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Introduction

Announced by the BC government in March 2005, the BC Early Hearing Program (BC EHP) is one component of a provincial screening program for early childhood detection of hearing problems in children in the province under age six.

The program is currently in development and will be delivered by health care professionals in BC’s six health authorities. Provincial standards and protocols such as this document are being established to ensure all infants receive the same level of consistent, high quality care.

This document is the result of work by the BC EHP Diagnostic Advisory Group, and describes BC EHP established protocols to date. However, this document is subject to change as determined by both empirical evidence and experience from clinical application. Constructive feedback from BC EHP Audiologists is welcomed.

Summary and Scope

This document addresses audiologic assessment ('Assessment') of infants and pre-school children registered in the BC Early Hearing Program (BC EHP). The document includes: (i) Procedures for History Taking, Otoscopy, Visual Reinforcement Audimetry (VRA), Otoacoustic Emissions (OAE) and Auditory Brainstem Response (ABR) testing, (ii) Discussion and guidelines for Audiologic Inferences and well as (iii) Technical Appendices. Key References can be found in Appendix R.

Core Principles

Assessments will be conducted in accordance with the BC EHP core principles of informed family/caregiver choice and consent, timely provision of unbiased information based on scientific evidence, and sensitivity to family culture and values.

Assessment Goals

The main goals of Assessment are (i) to determine the presence or absence of the BC EHP target ‘Permanent Childhood Hearing Impairment’ (PCHI), (ii) to provide a sufficient audiometric basis to begin service options to improve hearing and/or communication development before six months of age, wherever feasible and elected by the family, and (iii) to provide an ongoing, sufficient audiometric basis for follow-up services.

Assessment Specific Objectives

The specific objectives of the Assessment are to obtain valid and accurate estimates of ear-specific, frequency-specific hearing thresholds, and to determine the type of any hearing impairment present (conductive, sensorineural, mixed). In the event of a mixed PCHI, its components will be quantified to the fullest extent feasible with the procedures specified.
Target Impairments

The nominal target PCHI includes any hearing threshold equivalent to 30 dB HL or greater at any frequency in the range 0.5-4 kHz, in either ear. The target PCHI includes conductive impairment associated with structural anomalies of the ear but does NOT include impairment attributable to non-structural middle ear conditions. The target PCHI also includes Auditory Neuropathy/Auditory Dys-synchrony (AN/AD).
**DX 100: Competencies and Facility Requirements**

**101 Assessment Personnel**

All Assessments funded by the BC EHP will be conducted by audiologists who are registered with the BC EHP as having received approved training in this Assessment protocol. Assessments funded by BC EHP must be conducted by an audiologist who is registered with the BC EHP as having received specific, required training in this protocol. The rationale is: (i) this protocol is exceptionally demanding and contains elements that may be outside conventional experience of many pediatric audiologists, (ii) specialized training is required to maximize understanding of, and compliance with, a highly specific standard of care with many mandatory elements, and (iii) for fairness, the performance audit that is obligatory in a separately funded provincial program with defined deliverables requires a full, explicit and proven exposure to the procedures required and their rationale.

Assessment funding is administered locally by 12 regional BC EHP coordinating agencies, according to locally negotiated contracts within the provincial funding guidelines and envelope. Procedures in compliance with this protocol will normally qualify for BC EHP funding, and will not concurrently be billed to MSP or any other funding source.

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

**102 Universal Precautions**

All procedures must ensure the safety of the patient and clinician, and adhere to universal health precautions (e.g. prevention of bodily injury and transmission of infectious disease).

BC EHP supports best practice in infection control procedures. Infection Control is the “conscious management of the environment for the purposes of minimizing or eliminating the potential spread of disease” (Bankaitis and Kemp, 2003). It is essential that audiologists wash their hands between each patient and after handling equipment and supplies. This is to protect the patient-to-patient infection, patient-to-equipment infection, and equipment-to-patient infection, as well as to protect the audiologist from infection. The following techniques should prove helpful in providing a healthy environment for patients and audiology clinic personnel. Consult with your facility's Risk Manager (Infection Control person) to obtain specific procedures required for your hospital or clinic.

To be testing children, the audiologist must be:
• Free of transmissible infectious disease, for example, conjunctivitis, “active” cold/cough, and dermatitis.
• Any Herpes lesions (cold sores) must be dry and scabbed and covered whenever possible.
• Vaccinated against rubella if the staff member is susceptible.

Hand Washing

Hands must be washed thoroughly with facility approved soap immediately on arrival in a patient care area as well as:

• Before and after each patient contact.
• After contact with a source that is likely to be contaminated with blood or any excretions or secretions.
• Before and after assessing each child
• When hands are visibly soiled.
• Before and after handling and eating food.
• For personal hygiene (after using the toilet, blowing your nose or smoking).

General Hand Washing Procedure

• Remove all rings, bracelets, watch and put in a safe place.
• Ensure sleeves are above elbows.
• Stand with clothing clear of the sink and regulate water to warm.
• Clean under fingernails when visibly dirty or if nails are long.
• Wet hands and arms and apply soap from dispenser.
• Rub hands together for at least 30 seconds, washing between fingers, around nails, including the backs of the hands, wrists, including arms up to the elbows
• Rinse hands and arms under running water with fingers extended downwards.
• Use paper towel to thoroughly dry hands.
• Turn off water with paper towel.
• Discard paper towel into open, plastic lined receptacle or one with a foot-operated cover.

Clean equipment and work surfaces

Establish a daily cleaning routine including anything that will come in direct contact with the child or diagnostic equipment and supplies.

• Use cleaning materials recommended by your facility
• Discard individual disposable supplies in an approved receptacle after the assessment of each child.

103 Family Centred Care

All BCEHP diagnostic services are based first and foremost on a family-centered approach. Family centered care refers to the principle and practice that puts the family
at the heart or centre of services. The family is the driving force behind all diagnostic practices, based on the recognition of family strengths and competence.

Families should be actively involved in the assessment process to the extent they desire and to the extent feasible given the nature of the audiologic test procedure. The audiologist must engage the family in the case history and testing session(s), and the family must fully participate in deciding on intervention strategies. The family’s rights (including informed consent and confidentiality issues), reasonable expectations, reasonable needs, and preferences are paramount and must be considered (from ASHA Guidelines, 2004).

Should further audiologic assessment be declined, the "Declined Hearing Assessment Waiver" form (Appendix E) should be completed and signed by the family/care givers. The family should be made aware of results to date, and of the nature of the procedures that they are declining. They should also be given the contact information for their community Audiology clinic should they desire future assessment.

What is family centred care?

- Family Centered Care builds parent/professional partnerships and promotes parents as the decision makers for their children. Family choice and decision making occurs at all levels.

- Infants and toddlers are uniquely dependent on their families for their survival and nurturance. This dependence necessitates a family-centered approach.

- Programs define “family” in a way that reflects the diversity of family patterns and structures.

- Each family has its own structure, roles, values, beliefs, and coping styles. Respect for and acceptance of this diversity is a cornerstone of family-centered care.

- Clinicians honour the racial, ethnic, cultural, and socio-economic diversity of families. Efforts should be made to overcome potential linguistic and cultural barriers to effective communication.

- Families have access to services provided in as normal a fashion and environment as possible that promote the integration of the child and family within the community.

- Family Centered Care recognizes the strengths and expertise that all parties bring to the relationship but it also recognizes that it is the parents who will be the constant in the child’s life—not the service providers.

- Service Providers listen to and honour the family's knowledge, perspective and choices; they avoid making judgments about the family’s decisions.

- Complete and unbiased information is shared with families in ways that are useful. Families receive timely and accurate information in order to understand and effectively
participate in the care and decision making regarding their child. Service Providers avoid the use of any jargon that they don't first explain.

- Families have opportunities to discuss their options and understand implications of all decisions.

Adapted from: Guidelines and recommended practices for the Individualized Family Service Plan (2nd ed.). Association for the Care of Children's Health, Bethesda, MD 20814, 1991.

104 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 BC EHP funding unless the environment has been specifically and previously approved by the BC EHP.

For VRA, the room will be of sufficient size to accommodate the parent, infant and distractor 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 reinforcements.

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, but the examiner can see the infant clearly. Two-way communication must be available between the examiner and the distractor.

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 dBHL or better at 500 Hz through 4 kHz 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 ABR and OAE testing, well-fitted insert earphones can provide some protection against environmental noise, but the amount of protection is variable, small and not known exactly. Because the ABR is an averaged phenomenon, transient sounds may not have a significant effect on the accuracy of threshold estimates. Furthermore, because the BC EHP protocol does not pursue ABR thresholds to very low levels, 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 2 kHz. 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 soundroom, together with the infant, who may be in a bassinet, crib or pram. This may be reassuring to the parents, who may be reluctant to leave the child alone in what they may see as an intimidating test environment. It also facilitates the option of single-handed, unassisted testing.

The current diagnostic 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) should be done off-line, if necessary, so it is not absolutely necessary to power up the printer during testing. Alternatively, the printer may be located outside the soundroom, given adequate cable routing though the trap or connector panels.

Attendance of family members/caregivers during ABR testing is a matter of local preference, at the discretion of the BC EHP 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. However, family members differ widely in their knowledge and skills related to infants' sleeping habits. They may distract or excite the child, may use inappropriate strategies to promote sleep, or may otherwise compromise efficient and accurate testing. However, allowing parent(s) into the test room, at least initially, can alleviate their anxiety. Also, some parents are genuinely skilful, so allowing them to try and get their child to sleep may be helpful. Thus, a practice of allowing a limited time for parents to encourage sleep and then leave the soundroom is recommended. This general approach has been successful for many years in several centres. Primary factors in the choice of approach are the skills of the audiologist at sleep promotion and the pressure of time in local scheduling practices.

ABR threshold testing must be conducted in an audiometric soundroom satisfying 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 BC EHP review and acceptance of the proposed environment. In general, Assessments in any test environment other than an audiometric soundroom will not qualify for BC EHP funding unless the environment was approved by BC EHP management.

105 Test Equipment, Calibration and Supplies

VRA testing requires a clinical diagnostic 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 BC EHP protocol.
The BC EHP provides all the instrumentation and operating supplies necessary to conduct Assessments according to this protocol (See Appendix G: Diagnostic Instrumentation).

Instrumentation will be calibrated and maintained according to BC EHP specifications. The factory calibrations supplied with the BC EHP ABR instrumentation are not acceptable for BC EHP Assessments and will be modified according to BC EHP specifications (Appendix H: ABR Technical details).

Many factors affect the proper calibration of stimuli for tone pip ABR testing in infants. Important variables include subject age, stimulus route and transducer, frequency, envelope and repetition rate, the amount of averaging, EEG criteria for residual averaged noise, and definition of threshold. The amount of high-quality published data is limited but sufficient to establish normative calibrations. Provided that the key features of BC EHP 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 BC EHP is responsible for the determination and dissemination of reference settings for the calibration files that govern stimulus levels for ABR testing. Normally, ABR calibration files or lists of specific values will be distributed by e-mail or CD. The calibration data will be updated from time to time, as further information becomes available from published research or BC EHP clinical practice.

Because of the digital nature of modern ABR equipment, traditional calibration practices that were necessary for analogue instruments are moot. The main reason 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 BC EHP requirement. Calibration services will be arranged by the BC EHP, with reasonable notice to the Assessment centres. Because transducer malfunction can occur at any time, additional, frequent listening checks are required. The individual BC EHP audiologist is responsible for routine listening checks.

106 ABR Noise Standards

Diagnostic ABRs are typically done in the soundbooth but where not possible, the ABRs should be done in a quiet room with measured sound levels not exceeding those listed below:

- 22 dB SPL  500 Hz
- 30 dB SPL  1000 Hz
- 35 dB SPL  2000 Hz
- 43 dB SPL  4000 Hz

(Exact levels may be updated pending further information)

Octave band measurements: (see Appendix H - ABR Technical details)

107 ABR Calibration & Protocol Files
ABR calibration offset and test set-up files will be provided by BC EHP via disc or email media. Manufacturer’s default stimuli and calibrations are NOT acceptable. All BC EHP tests will be done using current BC EHP calibration and set-up files.

ABR instrumentation will be calibrated electroacoustically on an annual basis, as scheduled by BC EHP. Listening checks for transducer malfunction or problems in leads and connections will be done at least weekly or, if the test interval exceeds one week, just before testing.

108 Additional Room standards for ABR

Electrical isolation is required - i.e. more than 25 ft away from elevator shaft; more than 25 ft away from XRay equipment & power doors.

Other sources of electrical interference may exist that 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.

Dedicated circuit is not a requirement.

Access to a sink within close proximity to testing room.

109 Furnishings

Upholstered Recliner for parent to hold sleeping infant for one to two hours.

Alternate arrangement for baby to be sleeping (e.g. crib).

Pillow in plastic case with linens to allow greater comfort for parents when holding infant.

ABR equipment on a moveable cart/computer desk.

Comfortable chair with wheels for examining audiologist.

110 VRA Calibration

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). It is required that this calibration be done when the audiometer is installed (or moved), and then annually thereafter. EHP 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.

