BIAP Recommendation 12-8
Audiometric procedures in the first year of life

Part: 12-8.1.4: Auditory brainstem response

General foreword

This document presents a Recommendation by the International Bureau for Audiophonology BIAP. A BIAP Recommendation provides a reference standard for the conduct of an audiological or phonological intervention that represents, to the best knowledge of BIAP, the evidence base and good practice concerning the stated methodology and scope of the document at the time of publication.

Comments on this document are welcomed and should be sent to the Secretary-General of the International Bureau for Audiophonology BIAP. The address can be found on the BIAP website at www.biap.org.

Introduction

At the diagnostic hearing assessment after newborn hearing screening (NHS) the measurement of auditory evoked potentials (AEP) has a vital role in determining the child's hearing threshold and pathway integrity before reliable auditory behavioural responses at the threshold level can be achieved. However, behavioural responses can be observed very early in life and are an essential crosscheck of any AEP (see Rec. 12-8.1.5).

Because any AEP can be interfered with (disturbed) by movement artifacts, the patient has to be relaxed and is not allowed to move during the measurement. For very young children such quiet measuring conditions can only be achieved in natural sleep, in sedation or in general anaesthesia. Therefore AEP with very young children are mainly limited to Auditory Brainstem Responses (ABR) or Auditory Steady-State Responses (ASSR), which do not need the consciousness of the patient. To achieve optimal deep natural sleep conditions it is recommended to perform the ABR measurement as early as possible in the first few weeks of life. Parents are advised to try to keep the baby/child awake until the measurement and to feed the baby before the measurement so that the child enters postprandial sleep.
The measurement should only be performed under the close supervision of an audiologist experienced in pediatric testing. The ABR equipment should provide the options to perform a click ABR, a frequency-specific ABR and a bone-conduction ABR.

Auditory Evoked Potentials

This recommendation will focus on ABR measurements and ASSR.

ABR

At least one ABR test is recommended as part of a complete audiology diagnostic evaluation for children younger than three years for the confirmation of a permanent hearing loss, to estimate the maturation of the auditory pathways and to rule out auditory neuropathy spectrum disorder (ANSD) or retro-cochlear causes of the hearing loss.

Reliable hearing threshold estimation is only possible if the ABR measurement is performed under optimal measuring conditions.

a) Click-ABR

1. The click is a broadband stimulus (not frequency-specific) that contains more energy in the spectral band above 1000 Hz and evokes a large neural response playing an important role of assessing the neural integrity of auditory pathways.
2. The age-appropriate normative references for neural integrity such as absolute latencies (I, III and V) and inter-peak latency interval (I-III, III-V and I-V) are based on click stimulation studies. These normative references should be provided by the manufacturer of the ABR equipment. But it is recommended to use own normative data, which was gathered with the center specific stimulus parameters. The normative data should include age-appropriate references in monthly intervals at least for the first year of life. By approximately two years of corrected age, latencies (I, III and V) should become adult like.
   One must choose the analyzing time window of the equipment appropriate to the expected latencies of the early auditory potentials: 15 msec should be preferred to catch a delayed wave V, which may be produced by more apical cochlear areas in ski-slope hearing loss. An intensity-latency curve should be plotted, which can help to distinguish conductive hearing losses (with longer absolute latencies for all potentials, I-V) from sensorineural hearing losses or help to identify pronounced high-frequency hearing losses.
3. Any ABR measurement should include a sufficient masking of the non-test ear to rule out any contribution by the contralateral ear to the test results (cross-over problem). A calculator for the masking level can be found at: http://abrpeerreview.co.uk/resources.html
4. If the air-conduction (AC) ABR threshold is within the normal range (20-30 dB_{nHL}) the threshold evaluation is ended.
5. If the AC ABR threshold is elevated it is advisable to use bone-conduction (BC) click ABR to verify at this point in the diagnostics if it is a sensorineural, conductive or mixed hearing loss. The hearing loss type should be tested by BC click or BC 2000 Hz tone burst and be compared with the AC threshold.
6. It is highly recommended to use insert earphones:
   - to avoid collapse of the ear canals under normal headphones

