four months sleep more readily and with less dependence on position than older infants. At two months of age, the typical infant will preferably be tested lying supine. In that situation, changing ears and transducers is especially easy, although this is also quite feasible if testing were done in the caregiver’s arms.

Efficient testing strategies take into account probable patterns of hearing loss (Pittman & Stelmalchowicz, 2003) and implications of results for further action. A common example is the situation in which there is an early indication of a conductive component from MEA or from an air-bone gap, or both. In the absence of a known, structural abnormality, the most probable cause is otitis media. In that case, precise estimation of AC hearing thresholds over several frequencies may be unnecessary, because the hearing is likely to change over time or following medical intervention. An emphasis on reliable demonstration of a substantial conductive component and determination of BC thresholds seems a reasonable and sufficient approach. Precise quantification of the air-bone gap in
this situation may be an inefficient use of valuable program resources that could be directed more effectively, perhaps to re-assessment of infants with proven PCHL.

515. **Strategy for Stimulus Levels:**

The detailed tactics of selecting stimulus intensity levels have a large effect on overall test accuracy and efficiency. The most common cause of inefficiency is to use a step size that is too small, or to fail to make use of prior information in setting levels that will be close to threshold. The optimal result for any particular frequency and route of stimulation is to bracket the threshold with only two levels that are no more than 10 dB apart, in which case only two pairs of averages are needed to define the threshold. Skilled testers frequently can determine the threshold with only three pairs of averages, that is, by measurements at only three intensity levels. The more intensity levels required, the less efficient the strategy. An approach for selecting intensity levels that is generally efficient for the early stages of threshold estimation in the absence of prior knowledge is to approximately bisect the current range of intensities in which the threshold is believed to lie. Such a strategy yields important clinical information very quickly. For example, if there is clearly no response at 30 dBnHL, then an efficient next level is 60 dBnHL. This approximately bisects the current range of uncertainty about the location of the true threshold (30-90+), and is unlikely to disturb the infant. The outcome at 60 dBnHL is on average more efficient and informative clinically than an outcome at, say, 40 dBnHL would have been.

In the absence of prior information from previous BCEHP assessment that suggests otherwise, the most efficient intensity strategy starts at the lowest stimulus level required by the BCEHP for a given frequency and route of stimulation. This procedure is efficient, given that many initial assessments will reveal normal hearing.

Recordings at levels below the BCEHP minimum response levels are not generally required and should not be pursued. In special cases, such as baseline testing for ototoxic monitoring, testing at levels below the BCEHP minimum response levels may be helpful, but should only occur after BCEHP protocol has been completed.

If prior information about probable threshold is available, either from previous testing or from a threshold at some other test stimulus condition, then the starting level may be higher than the BCEHP minimum level. A **Refer result from a screening several days to weeks earlier is not sufficient information to begin at a higher stimulus level.**

For cases of no response at the minimal response level, ascent in steps of at least 20-30 dB and descent in 10 dB steps should be employed. Ascent by 5-10 dB will be avoided except in the rare situation of a questionable positive (replicated) response at the BCEHP minimum level for a given stimulus route and frequency. The descent step size may be varied, taking into account the size and clarity of any response-positive result. A 10-dB maximum separation of the contiguous response-positive and response-negative levels is generally acceptable. However, for thresholds that are likely to be greater than 70 dB, a final bracketing with 5 dB steps is **recommended**, because 5 dB may be important given very limited residual dynamic range of hearing.
The BCEHP protocol does NOT involve routine use of an intensity-latency (or intensity-amplitude) input-output function approach to threshold estimation, for which there is evidence of insufficient accuracy and reliability. Therefore, the general use of intensity series with small step size is specifically discouraged. The only situation in which a 10-dB ascent is likely to be generally efficient is that of questionable response presence at the BCEHP minimum level, given three replications averages at that level. An increase of 10 dB is then likely to be more efficient than further replication at the minimum level or testing with an ascent of 20-30 dB. Note, this applies to the situation where a response at the lowest level is possibly present. If clearly absent, it is not efficient to go up only 10 dB. Note, however, that the recommended test sequence should typically involve either switching to the other ear or obtaining bone-conduction results before testing higher intensities.

516. AC 2000 Hz

In the absence of prior BCEHP assessment results which indicate otherwise, testing will begin by AC at 30 dBnHL at 2000 Hz. Response or non-response at 30 dBnHL will normally be followed by testing the opposite ear in the same condition. If AC 2000 Hz is elevated, threshold bracketing will be done after BC assessment. Testing at AC 2000 Hz is a mandatory component of the initial assessment.

517. BC 2000 Hz

If there is no response to AC 2000 Hz in one or both ears (after testing both ears), then BC 2000 Hz at 30 dBnHL will be done in the ears with no AC response. Each ear should be tested at BC 2000 Hz if there is no response to AC 2000 Hz at 30 dBnHL for both ears. If BC 2000 Hz results are present at 30dBnHL, BC testing is usually considered complete. If no response to BC 2000 Hz is evident at 30dBnHL, BC 2000 Hz testing should proceed to the maximum stimulus level available (i.e., 60 dBnHL for BC 2000 Hz). If no BC response is seen at the maximum level, BC testing is complete. If a response is present, 2000 Hz BC threshold must be obtained. The decision to continue testing BC 2000 Hz at this point in time, or to defer BC 2000 Hz threshold determination until after AC threshold testing complete is left to the discretion of the audiologist. However, determination of actual BC 2000 Hz threshold (when BC elevated) is a mandatory component of this assessment protocol.

Recent research at BCCH indicate the BC ABR accurately indicates conductive vs SNHL status at 2000 Hz, as well as accurate indication of normal cochlear sensitivity vs mild/moderate SNHL (30-65dBHL) vs a more severe (>65dBHL) SNHL (Hatton, Janssen & Stapells, 2012).

518. AC 500 Hz

AC at a minimum of 35 dBnHL at 500 Hz. If there is no response (each ear), then threshold bracketing will be done after BC 500 Hz where indicated in this protocol. Testing at AC 500 Hz is a mandatory component of the initial assessment.
519. **BC 500 Hz**

BC at a minimum of 20 dBNHL 500 Hz is strongly recommended, where time permits, but is not mandatory if BC at 2000 Hz has been obtained. However, if the only AC abnormality is at 500 Hz, BC 500 Hz threshold is mandatory where the AC 500 Hz threshold is greater than 40 dBNHL in either ear. If BC 500 Hz is present at 20 dBNHL, BC testing is usually considered complete. If no response to BC 500 Hz is evident at 20dBNHL, BC 500 Hz testing should proceed to the maximum stimulus level available (i.e., 50 dBNHL for BC 500 Hz). If no BC response is seen at the maximum level, BC testing is complete. If a response is present, BC 500 Hz threshold must be obtained. The decision to continue testing BC 500 Hz at this point in time, or to defer threshold determination until after AC threshold testing complete is left to the discretion of the audiologist. However, determination of BC 500 Hz threshold (when BC elevated) is a mandatory component of this assessment protocol when AC 500 Hz only elevation.

Slight elevations of AC thresholds at 500 Hz do not trigger mandatory BC testing.

520. **BC at Other Frequencies**

BC testing will not be done at any frequency other than 500 Hz and 2000 Hz. Currently, BCEHP does not provide calibration values for other frequencies, and the current literature is not sufficient to support BC ABR testing at frequencies other than 500 Hz and 2000 Hz.

521. **AC 4000 Hz**

AC at a minimum of 25 dBNHL at 4000 Hz. If there is no response, threshold bracketing will be completed after AC 500 Hz and AC 2000 Hz testing. If both AC 500 Hz and AC 2000 Hz results are normal, AC 4000 Hz results are not mandatory; nevertheless, a determined effort should be made to obtain AC 4000 Hz results. Testing at AC 4000 Hz is mandatory if there are permanent threshold elevations at either AC 500 Hz or AC 2000 Hz. See Appendix 8: “Key Protocol Elements & Mandatory Components” for protocol details.

522. **BC Stimulus Artifact**

At higher BC stimulus levels (typically ≥40 dBNHL), 500 Hz stimulus artifact can be very large. This artifact is not normally a problem for response recording and interpretation. Using the IHS Smart-EP, BCEHP parameters are designed to (i) reduce rejection caused by stimulus artifact (by setting artifact rejection region after the stimulus), (ii) reduce artifact in the averaged response by using alternating polarity stimuli, and (iii) reduce contamination of objective measures (RN, SNR) by setting “SNR regions” to avoid stimulus artifact.

Uncancelled high-amplitude BC stimulus artifact can appear in the average records, especially at 500 Hz and at the highest stimulus levels available, which are typically 50 dBNHL for BC 500 Hz and 60 dBNHL for BC 2000 Hz. The IHS Smart-EP RN and SN response measures may be contaminated (and unreliable) when significant stimulus artifact is present (significant artifact also occurs with high-intensity AC stimuli, such as 100dBNHL stimuli). For this reason especially, alternating stimulus polarity must be used for BC stimuli. Even with alternating polarity, however, artifact is not entirely removed due to asymmetry of the BC transducer response with stimulus polarity inversion. For BC 500 Hz, the problem
is that such artifact can extend over a substantial region of the analysis epoch and can increase the difficulty of reliable ABR V-V' identification, because there is no useful EEG display prior to the putative response. Nevertheless, in the majority of cases, Wave V-V' remains identifiable. The amount of artifact and the difficulty caused by it vary dramatically from subject to subject, and the underlying factors are not fully understood.

Although BC 500 Hz stimulus artifact may occasionally make V-V' identification more difficult, there are other, more important problems with stimulus artifact. First, the large artifact may trigger the averager’s EEG artifact rejection – sometimes resulting in almost all trials being rejected. Modern ABR equipment such as the IHS Smart-EP have a feature that sets the artifact rejection region to ignore the stimulus portion of the EEG, removing this problem. Unfortunately not all ABR equipment has this important feature – when it is not available, the only option is to turn off the artifact rejection. An even larger problem is that BC 500 Hz stimulus artifact can (and does) contaminate the online residual noise levels, if correct SNR regions have not been set up prior to testing. See Appendix 3.

For BC 2000 Hz testing, uncancelled stimulus artifact may result in an early waveform that could be misinterpreted as “Wave I”. Evaluation of the rarefaction and condensation sub-averages, made possible using the IHS Smart-EP split buffer routine, will usually indicate that the “Wave I” is actually caused by asymmetric (and thus uncancelled) stimulus artifact. BCEHP clinicians must be careful to differentiate this artifact-created result from a real Wave I, which might indicate a neurologic or ANSD problem.

Special attention is required to the routing of BC transducer leads and electrode leads. The two types of leads should never be in contact, and the distance between them should be carefully maximized. The electrode leads should be routed away from the BC transducer as directly as possible, with the mastoid “inverting” electrodes low on the mastoids and their leads usually down the neck and away from the BC transducer and its lead.

If stimulus artifact problems persist, they are usually reduced dramatically by lowering the stimulus level by 5-10 dB, because artifact size is directly proportional to the stimulus driving voltage (artifact should be 50% lower with a 6-dB decrease in stimulus level). Furthermore, the amount of artifact pickup is likely to be directly proportional to the contact impedance of the mastoid electrodes.

523. BC Two-channel Recording

For BC ABR, simultaneous two-channel EEG recording (high forehead to ipsilateral and contralateral mastoids) and plotting is mandatory. It is essential that the mastoid corresponding to the channel labelling is interpreted correctly. For AC ABR, two-channel EEG recordings are not mandatory, but are recommended when significant AC threshold asymmetry exists between ears.

Two-channel EEG recordings must always be employed for BC testing. BCEHP ABR equipment setups will identify which ear was tested (i.e., BC transducer mastoid placement) and whether the EEG channel is ipsilateral or contralateral to the BC transducer side. The spatial correspondence between the channel labels and the averages in plotting intensity series must be carefully tracked, to avoid erroneous ear assignment.
524. BC Responding Cochlea Inference

The responding cochlea for BC measurements will be determined by evaluation of the response amplitude and latency differences in the ipsilateral and contralateral records, particularly at the minimum response levels. In the event of equivocal interpretation, changing stimulus levels 5-10 dB might help isolate the responding side.

As reported by Stapells (for review see Stapells 2011), the responding cochlea in young infants can usually be identified by comparing the ipsilateral and contralateral averages to the BC stimuli. At near-threshold levels, the V-V' complex is usually larger and wave V latency is usually earlier in the channel ipsilateral to the cochlea that is being excited more effectively by the BC stimulus. If these two indicators are in apparent conflict, the latency criterion should be assigned greater weight, provided that latency differences are clear and the wave identification and measures are confident (i.e., recordings with low noise).

This phenomenon is, at first sight, surprising, given that the non-inverting electrode is the one usually considered to contribute strongly to the Wave V-positive peak, and it is common to both the recording channels. The mechanism of the ipsi-contra effect is not well understood, but it may have to do in part with the generator orientation (although recent research has suggested delayed maturation of contralateral pathways). Nevertheless, experience from thousands of such measurements to date suggests that the inference is generally valid.

The asymmetries are most clear near threshold and for 2000 Hz. It is therefore important that BC results first be assessed at the BCEHP minimum BC levels (30 dBnHL for BC 2000 Hz; 20 dBnHL for BC 500 Hz) where asymmetries have been best studied (Stapells & Ruben, 1989). When sensorineural hearing loss exists, results at higher intensities are also typically interpretable, especially for BC 2000 Hz. Recent data at UBC suggests there is less interaural attenuation of BC energy at 500 Hz (compared to 2000 Hz) across infants’ skulls; thus, some difficulties with interpretation of ipsilateral/contralateral asymmetries may arise when higher BC 500 Hz levels (e.g., 40-50 dBnHL) are employed.

The ipsilateral/contralateral asymmetries decrease with maturation. Although often present in children older than 3-4 years of age, they are not always present and thus the absence of clear ipsilateral/contralateral asymmetries is not interpretable in these older children.

525. Interpretation of BC ABR Thresholds

In the absence of prior BC-ABR information, all BC-ABR measures should begin at the specified minimum levels, as ipsilateral/contralateral asymmetries are easiest to assess at these levels. When properly conducted, BC-ABR thresholds are valid estimates of sensorineural hearing loss (Hatton, Janssen, & Stapells,, 2012).

526. Interpretation of ABR Air-Bone Gaps

Clinically, the BC threshold estimate may be subtracted from the AC estimate in order to derive an estimated air-bone gap. There are three important points to bear in mind when interpreting such gaps. First, remember that eHLs are
statistical estimates of true perceptual thresholds and each nHL to eHL conversion may contain estimation error of 5-10 dB in either direction; when subtracting one threshold from another, these errors may also combine in either direction. Second, if the correction factors are chosen appropriately, on occasion small negative air-bone gaps of up to -10 dB may be seen. These should be disregarded completely and the AC threshold should be considered as valid. If a negative gap of 15 dB or more is observed, the accuracy of the threshold estimates should be reviewed carefully – was the BC response threshold estimate too high, or was the AC threshold too low? Third, small positive air-bone gaps may be observed when no gap truly exists. Therefore, a positive gap of up to 15 dB should be disregarded clinically, unless accompanied by a clearly abnormal tympanogram. Positive gaps of 20 dB or more should be considered as genuinely indicative of a conductive component, except when accompanied by a clearly normal tympanogram, in which case the thresholds leading to the gap should be reviewed carefully.

Given the defined minimum levels and the obtainable maximum levels for BC of 60 dBnHL at 2000 Hz and 50 dBnHL at 500 Hz, the effective dynamic range of positive gaps is only about 30-35 dB. Given the possible variability of gap estimates, actual clinical inferences from comparing AC and BC threshold estimates are basically 'no indication of a significant conductive component' (gaps ≤ +15 dB), 'minor conductive component' (gaps of 20-25 dB), and 'substantial conductive component' (gaps ≥ 30 dB). Of course, if there is an AC threshold estimate of > 60 dBeHL and no response at BC maximum level, a reliable inference of absent conductive component cannot be made, except tentatively on the basis of tympanometry.

527. Contralateral Masking for AC testing

To date, after many thousands of ABR assessments (including those in the Ontario IHP program), it is rare for contralateral masking to be essential for satisfactory audiometric interpretation. Nevertheless, in the case of an apparent large asymmetry between ears (60 dB or greater), results should be interpreted cautiously, and extra measures obtained. Two-channel EEG recordings have proven useful in determining the responding cochlea in infant AC threshold asymmetries, similar to that used for BC assessment. Nevertheless, in some cases, additional testing using contralateral masking (e.g., 50 dBSPL white noise) may be indicated.

528. AC 1000 Hz

AC at a minimum of 35 dBnHL at 1000 Hz, with bracketing if there is no response, will be done if there is a difference greater than 20 dB at 500 Hz and 2000 Hz. If the difference is 20 dB or less, testing at 1000 Hz is discretionary but not recommended until ALL mandatory thresholds have been obtained, and if time permits.

529. Deferring 1000 & 4000 Hz in Conductive hearing loss

In the event that a purely conductive hearing loss is clearly demonstrated at 2000 Hz and/or 500 Hz where indicated in this protocol (i.e., present BC-ABR at minimum level and elevated AC) determination of thresholds for 4000 Hz and 1000 Hz is NOT required. They should be tested at a repeat assessment,
following a waiting period with or without intervening medical treatment of a potentially transient middle-ear condition.

530. High-intensity Click ABRs

If there is no detectable ABR with clearly identifiable Wave V to tone pips at the highest available intensity levels at any frequency measured in an ear, or if Wave V thresholds indicate severe-profound EHL levels, then an AC click ABR test will be done at 95 dBnHL in that ear. Recordings to slow rate (19-21/s) condensation and rarefaction clicks will be recorded (and plotted) separately. To ensure these results are interpretable, records must be replicated, and have at least 2000 sweeps per replication with an overall noise criterion at or better than the BCEHP low RN criterion (especially if no response present).

In the BCEHP context of audiometry, based primarily on tone pip ABR by air and bone conduction, ABR measurements using clicks have a secondary, but important, role. Specifically, click-ABR may help distinguish between retrocochlear disorder, ANSD, and residual hearing.

531. Retrocochlear Disorder

The clinical implications of indications of retrocochlear disorder in the ABR (e.g., prolonged I-V interwave intervals) are not well established in infants. However, it is the accuracy of tone pip ABR threshold estimates that is the crucial issue here, due to inaccurate threshold estimates that may arise because of neuronal disorder which causes significant reduction or absence of the V-V’ complex. This may be due to a disorder affecting the integrity of neuronal response from afferent auditory brainstem pathways. Such disorders are not common in young children but include space-occupying lesions (such as in neurofibromatosis), neurodegenerative disorders, structurally-mediated disorders (such as in hydrocephalus) and vascular disorders. In the presence of such conditions, using click stimuli at a high intensity often makes it possible to observe an ABR morphology that suggests a retrocochlear location of disorder. Usually this involves the presence of one or more early waves, prolonged interwave intervals and/or depression or absence of later ABR waves.