111 Other Equipment Required

Diagnostic otoacoustic emissions equipment (within same room);

Diagnostic 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, diagnostic audiometer with capability of testing 250 Hz through 8000 Hz, to profound levels, meeting ANSI calibration specs, microphone, and CD input. The sound suite for behavioural assessment may not necessarily be in the same site or location as the ABR room, but must be available for diagnostic assessments.
DX 200: Data and Documentation

Pending
DX 300: Target Impairments

The BC EHP target impairment includes any PCHI for which there is reasonable evidence that it will compromise auditory development and speech perception, in the absence of intervention. Most PCHI includes a loss of sensitivity to sound, as reflected in audiometric thresholds. The target disorder includes pure tone threshold elevation to a level equivalent in an adult to 30 dBHL or greater at any frequency in the range 0.5 to 4.0 kHz.

Currently, there is no compelling scientific evidence that lesser severities of impairment 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 dBHL or greater in the better ear. Yet, from first principles of psychoacoustics it seems clear that such a conservative criterion will fail to address many children with a substantive perceptual disability or functional limitation.

Hearing impairment is considered ‘permanent’ by the BC EHP if it is genuinely irreversible or if it is likely to be sustained for more than one year. This includes all sensorineural impairment and most conductive impairment that has a ‘structural’ cause such as canal atresia or middle ear malformation.

It is considered appropriate to include children with unilateral PCHI because: (i) they are at risk for bilateral PCHI, (ii) they are at risk for increased disability should the normal ear acquire a conductive disorder, even if transient, and (iii) specific strategies are indicated to enhance hearing and/or communication development in such children.

The BC EHP target includes the cluster of disorders commonly termed ‘Auditory Neuropathy.’ This is referred to within the BC EHP as Auditory Neuropathy / Auditory Dys-synchrony (AN/AD). AN/AD is included in the target because it may be present in up to 10% of infants with PCHI 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 disorders such as threshold elevations due to middle ear infection are not targeted by BC EHP. Such disorders are the domain of the well-established, universal medical care system in BC. The BC EHP is NOT an alternate system for audiometric services in the context of active medical or surgical management of hearing disorders.

In practice, the ‘effective’ target disorder severity and frequency range for a UNHS program is dictated by the operating characteristics of the screening tests used. AABR screening is currently done using clicks. The click level is selected by BC EHP management and currently is equivalent to 35 dBNHL in an adult ear. That level may ultimately prove to be too high, given the target disorder definition. There are at least three factors that influence the severity of hearing impairment 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 that 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 ABR techniques at low stimulus levels. Third, the click ABR threshold will reflect most closely the best pure tone sensitivity in the frequency range 1-4 kHz, so children with hearing losses at low or very high frequencies or at isolated, specific frequencies may be missed.

Similarly, DPOAE screening typically addresses frequencies of 1.5 kHz or 2 kHz and higher, so hearing losses at 1 kHz and below will be missed. Current BC EHP settings for DPOAE screening are recording at 2, 3 and 4 kHz, 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.
DX 400  Overall Procedures

Assessments will comply with all current guidelines and protocols issued by BCASLPA, CASLPA and by the BC EHP. 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. Should this protocol and any professional practice guideline be perceived as in conflict, the CASLPA guideline will apply and BC EHP management will be advised promptly of the conflict.

401  Deviations from Protocol

Departures from the audiometric aspects of this protocol may be appropriate in individual infants and under special circumstances, and their nature and rationale will be documented. BC EHP management may seek to review documentation and clinical records involving any such departures from this protocol.

The BC EHP recognizes that special circumstances may indicate departures from some (but not all) of the procedures specified in this Protocol. Such departures are at the discretion of the BC EHP audiologist. This does not mean that this Protocol is generally discrentional. The BC EHP funding is predicated on specific deliverables in terms of quantity, quality and effectiveness. Every reasonable effort must be made to comply with this Protocol, in the interest of quality of care, consistency of care (equity), and evaluability of performance and outcomes. The evaluation requirement imposes a need for comprehensive and standardized documentation and clinical record keeping. In addition, all significant deviations from this Protocol will be documented sufficiently to permit independent review of their nature and rationale.

402  Infection Control standards

All Assessments will comply with any and all pertinent standards of the Assessment facility relating to infection control. In the absence of specific facility standards, generally accepted standards will apply.

403  Medication standards

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

404  History Taking

Obtaining a full case history is important in identifying those infants who are at risk for progressive hearing loss and therefore require ongoing audiologic monitoring. In instances where PCHI 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 diagnostics. 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 A should be obtained at the time of the first Diagnostic Assessment, with review of relevant factors at subsequent Assessments.

Essential components of a case history include: family history, perinatal history, maternal history, developmental history, otologic history, previous diagnostic/screening results, current health of child, and parental concern. A sample parent-friendly case history form is provided in Appendix B. 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.

405 Types of Assessment

There are two basic types of Assessment: ABR-based and Behaviour-based. The latter may entail VRA or play audiometry. 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 BC EHP 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 practicable 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 BC EHP, the full complement of tests is mandatory.

406 Assessment components

Wherever feasible, the initial ABR-based Assessment will include at least ALL of the following procedures, in BOTH ears.

- Tone pip ABR threshold estimation by air conduction (AC) at 2 kHz and 500 Hz and, where specified by this protocol, at 4 kHz and 1 kHz. Insert earphones will be used for all AC measurements, except where specifically contraindicated. Ipsilateral masking will not be applied;

- Tone pip ABR threshold estimation by bone conduction (BC), where specified by this protocol, at 2 kHz and, where indicated and feasible, at 500 Hz;

- In special circumstances, where specified by this protocol: High-intensity click-ABR measurement, and Click-ABR threshold measurement; where specified by this protocol: a click-ABR sub-protocol for AN/AD, including cochlear microphonic potentials and stimulus artefact analysis;

- Cursory otoscopy;
• OAE amplitude and noise floor measurements at 2 kHz through 4 kHz;

• Middle-Ear Analysis, which will include admittance tympanometry using a probe frequency of 1 kHz 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 1 kHz;

• A Real Ear to Coupler Difference (RECD) determination, where PCHI is confirmed and the RECD determination is deemed feasible.

**407 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 PCHI (see Appendix A: *BC EHP risk indicators*), or in the case of neonates not at risk, from an AOAE-AABR-two-step screening sequence.

Where not medically contra-indicated, initial Assessments of infants referred from BC EHP screening will be targeted at a corrected age of 4-8 weeks or before (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 SCN/NICU graduates after extended hospital stays, initial Assessment will be targeted within 4 weeks of discharge home, subject to appropriate health status. Infants meeting risk criteria as per Appendix A who pass screening will be scheduled for behavioural follow-up at age 9 to 12 months.

Follow-up Assessments in children with the target PCHI may be done by the behavioural Assessment type deemed by the EHP audiologist to be appropriate.

For any infant with a meningitis risk indicator, Assessment is indicated as soon as possible after recovery, if there is a referral into EHP. EHP Screening prior to full Assessment is not appropriate. Special, non-EHP, fast-track protocols for follow-up of meningitis may be in place locally.
**DX 500: Procedures - Auditory Brainstem Response (ABR)**

**501 Assessment Components**

For all infants under six months of age, and for some older infants, Assessment is based on objective, physiologic measures, primarily but not exclusively on tone pip ABR. It is usually possible to obtain accurate, frequency-specific and ear-specific pure tone threshold estimates using this technique. In most cases, tone pip ABR can provide audiology that is sufficient to fully inform communication development options, including amplification. If proper ABR techniques are used, unless there is a specific indication of unreliability of ABR findings, it is inappropriate to defer initiation of communication development options (where elected by the family), pending “behavioural confirmation” of threshold estimates.

It is necessary to obtain and weigh all types of information that may assist valid and accurate Assessment. Errors in Assessment can have serious consequences and every possible effort must be made to avoid them. Major errors have been reported in infant assessments. The most common sources of error relate to incorrect judgements about ABR presence or absence, and to misinterpretation of ABR absence.

Accordingly, ABR threshold estimation methods must be of the highest possible quality, and a multi-component approach to Assessment is required, so that redundancy of information (i.e., 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.

**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 BC EHP 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 arrive 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 infant who is not prepared appropriately will be stressed.

The infant's behavioural state on 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 to do and what not to do. Written instructions and telephone confirmation are recommended. The importance of preparation increases with age, as the infant's
amount of daytime sleep decreases. 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.

On 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 practicable 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

Excepting initial otoscopy, the order of procedures is discretionary. Order of testing should
proceed on the basis of the principle of obtaining the most important/most useful (for
diagnostic, 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, so 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 (i) it may
be difficult to obtain a successful OAE test after the child has woken up from the ABR,
(ii) having the OAE result immediately informs the tester about possible AN/AD, should
an absent or abnormal ABR be seen, and this may alter the ABR testing, and (iii) 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.

(i) ABR is the core procedure and that doing these other tests up front may irritate the
child or consume valuable sleep time, and prejudice ABR success. This may be a more
significant issue for older infants or those who are inherently irritable or disinclined to
sleep. (ii) OAE and MEA tests do not provide threshold information, and in many cases,
OAE and/or MEA are non-contributory. 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 present and normal do MEA or OAE results provide information. (Even when
“normal”, MEA and OAE results interpretation difficulties can occur due to immaturity or due to presence of AN/AD.) Presence or absence of ABR at minimum levels is always informative.

505 Sedation

Assessments under sedation will comply with generally accepted standards of care and all local risk management protocols. The BC EHP 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.

There is very extensive experience (from Ontario and from British Columbia) in infants indicating 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 diagnostic 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. Routine resort to sedation (or general anesthesia) 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, such that it is especially important to have a reasonable assurance of success.

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

If sedation is indicated and consented, 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 BC EHP 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 increased sedative dosage, by use of alternative medications, or by resort to light, general anesthesia. The indications for these procedures are a matter for local risk management protocols and standards of care.

While testing under sedation is generally easier than under natural sleep, not all BC EHP 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 may occur to another BC EHP audiologist who has a sedation practice. The BC EHP has facilitated the best possible access to testing under sedation, across the province, within resource constraints.

506 Otoscopy & Cerumen/Debris

Cursory otoscopy will be conducted at the start of any BC EHP Assessment. Its main purpose is to detect foreign bodies, canal occlusion and any physical condition of the ear that indicates referral to physician under standard red flags.

Detailed otoscopy and TM visualization can be difficult in the young infant and are 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, primarily for the visualization of any significant debris/cerumen in the ear canal.

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, and 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 eartip 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 ear cleaning 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 on eartip withdrawal.

507 ABR Stimulus Transducers

ABR measurements by air conduction (AC) will be done using insert earphones, except where specifically contraindicated, in which case supra-aural earphones (TDH/MX41) are
optional. Under typical situations, inserts can be placed in both ears simultaneously. Bone conduction (BC) ABR testing will be done with careful placement supero-posterior to the canal opening of the individual test ear. The 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. Application force measurements are not required.

In the absence of specific contraindications, insert earphones are the required transducer of initial choice for ABR testing by air conduction. Insert phones have several advantages over supra-aural earphones, including reduced stimulus artefact, 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, whether a parent holds their infant during testing or the infant is lying supine. This allows efficient switching between ears. Pediatric-sized foam ear tips, often cut down to size for a young infant, are preferred (and required for any later amplification fitting procedures). Use of impedance probe-tip adaptors often does not allow for both 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. It can be difficult for the audiologist to conduct the test and apply a supra-aural earphone without assistance, whereas with insert earphones a single tester is usually practicable. 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 normally 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 cannot 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. To achieve proper force and stability of the bone oscillator, the BC EHP Audiologist may either use a band of elastic fabric with Velcro attachments or, with training, use hand-holding.

Velcro bands are simple to construct, and a sample is provided at the Assessment training. 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; Google, for example, on ‘Design Veronique Universal Facial Band # 210’, from Pike Surgical, Calgary. 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 & Stapells, 2005) 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 strap. Provided they are seated comfortably next to the infant being tested, the BC EHP audiologist performing the assessment can often handhold 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. Under no circumstances should the transducer be held by an individual not trained in hand-holding the transducer, such as the infant’s parent.

The BC EHP 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 need not be removed for BC-ABR testing. The occlusion effect is not present at 2kHz in adults; more importantly, recent research at UBC (Small & Stapells, 2005) indicates young infants do not show an occlusion effect at 500, 1000, 2000 or 4000 Hz.

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 (noninverting), on each mastoid process (inverting) and on the lateral forehead at least 3 cm from the noninverting 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 1kOhm.

Use of four recording electrodes is required by the BC EHP. 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, in the midline. Inverting electrodes are placed on each mastoid area (as low as possible on the mastoid bone to avoid the post-auricular muscle and to be farther away from the bone-conduction transducer), and this develops two differential recording channels: forehead to L mastoid and forehead to R mastoid. The common electrode is placed elsewhere on the forehead, not within about 3 cm of the noninverting electrode. Electrode wires should be led away from where the transducers (air or bone, but
especially bone) are to be placed; they should be kept close together, short, and possibly braided to decrease 60-Hz artefact.