- to minimize the correction values, which are necessary to account for the smaller ear canal volume of babies
- to get better inter-aural attenuation and to decrease the need for masking

b) Click-ABR and auditory neuropathy spectrum disorder (ANSD)

1. To rule out ANSD it is highly recommended to use click-evoked ABR testing systematically. Both condensation and rarefaction single-polarity clicks are required to determine if a cochlear microphonic potential (CM) is present (with abnormal or absent ABR potentials) and so identify ANSD. CM are produced pre-synaptic in the inner ear and can therefore still be present in case of an ANSD.
2. In case of the ANSD (without post-synaptic "neural" potentials, which would ask otherwise to cover the CM) the CM gets visible as a potential starting within 1 ms after a click stimulus of more than 70 dB_{nHL}. The CM shows a variable duration of 1-2 to 5-6 ms. As the cochlear part of the potentials (CM) follows the polarity of the stimulus and the neural part does not, one can identify the cochlear part by its polarity change through superimposing a measurement of condensation and rarefaction clicks. In the case of an ANSD the CM waveforms elicited by the condensation and rarefaction clicks exactly mirror each other (whereas the neural potentials would appear in the same direction in both waveforms).
3. Another indicator to distinguish CM and neural potentials is the fact, that the CM shows a fixed latency, which does not change with the stimulus level. If the CM is present, it is independent from any neural ABR responses and unrelated to the hearing threshold.
4. To distinguish CMs from a stimulus artifact it is necessary to use insert earphones for the CM measurement and to clip/block the tube of the insert earphone for a second measurement. If "CM-like potentials" still persist in the measurement with the blocked tube, they are most likely a stimulus artifact. If the "CM-like potentials" only persist in the measurement with the open tube, a cochlear activity/response is confirmed and interference by a stimulus artifact can be ruled out.
5. The presence of CM with reduced or absent ABR potentials can also be documented through electro-cochleography (ECochG).
6. The presence of OAE with reduced or absent ABR potentials also indicates an ANSD. If the OAE disappear or are absent from the beginning, the assessment of ANSD relies on CM detection by evoked potential measurements.

c) Frequency-specific ABR (AC and BC)

1. A frequency-specific assessment of the ABR by using air-conducted frequency-specific stimuli (tone burst or chirp) and bone-conducted frequency-specific stimuli is required when a permanent hearing loss is detected, to

determine the degree and configuration of hearing loss in each ear and as the basis of fitting amplification devices in very young infants. It is necessary to obtain at least two reference points for low frequencies (around 500 Hz) and for high frequencies (around 2000-4000 Hz) to estimate the basic outline of the hearing threshold (whether its configuration is ascending, flat or ascending).

2. Frequency-specific ABR measurements are highly correlated with the degree of peripheral hearing sensitivity and behavioural responses. Depending on the type of stimulus (e.g. tone burst or chirp), the test frequency, the age of the patient and the type of equipment there are different offsets, and variation of such offsets between the ABR threshold and the real threshold of the patient. To estimate the “real threshold” of the patient it is necessary to use a correction table (e.g. tables provided by the British Society of Audiology). By applying these age- and equipment/stimulus-related correction values the dB_{nHL}-readings of the ABR equipment are converted into an "estimated hearing threshold" in dB_{eHL} (estimaleted hearing loss).
3. Most infants and children with sensorineural hearing loss (SNHL) show frequency-specific ABR thresholds that are within 10 dB of their pure-tone behavioural thresholds in the high frequency area above 1500 Hz.
4. Start the measurement with a 2000 Hz stimulus, followed by 500 Hz and 4000 Hz. If possible collect alternate responses from the ears, such as right ear at 2000 Hz, left ear at 2000 Hz, right ear at 500 Hz, left ear at 500 Hz, right ear at 4000 Hz and left ear at 4000 Hz. This approach helps to provide as much information as possible if a child in natural sleep wakes up too early and the measurement has to be aborted. If there is time left, perform 1000 Hz for both ears.
5. In case there is no clear response, a minimum number of 2000 sweeps is suggested, continuing the measurement up to 6000 sweeps if a wave V cannot be detected and the residual noise level stays low (check the published reference data for your equipment).
6. The collecting window has to be larger than that used for adults, especially for low-frequency ABR. Use a window larger than 20 ms.

d) Frequency-specific ABR by bone conduction

1. Besides obvious conductive hearing losses, as in the case of ear canal atresia, conductive losses due to middle ear ventilation problems and middle ear effusion are very common in children. In addition, a high number of babies who fail the newborn hearing screening fail because of middle ear ventilation problems. A reliable differentiation between conductive hearing loss and sensorineural hearing loss is essential for a proper assessment of any hearing impairment and the planning of the rehabilitation process. A BC ABR is therefore indispensable whenever a conductive hearing loss can be suspected (e.g. by elevated AC ABR threshold, by tympanometry, ear inspection…).