When a clear and reproducible Wave V or V’ is seen at any stimulus level in the course of tone pip ABR measurements, significant audiometric (threshold) inaccuracy due to a retrocochlear disorder is very unlikely. The presence of prolonged interwave intervals, by themselves, does not typically indicate ABR audiometric inaccuracy. Therefore, routinely measuring click ABRs is not considered necessary. However, if there is no clear Wave V-V’ at the highest tone pip levels available, an ABR measurement using a click at or near the highest level available (typically about 95 dBnHL) is required.

When recording click ABRs, separate measurements of responses to slow rate (19-21/s) condensation and rarefaction clicks are required. If either record individually shows a clear Wave V, the likelihood of substantial inaccuracy in the tone pip thresholds caused by retrocochlear disorder is low. Appropriate techniques must be carried out to ensure waves IV and/or VI are not mistakenly identified as wave V (e.g., rarefaction and condensation clicks, comparison of waveforms obtained using slow and fast click rates, and/or different intensities). If early waves are present, but a depressed or absent Wave V is seen in BOTH
rarefaction and condensation click records, then confidence in the accuracy of
tone pip threshold estimates, which are based mainly on Wave V, is reduced. If
no ABR Waves I through V are seen, then the interpretation depends on whether
or not there are indications of possible ANSD, as outlined below. A clear finding
that suggests retrocochlear disorder should be noted in the report, and a medical
referral is mandatory.

532. CM & Stimulus Artifacts

Clamped-tube recordings: If early waves are seen but there is no clear neural
response to AC clicks at 95 dBnHL, or if a clear Wave V is not identifiable, the 95
dB click records will be repeated with the earphone tubing clamped (using
haemostats, with tape or silicone tubing over the haemostats’ teeth to protect the
earphone tubes from damage). The insert earphones, driving transducer, and
electrode leads must not be moved from their positions for the previous 95
dBnHL recordings.

If early waves, but no Wave V are seen, one possibility is that there is a
retrocochlear disorder. The other is that the early waves are not neurogenic but
are cochlear microphonic potentials (CM) or stimulus artifact. These alternatives
can usually be discerned by the use of separate averages with condensation and
rarefaction clicks and use of clamped tube recordings. If the early waves do not
invert with stimulus polarity, they have a neuronal origin. If they invert, they are
likely to be either CM or stimulus artifact. To rule out stimulus artifact, the
stimulus delivery tube must be clamped. If the early waves remain, then they are
due to stimulus artifact and there is no reason to question the reliability of the
tone pip ABR thresholds. If the early waves are abolished, then they are likely to
be CM, in which case confidence in the tone pip thresholds is decreased, just as
it would be if the early waves were of neural origin. CM is multi-peaked and may
be large and prolonged if ANSD is present. Stimulus artifact is usually shorter in
duration and rarely manifests more than 2-3 peaks and troughs. The finding of a
clear and (usually) large CM and absence of neurogenic waves may suggest
ANSD: the validity of ABR thresholds as estimators of perceptual thresholds is
highly questionable in this case. In the presence of ANSD, ABR thresholds may
overestimate perceptual thresholds by an amount that may be very large.

533. Auditory Neuropathy Spectrum Disorder (ANSD) Inference

The ANSD protocol is currently under review.

The 95 dBnHL records will be assessed for the presence of cochlear
microphonics and stimulus artifacts. In conjunction with OAE records, the
evidence for ANSD will be evaluated. The absence of OAEs does not rule out
ANSD; whereas, the presence of OAEs and absence of ABR waveforms of
neural origin does make ANSD the primary inference. If OAEs are absent but the
ABR records show a clear and (usually) large CM with absent or very degraded
neurogenic waveforms, these records may also suggest ANSD; however, this
finding is less definitive and should be considered to yield a presumptive
inference.

ANSD is defined conventionally by a cluster of findings that includes normal or
near-normal OAEs, absent or severely abnormal ABRs, absent middle-ear
muscle reflexes, and actual hearing loss of any degree from mild to profound.
The disorder is more often, but not always, bilateral. OAEs may be absent for reasons related to middle ear conditions, so absence of OAEs does not rule out ANSD. In a small proportion of cases, in the absence of confounding middle-ear conditions, the OAEs are absent or degrade over time. The proposed mechanisms of ANSD include inner hair cell, synaptic and/or primary neuronal dysfunction, and any or all of these may be operative in the individual case. ANSD may or may not include a genuine neuropathy, and there may or may not be other, concurrent peripheral neuropathies present.

ANSD may represent as much as 5-10% of all sensorineural hearing loss in infancy, but its actual prevalence is not yet well-understood. There are several underlying variations, mechanisms and causes, at least some of which appear to be genetic. Hyperbilirubinemia is another risk indicator. It is also possible that auditory brainstem immaturity or damage recovery (such as from perinatal hypoxia) may masquerade as ANSD. In the presence of ANSD, ABR threshold estimates are not a reliable indicator of behavioural thresholds.

It is a feature of ANSD that the CMs are often large and easily recorded, but there are usually no neural ABR waves in response to either tone pips or clicks. Therefore, care must be taken to differentiate CM, stimulus artifact and neurogenic response, using the method noted above. The CM is readily apparent as a series of large deflections in the 0-5 ms latency region that should invert with change in click polarity. It is currently believed that, given the absence of or a highly abnormal click ABR (i.e., absent/abnormal wave V) and absent OAEs, the presence of a large CM suggests a provisional differential diagnosis of ANSD.

The appropriate course of action, given probable ANSD, is at the discretion of the individual BCEHP audiologist. An ancillary protocol that will address additional assessment procedures, such as slow cortical potentials as well as management issues, is in preparation. In the future, slow cortical evoked potentials may contribute to any such protocol (Rance et al., 2002), which may extend to include those cases of rare retrocochlear disorders such as brainstem lesions, wherein the tone pip ABR threshold estimates are also suspect.

534. **ANSD Implications**

If ANSD is the presumptive finding, tone pip ABR thresholds are an unreliable measure of actual thresholds, and regular follow-up assessments are mandatory. The audiometric picture will usually emerge when behavioural testing becomes viable. If the OAEs are not normal, a presumptive inference of ANSD will be clarified by a family report of the responsiveness and a behavioural observation by the BCEHP audiologist.

535. **ANSD Data Entry**

If ANSD is the definite or presumptive finding, the tone pip ABR thresholds are not valid. Currently, they will be entered in the frequency fields as if they were valid, typically as reflecting non-response at the highest available stimulus levels, but will be qualified by an entry indicating waveform abnormality. PCHL is reported as present.
536. **Click – ABR Thresholds**

These are only done when the BCEHP audiologist suspects ANSD or neurological involvement affecting tone-ABR threshold validity. If a clear and replicable response to clicks is identifiable at 95 dBNHL (in contrast to absent tone-pip ABR), the click-ABR (19-21/s) threshold will be determined by bracketing. The response need not contain waves that are clearly identifiable, (e.g., Wave III, Wave V) but there must be a replicable waveform in the range of 2-20 ms to determine response presence.

If a clear Wave V is seen in response to clicks, in the absence of tone pip responses at maximum AC levels, a possible cause is that there is better hearing at some frequency not yet tested by tone pips, in the range 0.5-8 kHz, that may be elicited by clicks. This might be explored by tone pip ABR measurements at the untested primary frequencies, at least in the range 1000-4000 Hz. It should be noted that BCEHP stimulus calibration values are not provided for 6000 and 8000 Hz. In this unlikely event, consultation with BCEHP is recommended.

Another possible cause of a Wave V-V to clicks but not to tone pips is that there is severe cochlear hearing loss and insufficient synchronous excitation of primary neurons with a frequency-specific stimulus; whereas, the click excites a broader region of the cochlear partition and with greater synchrony. In that situation, no tone pip response will be seen at any frequency, but the click threshold could be much lower. If this pattern of results is seen, the audiometric values reported should be based on the tone pip results, but the finding of a click response should be noted. A click response threshold should be determined by bracketing and noted as comment on the BCEHP report.

537. **Click – ABR Threshold Implications**

The click-ABR threshold gives limited information about hearing sensitivity. If there is evidence of ANSD, the inference is that at least one threshold in the 0.5-8 kHz range is as good as, or better than the click-ABR threshold, and that the absence of tone pip responses gives no information about those thresholds. If ANSD is NOT suspected, the inference from a clear click-ABR response is that the tone pip ABR thresholds are likely to be valid, but that there may be an island of hearing at some frequency other than those measured. If measured, the click-ABR threshold should be noted in the BCEHP report form but not entered in the frequency fields.

538. **Estimated Hearing Levels (EHLs)**

Tone pip ABR thresholds in dBNHL are not directly equivalent to perceptual thresholds in dBHL, and both dBNHL and dBHL are defined with reference to adult norms. ABR dBNHL thresholds are converted to bias-free estimates of the true perceptual threshold in dB HL by applying adjustment factors based on longitudinal validation studies.

ABR thresholds will be converted to estimates of the true perceptual threshold in dBHL by applying the threshold adjustment factors listed in Appendix 11 – “Calculations”. The resulting thresholds will be referred to in the BCEHP context as the Estimated Hearing Level or EHL thresholds, with units in dBEHL. EHL values will be entered as thresholds in the BCEHP report. For any condition of clear response at the BCEHP “normal” minimum level for any given stimulus
frequency and route, the EHL will be deemed to be 25 dBEHL with the exception of 500 Hz, where the minimum response level is equivalent to 20 dBEHL. However, all reports and outcomes data will indicate both the dBnHL threshold and the EHL value.

The thresholds derived by ABR measurements have an indirect and statistical relationship to true hearing levels. There are many factors affecting the relationship. First and foremost, the level at which an ABR is detectable depends upon a host of variables that affect ABR detectability, including EEG noise levels, filter bandwidths, averaging parameters, response detection criteria and threshold bracketing procedure. Second, the units of ABR thresholds are dBnHL, which is itself subject to many variables such as the stimulus envelope and repetition rate, which affect psychophysical energy integration. Such integration itself is affected by the type and degree of hearing loss, so threshold relationships may also depend on the type and degree of hearing loss. dBnHL is also defined with reference to adults, not infants. Furthermore, dBHL itself is defined with reference to adults, and it is known that in the maturing infant ear, canal SPLs and middle-ear transfer functions are different from those of adults, and also may change significantly over time, especially at frequencies above 1000 Hz and in the first six months of life.

ABR thresholds are conventionally expressed in dBnHL and are NOT generally equal to perceptual thresholds in dBHL. There is no reason why they should be equal. Therefore, an offset adjustment for bias of ABR thresholds is required. The adjustments are derived from normative data relating ABR thresholds in early infancy to subsequent behavioural thresholds. The BCEHP adjustments for EHL are typically between -15 and 0 dB, and may vary according to the type, frequency and severity of the hearing loss, as well as the subject’s age and ABR testing procedures. The evidence review to date indicates that, provided the protocol defined here is followed closely, a constant adjustment that is specific to each test frequency and route of stimulation will yield acceptable threshold estimates. Please see Appendix 11: “Calculations”.

The adjustment factors will be applied to each ABR threshold in order to derive an Estimated Hearing Level or EHL, which is a relatively bias-free estimate of the actual hearing level in dBHL that would be obtained if the child developed to adult anatomical and psycho-acoustical status, with no change in actual level of hearing loss. Given this approach, the target hearing loss is equivalent to ABR threshold estimates that are adjusted to greater than 25 dBEHL, and the ABR thresholds in dBEHL may be used directly in any subsequent prescription for amplification.

The EHL conversion adjustments are derived from longitudinal follow-up studies, primarily comparing early ABR with subsequent VRA thresholds (see Stapells, 2000, 2011). It should be noted that VRA thresholds are themselves generally greater than the true psycho-acoustical thresholds, which tends to reduce the observed differences between ABR and behavioural thresholds. Conversely, because of the effects of ear canal maturation, the observed relationships between ABR and behavioural thresholds will incorporate the effects of maturational SPL changes in the developing ear. Due to the effects of changing size/properties of the ear canal with age, less intensity is required to generate a given dB SPL at the eardrum in a neonate as would be required in an older child.
The actual SPLs in early infancy will be greater than those for the same stimulus at the point of subsequent behavioural threshold measurement, especially at higher frequencies, so the results may give an impression of progressive hearing loss.

There is a clinical impression that ABR thresholds are closer to behavioural thresholds, when hearing loss is severe, and this is often explained by appeal to a recruitment-like phenomenon. However, it is also likely that this impression is more related to technical factors such as recording time and the response signal-to-noise ratio. Another factor that affects threshold relationships is the spectral spread of ABR stimuli, which tends to lower ABR thresholds relative to true perceptual thresholds, especially at high frequencies and with severe, sloping high-frequency hearing losses. These many factors influence the key elements in normative threshold relationships that determine the adjustments to derive EHL estimates. Such adjustments are dependent on stimulus frequency, but currently the best evidence is that they do NOT depend substantially on stimulus level or, concomitantly, the true hearing level, over the range of interest in BCEHP threshold measurements. Accordingly, the current BCEHP conversion adjustments are specific to stimulus frequency, but not to the observed ABR threshold level.

539. **ABR Recording Sheet**

BCEHP audiologists will record information of acquired ABR waveforms on a recording form during the assessment. Please see [Appendix 12: “ABR Recording Form”](#). Information to be recorded includes the filename, stimulus parameters, IHS online noise measures (RN), and importantly waveform response presence/absence decisions (for the group of replications, not for individual waveform recordings), and any observations of relevant patient/test environment details. The recording sheet should be filled in concomitantly with waveform collection. The purpose is to provide a record of the order of acquisition of ABR waveforms, and the conditions in which they were recorded. If, for example, it is discovered that an insert earphone is out while acquiring data, this should be noted on the recording form. If the waveforms are reviewed at a later date, consultation of the log sheet will indicate why certain waveforms were to be disregarded; this information would not be available unless recorded at the time of data acquisition. Importantly, it will also provide information on the online decision analysis (i.e., “response present”, “response absent”, or “could not evaluate” for a group of replications) for a given ABR assessment; this will be important for later second-opinion/file review processes.
DX 600: Middle Ear Analysis (MEA)

601. MEA Protocol

All MEA tests funded by BCEHP will be done in compliance with this protocol and the technical parameters and interpretive criteria. See Appendix 13: “Middle Ear Analysis (MEA) Technical Details”.

602. Middle Ear Analysis

Middle Ear Analysis (MEA) is a mandatory component of initial BCEHP assessment, and has a secondary role in the context of follow-up BCEHP assessment, for which it is recommended that a MEA be done wherever practically feasible. The value of MEA ranges from negligible to substantial, depending on specific circumstances, some of which are noted below.

MEA includes tympanometry (measurement of otoacoustic immittance or its components), as well as measurement of Middle Ear Muscle Reflexes (MEMR). Tympanometry is a routine component of conventional audiometric assessment, and its rationale and contribution is also relevant to the BCEHP assessment. However, some changes in indications, procedure and interpretation are necessary to reflect the target population and operational context of testing. The MEA technical parameters are summarized in Appendix 13.

603. Tympanometry

All BCEHP audiology centres must have immittance instrumentation available, which is capable of performing all test components as described in this section. Test parameters for use in assessments will be specified by the BCEHP.

For infants up to and including six months corrected age:

- Tymanometry will be done using a 1 kHz probe frequency, with repetition as necessary and feasible to improve reliability.
- The key abnormality criterion is a compensated peak static admittance of \( \leq 0.6 \text{ mmho} \), compensated from the negative tail at -400 daPa.

For infants over six months corrected age:

- Tymanometry will be done using a 226 Hz probe frequency, with repetition as necessary and feasible to improve reliability.
- The key abnormality criterion in the age range 7-12 months is a compensated peak static admittance of 0.1 mmho, compensated from the positive tail at +200 daPa. From 13-18 months, the criterion is 0.15 mmho. From 19 months on, the criterion is 0.2 mmho.

There is evidence that tympanometry with a low frequency probe is insensitive to the presence of middle-ear fluid in infants under about 8 months of age. Paradise et al (1976) suggest that, in newborns and young infants, the meatal wall is distensible, and that this may cause a tympanometric peak artifact, and may mask reduced TM compliance due to a middle ear condition. That hypothesis has been disputed, in favour of a more complex dynamic mechanism of admittance peak generation.
Whatever the mechanism of falsely normal tympanograms, it appears that tympanometry with a high-frequency probe is more sensitive to the presence of middle-ear fluid. All tympanometric records will be printed out and retained. Irrespective of age, pressure change will be swept from positive to negative.

604. Middle-Ear Muscle Reflexes (MEMR)

The Joint Committee on Infant Hearing Position Statement (Pediatrics, 2007) states that “there are insufficient data for routine use of acoustic middle-ear muscle reflexes in the initial diagnostic assessment of infants younger than 4 months” (p 906). It is recommended that MEMR measurements be obtained, if possible, for their contribution to the test battery; however, results in this age group should be interpreted with caution. Ipsilateral MEMR measurements will be done with a 1 kHz probe and broadband noise (BBN) eliciting stimulus. 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. Given the broadband-nature of the stimulus and associated increase in perceived loudness compared to a pure tone, a lower starting intensity is recommended. The starting level will be 85 dB HL, with at least two replicates at any level considered to be reflex-positive. In infants under six months of age, the maximum level will not exceed 100 dB HL. For older infants, the maximum level is discreional. Reflex records will be plotted and retained on file.

The measurement of MEMRs is strongly recommended wherever feasible. The presence or absence of MEMRs will be measured in the ipsilateral mode with a BBN stimulus and a 1000 Hz probe. There is no age limit on the use of the high-frequency probe. There is substantial evidence that the likelihood of obtaining a reflex when middle-ear conditions are within normal limits is increased for ipsilateral stimulation and with the use of high-frequency probes.

With contralateral measurements, and with low-frequency probes, reflexes are absent in a high proportion of newborns and young infants with no evidence of a middle-ear disorder. Therefore, such measurements have little clinical utility, either with respect to middle-ear status or to rule out severe/profound hearing loss.

MEMR measurement at pure tone stimulus frequencies such as 1000 Hz is not a component of current BCEHP protocol. There is evidence to suggest that a significant proportion of the normal population will display an absence of reflexes to pure tone stimuli without any pathology.

Stimulus level will start at 85 dB HL and increase in 5 dB steps up to no greater than 100 dB HL. Note that for a given nominal level, real-ear SPLs in young infants may be up to 20 dB greater than in adults.

Reflex presence is defined by a clear, mostly likely negative, deflection that is repeatable at any stimulus level. In the case of a questionable elicited reflex, an increase of the stimulus intensity should result in an increase in the magnitude of the reflex.