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. Wherever practicable, impedances should be less than 3 kilOhms. 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 artefacts from movement of the electrode leads. Even more important is the symmetry of the two electrodes that form each differential pair. These should be as similar as is possible with reasonable effort. A difference of not more than 1 kilOhm 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 are configured as two EEG amplification channels, ipsilateral and contralateral to the stimulated ear. For AC stimuli, the contralateral channel has limited value and need not be retained in the audiologic records. However, it is sometimes helpful on-line in identifying errors of stimulated ear selection. It also may be useful to view ipsilateral/contralateral response asymmetries when a significant interaural threshold asymmetry is suspected.

When stimulating by bone conduction, the two channels are necessary in order to resolve the responding cochlea; wave V is 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. The use of **two recording channels in BC-ABR testing is mandatory.**
510 Tone pip ABR Measurement Parameters

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

Tone pip ABR is the method of choice for estimation of hearing thresholds in young infants. It is specifically recommended by the US Joint Committee on Infant Hearing (2000). 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). Therefore, for BC EHP Assessment, tone pip ABR is a required procedure for pure tone threshold estimation in infants under six months of age. It is also recommended strongly for use in older infants for whom VRA is deemed unfeasible or unreliable, and where VRA does not provide sufficiently ear-specific and frequency-specific information to satisfy the audiometric objectives of the BC EHP. Testing under sedation may be necessary, especially in older infants.

The evidence base for accurate estimation of hearing thresholds by BC ABR is less strong than that for air conduction, but the Ontario Infant Hearing Program (IHP), BC Children’s Hospital, and other experiences to date indicate that BC tone pip ABR measures can provide useful information, given correct technique.

Currently, there is insufficient evidence to consider ASSR as an alternative to tone pip ABR (Stapells et al., 2004). ASSR is under active evidence review and experimental evaluation by UBC and other researchers. BC EHP will continue to review this evidence and introduce changes when/if appropriate. The popular viewpoint that ASSR provides more accurate threshold information for severe or profound hearing impairments is considered to be unproven and potentially invalid. 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 BC EHP protocols.

Specific, mandatory recording parameters for the various components of ABR testing are given in Appendix H. 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 otoneurologic 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. Also, for threshold estimation the stimulus repetition rate should 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 BC EHP Assessments. These files will be updated from time to time, as the need for enhancements to the test protocols is determined. Because all BC EHP Assessments must be conducted under standard parameter conditions, local changes to test parameters are not permitted for BC EHP
Assessments. Audiologists are at liberty to use any parameters they see fit for non-BC EHP measurements, provided that those parameters are set up in non-BC EHP parameter files. Caution is required because the number of protocol files distributed by the BC EHP may increase over time, and distributed parameter files will overwrite local files.

The technical parameters in Appendix H are tightly coupled to BC EHP 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.

While 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. Also, it is 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 masking noise is not recommended within the BC EHP protocol.

511 Averaging & ABR Detection

Except in special circumstances (see below), determination of "response present" in the BC EHP protocol requires visual observation of the replicability of waveforms by the BC EHP audiologist performing the assessment. Any threshold or minimum response level determination requires replication of responses at the "threshold" level and replications of "no response" waveforms at the level below any elevated threshold (i.e., replications typically 10 dB below threshold level, except if threshold is >70dB nHL, where a final step size of 5 dB may be employed). Recordings at levels below the BC EHP minimum response levels are not required and should not be pursued. Typically, each replication will have at least 2000 trials in each average, although averaging may either be stopped (i) early if waveform residual noise levels (see below) reach criterion levels or (ii) after more than 2000 trials if waveform noise levels are high.

BC EHP ABR equipment will have online measures of waveform residual noise, and this measure should be used in determining when enough trials/replications have been obtained, especially if no clear response is present. Importantly, any determination of "no response" requires that the average of all waveforms/replications for a given condition not be greater than a minimum noise criterion (see below) before "no response" may be determined. If the overall residual noise level is higher than the criterion, these waveforms must not be interpreted for threshold purposes.

Replication of waveforms is not required under the following special circumstances: (i) waveform well below threshold that is below noise criterion, is flat, and shows no suggestion of expected waveform: this may be determined as "no response" provided it
is not at the level bracketing threshold (i.e., not at level immediately below threshold); and (ii) waveform above threshold showing clear response provided the response is typical/expected for condition and has a peak-to-peak amplitude that is at least four times (4x) the residual noise level amplitude and/or the IHS Smart-EP “SN” measure is at least 1.5. Importantly, this non-replicated “response” must not be at “threshold”, as BC EHP protocols require that any threshold determination involve replication of waveforms.

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 to determination of no-response. Determination of responses presence, and the number of trials/replications required to make this determination, must be made by the BC EHP 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.

ABR threshold is defined as the lowest level giving replicated response-positive records, either at the BC EHP minimum required level or with replicated response-negative records at a level not more than 10 dB lower. If such a procedure yields an ABR threshold of 80 dB or greater, use of a 5- dB final step is recommended, because increased precision may be clinically useful with limited residual dynamic range of hearing.

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 (2000). At present, there are few commercially available statistical response detection algorithms for toneburst ABRs in a diagnostic assessment context, in contrast to the situation for click screening, for which several algorithms are commercially available. However, at least two commercial ABR instruments provide online measures of waveform residual noise. These “RN” measures are useful for ensuring a waveform (or set of waveforms) where no response is obvious is quiet enough to be able to detect a very small response had one been present.

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. Typical past practice has required a minimum of two averages of about 2000 accepted sweeps each for any given stimulus condition; with liberal use of a third average in cases of uncertainty about response presence or absence strongly recommended (Ontario IHP Protocols, 2005; Stapells, 2000). However, modern techniques of recording and analysis, in particular measures of waveform residual noise, allow for more flexibility in averaging stopping rules (i.e., how many trials should be averaged). BC EHP ABR equipment (IHS Smart-EP) has an online measure of waveform residual noise (“RN”), and this measure should be used in determining when enough trials/replications have been obtained, especially if no clear response is present. Importantly, any determination of “no response” requires that the
average of all waveforms/replications for a given condition not be greater than a
minimum noise criterion (see below) before “no response” may be determined. If the
overall residual noise level is higher than the criterion, these waveforms apparently
without a response must not be interpreted for threshold purposes.

The routine use of more than four replications for a given stimulus condition is not
recommended – indeed, it would be unusual if more than three replications are required
often over many infants, and is likely indicative of a problem. In general, rather doing
more than 3-4 replications (assuming these are relatively noise free), it is more effective
to increase the stimulus level, where feasible, given persistent uncertainty about the
response.

Similarly, the routine use of larger numbers of averages more than about 4,000 sweeps
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. In order to decrease the likelihood of erroneously
accepting a non-response as “present”, averages of fewer than 1000 trials are strongly
discouraged. Further, in the interest of averaging efficiency, averages of greater than
10,000 trials each are also discouraged.

To reiterate: a single replication will NOT be used in the final bracketing of the
estimated ABR threshold. 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.

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 (this should be 3-4 times the size of the residual noise). 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 tonepips is very different from that seen in otoneurologic
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 2 kHz usually shows a wave V that is more
clearly defined and sharper than at 0.5 kHz, and the 4 kHz response can be quite similar
to conventional click responses. In a normal ABR, earlier waveforms (e.g. wave I, III)
may be seen at BC EHP minimum response levels.

With regard to latency, in the Assessment context the range of possible latency is so
broad that using specific targets for latency is unhelpful. 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 3-4 times the estimate of the residual noise level provided online by the equipment. Further, 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 artefact reject level.

The ability to judge when EEG conditions are acceptable is extremely important in ABR threshold estimation – far more important than it is in otoneurologic 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. BC EHP 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 and experience and individual skill.

512 60-Hz Artefact

Any ABR record may be contaminated by non-physiologic artefact, notably 60-Hz 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. 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 artefact is asymmetry of electrode impedances. Artefact 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 artefact presence. (Note: clamped-tube/no-sound control recordings cannot be used to determine presence/absence of a response.) Additionally, comparison of recordings with and without use of “60-Hz notch filter” will help confirm 60-Hz artefact presence versus a physiologic response. This notch filter, however, must not be used for threshold determination. If 60-Hz artefact is present, efforts must be made to reduce electrode impedance asymmetries as well as reducing the source of the artefact (e.g., dimmer switches, fluorescent lights); 60-Hz artefact can often be “unlocked” from the averaging by slight changes in the repetition rate and analysis.
sweep time. If large, irreducible 60-Hz artefact is present, records are not interpretable for response presence or absence. Consultation with BC EHP is recommended if artefact problems are persistent.

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

Power line artefact 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 artefact dramatically, relative to typical recording bandwidths for otoneurologic ABR (100-2000 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 BC EHP recordings, although they are useful for confirming presence of 60-Hz artefact. 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 artefact is to make a 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 in this context, to confirm 60-Hz artefact presence. (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 “60-Hz notch filter” will help confirm 60-Hz artefact presence versus a physiologic response. In the event that such interference is only seen on one side, asymmetry of impedances for the high-artefact side is the probable cause.

BC EHP and the Ontario are investigating last-resort strategies to deal with intractable 60 Hz artefact, 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 & Artefact Rejection

Amplifier gain will be set by the BC EHP. Gain (“sensitivity”) will not be changed if the EEG noise level increase/decreases during the test. Artefact 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 such that 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 artefacts.

Any infant may manifest high-amplitude myogenic bursts during a period of otherwise quiet EEG. Artefact 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 artefact 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 artefact 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.
Strategy for Stimulus Levels

The default strategy for threshold bracketing includes starting at the BC EHP minimum required level, followed by ascent in steps of at least 20-30 dB and descent in 10-dB steps. This procedure is efficient, given that many initial assessments will reveal normal hearing. Ascent by 10 dB will be avoided except in the single situation of a questionable positive (replicated) response at the BC EHP minimum level for a given stimulus route and frequency. The BC EHP protocol does NOT involve routine use of an intensity-latency (or intensity-amplitude) input-output function approach to threshold estimation, whether replicated or unreplicated.

The BC EHP protocol is based on direct estimation of thresholds by efficient bracketing and specifically does NOT invoke threshold estimation based upon amplitude or latency input-output functions, for which there is evidence of insufficient accuracy and reliability. Therefore, the general use of intensity series with small step size is specifically discouraged because it is relatively inaccurate and inefficient.

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 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, say, 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 general, in the absence of prior information from previous BC EHP Assessment suggesting otherwise, the most efficient intensity strategy starts at the lowest stimulus level required by the BC EHP for a given frequency and route of stimulus. Because many infants who refer from screening will have normal hearing at Assessment, a clear and reproducible response is often obtained at the lowest mandatory level. If prior information about probable threshold is available, either from prior testing or from a threshold at some other test stimulus condition, then the starting level may be higher than the BC EHP minimum level. A “refer” result from a screening several days to weeks earlier is not sufficient information to begin at a higher stimulus level.

Level ascent should be done with large step sizes (20-30 dB), followed by smaller steps (e.g., 10 dB in descent). 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 only situation in which a 10-dB ascent is likely to be generally efficient is that of questionable response presence at the BC EHP 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 would likely involve either switching to the other ear or obtaining bone-conduction results before testing higher intensities.

515  **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 2 kHz 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 include at a minimum 500 Hz and 2 kHz. Both are important generally and also particularly with regard to prescription of amplification. Even when 500 Hz and 2kHz are normal, time permitting, it is preferable to also attempt to obtain results for 4kHz (in order to rule out any high-frequency impairment).

If there is severe or profound impairment at 2 kHz, 0.5 kHz is a key measure of residual low-frequency hearing. If reliable thresholds have been obtained at 0.5 and 2 kHz, the clinical utility of measurements at 1 kHz depends on the 500Hz/2kHz threshold difference. If the threshold difference in dBnHL values is less than 20 dB, subsequent clinical interpolation of the 1-kHz 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 2 kHz greater than 20, then threshold measurement at 1 kHz 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.

ABR threshold measurement at 4kHz is mandatory if the ABR threshold at 2 kHz is more than 10 dB above the minimum mandatory level. Testing at 4 kHz is recommended also if the 2 kHz threshold is within normal limits but DPOAE results indicate a clear abnormality isolated at an F2 of 4 kHz. The 4 kHz threshold carries only limited information for immediate management, but it may be a risk indicator for progressive, high-frequency impairment and indicate a need for careful monitoring.

This Assessment protocol takes account of the epidemiologic and clinical characteristics of the presenting population. For example, data from screening programs suggest that the majority of infants who have failed AABR screening will be determined at the
Assessment not to have the target PCHI. 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 PCHI. 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 the most infants seen for BC EHP ABR Assessment aims to answer the following three questions, in order of priority:

1. Is an ear’s AC threshold normal or elevated? Is the other ear’s AC threshold normal or elevated?
2. If elevated, is the elevation conductive in nature or is there a sensorineural component?
3. If elevated, what are the specific thresholds (AC and/or BC)?

The first question is answered by testing each ear at the minimum level required for normal by BC EHP. It would not normally involve a threshold search. If the baby wakes up at the end of this, the BC EHP clinician is still able to state whether one or both ears’ thresholds are normal/elevated.

The second question is answered by BC testing the ear(s) with AC elevation(s) at the minimum BC level. If the infant wakes up at the end of this stage, the BC EHP clinician is able to state that the elevation in AC threshold is conductive in nature or has a sensorineural component. As the majority of BC EHP 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 thresholds for each required frequency are required for subsequent interventions, including amplification (when chosen by the family) when sensorineural hearing loss is present.