605. MEMR Interpretation

In the context of the assessment, the clinical utility of the MEMR is primarily to lend support to the ABR measurements. Misinterpretations of ABR records
resulting in drastic overestimation of hearing thresholds have been reported, and while it is anticipated that the expertise, training and protocol within the BCEHP will reduce the likelihood of such events, every reasonable additional precaution should be taken.

When the ABR results indicate at least a severe hearing loss, MEMR measurement should be attempted unless there is a contraindication. In this situation, reliable reflex presence is a significant finding that should result in a critical review of the threshold estimates.

Key issues are whether the ABR measurement conditions were appropriate, particularly with respect to EEG noise levels, the size of averages and the number of replicate averages. Reflex absence lends weak support to any ABR-based inference of severe or greater sensorineural hearing loss, except when there is evidence of a conductive component, in which case reflex absence is non-contributory.

Conventionally, the absence of a MEMR in conjunction with flat tympanograms is likely consistent with the presence of a conductive component [NB: although a sensorineural component cannot be ruled out unless ABR BC thresholds (or behavioural responses to BC) are within the normal range.] The MEMR is also reported to be generally absent in the presence of ANSD.

The clinical utility of other measures such as peak pressure, width and gradient is unclear in infants. Reported 90% range boundaries for TPP are from approximately (-150 to -100) up to (0 to 50) daPa.
**Otoacoustic Emissions (OAEs): Distortion Product Otoacoustic Emissions (DPOAEs) & Transient Evoked Otoacoustic Emissions (TEOAEs)**

### 701. Role of OAEs

OAEs reflect cochlear function, and their presence suggests that the peripheral auditory system, up to and including the outer hair cells, is functioning appropriately. They can be reliably recorded in sleeping newborns, given a quiet acoustical environment.

OAE measurement is a mandatory component of a complete audiology assessment when PCHL is identified. When AC tone pip ABRs are clear and reproducible at the lowest required stimulus levels, at both 500 and 2000 Hz in both ears, the contribution of both OAEs and MEA to the overall assessment is limited. In the circumstance of elevated tone pip ABR thresholds, the contribution of both OAE and MEA increases substantially, both in terms of the cross-check principle and for refining the overall description of otological status.

It is especially important that corroborative measures be sought if there is any uncertainty about the reliability of either OAE responses or ABR threshold estimates.

### 702. DPOAE Procedure

The required test parameters for non-screening DPOAE measurements specified by the BCEHP are in Appendix 14 – “OAE Technical Details.” The current protocol includes replicated DPOAE measurements at nominal (F2) frequencies of 1.5, 2, 3, 4 and where feasible 6 kHz. The f2/f1 ratio is 1.2, with f1 and f2 levels of 65 and 55 dBSPL.

DPOAE measurement at 1.5 kHz is attempted because of the importance of frequency-specific information about cochlear status at low frequencies, but it is especially vulnerable to the generally higher levels of physiological and environmental noise at low frequencies. The inclusion of 1.5 kHz often dominates measurement time, and is therefore not considered mandatory. Extension of measurements beyond 6 kHz is of questionable clinical utility, and is vulnerable to error arising from standing wave effects. However, when time permits, 8 kHz can also be recorded for cochlear status monitoring purposes.

The known fine structure of both the pure tone audiogram and the DP-gram means that on occasion, DPOAEs at individual frequencies may be of very low amplitude despite normal cochlear function.

### 703. Test Repetition

Regardless of the overall DPOAE test outcome, immediate repetition of the test is recommended, to confirm the measurements’ reliability. Repetition may be omitted if the DPOAE amplitudes exceed 5 dB and the signal to noise differences exceeds 10 dB at 1.5-6 kHz.

At each nominal DPOAE test frequency, the initial decision after measurement is whether the observed value of the DPOAE level represents a genuine DPOAE or is, in fact, inseparable from the noise floor. It is common to consider both the
apparent DPOAE amplitude and the distance from the noise floor in assessing whether an OAE is genuine. The absolute value of the noise floor is also relevant in determining whether the measurement conditions were such that a normal OAE would be detectable.

704. DPOAE Detection

Typical criteria for defining whether a DPOAE is present, for single stimulus frequency pair, are that its amplitude should exceed –5 dB SPL, and its distance from 2 standard deviations of the noise floor should exceed 3 dB. However, there is a substantial range of such detection criteria, as well as considerable variability in both test parameters (such as the amount of averaging) and definitions of measures (such as the signal to noise ratio). There are insufficient data for the BCEHP to define specific, quantitative criteria. Furthermore, the detection criteria are inherently statistical, with the usual associated concepts of false-positive and false-negative detection errors. In a rational and quantitative approach to the definition of DPOAE detection criteria, the costs associated with detection errors would be considered and would affect the chosen criteria. It is plausible that different criteria of DPOAE detectability should be used in different situations, but there is currently little quantitative basis for specific values. See Brown et al (2000) for illustrative data and discussion.

A test-retest maximum difference of 5 dB is required in order to consider a DPOAE to be definitely present. Published data suggest that an 8 dB difference criterion will yield a false-positive emission detection rate of about 1%; whereas, a 3 dB criterion will give about 10% false positive detection.

705. Noise Levels

Normative noise floor levels have typical 99th percentile values in normal young adults when tested in a sound room of about –8, -17 and -21dB at 1, 2 and 4 kHz, respectively. Observed noise levels much greater than these limit the opportunity for an OAE to be detected reliably. Noise levels are commonly elevated by 10 dB or more in environments other than audiometric sound rooms, at frequencies below about 2000 Hz.

706. DPOAE Display

The display of DPOAE results includes, in graphical and tabular form, the stimulus and OAE amplitudes in real-ear dBSPL, noise floor values in dBSPL and OAE/noise floor differences in dB, for various frequencies of stimulation. The display also shows the 90th and 95th percentiles of the distribution of amplitude for a population with impaired hearing, and the 5th and 10th percentiles of amplitude for a population with normal hearing. These are based on large-sample normative data obtained by Gorga et al (1997). It is clear from the percentile values that the ranges of DPOAE amplitude for the normal and abnormal populations are substantial, and that the tails of the two distributions overlap considerably.

It follows from the statistical distribution of DPOAE amplitude over subjects that there is a range of DPOAE amplitude which is neither clearly normal nor clearly abnormal. For the Biologic Scout, the fifth percentiles of the amplitude distributions for young normal adults are in the range about 4-8 dB SPL.
Therefore, any reproducible amplitude in the range about -10 to 5 dB may reflect a genuine DPOAE, but with reduced amplitude.

707. TEOAE Procedure and Detection

The required test parameters for non-screening TEOAE measurements will be specified by the BCEHP: see Appendix 14: “OAE Technical Details.” The current EHP protocol indicates a minimum of 50 sweeps averaged; the stimulus consists of a click presented at 19 clicks per second, at an intensity of 82 ± 3 dBSPL. Signal stability should be a minimum of 80% during acquisition. Averaging may be stopped after 50 sweeps if the minimum signal to noise ratio and reproducibility standards have been obtained.

The instrument displays a numerical assessment of the confidence of a true response (reproducibility) as well as a numerical assessment of the level of noise within each band. An upper limit to the number of sweeps to be averaged will be specified by the BCEHP protocol. Filtering to remove noise below 1 kHz is recommended. The data collection window is set at 4 to 10 or 12.5 msec, while the maximum recording time allowed is 6 minutes.

708. OAE Test Environment

The test environment must be quiet and free of continuous background noise. A good probe fit is essential prior to in-the-ear calibration. The examiner must check and adjust the stimulus level to achieve the target level, prior to recording.

Probes must be checked regularly for sound output and microphone sensitivity – every 50 babies, once per week, and after any changes made to the probe. With the parameters and procedures described above, a normal result is considered to be a response with a signal to noise ratio of 3 dB at 2 standard deviations above the noise floor at 2, 3, and 4 kHz, with mandatory presence at 2, 3, and 4 kHz. Testing above and below these frequencies (e.g. 1500 Hz to 8000 Hz) is discrentional.

709. Interpretation of TEOAEs and DPOAEs

Many factors, other than the target PCHL, may cause the reduction or absence of OAEs, and some subjects who have the target hearing loss at some specific frequencies may manifest normal OAEs at all frequencies, not just those remote from the target hearing loss. Given a quiet subject and an adequate acoustical environment, OAE recording is adversely affected by inappropriate probe placement (such as against the meatal wall), probe blockage (by vernix, cerumen or meatal debris), and the status of the middle ear. Active middle ear infection, negative middle ear pressure, fluid or debris in the middle ear, and ossicular abnormalities are likely to reduce or abolish the OAE. In the presence of otitis media, OAEs are rarely recorded unless the air-bone gap is less than about 15 dB. Furthermore, OAE development is generally (but statistically) a more sensitive indicator of cochlear status than are pure tone thresholds, so it is possible to have reduced or absent OAEs even though hearing is normal on conventional audiometric criteria and on BCEHP criteria.

OAE measurements do not yield threshold estimates and do not definitively categorize individuals as having normal or elevated hearing levels. There is a statistical, predictive relationship between OAE amplitude and the severity of
hearing loss. For hearing levels greater than about 40 dBEHL, an OAE is unlikely to be observed at the frequency of the loss, if the etiology is a cochlear disorder other than ANSD.

Because of the statistical relationship of OAEs to hearing sensitivity, and because the perception of sound requires much more than a functioning auditory periphery, a normal OAE as an isolated finding suggests absence of the target hearing loss, but does not guarantee it. For example, OAEs may be normal in the presence of ANSD or retrocochlear disorders and a wide range of actual, perceptual pure tone or speech hearing thresholds may be seen in such disorders.

Within the constraints of their statistical nature, generally the OAE results should be consistent with the threshold findings. An observation of normal OAEs and elevated thresholds should prompt careful review of the data. The first question is whether the cause is error or misinterpretation. For example, are the OAEs unequivocally present? Was the absence of ABR at lower stimulus levels genuine? Were the EEG noise conditions satisfactory, or is it possible that the ABR was obscured? Were the numbers of sweeps and replicates sufficient?

If the OAE are definitely present and sensorineural thresholds are elevated up to about 35 dBEHL, there is not necessarily any conflict. If the thresholds are 40 dBEHL or greater, the likelihood of seeing a clear OAE is negligible in a conventional cochlear hearing loss. If the threshold is greater than 40 dB, with no evidence of a conductive component, the likelihood of ANSD increases significantly.

The most probable cause of a finding of absent or depressed OAEs in the presence of normal or near-normal thresholds is a minor middle-ear disorder and the MEA may shed light on that possibility. If the MEA is normal, the apparent OAE/ABR discrepancy should prompt the repeat of the OAE with careful attention to probe placement and noise levels. If these variables appear satisfactory, it is important to consider the possibility that the ABR thresholds may have been underestimated; the records should be reviewed to look for possible false-positive response detection judgments at the lower levels. Because it is unlikely, but certainly possible, to see a clear response at 30dBEHL in the presence of slight hearing loss sufficient to degrade or abolish OAEs, these apparent contradictions of the test’s outcome should be seen primarily as an indicator that careful review of the findings is needed. If repeat testing is deemed appropriate in the light of a critical review, such testing should generally be very focused in its objectives and in the range of conditions explored.

OAE status can change and, therefore, should be repeated at subsequent audiological evaluations, when the purpose of the evaluation is to monitor and measure the degree of hearing loss during the infant years (and probably beyond, depending on previously determined hearing status and reason for monitoring, such as an ANSD or progressive/late onset risk factor).
801. **Summary**

Where developmentally appropriate, Visual Reinforcement Audiometry (VRA) will be used to obtain behavioural estimates of hearing sensitivity. Wherever feasible, VRA will address frequency-specific and ear-specific thresholds by air conduction, and *also by bone conduction* if indicated by conventional audiometric criteria.

All VRA testing funded/approved by the BCEHP will be conducted in accordance with the detailed procedures listed in this protocol. Critical elements include an appropriate conditioning strategy, a completed, appropriate audiogram worksheet and documentation of control trials.

It is recognized that a key factor influencing the likelihood of a successful VRA session is the audiologist’s responsiveness to the child’s state. It is important that the audiologist cultivate an awareness of a child’s behavioural signs, as these will indicate how to modify the test procedures so that full results are most likely to be obtained. Child behavioural states that are non-conducive to testing and which are often observable include non-responsiveness, habituation to stimuli, incomplete conditioning, and over-engagement by the distracter. Careful observation of the child’s behaviour will indicate when a change in stimuli may re-engage the child’s interest, as in the event of habituation, for example. While the procedures and protocols discussed below are recommended and, where stated, required, it is recognized that considerable flexibility is necessary when testing young children.

VRA sound field thresholds do not yield a sufficient basis for optimal intervention. Such thresholds are acceptable only if there is documentation of a failed, genuine effort to obtain ear-specific thresholds under insert phones and headphones. Sound field measurements are discretionary for purposes other than threshold estimation, such as demonstration of non-responsiveness. Sound field can be useful in conditioning trials, because some children do not respond as well to auditory stimuli from insert earphones. Initial conditioning in sound field may allow for reliable localized responses to occur quickly, at which point earphones can be inserted.

Sound field may also be useful with older children and toddlers, as they are not always compliant with wearing earphones. Although it may not provide sufficient data for the fitting of amplification, a sound field audiogram still provides some framework and is useful as a starting point. There are times when continuing to push the earphone testing leads to frustration and distress for the child, and the test session tends to prove unsuccessful. A positive experience in the sound booth facilitates successful testing at future appointments.

**VRA-based Assessment Requirements**

All VRA-based assessments will include *at least*:  
- Ear-specific AC threshold measurements at 2000 Hz and 500 Hz
• If AC elevations, BC threshold measurements at 2000 Hz (500 Hz not mandatory, unless AC elevation only at 500 Hz)
• Ear-specific AC threshold measurements at 4000 Hz and 1000 Hz, where indicated by rules previously specified for ABR-based assessments

Alternative requirements, if attempts at obtaining ear-specific behavioural results fail:
• Sound field AC threshold measurements at 2000 Hz and 500 Hz
• Sound field AC threshold measurements at 4000 Hz and 1000 Hz, where indicated by rules specified previously for ABR-based assessments
• TEOAEs/DPOAEs bilaterally (pass criteria = OAEs present at 2, 3, 4 kHz – see OAE protocol)

802. VRA Assessment Pass Criteria
• Ear-specific minimum response level (MRL) of ≤25 dB HL at 2000 Hz and 500 Hz
  AND
• Ear-specific MRL of ≤25 dB HL at 4000 Hz – OR – present OAEs at 4000 Hz bilaterally
  OR
• Sound field MRL of ≤ 25 dB HL at 2000 Hz and 500 Hz
  AND
• OAEs present at 2, 3, and 4 kHz bilaterally
  AND

See below for more details.

803. Test Personnel
Two testers are preferred to be involved in the VRA test - one as the examiner who presents the stimuli and visual reinforcement while recording the child's responses, and the other who is in the room with the child and acts as distracter. The examiner must be a BCEHP and CSHHPBC-certified audiologist.

The role of distracter may be assumed by another audiologist or by an individual who is supervised by the examining audiologist. In some instances, the parent may be used in this capacity, at the discretion of the audiologist.

804. Pre-test Preparation
Several issues should be discussed with the parent or guardian at the time that the VRA appointment is being made:

i) Because the VRA technique requires that the child be attentive to sensory stimulation during the test, the VRA appointment should be scheduled for a time of day when the child is most likely to be alert.

ii) The parents should be asked about the medical condition of the baby's ears. If possible, the child should be tested when s/he is clear of ear infection.
iii) The parents should be asked about the status of the child's vision. If the child has visual problems, the test environment may have to be adjusted (reinforcers moved closer to the child, room lights dimmed etc).

iv) Information about the child's developmental status can help to determine whether the VRA method is likely to be appropriate for the particular child. For example, if the baby, at eight months, is unable to sit up or turn his/her head, VRA should probably not be attempted until s/he has better motor control. However, many children with some degree of developmental delay can perform quite reliably in VRA. Greenberg et al. (1978) suggest that VRA might be successful with children with Down Syndrome when the children reach a mental age of 10 months. Thompson, Wilson, Moore (1979) also indicates a developmental age of 10 months as the criterion for children with developmental or cognitive delay.

The test procedure should be explained to the parents when they arrive for the test.

805. **Stimulus Transducers**

In the absence of specific contraindications, insert earphones (ER-3A) are the required transducers for air-conduction VRA testing. Insert earphones have several advantages over supra-aural earphones for this test method, including reduced acoustic crossover (increased inter-aural attenuation), decreased likelihood of collapsed external ear canals, accurate location of sound delivery, increased comfort, and reduced interference with head-turn response. Research has shown that tolerance of insert earphones by children is generally good once the earphones have been placed in the ears (Widen, 2000).

Supra-aural earphones (TDH/MX41 type) are to be used when insert phones are contra-indicated, such as when the ear canals are very small, or stenotic, or when the child does not tolerate the insert phones. Careful attention to accurate placement of a TDH earphone is especially important to ensure appropriate stimulus levels and to avoid collapsing ear canals. Soft padding between the headband and the top of the child’s head may be needed to ensure comfort and proper placement.

A bone vibrator as specified by the ANSI S3.6-1996 Specification for Audiometers is required. Establishment of bone conduction thresholds requires accurate and stable placement of the bone oscillator. If proper force and stability of the bone conductor cannot be achieved with the standard headband, a band of elastic fabric with Velcro attachments may be used (see ABR section on Stimulus Transducers).

806. **Visual Reinforcement**

A toy located in a smoked Plexiglas box that can be illuminated and animated is the recommended visual reinforcement. At least two such toys, one on each side of the room, are required; four toys - two on each side - are preferable. The toy in the box should not be clearly visible to the child unless the box is illuminated. A switch in the observation room controls the animation and bright illumination of each individual toy. Alternatively, a TV monitor capable of presenting visual stimuli is acceptable.
807. Test Set-up

In the test room, the child sits on the parent's lap, gently supported and facing forward. If appropriate, the child may instead be seated in a highchair (that meets all pertinent Canadian safety standards), or an older child may be seated on a low chair, with the parent seated beside and slightly behind the child. A low table may be placed in front of the child to provide a surface for the distracting toy or activity.

The distracter sits on a low chair on the other side of the table and facing the child, with a concealed collection of available toys, to be used to maintain the child's attention between stimulus presentations.

Situate the reinforcing toys at 90 degrees to the child's right and left sides. The reinforcing toys should be at the child's eye-level, to maximize their visibility and simplify the head-turn response. The angle between the reinforcers and the child may be reduced somewhat if the child is not physically able to give a full head-turn response.

The audiologist in the observation room must be able to clearly see the child's face and the distracter's activity. The audiometer, reinforcement controls and recording materials must be easily accessible. There must be good two-way communication between the examiner and distracter; however, the examiner's voice should not be audible to the child, unless it is being presented as a speech stimulus. The distracter in the test room may use an earphone, headphones or a bone conduction oscillator wired to the audiometer. Alternatively, an FM system or induction loop system may be used for examiner-distracter communication.

808. VRA Test Objectives

Wherever feasible, VRA will address frequency-specific and ear-specific thresholds by air conduction, and also by bone conduction, if indicated by conventional audiometric criteria.

The goal of VRA-based assessments is to establish minimum response levels (MRLs) for air-conducted tones in each ear for at least two frequencies (namely, 500 and 2000 Hz), and to establish a bone-conduction MRL for at least one of these two frequencies at which there is an air-conduction MRL of 30 dB HL or greater in both ears.

In most cases, it should be possible to obtain VRA MRLs for at least three frequencies (in the range of 500 to 4000 Hz). Consideration should be given to:

- The clinical relevance of the MRL at 1000 Hz increases with the increased difference between the MRLs at 500 and 2000 Hz.
- 3000 or 4000 Hz may be more important for hearing aid fitting than 1000 Hz.

For the purpose of this test protocol, MRLs of 25 dB HL or less are considered to be within normal limits. For more information, see section on interpretation of test results.

The audiologist may determine that, in some cases, presenting the stimuli in sound field is helpful for conditioning a child who is initially reluctant to wear insert earphones. However, as sound-field testing does not provide ear-specific
information, sound field thresholds do not yield a sufficient basis for optimal intervention. Such thresholds are acceptable only if there is documentation of two failed, genuine efforts to obtain ear-specific thresholds under earphones. Sound field measurements are discretionary for purposes other than threshold estimation, such as demonstration of non-responsiveness.

809. Order of Test Stimuli

For air-conduction testing, pulsed FM warbled tones of 1-2 seconds duration are presented through an insert earphone.

If the examiner has previous hearing threshold information about the child, it is recommended that the testing begin with the better ear, and with the frequency at which the hearing is the most sensitive, based on the previous assessments. This helps to ensure that the child is conditioned to the VRA task as efficiently as possible. If no previous information is available, or if previous information suggests no significant difference among frequencies or between ears, it is recommended that the air-conduction frequencies be tested in the following order:

i) 2000 Hz, followed by 500 Hz, in the first ear
ii) 2000 Hz, followed by 500 Hz, in the second ear
iii) 3000 or 4000 Hz, at the discretion of the audiologist and based on audioligic and/or amplification requirements, in each ear
iv) 1000 Hz, in each ear

2000 Hz and 500 Hz are tested first, in order to judge the stability of the hearing loss, based on the ABR results, and because of their importance in speech perception.

If there is a significant (30 dB or greater) difference between the MRLs for 500 and 2000 Hz, 1000 Hz could be tested before 3000 or 4000 Hz.

A bone conduction MRL will be established for at least one frequency where there is a bilateral air-conduction MRL of 30 dB HL or greater. The bone conductor will be placed on the side that has the lower (better) air-conduction MRL at the test frequency.

An air-conduction MRL for speech awareness should be established for each ear as a cross-check to behavioural responses to pure tone stimuli. Speech stimuli may be used during initial conditioning if the child does not respond readily to tones, or may regain the child’s attention if it is waning after several warbled-tone frequencies have been tested.

810. VRA Test Procedure

The recommended VRA protocol for determining minimum response levels is based on the procedure described by Widen et al. (2000). See Appendix 15: “VRA protocol procedures.”

Once the child and parent are seated in the test room, the audiologist will explain the test procedure to the parent, and emphasize to the parent the importance of not cueing the child to the signals, and of not distracting the child with noises. The foam tips, which are attached to the insert earphones, are placed in the
child’s ears, with the other end of the tubing clipped to the back of the child’s clothing. Supra-aural earphones may be used if the child’s ear canal(s) is/are extremely narrow or atretic, and/or if the child will not tolerate insert earphones.

Pulsed, warbled tones lasting 1-2 seconds will be used as the initial stimuli. The inter-stimulus interval (ISI) should be varied, and initially lengthened if random head-turns are frequent. Use a 10-dB step size (20 dB down, 10 dB up), in order to reach the MRL quickly. A short, live-voice speech signal (e.g., "Hello there," "Ba-ba-ba," "Hi, …child's name," ) or, if the child does not respond well to the tones, child-oriented music may be used during conditioning.

811. Role of the Examiner (Audiologist)

The audiologist, seated in the observation room outside of the test room, controls the presentation of stimuli and reinforcement. S/he observes the child’s behaviour, judges if the child has responded or not, and records these judgments on a Worksheet. S/he may also guide the distracter in keeping the child in the appropriate testing state.

812. Role of the Distracter

In order for VRA to be successful, the child must be attentive to the task of listening for the sound which signals that there is a visual reward to follow. The role of the distracter, who is in the room with the child, is to keep the child in an appropriate state of listening for the sound stimulus, while keeping the baby’s gaze toward the midline, so that the full 90-degree head-turn response can be seen easily when it occurs.

The distracter must maintain a fine balance between being sufficiently interesting to hold the child’s visual attention, and not so entertaining that the child ignores the sound signal and/or the visual reinforcer. The amount and type of distraction activity needed to maintain a child in a listening state will vary from child to child. The reliability of the responses may be a good indicator of whether or not the child’s attention to the task is being maintained. See Appendix 17: “Role of VRA Distracter,” for more information.

813. Paired Conditioning/Training Trials

Before determining the Minimum Response Level (MRL), it is important to establish that the child will respond to supra-threshold stimuli with the appropriate head-turn response. A clear head-turn, permitting the child to see the reinforcement object, is the required response. To be considered a response, the head-turn must occur within four seconds of the stimulus presentation. The visual reinforcement should be of sufficient duration for the child to see it briefly (0.5 to 1.0 second); longer reinforcement may lead to the response being extinguishing, especially with children who are approaching the upper age limit (24 months) of the target population (Culpepper and Thompson, 1994).

Two consecutive, reinforced responses at a supra-threshold level are required to establish that the child has been conditioned. It is recommended that the first air-conducted stimulus be presented through the insert earphone in the better ear (if known) at 55 dB HL, or at 10-20 dB above the previously established ABR EHL threshold for that ear and frequency (if known). The child may respond spontaneously the first time that s/he hears a sound, or may have to be trained to
do so. If the child responds by turning his/her head, the reinforcement should be presented. Once the child’s attention is returned to midline, the same stimulus should be presented again. If the child responds again, reinforcement is provided. These responses are recorded on the VRA Worksheet. A spontaneous response is recorded on the audiogram worksheet as “✓”. Absence of response is recorded as “NR.” If the child does not respond spontaneously to two presentations of the initial signal, the intensity is increased by 20 dB. If the child still does not respond, a speech or music stimulus may be employed at the discretion of the audiologist. If the child still does not spontaneously respond, the transducer should be changed to a bone conductor (placed on the child’s mastoid closest to the reinforcer) and the next signal should be a 40 dB HL, 250 Hz narrow-band noise that is paired with the presentation of the reinforcement. If the child does not turn to the reinforcement when it is activated, the distracter may have to point it out to him/her. This pairing of sound and reinforcement may be done twice, and then the signal should be presented alone, to see if the child now responds to the sound. If s/he does, two consecutive presentations resulting in clear responses must be given before changing the transducer back to insert phones and beginning the search for MRL. A paired stimulus and reinforcer conditioning trial should be marked as “P” on the audiogram worksheet to differentiate between a paired conditioning trial and a spontaneous response to a conditioning trial (marked “✓”). Before re-inserting the insert earphone(s), inspect them for wax occlusion and do a listening check of the equipment. If there is still no response to air-conducted stimuli, the intensity level may be increased, or the stimulus frequency or ear of presentation may be changed and the conditioning repeated until a response is observed.

If the child shows no interest in the visual reinforcement, and will not turn to look at the reinforcer after 5 to 10 trials, further testing with the VRA technique may not be possible or useful on this occasion.

814. Minimum Response Level (MRL) Search

Begin at 20 dB below the level where the child has just responded twice during the conditioning trials. If a clear response is noted at this lower level, reinforce and record the response (as a “✓”), and lower the intensity by 20 dB for the next stimulus presentation. If there is no response, raise the intensity by 10 dB. Bracket the threshold by using a 20 dB-down, 10 dB-up technique. A Minimum Response Level (MRL) is defined as the lowest intensity level that elicits two clear responses (out of three presentations). Where the MRL is greater than 25 dB HL, there must be at least two no-response trials at no more than 10 dB below the level reported as MRL. Normal hearing for this test protocol is defined as 25 dB HL, and testing at a given frequency may be discontinued for the tested ear if the criterion for MRL is met at 25 dB HL. The audiologist may, at his/her discretion, go beyond – i.e. lower than, this level – as long as this does not compromise obtaining MRLs at other required frequencies. Similarly, the audiologist may use a 5-dB step size when close to the MRL, as long as this does not compromise the test objectives. The response, or absence of response, to each trial signal must be recorded as “✓” or “NR” on the Audiogram Worksheet.

If, when the test ear is changed and a stimulus is presented in the second ear, the child turns toward the side of the previous reinforcement, this reinforcer is
activated. If the child turns in the direction of the new signal, the corresponding reinforcer is activated. Any definite head-turn in response to a signal must be reinforced. However, the use of the left-side reinforcement for left-ear stimulation and the right-side reinforcement for right-side stimulation will probably maintain the child’s interest longer than the use of reinforcement on a single side. Therefore, when the test ear is changed and the stimulus is presented, if the child turns to the side of the previous reinforcement, the examiner could illuminate the reinforcer on the side of the stimulus, and the distracter could point out the new reinforcer to the child.

The MRL for each frequency and ear is recorded as an “O” for right or an “X” for left on the Audiogram Report Form.

815. Control Trials

In order to have a measure of the reliability of the child’s head-turn responses, insert control trials at regular intervals (following a positive response). The control trial is a specific interval during which the audiologist determines whether a head-turn response occurs in the absence of auditory stimulation. The purpose is to determine how likely it is that the child is truly responding to the test sounds, and not just turning his/her head randomly in the hope of receiving reinforcement.

The protocol for the control trial is the same as that for a stimulus trial, except that no tone is presented, and no reinforcement is provided if the baby turns his/her head. The control trial is carried out when the child is in the appropriate state for a test stimulus presentation, i.e. when s/he is attentive and facing forward. The audiologist informs the distracter of the beginning of the control trial, and the child’s behaviour is observed to determine if a head-turn response occurs. The audiologist records the presence or absence of a response on the audiogram worksheet beside the indication for a control trial. When a child responds during a control trial, the audiologist must insert an additional control trial to reassess response reliability. The more often the child responds to the test sounds (for example, a baby who responds to all stimuli down to the criterion “normal” level of 25 dB HL), the more important the control trials are in establishing the response reliability. Even though the absence of response to a sound stimulus may represent a type of control trial, it is required that specific, no-sound control trials are used.

Without formal control trials to determine the response reliability, the validity of the VRA results is open to question, and the results cannot be used with confidence to plan the individual pattern of communication development services.

816. Probe Trials

Probe trials are trials of higher intensity, which allow the audiologist to judge if conditioning has been maintained. Probe trials may also allow the child to re-focus, to pull them away from the distracter and renew their interest in the reinforcer. Probe trials should be administered at a level where the audiologist is certain the child can hear (e.g., at the level of the conditioning trial) and should be presented once, after which the MRL search can be picked up at the level that was being attempted prior to administration of the probe trial. Probe trials can be presented at the discretion of the audiologist, at points in the test procedure where it is felt that the child may not be responding due to a loss of a conditioned
response, rather than due to the stimulus being below the child’s perceptual threshold. All probe trials must be recorded on the VRA worksheet as either a response (✓) or no response (NR).

817. Incomplete or Inconclusive Test Results

In order for the VRA assessment to be considered complete in the case of normal results, air-conduction MRLs must be established for at least two frequencies, with ear-specific information for both ears, either in the form of normal behavioural results or present OAEs. See section 602, “VRA Assessment Pass Criteria.” If there is an indication of hearing loss, at least one bone conduction MRL must be established at a frequency at which the air-conduction MRLs exceed 25 dBHL in both ears. Because sound-field testing does not provide ear-specific information, MRLs obtained in sound-field tests do not fulfill the requirements for completion of the VRA assessment if elevated.

Every attempt should be made to complete the VRA testing in one visit. However, if the test results are incomplete (fewer than two air-conduction MRLs, absence of ear-specific information, or no bone-conduction threshold obtained when MRLs are elevated bilaterally), or if the results were considered unreliable, the child may be scheduled for a retest: at a better time, if s/he seemed tired or irritable, or, if the problem seems to be related to his/her developmental level, when s/he is a little older. It is preferable that the child be seen within 1 month from the date of the initial assessment and no later than 3 months following the initial assessment.

For children with previously identified PCHL, a regular schedule of follow-up visits has been established. This will include quarterly assessments (with hearing aid re-evaluation if the child is using amplification) in the first year following the identification of hearing loss or post-hearing aid fitting, and semi-annually in the second year. For children receiving behavioural VRA assessment due to identification of a late onset risk indicator, the regular schedule of follow-up visits can be found in Appendix 18. Specific recommendations for infants and children followed by the BC Children’s Hospital Neonatal Follow Up (NFU) program can be found in Appendix 18, Carepath 3A and 3B.

If the child showed no interest at all in the visual reinforcement, or if no MRLs could be established during the first attempt, s/he may also be scheduled for retest at a better time or at a later date, preferably within 1 month. However, if no improvement in behavioural responses is expected or seen, or if ear-specific information cannot be established after repeated (no more than three) attempts, the audiologist may ultimately have to rely on the results of ABR testing under sedation to determine audiological thresholds.

If the degree of the child’s PCHL has already been established with satisfactory ABR results, but there have been no reliable VRA results, either under headphones or in a sound field after repeated attempts, an ABR under sedation should be considered. Each case should be assessed on an individual basis through review of the child’s entire clinical picture to determine if a referral for sedated ABR will be initiated. The audiologist will document the nature and outcome of the VRA assessment attempts, and the reason why reliable VRA results were not obtained.
If the child’s hearing status has not yet been identified reliably with ABR or previous behavioural means, and three attempts at VRA assessment have been made with no reliable ear-specific results, a referral for a sedated ABR is strongly recommended in the absence of contraindications.

BCEHP Quality Assurance will include provisions for evaluating the cause of repeated failure to achieve complete assessment results. This may include random audits of clinical records, site visits and/or other evaluative measures.
DX 900: Audiological Inference

901. General Approach

The overall audiological inference will be based on an integration and critical evaluation of all available findings, according to the principles outlined in this protocol. See the support text for a detailed discussion.

The suite of procedures in the core protocol offers many possibilities for evaluation of consistency or discrepancy among measures. The crucial decision is usually related to confirming the validity and accuracy of the ABR threshold estimates. The internal validity and reliability of threshold measurements are increased because of the BCEHP requirement for threshold estimates at 500 Hz, 2000 Hz, and 4000 Hz at a minimum, the use of both AC and BC routes, and the contingent click-ABR measurements in the event of no response at maximum levels. However, an important principle is that corroborative evidence for the ABR findings should be sought wherever possible.

The downside in seeking corroborative evidence is that the corroborative measures such as OAEs and MEA are themselves error-prone and subject to a host of variables: they must not be allowed to inappropriately undermine or compromise the primary inferences from the testing. Rather, the corroborative measures provide an indication for critical re-evaluation and, where necessary, a confirmation of findings. A balance is always required, and that is the nature of clinical judgment which is required from BCEHP audiologists.

The most probable scenarios that may lead to delay in definitive assessment are:

- An inability to obtain sufficiently reliable threshold estimates without resorting to sedation or general anesthesia.
- Audiometric uncertainty, arising from evidence of ABR waveform abnormality suggesting ANSD or other disorders that degrade neuronal synchrony in the auditory brainstem.
- Audiometric uncertainty due to a transient or fluctuating conductive overlay on a genuine sensory hearing loss.

Provided that ANSD and retrocochlear disorders are absent, it is usually possible to obtain reliable threshold estimates with tone pip ABR in ANY infant, provided there is a willingness to consider testing under sedation. By far, the most common cause of inadequate ABR results is poor EEG conditions due to electromyogenic artifacts associated with tension or gross movement.

Usually, as the infant gets older it becomes increasingly important to integrate VRA results into the overall audiometric picture. During the course of that transition, it should not be forgotten that a threshold estimate obtained by VRA represents responsiveness to, not perception of, sound. So the first question that arises is, if VRA results are worse than ABR results obtained with a high-quality protocol, whether there is a responsiveness issue. The second question is whether the hearing loss has progressed. Risk indicators should be carefully reviewed in relation to possible progressive loss. Conversely, if the VRA results are markedly better than those from the ABR, the first question is whether there
was adequate control of false-positive response in the VRA. A repeat ABR test under sedation may be required to resolve these situations definitively.

Equally, it should not be forgotten that the ABR is a proxy for perception, and that several factors can compromise the validity of that relationship. The most obvious of these are the possibility of inadequate procedure or interpretive error in the ABR. There is a need to take the strengths and weaknesses of both behavioural and electrophysiological assessment into account, to review findings critically, to repeat measures where necessary and, finally, to take family observations into account, in the pursuit of an accurate overall assessment.

When the array of test outcomes suggests the presence of ANSD or a retrocochlear disorder affecting the presence of Wave V, ABR thresholds based on Wave V-V' cannot be relied upon. They will tend to overestimate the true perceptual thresholds by an amount that depends on the level of dysynchrony present. When neurogenic early waves are present but Wave V-V' is not, the early waves may give some indication of hearing thresholds, but Wave I, for example, is limited in its sensitivity, and the extent to which the disorder affecting the later ABR waves may also compromise perceptual sensitivity is unknown.

For infants with ANSD or retrocochlear disorders, behavioural assessment is currently required to obtain more-valid estimates of hearing sensitivity. Reliable thresholds may not be available until VRA becomes accurate and specific. While there are reports that at least some infants with ANSD may do well with amplification or with cochlear implants, there is at present insufficient information to recommend a specific approach to communication development. The approach following a determination of ANSD is at the discretion of the BCEHP audiologist. The BCEHP is currently evaluating more advanced assessment methods to address these circumstances.

The medical community plays a key role in establishing the etiology of a hearing loss, in assessing treatment needs, in providing medical and surgical treatment of remediable conditions, and in the broader assessment of underlying disorders and conditions that are directly or indirectly related to the hearing loss. These processes may include a variety of investigations (such as ophthalmologic, radiologic, metabolic, neurodevelopmental, genetic) and referrals, such as for social supports.