The above does not indicate the priority sequence-of-testing for stimulus frequencies. In general, greatest priority is given to 2kHz, and results for this frequency are normally obtained first. 500 Hz is usually next in priority, with 4kHz and, if required, 1kHz 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 BC EHP ABR Assessment.

Many infants presenting for Assessment will have normal or near-normal hearing. The initial key question is whether the target disorder is present. The minimum required levels for definition of normal hearing in the BC EHP context are listed in Section 1000 of this Protocol. In the absence of prior audiometric data, testing should start at 2 kHz because it is clinically the most important single frequency. The choice of initial test ear should match the AABR screening result, if available. If referral were bilateral, the ear of convenience would be chosen. The AC route is used first, because it is overall hearing sensitivity that is important initially.

If the starting ear gives a clear and reproducible 2 kHz AC response at the minimum required level, the key question is now whether the other ear is normal at 2 kHz. Such ear switching requires an infant have insert earphones inserted into both ear canals simultaneously.

If no response is obtained for the initial 2 kHz condition, then the strategic question is to what accuracy should the 2 kHz 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. Common practice is to determine the 2 kHz threshold, before changing frequency or route. However, if then elevation 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). Importantly, appropriate management of the hearing loss and information provided to parents depends upon knowing the nature of the loss. Hence, bone-conduction testing likely becomes a higher priority than determining the air-conduction threshold.

Many clinicians are reticent to move quickly to BC testing, fearing that placement of the BC transducer may arouse the child. The result is the common practice is to complete at least the 2 kHz 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. In contrast, using handholding of a BC transducer by an individual trained in the procedure allows for a quick, and relatively non-disruptive check of bone-conduction hearing.

A number of other test sequences are commonly employed by clinicians, and in some circumstances, may be appropriate. Some clinicians switch ears and determine the 2 kHz and 500 Hz AC thresholds bilaterally, before going to BC. Alternatively, some clinicians on finding a substantial abnormality in the initial ear especially at 2 kHz, emphasize definitive measurement of one ear by both AC and BC, before changing ears. Under these circumstances, a second session will almost always be needed to complete the Assessment, so there is no clear argument for one strategy over the other. For most infants, however, a priority of testing based on the three question elucidated above will result in the most efficient test sequence, proving information required next steps and for the parents.
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 BC EHP 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 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 preferably will 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 account of probable patterns of hearing impairment 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 PCHI.

516 AC 2 kHz

In the absence of prior BC EHP Assessment results indicating otherwise, testing will begin by AC at 30 dBnHL at 2 kHz. Response or Non-response at 30 dB will normally be followed by testing the opposite ear in the same condition. If AC 2kHz is elevated, threshold bracketing will be done after BC assessment.

If no response to AC 2kHz in either ear (after testing both ears), then BC 2 kHz BC at a minimum of 30 dB nHL 2 kHz, will be done. Each ear should be tested at BC 2kHz if no response to AC 2kHz at 30 dBnHL for both ears.

517 AC 500 Hz

AC at a minimum of 35 dBnHL at 500 Hz. If no response (each ear), then threshold bracketing will be done after BC 500 Hz. Testing at AC 500 Hz is a mandatory component of initial Assessment.

518 BC 500 Hz

BC at a minimum of 20 dBnHL 500 Hz is recommended, where time permits, but is not mandatory if BC at 2 kHz has been obtained. If the only AC abnormality is at 500 Hz, BC 500 Hz is mandatory where the AC 500 Hz threshold is greater than 40 dBnHL. Slight elevations of AC thresholds at 500 Hz do not trigger mandatory BC testing.
519  BC at Other Frequencies

BC testing will not be done at any frequency other than 500 Hz and 2 kHz. Currently, BC EHP 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 2 kHz.

520  BC Stimulus Artefact

At 500 Hz, at the highest BC stimulus levels (typically 40 dB) stimulus artefact can be very large. Special procedures will be implemented to reduce artefact and improve interpretive reliability under these conditions. See the support text for options. The IHS Smart-EP RN and SN response measures may be contaminated (and unreliable) when significant 500-Hz stimulus artefact is present.

High-amplitude BC stimulus artefact can appear in the average records, especially at 500 Hz and at the highest stimulus levels available, which are typically 40-45 dBnHL for BC 500 Hz and 60 dBnHL for BC 2kHz. Especially for this reason, alternating stimulus polarity must be used for BC stimuli. Even with alternating polarity, however, artefact 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 artefact 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 artefact 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 artefact may occasionally make V-V' identification more difficult, there are other, more important problems with stimulus artefact. First, the large artefact may trigger the averager's EEG artefact rejection - sometimes resulting in almost all trials being rejected. Modern ABR equipment has a feature that sets the artefact rejection routine to ignore the stimulus portion of the EEG, removing this problem. (Not all ABR equipment, unfortunately, has this important feature - when not available, the only option is to turn off the artefact rejection.) An even larger problem is that BC 500 Hz stimulus artefact can (and does) contaminate the online residual noise levels, making these noise measures of little use when recording ABRs to BC 500 Hz at 40-45 dBnHL.

For BC 2kHz testing, uncancelled stimulus artefact may appear similar to a “wave I”. Evaluation of the rarefaction and condensation sub-averages, made possible using the IHS Smart-EP “split buffer” routine, will usually indicate the “wave I” is due to stimulus artefact. BC EHP clinicians must be careful to differentiate this artifactual result from a real wave I, which might indicate a neurologic or AN/AD 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, and the two leads for the ipsilateral differential pair should be as close to each other as possible behind or above the head, to minimize the loop area formed by them and subtended to the radiated field of the transducer and leads. If the problem persists, it is usually reduced dramatically by lowering the stimulus level by 5 dB, because the artefact size is directly proportional to the stimulus driving voltage. Furthermore, the amount of artefact pickup is likely to be directly proportional to the contact impedance of the ipsilateral mastoid electrode.

521  BC Two-channel Recording

For BC ABR, two-channel EEG recording (forehead to ipsilateral and contralateral mastoid) and plotting is essential. 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 may be helpful when significant threshold asymmetry exists between ears.

Two-channel EEG recordings must always be employed for BC testing. BC EHP ABR equipment setups will identify the ear tested (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.

522  BC Responding Cochlea Inference

The responding cochlea for BC measurements will be determined by evaluation of response amplitude and latency differences in the ipsi and contra records, particularly at the minimum response levels. In the event of equivocal interpretation, stimulus levels may be changed as necessary in an attempt to isolate the responding side.

As reported by Stapells, in young infants the responding cochlea can usually be identified by comparison of ipsilateral and contralateral averages to 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 the wave identification is confident.

This phenomenon is at first sight surprising, given that the noninverting 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. Nevertheless, experience to date over thousands of such measurements suggests that the inference is generally valid.

The asymmetries are most clear near thresholds and for 2kHz. It is therefore important that BC results first be assessed at the BC EHP minimum BC levels (30dBNHL for BC 2kHz; 20dBNHL for BC 500 Hz), where asymmetries have been best studied. When sensorineural hearing loss exists, results at higher intensities are also typically interpretable, especially for BC 2 kHz. Recent data at UBC suggests less interaural
attenuation of BC energy at 500 Hz (compared to 2kHz) across infants’ skulls, thus some interpretation difficulties may arise when higher BC 500 Hz levels (40-45 dBnHL) are employed.

The ipsilateral/contralateral asymmetries decrease with maturation. They are not reliably present in children older than 3-4 years of age.

523 Interpretation of BC ABR results

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. It is important to understand that the BC-ABR is not used to provide a specific estimate of the air-bone gap; rather, it provides an excellent estimation of the presence/absence of sensorineural component. It also may indicate whether the sensorineural component is in the mild/moderate range or is greater. BC-ABR at the minimum stimulus levels provides an excellent indication of whether the observed AC elevation (e.g., no response at 30dBnHL for AC 2kHz) is conductive in nature (BC-ABR present with normal asymmetry) or has a sensorineural component of undetermined size (BC-ABR absent or with opposite asymmetry). An absent BC-ABR at maximum BC level (45 dB at 500 Hz and 60 dB at 2kHz) indicates presence of significant sensorineural component. Finally, an elevated BC-ABR threshold with a present response at intensity above minimum level suggests a sensorineural component in the mild/moderate range; however, the specific amount of this elevation cannot be determined from current knowledge.

524 Contralateral Masking

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

525 AC 4 kHz

AC at a minimum of 25 dBnHL at 4 kHz, with threshold bracketing, will be done if there is no response at 30 dB for 2 kHz. Given abnormality at 2 kHz, the likelihood of significantly different abnormality at 4 kHz is high. Although not mandatory when 500 and 2kHz results are normal, it is strongly preferred that results for 4 kHz be obtained, even when other results are normal. An exception is that initial testing at 4 kHz is NOT recommended if there is a significant conductive component at 2 kHz.

526 DPOAE Indicator for 4 kHz
In the rare event that (replicated) OAE records in any ear are available and normal at mid-frequencies but clearly absent at a nominal F2 of 4 kHz, tone pip ABR testing will be done at 4 kHz, despite normal results at 2 kHz.

527  AC 1 kHz

AC at a minimum of 35 dBNHL at 1 kHz, with bracketing if there is no response, will be done if there is a difference greater than 20 dB in the dBNHL thresholds at 500 Hz and 2 kHz. If the difference is 20 dB or less, testing at 1 kHz is discretionary but not recommended until ALL mandatory thresholds have been obtained and time permits. An exception is that initial testing at 1kHz is NOT recommended if there is a significant conductive component at 500 Hz or 2 kHz.

528  Deferring 1 & 4 kHz in Conductives

In the event that a purely conductive hearing impairment is demonstrated clearly at 500 Hz and 2 kHz, and either the tympanometry is clearly abnormal and/or the BC-ABR indicates conductive (i.e., present BC-ABR at minimum level), the determination of thresholds for 4 kHz and 1 kHz, if indicated by the above criteria, is NOT required unless and until the criteria are fulfilled at a repeat Assessment following a waiting period with or without intervening medical treatment of a potentially transient middle-ear condition.

529  High-intensity Click ABRs

If there is no detectable ABR with identifiable wave V to tonepips at the highest available intensity levels at all frequencies measured in any ear, or wave V thresholds at severe-profound levels by AC or BC (if indicated), then an AC click ABR test will be done at 95 dBNHL in that ear. Condensation and rarefaction records will be plotted separately. To ensure these results are interpretable, records must be replicated, have at least 2000 sweeps per average with an overall noise criterion at or below criterion. In the BC EHP context of audiometry based primarily on tone pip ABR by air and bone conduction, ABR measurements using clicks have a secondary role, but an important one. There are three aspects of diagnostic inference that may be clarified by the use of click stimuli: retrocochlear pathology, AN/AD, and residual hearing.

530  Retrocochlear Pathology

The clinical implications of indications of retrocochlear abnormality in the ABR are not well-established in infants. However, it is the accuracy of tone pip ABR threshold estimates that is the crucial issue here, and inaccurate threshold estimates may arise because of neuronal dys-synchrony that 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 it is often 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 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, it is not considered necessary to measure click ABRs routinely. 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. Separate measurements of response to 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. If early waves are present but a depressed or absent wave V is seen in BOTH 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 AN/AD, as outlined shortly. A clear finding that suggests a retrocochlear disorder should be noted in the report, and a medical referral is mandatory.

531 CM & Stimulus Artefacts

“Clamped-tube recordings”: If early wave are seen but there is no clear neural response to AC clicks at 95 dB or if a clear wave V is not identifiable, the 95 dB click records will be repeated with the earphone tubing clamped (using hemostats, with tape or silicone tubing over hemostat teeth to protect earphone tubes from damage). The insert and the driving transducer will not be moved from their position for the previous 95 dB 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 artefact. These alternatives can usually be discriminated by the use of separate averages with condensation and rarefaction clicks. If the early waves do not invert, they have a neuronal origin. If they invert, they are likely to be either CM or stimulus artefact. To rule out stimulus artefact, the stimulus delivery tube is clamped (using hemostats with tape or silicone tubing over hemostat teeth to protect earphone tubes from damage). The insert and the driving transducer must not be moved from their position for the previous 95 dB recordings. If the early waves remain, then they are due to stimulus artefact 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 AN/AD is present. Stimulus artefact is usually shorter in duration and rarely manifests more than 2-3 peaks and troughs. The finding of a clear CM and absent neurogenic waves suggests AN/AD, and the validity of ABR thresholds as estimators of perceptual thresholds is highly questionable in that case. In the presence of AN/AD, ABR thresholds will overestimate perceptual thresholds by an amount that may be very large.
Auditory Neuropathy/Auditory Dys-synchrony (AN/AD) Inference

The 95 dB nHL records will be assessed for presence of cochlear microphonics and stimulus artefacts. In conjunction with OAE records, the evidence for AN/AD will be evaluated. Absence of OAEs does not rule out AN/AD, whereas presence of OAEs and absence of ABR does make AN/AD the primary inference. If OAEs are absent but the CM records suggest AN/AD, that finding is less definitive and should be considered to yield a presumptive inference.

Auditory Neuropathy/Auditory Dys-synchrony (AN/AD) 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 impairment of any degree from mild to profound. The disorder is usually but not always bilateral. OAEs may be absent for trivial reasons related to middle ear conditions, so absence of OAEs does not rule out AN/AD. 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 AN/AD include inner hair cell, synaptic and primary neuronal dysfunction, and any or all of these may be operative in the individual case. AN/AD may or may not include a genuine neuropathy, and there may or may not be other, concurrent peripheral neuropathies present.

AN/AD may represent as much as 5-10% of all sensorineural hearing impairment 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 also a risk indicator. It is also possible that auditory brainstem immaturity or damage recovery (such as from perinatal hypoxia) may masquerade as AN/AD. In the presence of AN/AD, ABR threshold estimates are not reliable and currently it is recommended to delay intervention such as hearing aids until at least some behavioural threshold information can be obtained. Slow cortical potential recordings may also be contributory.

It is a feature of AN/AD that the CMs are often large and easily recorded, but there are usually no ABR waves in response to either tonepips or clicks. Therefore, care must be taken to differentiate CM, stimulus artefact 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 an absent or highly abnormal click ABR, the presence of a large CM suggests a provisional differential diagnosis of AN/AD, especially when OAEs are absent.

The appropriate course of action, given probable AN/AD, is at the discretion of the individual BC EHP audiologist. An ancillary protocol that will address additional diagnostic procedures, such as slow cortical potentials, as well as management issues, is in preparation. It is likely that cortical evoked potentials will contribute to any such protocol, 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.

AN/AD Implications
If AN/AD 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. In some cases, Slow Cortical Potential (SCP) threshold testing may provide additional evidence of auditory capabilities [protocol to be developed for BC EHP]. If the OAEs are not normal, a presumptive inference of AN/AD will be clarified by family report of responsiveness and behavioural observation by the BC EHP audiologist. Intervention involving amplification or cochlear implants should not be initiated before reliable behavioural Assessment is obtained.

534  AN/AD Report Field Entry

If AN/AD 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. PCHI is reported as present.

535  Click-ABR Thresholds

Only done when the BC EHP audiologist suspects AN/AD or neurologic involvement affecting tone-ABR threshold validity. If a clear and replicable response to clicks is identifiable at 95 dBnHL, the click- ABR threshold will be determined by bracketing. The response need not contain waves that are clearly identifiable as e.g., wave III, wave V, but there must be a replicable waveform in the range 2-20 ms to determine response presence.

If a clear wave V is seen in response to clicks, in the absence of tone pip responses at maximum AC levels, a possible cause is that there is better hearing at some frequency not yet tested by tonepips, in the range 0.5-8 kHz that may be excited by clicks. This might be explored by tone pip ABR measurements at the untested primary frequencies, at least in the range 1-4 kHz. It should be noted that BC EHP stimulus calibrations values are not provided for 6 and 8 kHz. In this unlikely event, consultation with BC EHP is recommended.

Another possible cause of a wave V-V’ to clicks but not to tonepips is that there is severe cochlear impairment and insufficient synchronous excitation of primary neurons with a frequency-specific stimulus, whereas the click excites a broader region of the cochlear partition and with greater synchrony. In that situation, no tone 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 BC EHP report.

536  Click-ABR Threshold Implications

The click-ABR threshold gives limited information about hearing sensitivity. If there is evidence of AN/AD, the inference is that at least one threshold in the 0.5-8 kHz range is
as good or better than the click-ABR threshold, and that the absence of tone pip responses gives no information about those thresholds. If AN/AD 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, click-ABR threshold should be noted in the BC EHP report form but not entered in the frequency fields.

537  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 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 dB HL by the application of the threshold adjustment factors listed in Appendix F. The resulting thresholds will be referred to in the BC EHP context as ‘Estimated Hearing Level’ or EHL thresholds, with units in dB EHL. EHL values will be entered as thresholds in the BC EHP report. For any condition of clear response at the BC EHP minimum level for any given stimulus frequency and route, the EHL will be deemed to be 25 dB EHL with the exception of 500 Hz, where the minimum response level is equivalent to 20 dB EHL. 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 stimulus envelope and repetition rate, which affect psychophysical energy integration. Such integration itself is affected by the type and degree of hearing impairment, so threshold relationships may also depend on the type and degree of impairment. Also, dBnHL is 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 1 kHz 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 whatsoever 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. Such data are available, albeit of limited quality and diversity.

The BC EHP 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 subject 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 (See DX Appendix F: EHL 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 psychoacoustical status with no change in actual level of hearing impairment. Given this approach, the target disorder 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). It should be noted that VRA thresholds are themselves generally greater than the true psychoacoustical 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. The actual threshold SPLs in early infancy will be greater than those for the same stimulus at the point of subsequently behavioural threshold measurement, especially at higher frequencies, so the results may give an impression of progressive impairment.

There is a clinical impression that ABR thresholds are closer to behavioural thresholds, when hearing impairment is severe, and this is often explained by appeal to a recruitment-like phenomenon. Another factor that affects threshold relationships is 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 impairments.

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 BC EHP threshold measurements. Accordingly, the current BC EHP conversion adjustments are specific to stimulus frequency, but not to observed ABR threshold level.

All BC EHP ABR reports must provide the ABR thresholds in dBnHL and the estimated behavioural thresholds in dB EHL.

538 ABR Recording Sheet

BC EHP Audiologists will record information of acquired ABR waveforms on a recording form during the Assessment (see Appendix K for two versions of the BC EHP ABR recording form). Information to be recorded includes filename, stimulus parameters, IHS online noise measures (RN, SNR), waveform determination, 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 logsheet will indicate why certain waveforms were to be disregarded; this information would not be available unless recorded at the time of data acquisition. It will also provide information on the online decision analysis for a given diagnostic ABR Assessment; this will be important for later second-opinion/file review processes.
DX 700: Middle Ear Analysis (MEA)

701 MEA Protocol

All MEA tests funded by BC EHP will be done in compliance with this protocol and the technical parameters and interpretive criteria (See DX Appendix L: MEA technical details).

702 Middle Ear Analysis (MEA)

Middle ear analysis (MEA) is a mandatory component of initial BC EHP Assessment, and has a secondary role in the context of follow-up BC EHP Assessment, for which it is recommended that 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 BC EHP 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 L.

703 Tympanometry

All BC EHP Diagnostic Referral Centres must have available immittance instrumentation capable of performing all test components as described in this section. Test parameters for use in Assessments will be specified by the BC EHP.

For infants up to and including six months corrected age:
- Tymanometry will be done using a 1kHz 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:
- 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. It was suggested by Paradise et al (1976) that in newborns and young infants the meatal wall is distensible, and that this may cause an artifactual tympanometric peak and mask
reduced TM compliance due to a middle ear condition. That hypothesis has been disputed, in favour of a more complex dynamical 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.

**704 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 discrentional. Reflex records will be plotted and retained on file.

The measurement of MEMRs is recommended wherever feasible. The presence or absence of MEMRs will be measured in the ipsilateral mode with a BBN stimulus and a 1 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 impairment.

MEMR measurement at pure tone stimulus frequencies such as 1 kHz is not a component of current BC EHP protocol. There is evidence to suggest that a significant proportion of the normal population will display absent reflexes to pure tone stimuli in the absence of 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 the stimulus intensity should result in an increase in the magnitude of the reflex.

705 MEMR Interpretation

In the context of the assessment, the clinical utility of the MEMR is primarily to lend support to the ABR measurements. Mis-interpretations 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 BC EHP will reduce the likelihood of such events, every reasonable additional precaution should be taken.

When the ABR results indicate at least a severe hearing impairment, 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 impairment, except when there is evidence of a conductive component, in which case reflex absence is non-contributory.

Conventionally, the absence of an 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 Auditory Neuropathy/Auditory Dys-synchrony.

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.
DX 800: Procedures - Otoacoustic Emissions (OAEs)

Otoacoustic Emissions (OAEs): Distortion Product Otoacoustic Emissions (DPOAEs) & Transient Evoked Otoacoustic Emissions (TEOAEs)

801 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 diagnostic audiology assessment in the Early Hearing Program, and it should be done whenever practically feasible. When AC tone pip ABRs are clear and reproducible at the lowest required stimulus levels at both 0.5 and 2 kHz in both ears, the contribution of both OAEs and MEA to the overall assessment is limited. In the circumstance of abnormal tone pip ABRs, the contribution of both OAE and MEA increases substantially, both in terms of the cross-check principle and for refining the overall description of otologic 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.

802 DPOAE Procedure

The required test parameters for diagnostic DPOAE measurements specified by the BC EHP are in Appendix M - OAE technical details. The current protocol includes replicated DPOAE measurements at nominal (F2) frequencies of 1.5, 2, 3 and 4 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 in the diagnostic context 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 physiologic 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 4 kHz is of questionable clinical utility, and is vulnerable to error arising from standing wave effects. However, in time-permitting situations, 6kHz and 8kHz 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.

803 Test Repetition

Regardless of the overall DPOAE test outcome, immediate repetition of the test is recommended, to confirm reliability of measurements. Repetition may be omitted if the DPOAE amplitudes exceed 5 dB and the signal to noise differences exceeds 10 dB at 1-4
kHz. DPOAE testing additional to the BC EHP protocol is not recommended, because it takes time and adds little relevant information.

At each nominal DPOAE test frequency, the initial decision after measurement is whether the observed value of DPOAE level represents a genuine DPOAE or is in fact due to noise alone. 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.

804 DPOAE detection

Typical criteria for defining a DPOAE to be 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 BC EHP to define specific, quantitative criteria. Furthermore, the detection criteria are inherently statistical, with the usual associated concepts of false-positive and false-negative detection error. 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 criteria chosen. It is plausible that different criteria of DPOAE detectability should be used in different diagnostic 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.

805 Noise levels

Normative noise floor levels have typical 99th percentile values in normal young adults when tested in a soundroom 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 soundrooms, at frequencies below about 2 kHz.

806 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 that 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.

807 TEOAE Procedure and Detection

The required test parameters for diagnostic TEOAE measurements will be specified by the BC EHP (see Appendix M: OAE technical details). The current EHP protocol indicates a minimum of 260 sweeps averaged; the stimulus consists of a click presented at 75 to 100 pps, at an intensity of 82 ± 3 dB SPL. 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 BC EHP protocol. Filtering to remove noise below 1 kHz is recommended. The data collection window is set at 4 to 10 or 12.5 msec. A maximum recording time of 6 minutes is allowed.

808 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 4kHz. Testing above and below these frequencies (e.g. 1500Hz to 8000Hz) is discrentional.

809 Interpretation of TEOAEs and DPOAEs

Many factors other than the target PCHI may cause reduction or absence of OAEs, and some subjects who have the target disorder at some specific frequencies may manifest normal OAEs at all frequencies, not just those remote from the target disorder. 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 BC EHP criteria.

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

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 disorder but does not guarantee it. For example, OAEs are routinely normal in the presence of AN/AD 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 abnormal thresholds should prompt careful review of the data. The first question is whether there has been 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 dB EHL, there is not necessarily any conflict. If the thresholds are 40 dB EHL or greater, the likelihood of seeing a clear OAE is negligible in a conventional cochlear impairment. If the threshold is greater than 40 dB, with no evidence of a conductive component, the likelihood of AN/AD 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 MEA is normal, the apparent OAE/ABR discrepancy should prompt 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 30dB EHL in the presence of slight hearing loss sufficient to degrade or abolish OAEs, these apparent contradictions of test outcome should be seen primarily as an indicator for careful review of the findings. If repeat testing is deemed appropriate in the light of 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 degree of hearing loss, during the infant years (and probably beyond, depending on diagnosis and reason for monitoring e.g. AN/AD or progressive/late onset risk factor).
**DX 900: Procedures - Visual Reinforcement Audiometry (VRA)**

**901 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 EHP 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 that are often observable include non-responsiveness, habituation to stimuli, incomplete conditioning, and over-engagement by the distractor. Careful observation of the child's behaviour will indicate when a change in stimuli may re-engage the child's interest 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. Soundfield can be useful in conditioning trials, as some children do not respond as well to auditory stimuli under insert earphones. Initial conditioning in soundfield may allow for reliable localized responses to occur quickly, at which point earphones can be inserted.

Soundfield 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 soundfield 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 soundbooth facilitates successful testing at future appointments.

**VRA-based assessment requirements**

All VRA-based assessments will include at least:

Ear-specific AC threshold measurements at 2 kHz and 500 Hz
Ear-specific AC threshold measurements at 4 kHz and 1 kHz, where indicated by rules specified previously for ABR-based assessments.

Alternative requirements if attempts at obtaining ear-specific behavioural results fail:

Soundfield AC threshold measurements at 2 kHz and 500 Hz

Soundfield AC threshold measurements at 4 kHz and 1 kHz, where indicated by rules specified previously for ABR-based assessments

TEOAEs/DPOAEs bilaterally (pass criteria = OAEs present at 2, 3, and 4 kHz – see OAE protocol)

\[902\] VRA Assessment pass criteria

Ear-specific minimum response level (MRL) of \(\leq 25\) dB HL at 2000 Hz and 500 Hz

AND

Ear-specific MRL of \(\leq 25\) dB HL at 4000 Hz – OR – present OAEs at 4000 Hz bilaterally

OR

Soundfield MRL of \(\leq 25\) dB HL at 2000 Hz and 500 Hz

AND

OAEs present at 2, 3, and 4 kHz bilaterally

AND

Ear-specific MRL of \(\leq 25\) dB HL at 4000 Hz – or – present OAEs at 4000 Hz bilaterally

See below for more details

\[903\] Test personnel

It is required that two testers be involved in the VRA test - one as examiner who presents the stimuli and visual reinforcement and records the child's responses, and the other who is in the room with the child and acts as distractor. The examiner must be an audiologist who is certified with CASLPA or ASHA and who has successfully completed the VRA training workshop and participated in ongoing training provided.