The BCEHP is collaborating with the medical community to establish guidelines for medical management of infants identified by the program, and to facilitate effective and efficient means of referral to appropriate physicians and medical services throughout the province. It is particularly important to provide family physicians, pediatricians and otolaryngologists with the information they need so that they will support and encourage families to follow program recommendations. It is also essential to establish fast-track referral mechanisms to otolaryngologists with pediatric experience; these procedures have been established by the BCEHP in conjunction with the BCEHP Medical Advisory Group, and are described in section 1000.
902. Normal Hearing

The child will be reported to BCEHP as audiometrically normal if AC EHLs are estimated with confidence at 25 dB or better for ALL frequencies that are mandatory under this protocol, and in NO other circumstance.

From the BCEHP perspective, hearing is normal when the target hearing loss is deemed not to be present. This is not the same thing as the conventional, clinical meaning of normal hearing. In ABR-based assessments, clear and reproducible ABRs by air conduction at 500 Hz, 2000 Hz, and preferably 4000 Hz, in each ear at the mandatory minimum levels are sufficient to define normal hearing from the BCEHP perspective. If any other frequency is tested for any reason, a similar result is required. In VRA-based assessments, a similar inference applies.

Because there are many causes of absent or depressed OAEs, normality of OAEs at all frequencies is not necessary for an overall conclusion of BCEHP normal hearing, except in the case of a VRA assessment where ear-specific behavioural results could not be obtained.

When a normal hearing determination is made, the family should be counselled fully about what exactly is meant by such a result and about the need for continued vigilance. The family should be provided with standard BCEHP documentation covering issues such as risk indicators, communication development milestones and actions if a concern develops. This information should be provided in the most relevant language available from the BCEHP.

903. PCHL Confirmed

The BCEHP report field indicating the presence of PCHL is YES if:

i) Any BC-ABR indicates no response at minimum test levels (i.e., elevated threshold).

ii) The behavioural threshold is estimated with confidence (either by ABR or VRA) at 30 dBEHL or greater, or if the presence of ANSD is strongly indicated.

The infant is defined to have the target PCHL by any elevation of BC tone pip ABR threshold or BC VRA MRL of 10 dB or more above the required minimum test levels at 500 Hz or 2000 Hz, in either or both ears. In the event that BC testing has proved unfeasible or inconclusive, AC threshold measurements may serve to define sensorineural hearing levels provisionally, provided that immittance results are clearly normal. Nevertheless, BC ABR results should be given high priority when AC levels are elevated. PCHL is also deemed to be present if AC thresholds are clearly higher than those that could be attributed to purely conductive hearing loss. PCHL is also deemed to be present if test results indicate the presence of ANSD.

904. Summary of mandatory requirements for complete assessment

See appendix 8 for specific details regarding ABR.

In the case of normal hearing as per the BCEHP protocol, the following results are mandatory for a complete audiology assessment:
ABR (normal results):

- responses at 20 dBEHL at 500 and 25 dBEHL at 2000 Hz bilaterally;
- 4000 Hz is not mandatory, although a determined effort should be made to get results at 4000 Hz at 25 dBEHL
- 1000 Hz is not mandatory; however, if tested, responses should be present at 25 dBEHL

Behavioural:

- ear-specific responses at 25 dBHL at 500 and 2000 Hz bilaterally; OR
- responses at 25 dBHL at 500 and 2000 in soundfield AND present OAEs at 2000, 3000 and 4000 Hz bilaterally
- 4000 and 1000 Hz are not mandatory; however, if tested, responses should be present at 25 dBHL

In the case of normal results, acoustic immittance measures and otoacoustic emissions are not mandatory (with the exception of when soundfield results have been obtained), but are recommended for a complete assessment.

In the case of PCHL confirmed as per the BCEHP protocol, the following results are mandatory for a complete audiology assessment:

ABR (PCHL):

- AC thresholds at 500, 2000, and 4000 Hz bilaterally;
- AC thresholds at 1000 Hz if difference between 500 and 2000 Hz thresholds is greater than 20 dB nHL
- BC threshold at 2000 Hz where 2000 Hz AC is elevated
- BC at 500 Hz is not mandatory if recordings to BC 2000 Hz have been obtained; however, BC threshold at 500 Hz is mandatory if AC 500 Hz is the only elevation
- evaluation of high-intensity click recordings in the event of thresholds in the severe-profound range, or absent ABR wave V at maximum intensities

Behavioural:

- AC thresholds at 500 and 2000 Hz bilaterally;
- AC thresholds at 4000 if threshold at 2000 Hz is elevated
- AC thresholds at 1000 Hz if difference between 500 and 2000 Hz thresholds is greater than 20 dB HL
- BC at 2000 Hz if 2000 Hz AC is elevated
- BC at 500 Hz is not mandatory if responses to BC 2000 Hz have been obtained, unless 500 Hz AC is the only elevation
In the case of abnormal results (i.e., PCHL confirmed), acoustic immittance measures and otoacoustic emissions are mandatory for a complete audiology assessment.

905. **Summary of Required Thresholds for Fitting of Amplification (if chosen by the family)**

Fitting of amplification for a hearing loss with less than 2 confirmed thresholds per ear (2000 Hz and 500 Hz) is not advised/not supported. A minimum of 4 (500, 1000, 2000, 4000 Hz) and ideally, 5-6 frequencies (250, 500, 1000, 2000, 4000, 6000 Hz) per ear must be established to enable appropriate fitting. Amplification can be fit conservatively if only 2 thresholds are known (or no response on the ABR) until such time as the other thresholds are established. ABR threshold information will be reported in both nHL and EHLs. The EHLs will be used in the hearing aid fitting protocol (e.g. DSL™ V5).

906. **Follow-up Recommendations**

Once hearing status has been confirmed, appropriate plans for follow-up should be made. For infants confirmed to have PCHL:

1. Review the results of the audiologist’s assessment, implications of the audiologic findings, and recommendations for intervention with the parents/caregivers, including:
   a. Information regarding hearing loss type, degree and the need for medical evaluation.
   b. Amplification options.
   c. Information regarding the need for continued monitoring of hearing status.
   d. Information regarding the importance of early intervention.
   e. Information regarding communication options for young children with permanent hearing loss.
   f. Information regarding the availability and importance of parent-to-parent support.

2. Refer the infant/family to an otolaryngologist for medical assessment in consultation with the infant’s primary care provider. See section 1000: “Medical Referral Process for PCHL.”

3. Initiate the amplification process, if appropriate, and ensure that medical clearance for amplification has been obtained, as per section 1000: “Medical Referral Process for PCHL.”

4. Any newly identified hearing loss entered in the BCEHP database will automatically generate a referral for BCEHP intervention coordination. However, intervention coordination will be declined if the child is over 2 years of age.

5. Report, with consent, to the family/care-giver, to the infant’s primary care provider (i.e. family physician or pediatrician), and to the referral source,
as well as any other persons or agencies as indicated by the family/care-giver.

For infants confirmed to have normal hearing:

1. Review the results of the audiologist’s assessment, implications of the audiologic findings, and recommendations for intervention with the parents/caregivers, including:
   a. Information about risk indicators for progressive and delayed-onset hearing loss
   b. Information about typical speech, language, and listening developmental milestones.

2. Report, with consent, to the family/care-giver, to the infant’s primary care provider (i.e. family physician or pediatrician), and to the referral source, as well as any other persons or agencies as indicated by the family/care-giver.

Adapted from ASHA Guidelines, 2004
DX 1000: Medical Referral Process for PCHL

Children confirmed to have PCHL and who are under consideration for amplification require an expedited medical assessment process and authorization for fitting of amplification by an otolaryngologist. The procedure described below is intended to augment and expedite the current processes in use by audiologists to obtain medical approval for the fitting of amplification. The BCEHP Medical Advisory Group has designated otolaryngologists from each health authority through which audiologists can initiate a medical referral; the role of these otolaryngologists is to: provide the medical authorization for amplification; facilitate the referral for the otolaryngology consult; and ensure provision of a medical evaluation for children identified with PCHL. The designated otolaryngologists are responsible for ensuring that the required medical referrals are in place for the purposes of providing medical care. These procedures have been presented to, and are supported by, the BC Otolaryngology Society (BCOS).

The purpose of the medical evaluation is to determine the etiology of the hearing loss, to identify related physical conditions, and to provide recommendations for medical/surgical treatment (if applicable) as well as referral for other services.

The BCEHP Medical Advisory Group and the BCOS are in agreement that medical authorization is not required for public health audiologists to take ear mould impressions.
**Procedure: Obtaining Medical Authorization for Fitting of Amplification**

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**Required Review Participants:** Medical Advisory Group, Diagnostics Advisory Group, Regional Coordinators Council and Provincial Coordinator

**Scope:** This procedure applies to infants and young children who are referred by the BCEHP who have confirmed permanent congenital hearing loss (sensorineural hearing loss, auditory neuropathy, permanent conductive hearing loss) and where expedited medical investigation and/or authorization for amplification are required to meet the BCEHP program benchmarks. Referral may initiate from the newborn hearing screening or from surveillance for late onset hearing loss.

**Background Information:** There is a critical window of opportunity within the first six months of life to intervene with children with congenital permanent hearing loss. Children who have confirmed hearing loss and are under consideration for amplification require an expedited Medical Assessment process and authorization for fitting of amplification by an Otolaryngologist. This procedure is intended to augment and expedite current processes that audiologists use to obtain medical approval for fitting of amplification.

The BCEHP Medical Advisory Group has recommended that there be Otolaryngologists from each Health Authority who will provide the medical authorization for amplification and facilitate the referral for the otolaryngology consult, and may provide the medical evaluation of infants identified with sensorineural hearing loss, auditory neuropathy and permanent conductive hearing loss. The designated otolaryngologists are responsible for ensuring that the required medical referrals are in place for the purposes of providing medical care. These procedures have been presented to and supported by the BC Otolaryngology Society (BCOS).

The BCEHP Medical Advisory Group and the BCOS are in agreement that medical authorization is not required for public health audiologists to take ear mould impressions.

For further information on the BCEHP Medical Assessment Process, refer to the website [www.phsa.ca/earlyhearing](http://www.phsa.ca/earlyhearing) or the Community of Practice site [https://bcehp.phsa.ca](https://bcehp.phsa.ca).

Medical Approval Forms are located on the Communities of Practice (CoP) Site. These forms are not provided through the Provincial Office and can be printed from the CoP site.

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**BCEHP Relevant Benchmarks**

**Benchmark 1 (Hearing Devices):** # and % of infants and/or children who are fit with hearing devices within 2 months of confirmation of hearing loss.

**Benchmark 3 (Identification):** # and % of infants and/or children with confirmed hearing loss who have received a medical assessment for hearing loss within 3 months of diagnosis date.
Procedure for referral to designated Otolaryngologists for BCEHP clients:

1. Audiologist completing the audiology assessment confirms hearing loss including type, degree and ear and determines if amplification is to be provided.

2. Audiologist reviews the list of participating Otolaryngologists for their Health Authority (see Appendix 20: “Table of Otolaryngologists”).

3. Audiologist completes the BCEHP Medical Approval Form found on the Communities of Practice (CoP website; see Appendix 21: “Medical Approval Form”), the family physician information letter (see Appendix 22: “Family Physician Information Letter”), attaches a copy of the Assessment report/results, and has the three items faxed to a participating Otolaryngologist for their Health Authority.

4. A copy of the family physician letter and a copy of the Audiology Assessment report/results are sent to the family physician and pediatricians, if applicable. The purpose is to inform the family physician and pediatrician about the process for medical approval and if applicable, to generate the medical referral to the designated Otolaryngologists.

5. The original BCEHP Medical Approval Form, the original “Family Physician Information Letter” and Audiologist results/report are attached to the client file with a bring forward date of 2 business days. Note that the Medical Approval Form is only sent to the Otolaryngologist.

   a. If after 2 business days, a signed Medical Approval Form has not been received at the Clinic, the Hearing Clinic initiates a phone call to the Otolaryngologist office to check on status of Medical Approval Form.

   b. A bring forward is set for a further 3 business days.

   c. If after 5 business days, a signed medical approval form has not been received at the Clinic, a second call is made to the otolaryngologist’s office by the audiologist.

   d. If after 7 business days, a signed medical approval form has not been received, the audiologist emails the BCEHP Provincial Office and faxes a copy of the medical Authorization request. The BCEHP Provincial Office will follow-up through the Medical Advisory Group and respond to the audiologist within 5 business days.

   e. Once a signed Medical Approval Form has been received, it is attached to the file and fitting of amplification can proceed.
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Appendix 2 – BC Hand-held Transducer Instructions

Responsibility for appropriate application of the BC transducer lies with the testing audiologist. If BC ABR results are elevated, the audiologist must ensure it is not due to BC incorrect technique.

BCEHP recommends that the transducer be held by the audiologist or a trained assistant. When unavoidable, a family member may hold the transducer after instruction. A note of this should be provided on the ABR recording sheet.

**Position**

The transducer should be applied to the upper mastoid area/temporal bone superior to the meatal opening. It should not come into direct contact with any electrode or electrode lead. Electrode leads should be directed away from the transducer and its supply leads, to the extent possible.

**Holding**

The transducer should be applied to the baby’s head with the thumb and middle finger holding the supply lead at the point of attachment and the index finger applying force towards the head on the rear surface of the transducer. It should not be held by its sides.

**Force**

The application force should be approximately 400g (about 14 oz, or 1 lb). The force should be firm and steady but not excessive. Opposing force on the other side of the head may be required.

**Trial**

Before testing, the family member should demonstrate the holding technique and application force on the audiologist’s hand.

**Alerting**

The family member should be encouraged to alert the audiologist if for any reason the required positioning and force are not maintained during an ABR measurement.
Appendix 3 – ABR Technical Details

ABR IHS Smart-EP CALIB File Offsets for BCEHP: nominal 0 dBnHL at dial 0 dB

These values are numbers specified by the BCEHP in the EP Utilities/EPSetUP/Calib file that are intended to produce appropriate stimulus levels, such that dial values approximate dBnHL values. These numbers apply to the Intelligent Hearing System SmartEP system ONLY, as this is the required instrumentation for evoked potentials within the BCEHP.

It should be noted that simply entering the number as listed below into the IHS SmartEP parameters does NOT ensure actual SPL (or force level for BC) will be correct due to transducer differences and especially transducer changes (due to age, overuse, damage, etc.). Calibration (at least annual) is required to ensure appropriate levels are generated by the transducers.

Stimulus Transducers

Air Conduction: insert earphones (ER-3A) except where specifically contraindicated, in which case supra-aural earphones (TDH/MX41 type) are optional.

Bone Conduction: B71 bone vibrator as specified by ANSI S3.6-1996, held in place by hand or custom Velcro band.

Air Conduction (in dB SPL) from Stapells 2011

<table>
<thead>
<tr>
<th>Frequency</th>
<th>ER3A dBppeSPL</th>
<th>TDH49 dBppeSPL</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>22 dB ppe</td>
<td>25 dB ppe</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>25 dB ppe</td>
<td>23 dB ppe</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>20 dB ppe</td>
<td>26 dB ppe</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>26 dB ppe</td>
<td>29 dB ppe</td>
</tr>
<tr>
<td>Clicks</td>
<td>31 dB peak</td>
<td>36 dB peak</td>
</tr>
</tbody>
</table>

Bone Conduction (in dB re 1μN) from Stapells 2011

<table>
<thead>
<tr>
<th>Frequency</th>
<th>B71 dB Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>67 dB ppe</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>49 dB ppe</td>
</tr>
<tr>
<td>Clicks</td>
<td>51 dB peak</td>
</tr>
</tbody>
</table>

(from Richter & Fedtke, 2005)

Protocol (.set) Files

As distributed by BCEHP
Electrode Sites
Non-inverting: High midline forehead, referenced to

Inverting Channel 1: 
Right mastoid

Inverting Channel 2: Left mastoid

Common: Lateral forehead > 3cm from Non-inverting

Electrode Impedance
≤ 3 kOhms for all electrodes
difference between electrodes within a channel of ≤ 1 kOhm

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

Filters
High-pass (Low) 
Tone pip thresholds 30 Hz
All click recordings 30 Hz

Low-pass (High) 
Tone pip thresholds 1500 Hz
All click recordings 3000 Hz (required for CM recordings)

Notch filter Off

Artifact Reject
On, typically +/-15-25 μV (+/-25 μV in .set files provided by BCEHP)

Amplifier Gain
100,000-150,000 (100,000 in .set files provided by BCEHP)

Averaging
1000-10000 accepted sweeps per average, 2 or 3 averages per condition.
See residual noise levels

**SNR/RN/Correlation (CCR) Time Regions**

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>RN, SNR &amp; Correlation (CCR) Window</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clicks</td>
<td>1.8 – 11.8 ms</td>
</tr>
<tr>
<td>AC 500 Hz tones</td>
<td>10.5 – 20.5 ms</td>
</tr>
<tr>
<td>BC 500 Hz tones</td>
<td>20 dBnHL: 10.5 – 20.5 ms</td>
</tr>
<tr>
<td></td>
<td>30-50 dBnHL: 14 – 24 ms (only RN valid)</td>
</tr>
<tr>
<td></td>
<td>Note: higher BC is later because of stimulus artifact</td>
</tr>
<tr>
<td>AC 1000 Hz tones</td>
<td>7.5 – 17.5 ms</td>
</tr>
<tr>
<td>AC/BC 2000 Hz tones</td>
<td>6.5 – 16.5 ms</td>
</tr>
<tr>
<td>AC 4000 Hz tones</td>
<td>5 – 15 ms</td>
</tr>
</tbody>
</table>

**SNR Criterion**
- If the SNR is **greater than or equal to 1.0** then a response is likely present.
- Sometimes response is visually present with an SNR lower than 1.0.
- Visual determination of response present is currently the primary method to determine response presence.

**CCR Criterion**
- **CCR no longer required on IHS (SNR preferred measure).**
- A response is likely to be present if the correlation between two waveforms for a given condition is \( \geq 0.46 \).
- The time window for correlation must be set as above, or as a 10-ms window around the peak in question.

**Online Residual Noise Criteria**
To determine “no response” for a given set of waveforms, the RN must be less than or equal to:
- **0.11 \( \mu \)V** for an individual waveform (must have at least two replications, all must be NR, and all with RN less than .11\( \mu \)V), or
- **0.08 \( \mu \)V** for an added waveform (composite average of all replications)
• Even if RN meets criteria, waveforms must be **visually flat** at a reasonable display scale (e.g., 0.5μV and 25% plot size)

**Epoch length**
23-25 ms for tone pips (25.6 ms on IHS Smart-EP)
12-13 ms for clicks (12.8 ms on IHS Smart-EP)

**Analysis Offset**
Zero ms

**Visual Display Scale**
Tones: Typically, 0.5μV and 25% plot size
Clicks: Typically, 0.7-1.0μV and 25% plot size

**Stimulus Parameters**
Tone pips: Linear ramp (trapezoidal envelope), 2-1-2 cycle rise/plateau/fall times; or 5-cycle exact-Blackman window (no plateau): Alternating polarity; Repetition rate ~39.1/s.

Clicks: 100-μs pulse duration; recordings to single polarity condensation and rarefaction polarity as specified (i.e., do not use “alternating” polarity); Repetition rate 19.1-21.1/s.
Higher rates (61.1-94.1/s) may aid identification of wave V.

**Masking**
Ipsilateral: None.
Contralateral: discrentional.
### Appendix 4 – BCEHP Regional Contacts

**BCEHP Provincial Office**  
BC Early Hearing Program, Provincial Health Services Authority  
Suite 301 – 931 Fort Street  
Victoria BC V8V 3K3  
[bcceph@phsa.ca](mailto:bcceph@phsa.ca)  
Phone: 250-519-5725  
Phone: 1-866-612-2346  
Fax: 250-519-2015

- **Ann Marie Newroth**  
  anewroth@cw.bc.ca  
  Provincial Director  
  1-250-519-5724

- **Shelley Travis**  
  shelley.travis@phsa.ca  
  Program Administrative Coordinator  
  1-250-519-5727

- **Sharon Tavarez**  
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  Program Assistant  
  1-250-519-5730

- **Sewailu (Ella) Auzins**  
  sewailu.auzins@phsa.ca  
  Program Assistant  
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  Program Assistant  
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- **Susan Lane**  
  slane@cw.bc.ca  
  Provincial Early Intervention Coordinator  
  1-604-312-5110

- **Diane Bremner**  
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  Program Manager  
  1-604-816-7449

- **Jenny Hatton**  
  jhatton@cw.bc.ca  
  Clinical Audiologist  
  Program Support Audiologist  
  ext. 7407

- **Alison Beers**  
  abeers@cw.bc.ca  
  Clinical Audiologist  
  Program Support Audiologist  
  ext. 5630

- **Annie Tseng**  
  atseng@phsa.ca  
  System Analyst (BEST Support)  
  1-866-612-2347

**Regional Coordinators**  

- **Samantha Trowell-Martin**  
  Samantha.Trowell-Martin@fraserhealth.ca  
  Regional Coordinator  
  Fraser Health Authority  
  1-604-587-7936
Cleft Lip and Palate Programs in BC

BC Children’s Hospital
Sandra Robertson (Nurse Clinician/Coordinator)
BCCH Cleft Palate/Craniofacial Program
4480 Oak Street
Vancouver, BC, V6H 3V4
(604) 875-2345, local 7057
Toll Free: 1-888-300-3088
Email: srobertson@cw.bc.ca

Victoria
Maureen O’Brien (Cleft Palate Clinic Coordinator)
VIHA – Queen Alexandra Centre for Children’s Health
2400 Arbutus Road
Victoria, BC, V8N 1V7
(250) 519-6807
Email: Maureen.M.Obrien@viha.ca

Kelowna
Lynda Martyn (Coordinator)
Interior Cleft Lip and Palate Clinic
1340 Ellis Street
Kelowna, BC, V1Y 1Z8
(250) 868-7809
Email: Lynda.Vivian@interiorhealth.ca

BCEHP website: www.phsa.ca/earlyhearing
BC Early Hearing Resource Tool (BERT): http://pod/bcehp
BEST Live site: https://ehp.phsa.ca
Appendix 5: History Form

Childhood Hearing Questionnaire

Name of Child: _______________________________
Child’s Birth Date: _______________________________
Name of person filling out this form: _______________________________
Relationship to child: _________________________

1. For what reason was this hearing test arranged?
   ________________________________________________

2. Has your child ever had a hearing test? Yes No

3. Do you have any concerns about your child’s hearing? Yes No

4. Does your child seem to hear better on some days than others? Yes No

5. Does anyone in the family (sisters, brother, aunts, grandparents, etc) have a history of hearing loss in childhood? Yes No

6. Were there any complications during pregnancy or delivery? Yes No

7. Were any of the following present after your child’s birth or during the first two months?
   Stayed in hospital after mother
   Birth weight less than 1500 g (3.3 lbs)
   Did not respond to sounds or people
   Was in an incubator or isolette
   Difficulty breathing/ventilation
   High fever
   Prematurity
   Infections
   Poor weight gain
   Appeared yellow/jaundiced
   Brain problems

8. What is your child’s general health? Good Poor

9. Is your child taking any medication now? Yes No

10. Has your child ever been hospitalized? Yes No

11. Has your child experienced ear infections or other ear disorders? Yes No

12. Has your child had any ear surgery? Yes No
13. What illnesses has your child had?

- High fever
- Convulsions/seizures
- Head or ear injury
- Encephalitis
- Meningitis
- Tonsillitis
- Pneumonia
- Heart problems
- Rheumatic fever
- Allergies
- Asthma
- Other: _______________________

14. Has your child ever received speech therapy?  
Yes  No

15. Do you have any concerns about your child’s speech and language?  
Yes  No

16. List any languages that your child is exposed to:

_________________________________________________________________

17. Do you have any concerns about your child’s physical or mental development?  
Yes  No

18. Does your child have any behavioural issues?  
Yes  No

20. Who would you like to receive copies of the report?

- IDP/CDC  
- Family Physician  
- Paediatrician  
- Other physicians  
- Speech-Language Pathologist  
- MCFD  
- Other

Date: _______________________

BC Early Hearing Program
A service of BC Children’s Hospital and the Provincial Health Services Authority
Appendix 6 – ABR Test Instructions for Parents

Dear Parents,

Your child has been scheduled for a tone-evoked Auditory Brainstem Response (ABR) assessment.

ABR assessments are done while your baby sleeps. The ABR test measures how well the hearing pathway responds to sound while your baby is sleeping. We place four recording sensors on your baby’s head and play soft sounds through earphones that fit in the ears. The ABR is painless and will not harm your baby in any way. We schedule 2-3 hours for the ABR appointment, although the testing time is usually not that long. We allow extra time as it can take a while for your baby to fall asleep.

Your baby must be asleep for testing. Please do what you can to bring your baby to the appointment awake but ready to sleep once the testing has started. We realize this is not easy, but please do your best. Here are some suggestions to help your baby sleep during testing:

**How parents can prepare their baby for ABR testing**

- Keep your baby awake for at least an hour before the test.
- If driving to the appointment, have an extra adult in the car to play with your baby and keep the baby awake.
- Bring any special blankets or items that may help your baby to sleep.
- Please try to delay feeding your baby for about one and a half hours before the appointment. It often works well if parents feed their baby as testing begins, helping the baby to fall asleep.

You will be in a comfortable chair with your baby for the duration of the test. There are no supervised play areas in the hearing clinic. If you must bring other children with you, please bring another adult to look after them.

In most cases, the results of the test will be explained to you immediately after the test.
Appendix 8 – Key Protocol Elements & Mandatory Components

This Appendix contains a summary of important elements of the protocol for the ABR-based initial audiology assessment. The BCEHP protocol is directed at achieving consistent, high quality of clinical measurement and interpretation. All mandatory elements reflect evidence-based best practice.

**Mandatory elements are bolded** and are always completed except under exceptional circumstances. When mandatory elements are not fulfilled, a brief explanation is entered in the clinical record. Exceptions are evaluated as part of the ABR CQI process.

**Interpretation of averages for a single stimulus condition**

• **Response Present**
  – **The response waveforms show visual (subjective) replicability**
  – Peak-to-peak response amplitude should be at least 3x the largest difference between replications in the 10-ms window centered on the peak (display scale typically 0.5-0.7 µV/div with 25% plot size)
  – The overall SNR value of the average of all replicates should be (but is not always) at least 1.0
  – There is no specific value of RN required for judgement of response presence
  – For accurate assessment of waveshapes or peak latencies, such as for BC ipsi/contra comparisons and click-ABR CM/wave I determination, it is desirable that the overall RN of all waves added be in the range 0.04-0.08 µV, requiring larger number of trials averaged or more replicates than are typical for ABR threshold estimation

• **No Response**
  – **The averages show “No Response” visually (subjective)**
  – Averages appear quiet and flat at a display scale of 0.5 µV/div (25% plot size)
  – The RN of each replicate is ≤ 0.11 µV or the overall RN is ≤ 0.08 µV

• **Could Not Evaluate, if**
  – Neither “Response Present” nor “No Response” criteria above can be satisfied
  – Overall average of replications appears non-flat and/or noisy at a display scale 0.5 µV/div (25% plot size)
  – The overall average of all replicates has an RN >0.08 µV
ABR Threshold Estimation – General Aspects

- Threshold testing is preceded by cursory otoscopy
- Threshold is defined by findings of “Response” at given stimulus level and “No Response” at a level not more than 10 dB below the lowest level with “Response”. The exception is finding of “Response” at a BCEHP minimum (“normal”) level
- Averages at the threshold bracket levels (or the minimum required level) are replicated and include at least 1000 accepted sweeps per average
- Unless clearly contraindicated, initial testing begins with 2000 Hz AC at the BCEHP minimum level
- To determine rapidly the hearing status of both ears, it is strongly recommended that the test ear be switched, regardless of the result in the initial test ear. To facilitate this, a determined effort to place inserts in both ears initially should be made
- If the AC threshold is elevated in one or both ears, 2000 Hz BC testing is initiated immediately after determining presence of elevation (i.e., before AC threshold determination)
- If 2000 Hz BC is elevated, BC 2000 Hz threshold is obtained
- Large step sizes are used initially to bracket elevated threshold efficiently
- Prior BCEHP threshold ABR test results may alter the sequence indicated above

Minimum results necessary to infer:

- **Normal Hearing**
  - 2000 Hz AC (response at 30 dBnHL) both ears and 500 Hz AC (response at 35 dBnHL) both ears
  - 4000 Hz AC (response at 25dBnHL) is strongly recommended where feasible (OAEs are an acceptable alternative)
  - Printed copies of acoustic immittance and OAE results are recommended if completed

- **Conductive Hearing Loss**
  - Elevated 500 Hz or 2000 Hz AC with normal BC at the corresponding frequency (i.e., at 30 dBnHL for 2000 Hz BC; at 20 dBnHL for 500 Hz BC). BC 500 Hz only required if 500 Hz AC is the only elevation
  - Printed copies of acoustic immittance results
  - OAEs are discretionary
  - 4000 Hz AC and 1000 Hz AC may be deferred

- **Sensorineural Component to the Hearing Loss**
  - Elevated threshold(s) for 2000 Hz AC, &/or 500 Hz AC, &/or 4000 Hz AC
  - 2000 Hz BC threshold (min level 30 dBnHL) if 2000 Hz AC is elevated
- 500 Hz BC threshold (min level 20 dBnHL) if 500 Hz AC is only elevation and >40 dBnHL
- 1000 Hz AC threshold time permitting or if >20 dBnHL difference between thresholds at 500 and 2000 Hz
- Printed copies of acoustic immittance and OAE results

ANSD

- If Wave V is not clearly present at all frequencies in one or both ears, do click ABR for ANSD/neurologic assessment, including CM and stimulus artifact analysis.
  - Separate recordings of rarefaction and condensation (at least 2 replications for each) at 95 dBnHL. Slow rate (19.1-21.1/s) to allow comparisons of neural components and cochlear microphonics.
  - Click ABR recommended for more severe SNHL losses even if tone-ABR wave V present
  - If responses are small (e.g., CM &/or wave I) or inter-wave intervals are to be assessed, it is desirable that the overall RN of all waves added be in the range 0.04-0.08 µV (or better), requiring larger number of trials averaged or more replicates than are typical for ABR threshold estimation

General Documentation & Reporting

- ABR recording sheets(s), including file names, stimulus parameters, response judgements for groups of replications (i.e., ✓, X, CNE), relevant patient/test environment issues, rationale for departures from protocol
- Entry of results in BEST, including frequency-specific test-specific data entry (e.g., actual ABR nHL result for each frequency)
- Summary clinical report in the patient/client chart, signed by the testing audiologist and with printed name, regardless of whether any external report is being issued.
Appendix 9A – Late Onset/Progressive Hearing Loss Risk Factors

RISK FACTORS

A. Craniofacial – an obvious craniofacial anomaly (not pits or tags) e.g. cleft palate – NOT cleft lip in isolation – microtia/atrophia.

B. Family history of permanent hearing loss in a relative – first cousin or closer to baby (parents, siblings, uncle/aunt, cousin, grandparent) – in early childhood (before age 12 years) irrespective of degree of hearing loss.

C. Syndrome associated with progressive/late onset hearing loss, (e.g. Pendred, Brachio-Oto-Renal, Alport, Usher, LVA, FAS, neurofibromatosis, osteopetrosis, Down Syndrome).

D. Birth weight less than 1200 grams.

E. Breathing problems:
   i. Five-minute APGAR score less than or equal to 3
   ii. Hypoxic-Ischemic Encephalopathy (HIE) moderate/severe, (Sarnat II or III)
   iii. Congenital Diaphragmatic Hernia (CDH) or Extra-Corporeal Membrane Oxygenation (ECMO)
   iv. Inhaled Nitrous Oxide (iNO) or High-Frequency Oscillatory (HFO) or Jet (HFJ) ventilation

F. Brain dysfunction:
   i. Intra-ventricular Haemorrhage (IVH), Grade III
   ii. IVH Grade IV and Peri-ventricular Leukomalacia (PVL) IV (seen by Neonatal Follow-up)
   iii. Hydrocephalus

G. Hyperbilirubinemia ≥ 400 µM OR meeting any standard criteria for exchange.

H. Lab-proven infection:
   i. Perinatal (in the baby) TORCHES infection (toxoplasmosis, rubella, Cytomegalovirus (CMV), herpes, syphilis)
   ii. Meningitis

I. High dosage (five-fold or greater) of Gentamycin or other aminoglycosides

Note: If an unusual medical condition or questionable risk factor is present, contact your Regional Coordinator who will determine if a special follow up is required.
Appendix 9C – Syndromes Commonly Associated with Hearing Loss in Children

It is estimated that at least 50% of congenital hearing loss is due to hereditary factors. Approximately 70% of hereditary hearing loss is non-syndromal.

Patterns of inheritance of non-syndromal hearing loss can be autosomal recessive, autosomal dominant, x-linked, and mitochondrial.

Here is a list of syndromes commonly associated with hearing loss:

**Alport syndrome**: collagen synthesis disease characterized by renal disease

**Alström syndrome**: pigmentary retinopathy, diabetes mellitus, and obesity

**Apert Syndrome**: craniosynostosis, syndactyly of hands and feet, mental retardation

**Branchio-Oto-Renal syndrome**: kidney, ears, and neck abnormalities

**Charcot-Marie-Tooth**: motor and sensory neuropathy, nephritis

**CHARGE syndrome**: acronym for the set of congenital features: Coloboma of the eye, Heart defects, Atresia of the nasal choanae, Retardation of growth and/or development, Genital and/or urinary abnormalities, and Ear abnormalities and deafness.

**Chondrodysplasias**, e.g. achondroplasia

**Crouzon Syndrome**: craniosynostosis, maxillary hypoplasia, shallow orbits

**DiGeorge sequence**: cardiac defects, Thymus hypoplasia and/or T cell-mediated immunodeficiency, and hypocalcemia and/or absence of parathyroids (part of deletion 22q11 spectrum)

**Down Syndrome aka Trisomy 21**

**Ehlers-Danlos syndrome**: synthesis of collagen defects, characterized by hypotonia, ocular abnormalities, joint hypermobility

**Friedreich ataxia**: spinocerebellar, resulting in progressive gait ataxia

**Goldenhar syndrome**: incomplete development of the ear, nose, soft palate, lip, and mandible (part of the oculo-auriculo-vertebral spectrum)

**Hemifacial microsomia**: abnormal development of the lower half of the face, most commonly the ears, the mouth and the mandible (part of the oculo-auriculo-vertebral spectrum)

**Hunter syndrome** (mucopolysaccharidosis II): a lysosomal storage disease characterized by progressive intellectual impairment, death between 10 and 15 years

**Hurler syndrome** (mucopolysaccharidosis I): a lysosomal storage disease characterized by coarse facial features, skeletal malformations, recurrent otitis media, hepatosplenomegaly, and macroglossia, developmental delay, death by 10 years

**Jervell and Lange-Nielsen syndrome**: variant of long QT syndrome (see below)

**Klinefelter syndrome (XXY)**: hypogonadism, infertility

**Klippel-Feil Sequence**: fused cervical vertebrae, webbed neck, can have cleft palate.
Kabuki: postnatal growth deficiency, onset <1st year, craniofacial anomalies, some have cleft palate, some have cardiac deficiencies.

Large Vestibular Aqueduct Syndrome: enlargement of vestibular aqueduct in the inner ear

Long QT syndrome: prolongation of QT on ECG, syncope, and sudden death

Neurofibromatosis II (NF2): tumours of the central and peripheral nervous system, including non-malignant vestibuloschwannomas

Noonan syndrome: short stature, characteristic facial features, hypotonia, cardiac abnormalities

Norrie syndrome: retinal detachment, possible mental retardation

Ohdo syndrome: mental retardation, congenital heart disease, blepharophimosis/ptosis, hypoplastic teeth

Osteogenesis imperfecta: disorder of type I collagen metabolism characterized by bone fragility

Osteopetrosis: increased osseous density due to defects in osteoclastic resorption

Pendred syndrome: goitre and hypothyroidism

Pfeiffer syndrome: craniosynostosis

Pierre Robin sequence: craniofacial abnormalities

Refsum syndrome: phytanic acid storage disease characterized by microcephaly, severe developmental delay, hypotonia, hepatomegaly, retinitis pigmentosa and dysmorphic facial features

Saethre-Chotzen Syndrome: craniofacial anomalies including variable craniosynostosis

Stickler syndrome: flat midface, cleft palate, myopia with retinal detachment and cataracts, musculo-skeletal findings

Treacher Collins syndrome: craniofacial abnormalities

Turner syndrome: XO genotype characterized by short stature, infertility, renal abnormalities, chronic otitis media

Usher syndrome: retinitis pigmentosa and vitiligo

Velocardiofacial Syndrome (also called DeGeorge): (part of 22q11 deletion spectrum) typical characteristics include cardiac abnormality (especially Fallot's Tetralogy), abnormal facies, thymic aplasia, cleft palate, hypocalcemia

Waaldeburg Syndrome: white forelock, heterochromia of irises

Primary reference:

Appendix 10 – Communication Milestones

As your baby grows check speech, language and listening:

**By Two Months, your baby...**
- ♥  Startles to loud sound
- ♥  Quiets to familiar voices
- ♥  Makes vowel sounds like “ohh” and “ahh”

**By Four Months, your baby...**
- ♥  Looks for sounds with eyes
- ♥  Starts babbling
- ♥  Uses a variety of pitches in squeals, whimpers, chuckles

**By Six Months, your baby...**
- ♥  Turns head toward sound
- ♥  Tries to imitate changes in voice pitch
- ♥  Babbles (*baba, mama, gaga*)

**By Nine Months, your baby...**
- ♥  Imitates speech sounds of others
- ♥  Understands “no-no” or “bye-bye”
- ♥  Will locate sound source at eye level or below

**By 12 Months, your baby...**
- ♥  Correctly uses “ma-ma” or “da-da”
- ♥  Gives toy when asked for
- ♥  Responds to singing or music

**By 18 Months, your baby...**
- ♥  Points to some body parts when asked
- ♥  Says seven to twenty words

**By 24 Months, your toddler...**
- ♥  Points to pictures when they’re named
- ♥  Puts two or more words together “more milk”
- ♥  Knows names of familiar objects and family members
- ♥  Says “No” or “No want”, “No go”
- ♥  Imitates sounds, such as animal sounds
- ♥  Follows simple directions
By 3 years, your toddler…
♥ Hears you when you call from another room
♥ Hears television or radio at the same loudness as other family members
♥ People outside the family can usually understand child’s speech
♥ Uses a lot of sentences with 4 or more words
♥ Can sing songs and nursery rhymes

By 4 years, your child…
♥ Communicates easily with other children and adults
♥ Pays attention to a short story and answers simple questions about it
♥ Hears and understands most of what is said
♥ If using a telephone, can listen with either ear
♥ Tells stories that stick to topic

Routine communication development check by families is recommended for all infants and toddlers even with no risk factor. If parents have concerns about communication, they should always be advised to contact their local Speech and Hearing Clinic or Public Health Nurse.