The role of distractor 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.

\[904\] 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).

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) suggested 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 indicated 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.

905 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).

906 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.

**907 Test Set-up**

In the test room, the child is seated 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 distractor is seated on a low chair on the other side of the table and facing the child, with a concealed collection of toys available to be used to maintain the child's attention between stimulus presentations.

The reinforcing toys are at 90 degrees to the child's right and left side. 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 see clearly the child's face and the distractor's activity. The audiometer, reinforcement controls and recording materials must be easily accessible. There must be good two-way communication between examiner and distractor. However, the examiner's voice should not be audible to the child unless it is being presented as a speech stimulus. The distractor in the test room may use an earphone, headphones or a bone conduction oscillator wired to the audiometer, or an FM system or induction loop system may be used for examiner-distractor communication.

**908 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 following:

- 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. (See section on interpretation of test results.)
The audiologist may determine that, in some cases, presenting the stimuli in sound field is helpful in 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.

909 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 diagnostic 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.

910 VRA Test Procedure

The recommended VRA protocol for determining Minimum Response Levels is based on the procedure described by Widen et al. (2000) (See DX Appendix N: 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 causing distracting noise. The foam tips 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 extremely narrow or atretic.

Pulsed, warbled tones of 1-2 seconds’ duration will be used as the initial stimuli. The inter-stimulus interval (ISI) should be varied, and initially lengthened if random head-turns are frequent. A 10-dB step size is used (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" or "Hi, ...child’s name") or child-oriented music may be used during conditioning, if the child does not respond well to the tones.

911 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 the BC EHP VRA Worksheet (see Appendix P: VRA Worksheet). S/he may also guide the distractor in keeping the child in the appropriate state for testing.

912 Role of the distractor

In order for VRA to be successful, the child must be attentive to the task of listening for the sound that signals that there is a visual reward to follow. The role of the distractor, 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 distractor 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 an 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 O: Role of VRA distractor, for more information.

913 Paired Conditioning/Training trials

Before determining the 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 extinguishing of the response, 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 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 distractor may have to point it out to him/her. This pairing of sound and reinforcement may be done twice, then the signal should be presented alone, to see if the child would now respond 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 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 reinforcement toys after 5 to 10 trials, further testing with the VRA technique may not be possible or useful on this occasion.

914 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. Threshold is bracketed by using a 20 dB-down, 10 dB-up technique. 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 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 distractor 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.

915 Control Trials

In order to have a measure of the reliability of the child’s head-turn responses, control trials are inserted 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 distractor 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.

916 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 distractor 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).

917 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 602 VRA Assessment Pass Criteria). If there is 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 do not fulfill the requirements for completion of the VRA assessment in the case of abnormal results.

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 retest, perhaps at a better time (if s/he seemed tired or irritable), or when s/he is a little older (if the problem seems to be related to his/her developmental level). 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 PCHI, 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 post-diagnosis or post-hearing aid fitting, and biannually 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 D – Diagnostic Flow charts.

If the child showed no interest in the visual reinforcement at all, 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 (i.e., 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 audiolologic thresholds.
If the degree of the child's PCHI has already been established with satisfactory ABR results, but there have been no reliable VRA results either under headphones or in soundfield for the child after repeated attempts, 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 for failure to obtain acceptable results.

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.

BC EHP 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 1000: Audiologic Inference

1001 General Approach

The overall audiologic 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 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 BC EHP requirement for threshold estimates at 0.5 kHz and 2 kHz at a minimum (preferably with 4kHz as well), 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 when 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 undermine or compromise inappropriately the primary inferences from the testing. Rather, the corroborative measures provide an indication for critical re-evaluation and where necessary, confirmation of findings. A balance is always required, and that is the nature of clinical judgment required from BC EHP audiologists.

The most probable scenarios that may lead to delay in definitive Assessment are: (i) inability to obtain sufficiently reliable threshold estimates without resorting to sedation or general anesthesia, (ii) audiometric uncertainty arising from evidence of ABR waveform abnormality suggesting AN/AD or other disorders that degrade neuronal synchrony in the auditory brainstem, and (iii) audiometric uncertainty due to a transient or fluctuating conductive overlay on a genuine sensory impairment.

Provided that AN/AD 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 artefacts associated with tension or gross movement.

Usually, as the infant gets older it will be 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 not perception of sound, but responsiveness to it. So the first question that arises if VRA results are worse than ABR results obtained with a high-quality protocol is whether there is a responsiveness issue. The second question is whether the hearing impairment has progressed. Risk indicators should be reviewed carefully in relation to possible progressive impairment. 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 is 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
electrophysiologic 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 suggest the presence of AN/AD or a retrocochlear
disorder affecting 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 dys-synchrony 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 AN/AD or retrocochlear disorders, currently behavioural assessment is
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 AN/AD 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 AN/AD is at
the discretion of the BC EHP audiologist. The BC EHP is currently evaluating more
advanced assessment methods to address these circumstances.

The medical community plays a key role in establishing etiologic diagnosis of the hearing
impairment, 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 related directly or indirectly to the hearing impairment. These
processes may include a variety of investigations (such as ophthalmologic, radiologic,
metabolic, neurodevelopmental, genetic) and referrals, such as for social supports.

The BC EHP 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, and efforts
to facilitate these mechanisms have been initiated.

1002 Normal Hearing
The child will be reported to BC EHP 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 BC EHP perspective, hearing is “normal” when the target disorder 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 0.5 kHz and 2kHz (and 4kHz, if possible) in each ear at the mandatory minimum levels are sufficient to define “normal” hearing from the BC EHP 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 BC EHP “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 BC EHP 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 BC EHP.

1003 PCHI Confirmed

The BC EHP report field indicating presence of PCHI is YES if (i) any BC-ABR indicates no response at minimum test levels (i.e., elevated threshold), or (ii) if behavioural threshold is estimated with confidence (either by ABR or VRA) at 30 dB EHL or greater, or if any AC threshold at 2 kHz or 4 kHz is estimated with confidence at 70 dB EHL or greater, or if the presence of AN/AD is strongly indicated.

The infant is defined to have the target PCHI 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 2 kHz, 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. PCHI is also deemed to be present if AC thresholds are clearly higher than those that could be attributed to purely conductive impairment. PCHI is also deemed to be present if test results indicate the presence of AN/AD.

1004 Follow-up Recommendations

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

1. Review results of the audiologist assessment, implications of the audiologic
diagnosis, and recommendations for intervention with the parents/caregivers, including:

a. Information regarding the need for medical evaluation and diagnosis
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 DX 1100: Medical referral process for PCHI).

3. Initiate the amplification process if appropriate and ensure that medical clearance for amplification has been obtained (as per DX 1100: Medical referral process for PCHI).

4. If the child has come through BC EHP screening, refer the family to the BC EHP Early Intervention Coordinator (documentation for process pending).

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 results of the audiologist assessment, implications of the audiologic diagnosis, 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 1100: Medical referral process for PCHI

Children confirmed to have PCHI 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 BC EHP 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: (1) provide the medical authorization for amplification, (2) facilitate the referral for the otolaryngology consult, and (3) ensure provision of a medical evaluation for children identified with PCHI. 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 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 BC EHP 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:

1. PCHI is diagnosed, including type, degree and ear. If it is determined that amplification will be pursued, a referral for medical evaluation/clearance for amplification should be initiated by the Audiologist who made the PCHI diagnosis. The list of BC EHP-designated Otolaryngologists to whom referral can be made is shown in Appendix Q.

2. The BC EHP Medical Approval Form (see Appendix Q) and a copy of the Diagnostic Audiology Assessment report/results should be sent to the Otolaryngologist by the Audiologist who made the PCHI diagnosis.

3. The Family Physician Information Letter (see Appendix Q) and a copy of the Diagnostic Audiology Assessment report/results should be sent to the family physician and pediatricians, if applicable, by the Audiologist who made the PCHI diagnosis. The purpose is to inform the family physician and pediatrician(s) about the process for medical approval. Note that the Medical Approval Form is only sent to the Otolaryngologist.

4. The original BCEHP Medical Approval Form and the original Family Physician Information Letter should be kept in the client file with a bring-forward date of 2 business days.

   a. If after 2 business days a signed Medical Approval Form has not been received at the Clinic, the Hearing Clinic should contact the Otolaryngologist’s office to
enquire re: status of the Medical Approval Form. A bring-forward should be set for a further 3 business days.

b. If after 5 business days, a signed Medical Approval Form has not been received by the Audiology Clinic, a second call should be made to the Otolaryngologist’s office by the audiologist.

c. If after 7 business days, a signed medical approval form has not been received, the Audiologist should contact the BC EHP Provincial Office and fax a copy of the Medical Referral Form. The BC EHP Provincial Office will follow-up through the Medical Advisory Group and respond to the Audiologist within 5 business days.

5. Once a signed Medical Approval Form has been received, it is attached to the client file and the fitting of amplification can proceed.
APPENDICES

A. : BC EHP Risk indicators for progressive/late onset hearing loss

A. Craniofacial – an obvious craniofacial anomaly (not pits or tags), e.g. cleft palate (NOT cleft lip in isolation), microtia/atroia
B. Family history of permanent hearing loss in early childhood before age 12 years, first cousin or closer to baby (parents, siblings, uncle/aunt, cousin, grandparent), irrespective of degree of hearing loss.
C. Syndrome associated with progressive/late onset hearing loss (e.g. Pendred, Branchio-Oto-Renal, Alport, Usher, LVA, neurofibromatosis, osteopetrosis, Down Syndrome)
D. Birthweight 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)
   iv. Extra-Corporeal Membrane Oxygenation (ECMO) or inhaled Nitrous Oxide (iNO) or High-Frequency Oscillatory (HFO) or Jet (HFJ) ventilation
F. Brain dysfunction:
   i. Intra-ventricular Hemorrhage (IVH), Grade III or IV (IV are seen by Neonatal Follow-up)
   ii. Peri-ventricular Leukomalacia (PVL)
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, irrespective of the pathogen.
I. Accidental overdose of Gentamycin or other aminoglycosides, five-fold or greater
**B. : History Form**  
Childhood Hearing Questionnaire

Name of Child:  

Child’s birth date:  

Name of person filling out this form, and 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 problems 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?  

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stayed in hospital after mother</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prematurity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight less than 1500 g (3.3 lbs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infections</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Did not respond to sounds or people</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor weight gain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Was in an incubator or isolette</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appeared yellow/jaundiced</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty breathing/ventilation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brain problems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High fever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical deformities</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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?

<table>
<thead>
<tr>
<th>Condition</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td>High fever</td>
<td></td>
</tr>
<tr>
<td>Pneumonia</td>
<td></td>
</tr>
<tr>
<td>Convulsions/seizures</td>
<td></td>
</tr>
<tr>
<td>Heart problems</td>
<td></td>
</tr>
<tr>
<td>Head or ear injury</td>
<td></td>
</tr>
<tr>
<td>Rheumatic fever</td>
<td></td>
</tr>
<tr>
<td>Encephalitis</td>
<td></td>
</tr>
<tr>
<td>Allergies</td>
<td></td>
</tr>
<tr>
<td>Meningitis</td>
<td></td>
</tr>
<tr>
<td>Asthma</td>
<td></td>
</tr>
<tr>
<td>Tonsillitis</td>
<td></td>
</tr>
</tbody>
</table>

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. What languages is your child 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

19. What questions would you like to have answered as a result of today’s hearing test?

____________________________________________________________________
____________________________________________________________________

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

- [ ] IDP/CDC
- [ ] Family Physician
- [ ] Pediatrician
- [ ] Other physicians
- [ ] Speech-language pathologist
- [ ] MCFD
- [ ] Other
C. Client criteria

Target Population for VRA

Within BC’s EHP, an infant identified as having PCHI 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 BC EHP 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) suggested "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 BC EHP is available to babies and young children who are determined to be at risk for PCHI, by virtue of a refer result on BC EHP screening or by referral into BC EHP, or to have PCHI (shown by previous BC EHP 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 BC EHP.

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 BC EHP surveillance procedures for high-risk infants, or through external referral-in of infants discovered to be at risk for hearing impairment. All candidates for BC EHP follow-up Assessments will have received an initial Assessment within BC EHP.
D. : Diagnostic Flow Charts

Dx Aud Workup
4 – 8 weeks C.A.