References:

See “Baby’s Best Chance” and “Toddler’s First Steps” for developmental milestones.
Appendix 11 - Calculations

Estimated Hearing Level (EHL) Calculations

BCEHP Minimum Required Levels in dBnHL and ABR threshold adjustment factors for Estimated Hearing Level (EHL) derivation.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Air Conduction</th>
<th>Bone Conduction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500 1k 2k 4k</td>
<td>500 2k</td>
</tr>
<tr>
<td>Minimum Level (dBnHL)</td>
<td>35 35 30 25</td>
<td>20 30</td>
</tr>
<tr>
<td>Adjustment (dB)*</td>
<td>-15 -10 -5 -0</td>
<td>+5 -5</td>
</tr>
</tbody>
</table>

* For AC ABR threshold estimates greater than 70 dBnHL, if a 5-dB final step size is used, the absolute value of the adjustment should be reduced by 5 dB at all frequencies.

The rationale is that, with a 10 dB step size, the possibility of response presence at a level 5 dB lower (untested) is included in the statistical adjustment for bias; whereas, with a 5 dB step there is no such possibility, since the lower level is now demonstrated to be response-negative.

Examples: 2k 80 dBnHL (+), 70dBnHL (-): EHL = 80 -5 = 75 dBEHL
2k 80 dBnHL (+), 75dBnHL (-): EHL = 80 -5+5 = 80 dBEHL

where (+) and (-) represent definite response detection outcomes.

In most cases, the above correction factors will be accurate within ±5dB. Occasionally, differences of ±10-15dB are seen.
## Appendix 12 – ABR Recording Form

### DIAGNOSTIC ABR RECORDING SHEET

<table>
<thead>
<tr>
<th>FILENAME</th>
<th>EAR</th>
<th>INTEN (dBnHL)</th>
<th>STIM</th>
<th>CHAN* (if BC: 1/C)</th>
<th>SNR*</th>
<th>RN* (µV)</th>
<th>RESP PRES?</th>
<th>COMMENTS</th>
</tr>
</thead>
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</tr>
</tbody>
</table>

**FILENAME**
Time start Recording:
Both ear inserts: y/n

**EARMAN**
R/L

**INTEN (dBnHL)**
AC
BC

**STIM**
FREQ
RC or CC

**CHAN* (if BC: 1/C)**

**SNR***

**RN* (µV)**

**RESP PRES?**

**COMMENTS**
Patient State:
Quiet/Noisy/Asleep etc.

1-V SPL (for clicks when appropriate; indicate if "norm")

**KEY:**
AC: air conduction; BC: bone conduction; RC: rarefaction click; CC: condensation click; ALT: alternating polarity;
y: response present; X: response absent; CNE: could not evaluate/indeterminate; RN: residual noise; SNR: signal-to-noise ratio

**NOTES:**
to determine response absent: RN must be ≤0.11 µV for each waveform or ≤0.08 µV for combined (added) waves; SNR≥1.0;
likely response (however, replications required to determine threshold); SmartEP "SNR Region" must be set correctly (10-µs wide window) for recordings and for offline "additions" using exact windows specified by setup files; *strongly preferred but not mandatory

---

1 If not, add in comments what the circumstances were that prevented both inserts from being placed simultaneously.

---

2 If not, add in comments what the circumstances were that prevented both inserts from being placed simultaneously.
Appendix 13 – Middle Ear Analysis (MEA) Technical Details

**Tympanometry**

Tympanometry will be completed with a 1000 Hz probe for infants under six months corrected age, and with a 226 Hz probe for infants aged 6 months or more. The tympanogram will be replicated immediately if the trace is noisy. Tympanograms will be plotted and retained on file.

The BCEHP Immittance Protocol is based on the Ontario IHP Protocol.

**For Infants up to and Including Six Months Corrected Age**

- Tympanometry will be done using a **1000 Hz** probe frequency, with repetition as necessary and feasible, to improve reliability.
- The key abnormality criterion is a compensated peak static admittance of <= 0.6 mmho, compensated from the **negative** tail at -400 daPa.

**For Infants Over Six Months Corrected Age**

- Tympanometry will be done using a **226 Hz** probe frequency, with repetition as necessary and feasible, to improve reliability.
- The key abnormality criterion in the age range 7-12 months is a compensated peak static admittance of 0.1 mmho, compensated from the **positive** tail at +200 daPa. From 13-18 months, the criterion is 0.15 mmho. From 19 months on, the criterion is 0.2 mmho.

**Middle-Ear Muscle Reflexes**

- Irrespective of age, acoustic reflexes will be elicited with a Broadband noise stimulus and measured ipsilaterally, using a 1000 Hz probe frequency.
- Stimulus level will start at 85 dB HL and increase in 5-dB steps up to no greater than 100 dB HL. Note that for a given nominal level, real-ear SPLs in young infants may be up to 20 dB greater than in adults.
- Reflex presence is defined by a clear, mostly likely negative deflection that is repeatable at any stimulus level. In the case of a questionable elicited reflex, an increase the stimulus intensity should result in an increase in the magnitude of the reflex.

**Key Points**

- Tympanometry criteria are set at the 5th percentiles of age-specific normative distributions.
- In the case of double peaks, the large peak is used.
- Admittance change without development of a genuine peak is abnormal regardless of change size.
- Caution is required in applying these criteria to young neonates, in whom canal wall collapse may lead to steep negative tails.
# Appendix 14 – OAE Technical Details

## 1. Otoacoustic Emissions

<table>
<thead>
<tr>
<th>Stimulus Parameters</th>
<th><strong>DPOAE</strong></th>
<th><strong>TEOAE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stimulus</strong></td>
<td>Type: 2 primary pure tones, response measured at 2f1-f2 for each stimulus tone pair;</td>
<td>Type: click</td>
</tr>
<tr>
<td><strong>Nominal (F2) frequency:</strong></td>
<td>2, 3 and 4 kHz</td>
<td>– Click rate: less than 60 per second</td>
</tr>
<tr>
<td><strong>Frequency ratio (F2/F1):</strong></td>
<td>1.2</td>
<td>– Frequency region: 2, 3 and 4 kHz</td>
</tr>
<tr>
<td><strong>Intensity:</strong></td>
<td>L1 of 65; L2 of 55 dBSPL</td>
<td>– Analysis window: 4-10 or 12.5 msec</td>
</tr>
<tr>
<td><strong>Stimulus Parameters</strong></td>
<td><strong>Recording Details</strong></td>
<td><strong>TEOAE</strong></td>
</tr>
<tr>
<td><strong>DPOAE</strong></td>
<td>IHS - SmartDPOAE:</td>
<td>– Intensity: 82 dBpeSPL, variation +/- 3 dB</td>
</tr>
<tr>
<td>- Type: click</td>
<td>- General:</td>
<td></td>
</tr>
<tr>
<td>- Click rate: less than 60 per second</td>
<td>- Sweeps:16</td>
<td></td>
</tr>
<tr>
<td>- Frequency region: 2, 3 and 4 kHz</td>
<td>- Block Size:8</td>
<td></td>
</tr>
<tr>
<td>- Analysis window: 4-10 or 12.5 msec</td>
<td>- Level 1 (dB SPL): 65</td>
<td></td>
</tr>
<tr>
<td>- Intensity: 82 dBpeSPL, variation +/- 3 dB</td>
<td>- Level 2 (dB SPL): 55</td>
<td></td>
</tr>
<tr>
<td>- Artefact: 10</td>
<td>- Frequency:</td>
<td></td>
</tr>
<tr>
<td>- Retry: 5</td>
<td>- Start: 2000</td>
<td></td>
</tr>
<tr>
<td>- Frequency:</td>
<td>- End: 4000</td>
<td></td>
</tr>
<tr>
<td>- High to low: ticked</td>
<td>- Frequency/Octave: 2.15</td>
<td></td>
</tr>
<tr>
<td>- Advanced:</td>
<td>- F1/F2: 1.22</td>
<td></td>
</tr>
<tr>
<td>- Max level (dB SPL): 80</td>
<td>- Ear correction: ticked</td>
<td></td>
</tr>
<tr>
<td>- ISI Period: 1600</td>
<td>- Stopping:</td>
<td></td>
</tr>
<tr>
<td>- Max ear correction: 5</td>
<td>- On pass at that frequency: ticked</td>
<td></td>
</tr>
<tr>
<td>- Ear correction: ticked</td>
<td>- On overall pass: ticked</td>
<td></td>
</tr>
<tr>
<td>- On no chance to pass: not ticked</td>
<td>- (Under “System” menu at the top, select “Passing criteria”)</td>
<td></td>
</tr>
<tr>
<td>- (Under “System” menu at the top, select “Passing criteria”)</td>
<td>- Passing:</td>
<td></td>
</tr>
<tr>
<td>- Passing:</td>
<td>- DPs-Ns=SNR: 3</td>
<td></td>
</tr>
<tr>
<td>- Overall:</td>
<td>- DPs-Ns: 2</td>
<td></td>
</tr>
<tr>
<td>- Percentage passed from all: blank</td>
<td>- DP Value: -5</td>
<td></td>
</tr>
<tr>
<td>- Percentage in every octave: greyed out 100 (blank)</td>
<td>- Percentage passed frequency range (#1): 100%</td>
<td></td>
</tr>
<tr>
<td>- Percentage passed frequency range (#1): 100%; from (Hz): 2000 to 4000</td>
<td>- Percentage in #2 and #3: blank</td>
<td></td>
</tr>
<tr>
<td>- Percentage in #2 and #3: blank</td>
<td>- Percentage in #2 and #3: blank</td>
<td></td>
</tr>
</tbody>
</table>
## Audiology Assessment Protocol

### DPOAE

- mandatory presence of 2, 3, and 4 kHz
- SNR at least 3 dB above 2 standard deviations of the noise floor;
- absolute amplitude of at least -5 dB and an acceptably low noise floor: i.e. -4 dB SPL or less
- test-retest max difference of 5 dB; or
- SNR > 10 dB at all frequencies and amplitudes > 5 dB Individual frequency response: amplitude > -10 dB SPL and distance from noise floor > 5 dB

### TEOAE

ILO:
- SNR criteria: overall min amplitude (wideband) response > 6 dB; ≥ 70% reproducibility
  - ≥3 dB SNR for 1 or 1.5 kHz
  - ≥6 dB SNR for 2 or 4 kHz
IHS:
- TEOAEs not recommended

### Test Environment

Test environment should be quiet and free of continuous background noise; Good probe fit is essential prior to in-the-ear calibration; Instruments should provide a means of checking and adjusting the stimulus level to achieve the target level

(same as DPOAE test environment)

### Interpretation

Presence of DPOAE may miss very mild hearing loss
OAEs do not relate to hearing thresholds
Presence of OAEs do not rule out retrocochlear hearing loss (such as ANSD)
Absence of DPOAE at 4 kHz, when emissions are present at 2 and 3 kHz, is an indicator to proceed with 4 kHz tone pip ABR threshold search
Absence of OAEs may be due to poor probe placement, probe blockage, status of ME or presence of target hearing loss (SNHL ≥ 30 dBHL)
Presence of OAEs indicates normal cochlear function at or near the frequencies present in the emission

(similar to DPOAE)
Normal-hearing ears produce a wide range of TEOAE intensity and waveforms.

### Equipment Checks

(Varies with equipment)
Calibration must be checked regularly for sound output and microphone sensitivity (every 50 babies, 1x a week, and after any changes made to the probe)
2. IHS (DPOAE) Recording Parameters Set Up

1. Click on “Params,” and on the sub-menu:
   a. The General tab:
      i. Sweeps: 16
      ii. Block size: 8
      iii. Level 1 (dB SPL): 65
      iv. Level 2 (dB SPL): 55
      v. Artefact (dB): 10
      vi. Retry: 5

   b. The Frequency tab:
      i. Start Freq: 2000
      ii. End Freq: 4000
      iii. Freq/Oct: 2.1
      iv. F2/F1: 1.22
      v. Presentation: High to low
c. Advanced:
   i. Max Level (dB SPL): 80
   ii. ISI Period: 1600
   iii. Max Ear Corr (dB SPL): 5
   iv. Ear correction: ticked

d. Stopping:
   i. On pass that frequency: ticked
   ii. On overall pass: ticked
   iii. On no chance to pass: not ticked
2. Under the System menu, at the top, select “Passing Criteria.”

a. Criteria at a given frequency:
   i. (ticked) DP – Ns = SNR (dB SPL): 3.0
   ii. (ticked) DP – Ns (in units of Std Dev): 2.0
   iii. (ticked) DP value (dB SPL): -5.0

b. Overall:
   i. (not ticked) Percent passed for all freqs
   ii. (not ticked) Percent passed in every octave
   iii. (ticked) Percent passed in freq range (# 1): 100
   iv. from Hz: 2000 to 4000
   v. (not ticked) Percent passed in freq range (# 2)
   vi. (not ticked) Percent passed in freq range (# 3)
Appendix 15 – VRA Protocol Procedure

Adapted from Widen et al. (2000)

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

Begin with 2000 Hz warbled tone in insert phone (or best frequency in better ear, if known).

- 55 dB HL… if baby turns naturally or alerts, reinforce.
  - If 2 correct consecutive responses (head-turns), go to Test Protocol
  - If no head turn or alert then increase intensity until response obtained
- 75 dB HL… if head-turn or alert, reinforce
  - If 2 consecutive responses (head-turns), go to Test Protocol.
  - If no head-turn, go to Paired Conditioning Trials.

Paired Conditioning Trials

- 40 dB HL NBN 250 Hz via bone-conductor paired with reinforcement, 2 times
- 40 dB HL NBN 250 Hz “probe” – using bone-conductor ….if head-turn, reinforce … 2 consecutive head-turns prior to reinforcement, go back to insert phones. Before re-inserting inserts, inspect for wax and do listening check.
  - 75 dB HL warble tone through insert.
  - If 2 consecutive head turns, go to Test Protocol.
  - If no turn on returning back to inserts: hearing problem or conditioning problem? Change stimulus frequency? Increase stimulus intensity? Change stimulus type (e.g. speech, music)? Change ear? Try sound field?

Test Protocol …after 2 consecutive head-turns prior to reinforcement

First ear

- Down 20 dB, up 10 dB for MRL search
- Insert Control Trials according to Worksheet schedule
- Test down to 25 dB HL (2 responses out of 4 presentations) OR
- Test down to lowest level at which 2 responses out of 4 presentations are obtained.

- 2nd frequency: 500 Hz in same ear, begin at level of previous response
  - if 2 consecutive responses, continue MRL search
  - if no response, increase intensity until response obtained 2 times continue MRL search

Second ear

- 2000 Hz at 55 dB HL…if head-turn (either side), reinforce on side of turn.
  - proceed with MRL search
  - if no head-turn, increase intensity until response obtained 2 times, continue with MRL search
- 500 Hz - proceed as above for 2000 Hz
• 3rd and 4th frequencies (3000/4000 Hz and 1000 Hz) - as for 1st and 2nd frequencies, in each ear.
• Deviations from this order may be made if child begins to habituate:
  o change stimuli, or re-condition at a level responded to previously

Bone-conduction MRL
• For at least one frequency where AC MRL is >25 dB HL bilaterally.
  o Vibrator on mastoid of ear with better AC MRL.
  o Start with intensity at or below air-conduction MRL.
  o Use same test protocol to find MRL.
Appendix 17 – Role of VRA Distracter

(from J.Widen: Suggestions for VRA)

The role of the distracter in the room with the child is to keep the child appropriately attentive to the task of detecting the discriminative stimulus (tones or speech), which alerts her/him to the availability of the reward (lighting and activation of the toy in the Plexiglas box). The distracter in the room is at least as important as the examiner at the audiometer in achieving a valid and reliable VRA audiogram.

It takes skill and practice to maintain appropriate attention – to keep the child in what we assume is a listening posture, so that s/he wants to see the reinforcer toy more than anything else while still allowing its attention to be drawn away so that a head-turn response can be easily judged. As Wes Wilson used to say, “The reinforcer must be the biggest show in town.” Thus, the distracter and his/her actions must not be more rewarding than the reinforcer toys. The distracter should not talk to or smile or make faces at the baby. A bland test room distracter is preferable to an engaging one in most instances.

The actions of the test room distracter should not compete or interfere with the stimulus trials, thus she should not talk* or make noises that might be misinterpreted as test stimuli. Nor should the distracter’s actions compete or interfere with the reinforcer (i.e. do not use toys or lights similar to the reinforcers to distract the child between trials).

* Of course, another reason for not talking or making any noise is to maintain a quiet environment so the child can hear the test signals. When the distracter wears earphones to communicate with the examiner outside the booth, his hearing of the sounds he himself makes with the distracting toys may be masked -- be sure to distract quietly!

* Social reinforcement - a "good for you" or a pat on the back, etc. – is allowed by the test room distracter during the activation of the toy reinforcer.

For placid babies, who sit quietly, facing forward, the distracter may need to do nothing. For babies who appear eager to see the reinforcing toys (i.e. stare at the dark Plexiglas box as if waiting for it to come on again or turn repeatedly to the toy boxes in the period between stimulus trials) the distracter may have to engage them by changing distracting toys frequently and manipulating them in ingenious ways to keep their attention at midline (or away from the reinforcers). For babies who become engrossed in the distracter toys, the distracter will have to tread a fine line between keeping their attention away from the reinforcers while not allowing them to get too involved in the distracter toys or activities. To judge this fine line the examiner at the audiometer should inform the test room distracter of the child’s reliability. For example, if the child's attention can still be pulled away from the distracters when a stimulus is presented at levels s/he’s previously responded to, then the child's attention is still appropriate. If, however, the child fails to respond at previous levels, it is a sign that the distracter may need to modify her activities.

Slow movements of the distracting toys are more effective than fast or frenetic ones for calming children and putting them in an attentive state. By doing things with the hands, such as having toys interact with one another or moving the toys through the air so the child can track the movement, the distracter can often keep the child's gaze away from the reinforcers. The distracter should maintain some distance between the child and
himself and the distracting toys to encourage the child to watch the activities and not become too involved. The child should be allowed to hold a toy only if s/he does not become too engrossed in it or make noise with it, OR if that is the only way to get any cooperation at all.

The distracter should be careful that she not cue the child to the presentation of a stimulus by stopping her activity for each stimulus trial (or each observation interval). She should also be watchful that the parent does not cue the child.

A final role of the distracter is to maintain rapport with and cooperation of the parent. The parent who is comfortable in the situation is likely to transmit that comfort to the child. Likewise, unease and discomfort may also influence the child's behaviour. The distracter needs to enlist the parent's cooperation in holding the child in a manner that promotes good testing. For example, a child sitting upright rather than lounging back against the parent seems more prone to alert and distinct head-turns. The child needs to be seated at midline, or even angled away from the reinforcer boxes, so that head turns are clearly evident. The parent needs to keep the child's hand away from the earphone.
Newborn Hearing Screen: Stage II Refer

ABR (4-8 weeks C.A.)

U*  PHL  TCHL  N

OAE/Immittance mandatory

ABN  N  ABN  N  ABN  N

Counseling
Expedited Medical (ENT etiology & medical release)****
Referral to BCEHP Intervention Coordination +/- Amplification

ABN  N

OAE/Immittance mandatory

OAE/Immittance mandatory

OAE/Immittance when possible

Discharge from BCEHP

Review ABR

Borderline SNR + visual

Good SNR + visual

Second Opinion

Discharge from BCEHP

Ongoing monitoring*** amplification by 6 months C.A. (if chosen by the family)

IFSP and Team Meeting: Identify case manager, plan coordination of early intervention, medical, audio logical management

Discharge from BCEHP

Additional monitoring as per PHA Mandate

6 month Aud. Assessment***

Note: IFSP and team meeting usually developed within 3 months after starting intervention services.

* Maximum of 2 assessment attempts with unknown hearing status, then consultation with BCEHP Clinical Audiologist

** Maximum of 2 assessment attempts with unknown hearing status, consider sedated ABR Testing

**** Each GP/ENT visit may initiate a referral to PHA/Team audiologist and/or medical monitoring

Outcomes
Tests
Referrals

BC Early Hearing Program
A service of BC Children’s Hospital and the Provincial Health Services Authority

Appendix 18 –Flow Charts

AUDIOLOGY ASSESSMENT WORKUP

By 1st month

By 3rd month

By 6th month

~ 7th month

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Audiology Assessment Protocol
CARE PATH FLOW CHART

Newborn Hearing Screen

Determine Risk Factor

Low Birthweight, low APGAR, TORCHES, Respiratory Distress, Head Trauma or Brain Disorder, Hyperbilirubinemia

1

Cleft Palate, Craniofacial, Syndromic

2

a,b,c,d,e

BCCH Neonatal Follow Up

3a General

3b CDH and/or ECMO

Neonatal Meningitis

4

Family History

5
1. CARE PATH
Low Birthweight (<1200 gr), Low APGAR, TORCHES, Respiratory Distress, Head Trauma or Brain Disorder, Hyperbilirubinemia

Newborn Hearing Screen

Behavioural Aud Assessment at 6-9 months CA in community

U*  PHL  TCHL  N

Note: Children can enter path at anytime if their medical or developmental status changes.

Expeditied Medical & Referral to BCEHP Intervention Coordination

Ongoing Monitoring/Amplification

Behavioural Aud Assessment at 36 months CA in community

U***  PHL  TCHL  N

Expeditied Medical & Referral to BCEHP Intervention

Ongoing Monitoring/Amplification

DISCHARGED from BCEHP at age 3 years

Outcomes
Tests
Referrals

* Maximum of 2 assessment attempts with unknown hearing status, then consultation with BCEHP Clinical Audiologist
*** Maximum of 2 assessment attempts with unknown hearing status, consider sedated ABR Testing
**** Each GP/ENT visit may initiate a referral to PHA/Team audiologist and/or medical monitoring
CAREPATH 2 may be found at:

http://www.bcchildrens.ca/Services/ClinicalDiagnosticFamilyServices/Audiology/forprofessionals/practice-guidelines/cleftpalatecraniofacialsyndromic
3A. CAREPATH: BCCH Neonatal Follow Up Program
Birthweight ≤ 800 gr, Gestational age ≤ 25 weeks, IVH Grade 4, PVL, ECMO/CDH*, ROP Grade 4/lasered, Funded Studies, Directors Discretion

Newborn Hearing Screen

Aud Assessment at age 8 months CA at BCCH**

U***

PHL

TCHL

N

Expeditied Medical & Referral to BCEHP Intervention

Ongoing Monitoring/Amplification

Aud Assessment at 18 months, 3 & 4½ years**

U***

PHL

TCHL

N

Expeditied Medical & Referral to BCEHP Intervention

Ongoing Monitoring/Amplification

DISCHARGED from BCEHP at age 3 years; continued monitoring as per BCCH NFU schedule recommended

Outcomes

Tests

Referrals

*See separate CAREPATH (3B) for ECMO/CDH
**NFU intake review completed 2 months prior to corrected dates & BCCH audiology determines whether their audiology assessment is needed for that particular child. Most typically seen at 8 months and 3 years.
*** Maximum of 2 assessment attempts with unknown hearing status, then consultation with BCEHP Clinical Audiologist and consideration of sedated ABR Testing
**** Each GP/ENT visit may initiate a referral to PHA/Team audiologist and/or medical monitoring
Note: Children can enter path at anytime if their medical or developmental status changes.

**Audiology Assessment Schedule:**
- 8 months CA (BCCH)
- 12 months CA (community)
- 18 months CA (BCCH)
- 24 months CA (community)
- 30 months CA (community)
- 3 years CA (BCCH)
- 3.5 years CA (community)
- 4 years CA (community)
- 4.5 years CA (BCCH)
- Additional assessments every 6 months until age 7 years (community)

* Maximum of 2 assessment attempts with unknown hearing status, then consultation with BCEHP Clinical Audiologist
** Maximum of 2 assessment attempts with unknown hearing status, consider sedated ABR Testing
*** Each GP/ENT visit may initiate a referral to PHA/Team audiologist and/or medical monitoring
4. CARE PATH
Neonatal Meningitis

**Note:** Children can enter path at anytime if their medical or developmental status changes.

**Outcomes**

**Tests**

**Referrals**

* Maximum of 2 assessment attempts with unknown hearing status, then consultation with BCEHP Clinical Audiologist

*** Maximum of 2 assessment attempts with unknown hearing status, consider sedated ABR Testing

**** Each GP/ENT visit may initiate a referral to PHA/Team audiologist and/or medical monitoring
5. CARE PATH
Family History of Hearing Loss

Newborn Hearing Screen

Aud Assessment at age 3 years

U***

PHL

TCHL

N

Expeditied Medical & Referral to BCEHP Intervention

Ongoing Monitoring/Ampification

DISCHARGED from BCEHP at age 3 years

Note: Children can enter path at anytime if their medical or developmental status changes

Outcomes
Tests
Referrals

*** Maximum of 2 assessment attempts with unknown hearing status, consider sedated ABR Testing
**** Each GP/ENT visit may initiate a referral to PHA/Team audiologist and/or medical monitoring
<table>
<thead>
<tr>
<th>Legend for all Care Pathways</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABN</td>
</tr>
<tr>
<td>Aud</td>
</tr>
<tr>
<td>BCEHP</td>
</tr>
<tr>
<td>CP/CF</td>
</tr>
<tr>
<td>ENT</td>
</tr>
<tr>
<td>GP</td>
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<td>IFSP</td>
</tr>
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</tr>
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<td>PHA</td>
</tr>
<tr>
<td>PHL</td>
</tr>
<tr>
<td>TCHL</td>
</tr>
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<td>U</td>
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Appendix 19 – ABR Troubleshooting High RN on the IHS

Things to try to reduce/investigate noise while testing (i.e. patient present)

- Reduce potential sources of artifact: turn off all unnecessary dimmer lights, lights, equipment.
- Ensure electrodes are braided/taped together.
- Observe the EEG – does the noise look rhythmic (more likely electrical) or random (more likely physiologic)? If physiological, perhaps baby needs to fall into a deeper sleep. If electrical, focus efforts on reducing potential sources of electrical artifact.
- Stretch out all cables/wires, as coiled wires act more like an antenna.
- Ensure wires from electrodes do not cross wires from transducers.
- Have patient as far away from computer, and other sources of electrical artifact as possible.
- Ensure electrode impedance is as low as possible and the same on all channels.
- Try changing rate from 39.1 to 38.5 or 39.8 (only small changes are necessary).
- Use line filter (tick line filter box in EEG window to activate when not acquiring) as a diagnostic: does the amplitude decrease significantly when line filter is on? If so, you have 60-Hz noise, and you may need to reposition. Only as a last resort should you actually collect data with the line filter on, as low-frequency EEG information contributes significantly to the response. Note this on the ABR recording sheet.
- Wait until baby is in a deeper sleep.
- Reposition baby for more neck relaxation.
- Move amplifier box to see if another position might be better (sometimes small moves can make a big difference).
- If nothing works to improve situation, start recording anyway: if the baby is normal, you may still be able to see waveforms. If baby is not normal, you may not be able to get a low enough RN to establish NR.

Things to try when patient not present

1. Turn on amplifier (USB box) without electrodes or Y-cord, and begin collecting. You should get RN of around 0.04 μV. If the RN is large, this is an indication of internal (IHS) noise.
2. Short the + and – together for one channel (using the y-cord), and collect data from that channel. You should get a low RN value (0.08 μV or less).
3. Plug in all cords as you would for a 2-channel recording, place the recording end of the electrodes in the location of interest (e.g. where baby’s head will likely be in a real testing situation) and begin collecting. This will give you an indication of noise for that given location (assuming no internal IHS noise issues). You should find that the EEG is noisier when closer to sources of interference such as lights and computers. You should also be able to find areas of less EEG noise as well, which should be better for testing.
4. Attach electrodes in normal array for 2-channel recording to a volunteer. Attach headphones; collect with your subject as relaxed as possible (neck supported, as close to asleep as possible) using a stimulus at 40 to 50 dBNHL. You should be able to see a response (ensure you are using a normal-hearing subject) as well as obtain low RN values.
## Appendix 20 – Designated BCEHP Otolaryngologists

<table>
<thead>
<tr>
<th>Health Authority</th>
<th>Otolaryngologist</th>
<th>Contact Information</th>
<th>Location</th>
</tr>
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<tbody>
<tr>
<td>FHA</td>
<td>Dr. Matt Dickson</td>
<td>1-604-588-8883</td>
<td>Surrey</td>
</tr>
<tr>
<td>FHA</td>
<td>Dr. Tyler Mori</td>
<td>1-604-545-5321</td>
<td>Surrey</td>
</tr>
<tr>
<td>IHA</td>
<td>Dr. Ryan Cain</td>
<td>1-250-489-3323</td>
<td>Cranbrook</td>
</tr>
<tr>
<td>IHA</td>
<td>Dr. David Kramer</td>
<td>1-250-374-1488</td>
<td>Kamloops</td>
</tr>
<tr>
<td>IHA</td>
<td>Dr. Tim Kramer</td>
<td>1-250-861-5578</td>
<td>Kelowna</td>
</tr>
<tr>
<td>NHA</td>
<td>Dr. Sergei Filatov</td>
<td>1-250-562-3733</td>
<td>Prince George</td>
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<tr>
<td>VCHA</td>
<td>Dr. Fred Kozak</td>
<td>1-604-875-2113</td>
<td>Vancouver</td>
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<tr>
<td>VIHA</td>
<td>Dr. Jaymi Dumper</td>
<td>1-250-755-1763</td>
<td>Nanaimo</td>
</tr>
<tr>
<td>VIHA</td>
<td>Dr. Kevin Clarke</td>
<td>1-250-595-7564</td>
<td>South Vancouver Island</td>
</tr>
</tbody>
</table>
Appendix 21 – Medical Approval Form

BC Early Hearing Program
A service of BC Children's Hospital
and the Provincial Health Services Authority

To: Dr. ____________________________  Date: ____________________________

Request for Medical Approval and Authorization

_________ has a _______________ and fitting of amplification and /or FM is recommended. This approval must be signed, dated and faxed back to the Public Health Audiology Clinic listed below before any further follow-up can be provided for this child. Timely return of this approval will authorize the audiologist to initiate fitting of appropriate hearing devices as indicated. Delays in medical approval will delay the access to amplification for the infant or child.

RE:  Client name: ____________________________

Date of birth: ____________________________

Address: ____________________________

Mother’s name: ____________________________

Phone: ____________________________

BCEHP number: ____________________________

Client hearing diagnosis (filled in by hearing clinic): ____________________________

Audiologist Completes:  Physician Completes:

Medical approval and clearance is requested for the above client. The medical clearance and approval is requested for:

(Audiologist selects relevant parts)

☐ Y ☐ N Right ear earmold impression and fitting of amplification/FM if indicated

☐ Y ☐ N Left ear earmold impression and fitting of amplification/FM if indicated

☐ Y ☐ N SWIM-moulds indicated: Please select ear: ☐ R ☐ L

Audiologist name: ____________________________

Audiologist signature: ____________________________

Health authority and clinic location: ____________________________

Phone: ____________________________

Fax: ____________________________

Approved as requested: ____________________________

Partial approval. Specify: ____________________________

Not approved. Reason: ____________________________

Comments: ____________________________

Medical contraindications if any: ____________________________

Right ear: ____________________________

Left ear: ____________________________

The signing physician is responsible for arranging and ensuring medical referral, and for ensuring that the medical assessment of this child is completed as per BCEHP Medical Assessment Guidelines for Children with Sensorineural Hearing Loss.

Physician name: ____________________________

Physician signature: ____________________________

Phone: ____________________________

Date: ____________________________

Instructions to audiology clinic administrative support staff: This form is faxed to the otolaryngologist as per BCEHP processes. A copy of the audiology diagnostic report is required to accompany this form. If not received back within two business days, please contact the physicians office to check on status.

Physicians administrative staff: please confirm receipt of this form with the audiology clinic.
Appendix 22 – Family Physician Information Letter

Instructions: The “Family Physician Information Letter” is initiated at the referring audiology clinic. The minimal content requirements are as follows. Additional information can be added at the discretion of the referring Audiologist.

Date
Clinic Address
Re: Patient Name
   DOB:
   Address
   Phone Number
   Parent/Guardian Name
   Parent/Guardian Name (if different from above)

Dear Dr.______________,

This patient requires urgent and more detailed medical assessment by an Otolaryngologist for hearing loss. Designated otolaryngologists, familiar with the “BC Early Hearing Program Medical Assessment Guidelines for Young Children with Sensorineural Hearing Loss” will accept referral and expedite the assessment of this patient to prevent a delay in the fitting of amplification or other hearing devices. To assist in expediting the process, please complete a referral to Dr._______________. If you would like more information about the medical assessment process, please visit the BCEHP website.

(insert table of Health Authority Name, physician Name, contact information)

Thank you for your assistance. If you require further information about this patient’s hearing services, please contact:

Name of Audiologist:
Clinic Location:
Contact Information:
Appendix 28 – Client Criteria

Target Population for VRA

Within the BCEHP, an infant identified as having PCHL on the basis of the ABR-based assessment will require a behavioural follow-up assessment. Infants from 6 months corrected age and up to approximately 24-30 months of age, who are referred through the BCEHP, are also candidates for VRA. VRA testing at a corrected age of 9 to 10 months for most infants is considered to be optimal. For premature infants, Moore, Thompson, Folsom (1992) suggest “a corrected age of 8 months and/or a mental age of 6 months is typically required for acceptable performance using VRA.” Infants with developmental delay may not be ready for behavioural testing using VRA at 8 to 12 months of age, so information about an infant's cognitive developmental status may be useful in deciding when to schedule the infant for this test (see section on Pre-test Preparation).

Assessment Candidacy

Assessment under BCEHP is available to babies and young children who are determined to be at risk for PCHL, by virtue of a refer result on BCEHP screening or by referral into BCEHP, or to have PCHL (shown by previous BCEHP assessment). In any other circumstance, audiometry may be provided under alternate, medically based funding schemes, such as MSP. Audiometry for children under active medical management for middle-ear conditions will not be funded by the BCEHP.

Most candidates for initial assessment will have had a Refer result on neonatal click AABR screening in one or both ears. Some infants will present later, through BCEHP surveillance procedures for high-risk infants, or through external referral-in of infants discovered to be at risk for hearing loss. All candidates for BCEHP follow-up assessments will have received an initial assessment within BCEHP.
Appendix 29 - Waiver

DECLINED HEARING ASSESSMENT WAIVER

Audiology Site _________________________
Health Authority _________________________
Physician _________________________

Child Name _________________________________
Child DOB _________________________________

I, ___________________(parent or guardian), request that the audiology assessment NOT be done on my child by the BC Early Hearing Program (BCEHP).

I release the audiology site, health authority and the physician named above, and BCEHP of any liability related to not assessing my baby.

I have been advised that the audiology assessment procedure is safe, painless, and may provide information that is important to the development of my child.

I am aware that children whose hearing loss is discovered early and who receive special services before six months of age are more likely to develop normal communication skills than children who are identified later.

I have been provided the opportunity to ask questions about the risks and benefits of the audiology assessment procedure.

I understand that I can contact a local Hearing Clinic at anytime in the future and request a hearing assessment for my baby.

Nevertheless, I accept all responsibility and liability for choosing not to have this assessment performed.

Name _____________________________________
Relationship to Child _____________________________________
Signature (parent/guardian) _____________________________________
Date _____________________________________

Name of witness _____________________________________
Position _____________________________________
Signature of witness _____________________________________
Date _____________________________________