Threshold ABR
  ↓
  Refer

OAE/Immittance (mandatory)
  ↓
  Interpretation

Permanent HL
  ↓
  Counseling
  ↓
  ENT etiology & medical release
  ↓
  Clearance Rec’d
  ↓
  Intervention +/- H.Aids
  ↓
  Behav. Dx (complete) @ 6 months

OAE/Immittance when possible
  ↓
  Refer

Review ABR Results
  ↓
  Borderline SNR
  ↓
  Second Opinion

Conductive
  ↓
  ENT etiologic
  ↓
  ENT Intervention

Response fr. ENT
  ↓
  Immittance & OAE
  Refer
Behav. @ 6 months
  ↓
  Discharge

Good SNR
  ↓
  Discharge

Pass
  ↓
  Discharge

E.M.I.’s

Pass
  ↓
  Discharge

Refer (visual judge)
Delayed Onset Risk Monitoring:
Diagnostic Audiology Clinical Path

Stage I or II Screen Pass
With Late Onset Risk Factor

Determine Risk Factor

- Family History, Low Birthweight, Low Apgar, TORCHS, Respiratory Distress, Head Trauma or Brain Disorder, Suspected syndrome
- Cleft Palate and Craniofacial
- ECMO CDH
- Neonatal Meningitis

1
2
3
4
Delayed Onset Risk Monitoring:
Family History, Low Birthweight, Low Apgar, TORCHS, etc

1

Behavioural Audiology appt at 6 to 9 months C.A.

Pass/Refer

NORMAL HEARING
Report to RC

Behavioural Audiology appt at 36 months

Go To Diagnostic Clinical Path

NORMAL HEARING
Report to RC

Pass/Refer

Discharge from BCEHP
At 36 months

1 – Family History, Low Birthweight, Low Apgar, TORCHS, Respiratory Distress, Head Trauma or Brain Disorder, Suspected syndrome (not including Cleft Palate – see 2)
Behavioural audiology at 6 to 9 months C.A.

2 – Cleft Palate and Craniofacial

NORMAL HEARING
Report to RC

Behavioural audiology workup every 6 months

Go To Diagnostic Clinical Path

REFER
Report to RC
Diagnostic ABR workup
At 4 months C.C.A. at BCCH

NORMAL HEARING
Report to RC

Behavioural audiology workup at 8 months C.C.A. at BCCH

NORMAL HEARING
Report to RC

Behavioural audiology workup at 12 months C.C.A. in community

NORMAL HEARING
Report to RC

Behavioural audiology workup at 18 months C.C.A. at BCCH

NORMAL HEARING
Report to RC

Behavioural audiology workup at 24 months C.C.A. in community

NORMAL HEARING
Report to RC

Behavioural audiology workup at 36 months C.C.A. at BCCH

NORMAL HEARING
Report to RC

Discharge from BCEHP
At 36 months

Pass/Refer

REFER
Report to RC

Go to Diagnostic Clinical Path

3 – ECMO & CDH
Delayed Onset Risk Monitoring: Neonatal Meningitis

4 – Neonatal Meningitis

Diagnostic ABR workup ASAP

- Pass/Refer
  - NORMAL HEARING Report to RC
  - Refer

Bring forward in 2 months for Diagnostic ABR workup

- Pass/Refer
  - NORMAL HEARING Report to RC

Behavioural audiology workup every 6 months until 36 months

Go To Diagnostic Clinical Path

Refer Report to RC
Diagnostic Audiology Clinical Path:
Level One

By 1 month
- Initial Diagnostic Appointment made within 4-8 weeks C.A. or at refer from DORM
  - Threshold ABR
    - Pass/Refer
      - Refer to RC
    - OAE/Immittance when possible
      - Pass/Refer
        - Report to RC
      - Refer
        - Report to RC
  - OAE/Immittance
    - Permanent CHL OR Conductive HL
      - Medical Referral/ENT consult
      - Medical Diagnosis
        - Yes: Audiology monitoring (Immittance/OAE)
        - No: Permanent HL?
          - Yes: Amplification May in some cases be initiated prior to completion of diagnostic work up
          - No: Referral to BCEHP Early Intervention Coordinator as soon as PCHL is suspected – may be prior to completion of Diagnostic workup
            - Medical Referral
              - Team Conference: Identify case manager, plan coordination of early intervention, medical, audiological management
              - Discharge from BCEHP; monitor per Public Health mandate
            - By 1 month
              - By 3rd month
                - By 6th month
E. : Declined Hearing Assessment Waiver

BC Early Hearing Program

A service of the Provincial Health Services Authority

DECLINED HEARING ASSESSMENT WAIVER

Diagnostic Site _________________________
Health Authority _________________________
Physician _________________________
Child Name _________________________________
Child DOB _________________________________

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

☑️ I release the diagnostic 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 diagnostic 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 diagnostic 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 _____________________________________
# Things to Watch for While Your Baby is Growing

## Birth to 2 Months
- startles to loud sounds
- quiets to familiar voices
- makes vowel sounds like “ohh” and “ahh

## 2 to 4 Months
- looks for sounds with eyes
- starts babbling
- uses a variety of pitches in squeals, whimpers

## 4 to 6 Months
- turns head towards sound
- tries to imitate changes in voice pitch
- babbles (ma-ma, ga-ga, ba-ba)

## 6 to 9 Months
- imitates speech sounds of others
- understands “no-no” or “bye-bye”
- will locate sound source at eye-level or below

## 9 to 12 Months
- correctly says 2 or 3 words
- gives toy when asked for
- responds to singing or music
F. : Estimated Hearing Level (EHL) calculations

BC EHP 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</td>
<td>2k</td>
</tr>
<tr>
<td>Minimum Level (dBNHL)</td>
<td>35      35</td>
<td>30</td>
</tr>
<tr>
<td>Adjustment (dB)*</td>
<td>-15     -10</td>
<td>-5</td>
</tr>
</tbody>
</table>

* For AC ABR threshold estimates greater than 70 dBNHL, if 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 80dBnHL (+), 70dBnHL (-): EHL = 80 -5 = 75 dBEHL
- 2k 80dBnHL (+), 75dBnHL (-): EHL = 80 -5+5 = 80 dBEHL

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

** For any AC ABR threshold, it is discretionary to reduce the absolute value of the Adjustment by 5 dB, if the response at the lowest level considered positive is minimal AND the EEG noise level is very low.

The rationale is that with exceptionally quiet EEG, the ability to identify small, near-threshold responses is increased, and if such a response is seen, the negative offsets normally used are likely to be on average excessive.

Examples:

- 500 Hz 60dBnHL (+), 50dBnHL (-): EHL = 60 -15 = 45 dBEHL
- 500 Hz 70 dBnHL (+), 60 dBnHL (small V; low RN), 50 dBnHL (-): EHL = 60 – 15 + 5 = 50dBEHL

Note that application of these adjustment factors may occasionally yield small, negative air-bone gaps. Such a finding is to be expected, given that the adjustments are based on group mean normative data.
## G. Diagnostic instrumentation

**Instrumentation**

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABR</td>
<td>Intelligent Hearing Systems Smart-EP (USB version)</td>
</tr>
<tr>
<td>MEA</td>
<td>Discretional</td>
</tr>
<tr>
<td>OAE</td>
<td>Discretional (IHS for TEOAE not recommended)</td>
</tr>
<tr>
<td>VRA</td>
<td>Discretional</td>
</tr>
<tr>
<td>Play</td>
<td>Discretional</td>
</tr>
<tr>
<td>RECD</td>
<td>Audioscan RM500, Verifit</td>
</tr>
</tbody>
</table>
H. : ABR technical details

ABR IHS Smart-EP CALIB file offsets for BC EHP nominal 0 dBnHL at dial 0 dB

These values are numbers specified by the BC EHP in the EP Utilities/EPSetUP/Calib file that are intended to produce appropriate stimulus levels, such that dial values approximate dBnHL values. The numbers are NOT actual values of dB SPL ppe; the current values yield actual SPLs or force levels in dB ppe at BC EHP nominal 0 dB nHL that are close to those recommended by Stapells, with the exception of a 6 dB difference for BC at 2k. This deviation is being reviewed.

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

Air Conduction

<table>
<thead>
<tr>
<th>Frequency</th>
<th>TDH49 Calib</th>
<th>ER3A Calib</th>
<th>ER3A dBSPL</th>
<th>ER3A Stapells</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>25</td>
<td>22</td>
<td>19</td>
<td>22</td>
</tr>
<tr>
<td>1000 Hz</td>
<td>23</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>26</td>
<td>20</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>4000 Hz</td>
<td>29</td>
<td>26</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>Clicks</td>
<td>35</td>
<td>35</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bone Conduction

<table>
<thead>
<tr>
<th>Frequency</th>
<th>B71Actual Calib</th>
<th>Stapells dB Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 Hz</td>
<td>61</td>
<td>64</td>
</tr>
<tr>
<td>2000 Hz</td>
<td>67</td>
<td>55</td>
</tr>
</tbody>
</table>

Protocol Files: As distributed by BC EHP

Electrode sites: Noninverting: High midline forehead, referenced to
Inverting Channel 1: Right mastoid
Inverting Channel 2: Left mastoid
Common: Lateral forehead > 3cm from Noninverting
**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 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 1500 Hz  
Notch filter: Off

**Artefact reject:** On, typically +/-15-25 μV

**Amplifier Gain:** 100,000-150,000

**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>
</tbody>
</table>
| BC 500 Hz tones   | 20 dBnHL: 10.5 – 20.5 ms  
                  | 30-45 dBnHL: 14 – 24 ms (only RN valid)  
                  | Note: higher BC is later because of stimulus artefact |
| AC 1000 Hz tones  | 7.5 – 17.5 ms                                          |
| AC/BC 2000 Hz tones | 6.5 – 16.5 ms                                    |
| AC/BC 4000 Hz tones | 5 – 15 ms                                          |
**SNR criterion:**
- If the SNR is greater than 1.5 then a response is likely present
- If the SNR is less than 0.8 the response is likely absent
Visual determination of response present is currently the preferred method

**CCR criterion:** 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 should be less than or equal to:
- **0.11 \( \mu V \)** for an individual waveform (must have at least two averages with NR)
- **0.08 \( \mu V \)** for an added waveform (composite of several averages)

**Epoch length:**
- 23-25 ms for tone pips
- 12-13 ms for clicks

**Analysis Offset:** Zero

**Stimulus Parameters**

**Tonepips:**
Linear ramp (Trapezoidal envelope), 2-1-2 **cycle** rise/plateau/fall times; Alternating polarity; Repetition rate ~39.1/s.

**Clicks:**
100 \( \mu s \) drive voltage pulse duration; Alternating, condensation, rarefaction polarity as specified; Repetition rate 21.1/s

**Masking:**
Ipsilateral: None. Contralateral: discretion.al.
I. ABR protocol procedure

Waveform determination:

- **Response**
  - The peak-to-peak amplitude of the response is at least 3x the difference between the replications (in the 10 ms window around the peak)

- **No Response**
  - No apparent response
  - RN of each wave ≤ 0.11 μV or...
  - overall RN ≤ 0.08 μV (i.e. RN of all waves added)
  - Looks quiet at a reasonable amplitude scale (between 0.3 and 0.7 μV)

- **Cannot Evaluate**
  - No replicable response
  - RN above 0.11 for all recordings (or overall >0.08)
  - Looks noisy at a reasonable amplitude scale (between 0.3 and 0.7 μV)

Dx ABR Assessment required results:

- **Tonepip ABR thresholds**
  - 2000 Hz AC (minimum of 30 dB nHL) both ears
  - 500 Hz AC (minimum of 35 dB nHL) both ears
  - 4000 Hz AC (minimum of 25 dB nHL) time permitting; mandatory if OAEs are present at mid-frequencies but absent at 4000 Hz
  - 1000 Hz AC (minimum of 35 dB nHL) time permitting or if there is more than a 20 dB nHL difference between thresholds at 500 and 2000 Hz.
  - 2000 BC if 2000 Hz AC is elevated (minimum of 30 dB nHL)
  - 500 BC is not mandatory given elevated 500 Hz AC if you have 2000 BC
  - 500 BC is mandatory if 500 Hz AC is only elevation and AC threshold is greater than 40 dB nHL

- **Given absent wave V at all frequencies in one or both ears, click-ABR for AN/AD, including cochlear microphonic potentials and stimulus artifact analysis.**
  - Rarefaction and condensation (at least 2 replications) at 95 dB nHL
  - Clicks are recommended for more severe SNHL losses even if you do have wave V

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

The requirement to reach noise criterion applies to determination of no-response
Order of Acquisition of ABR data:

- Sample sequence for normal ABR:
  1. 2000 Hz at 30 dBnHL each ear
     Present bilaterally
  2. 500 Hz at 35 dBnHL each ear
     Present bilaterally
  3. 4000 Hz at 25 dBnHL each ear
     Present bilaterally
  4. 1000 Hz at 35 dBnHL each ear
     Present bilaterally

- Sample sequence for conductive HL:
  1. 2000 Hz AC at 30 dBnHL each ear
     Absent in one or both ears
  2. 2000 Hz BC at 30 dBnHL each ear where 2000 AC elevated
     Present bilaterally
  3. 500 Hz BC at 20 dB nHL
     Present bilaterally

  (NB: can do 500 BC after step 5 instead)
  4. 2000 Hz AC threshold both ears (where elevated)
  5. 500 Hz AC threshold (if elevated)
  6. 1000 and 4000 Hz AC can be deferred if fluctuating middle ear involvement suspected

- Sample sequence for sensorineural HL
  1. 2000 Hz AC at 30 dBnHL each ear
     Absent in one or both ears
  2. 2000 Hz BC at 30 dBnHL each ear where 2000 AC elevated
     Absent
  3. 2000 Hz BC at 60 dB nHL (finding threshold for 2000 BC can be deferred)
  4. 2000 Hz AC threshold both ears (where elevated)
  5. 500 Hz AC threshold both ears
6. 4000 Hz AC threshold both ears

7. 1000 Hz AC threshold if difference between 500 and 2000 Hz is > 20 dB
J. : 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 physiologic, 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 when not acquiring to activate) 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.
- 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.
## ABR recording form

### K.1. Version 1

**BC Early Hearing Program**

**TONE-EVOKED AUDITORY BRAINSTEM RESPONSE ASSESSMENT**

**ABR RECORDEING SHEET**

**TEST DATE: ____________**

**TESTER(TE): ____________**

### PATIENT'S NAME: __________________

**CorrAGE: ____________**

**BIRTHDATE: ____________**

**CHART/MRUN#: ______________**

**DIRECTORY or IHS-IDENTIFIER: ______________**

**EEG Ch1#: ______________**

**IMPED: 100KΩ**

**EEG Ch2#: ______________**

**IMPED: 100KΩ**

**EQUIPMENT:**

- **KEY:** AC: air conduction, BC: bone conduction, RC: rarefaction click, CC: condensation click, ALT: alternating polarity
- **Online/Offline decisions:** ✓ = response present, x = response absent, ? = unclear/indeterminate
- **SmartEP measures (10-ns wide window must be correct):** RN: residual noise, SNR: signal-to-noise ratio

<table>
<thead>
<tr>
<th>FILENAME</th>
<th>EAR</th>
<th>INTEN</th>
<th>STIM</th>
<th>CHAN (dB BC)</th>
<th>RN (dBF)</th>
<th>S N R</th>
<th>REAP PRESSED</th>
<th>Y/N</th>
<th>COMMENTS</th>
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</table>

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

**One rep RN > 0.11μV = noisy, Average of all reps RN > 0.08μV = noisy; SNR < 1 = unlikely response**
ABR recording form
K.2. Version 2

BC Early Hearing Program ABR Log Sheet

Patient name: ___________________________  DOB: _____________

Age on day of ABR (corrected): ____________________________

Tester(s): _____________________________________________  Date of test: ______________

Equipment:  IHS SmartEP  Impedance: ___ ≤ 3KΩms  ___ Other: _____________________________

<table>
<thead>
<tr>
<th>File Name</th>
<th>Ear (R/L)</th>
<th>Inten (dBN HL)</th>
<th>Stimuli</th>
<th>Channel (BC)</th>
<th>SNR</th>
<th>RN</th>
<th>Resp Prs?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td>AC BC</td>
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</table>

Both ear inserts: y/n? If not, add in comments about what the circumstances were that prevented both inserts from being placed simultaneously.

Key: AC: air conduction; BC: bone conduction; RC: rarefaction click; CC: condensation click; ALT: alternating polarity; ✓: response present; x: response absent; ?: questionable; RN: residual noise; SNR: signal-to-noise ratio; RN should be ≤0.11 µV for each waveform or ≤0.08 µV for combined waves.
L. Middle-Ear Analysis (MEA) technical details

Tympanometry

Tympanometry will be completed with a 1 kHz probe for infants under six months corrected age, and with a 226 Hz probe for infants aged 6 months or more/children. The tympanogram will be replicated immediately if the trace is noisy. Tympanograms will be plotted and retained on file.

The BC EHP 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 1kHz probe frequency, with repetition as necessary and feasible, to improve reliability.

- The key abnormality criterion is a compensated peak static admittance of \( \leq 0.6 \) 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 1 kHz 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.
### M.: Otoacoustic Emissions technical details

<table>
<thead>
<tr>
<th></th>
<th>DPOAE</th>
<th>TEOAE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stimulus parameters</strong></td>
<td><strong>Type</strong>: 2 primary pure tones, response measured at 2f1-f2 for each stimulus tone pair;</td>
<td><strong>Type</strong>: click</td>
</tr>
<tr>
<td></td>
<td><strong>Nominal (F2) frequency</strong>: 2, 3 and 4 kHz</td>
<td><strong>Click rate</strong>: 75 to 100 pps</td>
</tr>
<tr>
<td></td>
<td><strong>Frequency ratio (F2/F1)</strong>: 1.2</td>
<td><strong>Frequency region</strong>: 2, 3 and 4kHz</td>
</tr>
<tr>
<td></td>
<td><strong>Intensity</strong>: L1 of 65; L2 of 55 dBSPL</td>
<td><strong>Analysis window</strong>: 4-10 or 12.5 msec</td>
</tr>
<tr>
<td></td>
<td><strong>Type</strong>: click</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Click rate</strong>: 75 to 100 pps</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Frequency region</strong>: 2, 3 and 4 kHz</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Analysis window</strong>: 4-10 or 12.5 msec</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Intensity</strong>: 82 dBpeSPL, variation +/- 3 dB</td>
<td></td>
</tr>
<tr>
<td><strong>Recording Details</strong></td>
<td><strong>IHS - SmartDPOAE</strong>:</td>
<td><strong>ILO</strong>:</td>
</tr>
<tr>
<td></td>
<td>- <strong>General</strong>:</td>
<td>- Sweeps recorded: 260 or a minimum of 50 if min SNR and reproducibility standards have been obtained (see “pass criteria” below)</td>
</tr>
<tr>
<td></td>
<td>- Sweeps: 16</td>
<td>- Data rejection level: ≤ 55 dB peSPL (low frequency noise filter)</td>
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<tr>
<td></td>
<td>- Block Size: 8</td>
<td>- Reproducibility: ≥ 50%</td>
</tr>
<tr>
<td></td>
<td>- Level 1 (dB SPL): 65</td>
<td>- Probe stability: ≥ 70%</td>
</tr>
<tr>
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<td>- Level 2 (dB SPL): 55</td>
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<td>- Artifact: 10</td>
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<td>- Retry: 5</td>
<td>Testing time: max 6 minutes</td>
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<td>- <strong>Frequency</strong>:</td>
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<tr>
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<td>- Start: 2000</td>
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<td>- End: 4000</td>
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<td>- Frequency/Octave: 2.15</td>
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<td>- F1/F2: 1.22</td>
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<td>- High to low: ticked</td>
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<td></td>
<td>- <strong>Advanced</strong>:</td>
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<td></td>
<td>- Max level (dB SPL): 80</td>
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<tr>
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<td>- ISI Period: 1600</td>
<td></td>
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<td></td>
<td>- Max ear correction: 5</td>
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<tr>
<td></td>
<td>- Ear correction: ticked</td>
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<td>- <strong>Stopping</strong>:</td>
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<td>- On pass at that frequency: ticked</td>
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<td>- On overall pass: ticked</td>
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<tr>
<td></td>
<td>- On no chance to pass: not ticked</td>
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<td>- (Under “System” menu at the top, select “Passing criteria”)</td>
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<tr>
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<td>- <strong>Passing</strong>:</td>
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<td>- DPs-Ns=SNR: 3</td>
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<td>- DPs-Ns: 2</td>
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<td></td>
<td>- DP Value: -5</td>
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<td>- <strong>Overall</strong>:</td>
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<td>- Percentage passed from all: blank</td>
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<td>- Percentage in every octave: greyed out 100 (blank)</td>
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<td></td>
<td>- Percentage passed frequency range (#1): 100%; from (Hz): 2000 to 4000</td>
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<td>- <strong>Pass criteria</strong></td>
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<td></td>
<td>- mandatory presence of 2, 3, and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- SNR criteria: overall min amplitude</td>
<td></td>
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</tbody>
</table>
| 4kHz | (wideband) response ≥ 6dB; ≥ 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 | (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 retro cochlear hearing loss (such as AN/AD)  
Absence of DPOAE at 4kHz, when emissions are present at 2 and 3 kHz, is an indicator to proceed with 4kHz tonepip ABR threshold search  
Absence of OAEs may be due to poor probe placement, probe blockage, status of ME or presence of target disorder (SNHL > 30dBHL)  
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) |
M2 : Recording parameters set up for IHS (DPOAE)

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

   b. “ Frequency”:
      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
Stop acquiring at a given frequency:
On pass at that freq:  ✔

Stop acquiring altogether:
On overall pass:  ✔
On no chance to pass:  □
2- Under “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
       1. from Hz: 2000 to 4000
   iv. (not ticked) Percent passed in freq range (# 2)
   v. (not ticked) Percent passed in freq range (# 3)
**N.: VRA Protocol procedure**
Adapted from Widen et al. (2000)

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

**BEGIN** with 2kHz warbled tone in insert phone (or best frequency in better ear, if known).
- 55 dB HL... if baby turns naturally or alerts, reinforce
  - 2 correct consecutive responses (head-turns), go to **TEST PROTOCOL**
- 55 dB HL... no head-turn or alert then
- 75 dB HL... if head-turn or alert, reinforce
  - 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
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 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:
- 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.
Vibrator on mastoid of ear with better AC MRL
Start with intensity at or below air-conduction MRL

Use same test protocol to find MRL.
**O. : Role of VRA distractor**  
(from J.Widen: Suggestions for VRA)

The role of the distractor 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 plexiglass box). The distractor 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 use to say, "The reinforcer must be the biggest show in town". Thus, the distractor and his/her actions must not be more rewarding than the reinforcer toys. The distractor should not talk to or smile or make faces at the baby. A bland test room distractor is preferable to an engaging one in most instances.

The actions of the test room distractor 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 distractor'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 distractor 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 distractor during the activation of the toy reinforcer.

For placid babies, who sit quietly, facing forward, the distractor may need to do nothing. For babies who appear eager to see the reinforcing toys (i.e. stare at the dark plexiglass box as if waiting for it to come on again or turn repeatedly to the toy boxes in the period between stimulus trials) the distractor 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 distractor toys, the distractor 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 distractor toys or activities. To judge this "fine line" the examiner at the audiometer should inform the test room distractor of the child's reliability. For example, if the child's attention can still be pulled away from the distractors 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 distractor 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 distractor can often keep the child's gaze away from the reinforcers. The
The distractor 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 distractor 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 distractor 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 behavior. The distractor 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.
P.: VRA Worksheet

Audiology Assessment Recording Sheet

Date: __________________________
Name: __________________________
Date of birth: ____________________
Audiologist: ______________________
Distractor: ________________________
Audiometer: ______________________

<table>
<thead>
<tr>
<th></th>
<th>RIGHT ear</th>
<th>LEFT ear</th>
<th>Soundfield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (Hz)</td>
<td>500</td>
<td>1000</td>
<td>2000</td>
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<tr>
<td>Ctr</td>
<td>False *</td>
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Minimum Response Level (MRL) in dB HL:

Air Conduction

Stimuli
- Live Voice
- Music
- Other

Test Reliability
- Good
- Fair
- Poor

Transducer
- Insert
- Suprathreshold
- Standard

Bone Conduction

Stimuli
- Live Voice
- Music
- Other

Test Reliability
- Good
- Fair
- Poor

Transducer
- Insert
- Suprathreshold
- Standard

Comments: ____________________________

Minimum BC EHPP PASS criteria for 9-12 month old infants:

1. Attempt ear specific VRA with responses of ≤ 25 dB HL at a minimum of 500 and 2000 Hz
2. If ear specific VRA is not possible, infant must show responses of ≤ 25 dB HL at a minimum of 500 and 2000 Hz in the soundfield
   and either present OAEs or a VRA soundfield response at 4000 Hz. Please refer to BC EHPP VRA protocol for further details.

Pilot 2 - August 2007
BC EHP Medical Approval Form

BC Early Hearing Program
A service of 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:
Medical approval and clearance is requested for the above client. The medical clearance and approval is requested for:

(Audiologist circles 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 circle ear: Right ear Left ear

Audiologist name (please print): __________________________
Audiologist signature: __________________________
Health authority and clinic location: __________________________
Phone: __________________________
Fax: __________________________

Physician Completes:
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 (please print): __________________________
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.
Primary care Physician Information Letter Content

Date

Clinic Address

Re:  Patient Name
DOB:  
Address  
Phone Number  
Parent/Guardian Name

Dear Dr. ______________

This patient has been confirmed to have permanent hearing loss and requires an urgent medical assessment by an Otolaryngologist prior to the fitting of amplification. Designated Otolaryngologists (listed below) familiar with the “BC Early Hearing Program Medical Assessment Guidelines for Young Children with Sensorineural Hearing Loss” will accept referrals to expedite the assessment of children with confirmed permanent hearing loss. This will aid in preventing 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 BC EHP website at:

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

Name of Audiologist:  
Clinic Location:
R. : Key References


- Guidelines and recommended practices for the Individualized Family Service Plan (2nd ed.). Association for the Care of Children’s Health, Bethesda, MD 20814, 1991.


- Stapells DR. HAPLAB Website: a good source of information on AEPs generally and tone pip ABR specifically: www.audiospeech.ubc.ca/haplab/ThreshABR.html