2. As the waveform of the click itself will be significantly altered by transmission through a bone conductor it is highly recommended to use more harmonic stimuli such as a chirp, the waveform of which can be transmitted by the bone conductor much more faithfully and efficiently.
3. Bone-conduction ABR should be performed with sufficient masking of the non-test ear. In case of a masking dilemma, it can be helpful to use a two-channel recording, so that the latencies and the amplitudes from both sides can be compared, to provide information on which side contributes more to the potentials. For babies younger than 12 months bone-conduction signals up to $15dB_{eHL}$ may require no masking because of less cross-over.
4. The bone conductor has to be placed away from the electrode at the mastoid (e.g. bone conductor at the upper part of the mastoid and the electrode at the bottom end of the mastoid) and the lead of the bone conductor must be kept separate from the cables of the electrodes. A suitable place for the bone conductor may be the temporal bone.
5. A reliable calibration process of the bone conductor for use with babies, taking into account the soft bone of the baby`s skull, the open sutures and the smaller volume of the baby’s head, is still an open question. However, suggestions for appropriate correction values are available and must be applied (see references by the British Society of Audiology).
6. Neonatal and infant diagnostic testing are usually done during natural sleep, and in order to save time it is wise to start with minimum response intensity (Figure 1).
7. Blocking the BC stimulus artifact onset minimizes interference (example: click 0.2 ms).

ASSR

Auditory Steady-State Responses reflect the ability of the neural activity in the brain to phase-lock to temporal modulations in auditory stimuli. This allows automatic detection of ASSR by the computer, with the goal of minimizing the number of falsely detected responses by applying appropriate statistical tests to a sample of stimulus-related epochs of the electroencephalogram. This analysis provides a likelihood at a certain sound pressure level that an ASSR potential is detected. By decreasing the sound pressure level of modulated tonal stimuli the computer defines the hearing threshold as the level at which an ASSR potential can no longer be detected.
Besides the automatic threshold search and detection, ASSR allow delivery of stimuli at higher intensities than the ABR (up to 110/120dB HL), so an ASSR measurement is capable of defining the threshold of severe to profound hearing losses even above 90 dB.
The limitations of the ASSR measurement are more or less the same as in the classic ABR measurement: a calm, quiet, relaxed patient is essential. Using chirp stimuli will improve less offset between the ASSR threshold and the real threshold of the patient.

Despite the number of improvements in the ASSR technique, conflicting test results (e.g. when the computer detects a response at 40 dB HL, but not at 50 and 60 dB HL) may still occur and require additional runs. To minimize such conflicting test results and to obtain data that reflect the real hearing threshold of the patient, the ASSR measurement has to be performed under optimal measuring conditions with a minimum of internal noise (the best can be under general anaesthesia) in the hands of an experienced clinician. The clinician has to be well familiar with the technique in order to make the proper decisions. The objective result analysis from the equipment has to be carefully analyzed by the clinician. The ASSR should not be recorded in isolation but as part of an appropriate battery of tests. It can be used complementarily to an ABR measurement (Hall III, June 2016).

Making use of the ABR (or ASSR) threshold estimation

The primary aim of ABR measurements on children, and especially babies, is to provide a reliable estimation of the hearing threshold, and in some cases the assessment of some neurological questions. The threshold is needed as the basis for the diagnosis of a hearing loss as well as being fundamental to the rehabilitation process, especially the fitting of hearing aids.

The paediatric audiologist should include in his final threshold estimation all the information from the anamnesis and the other hearing tests: behavioural observation audiometry (BOA), visual reinforcement audiometry (VRA), tympanometry, stapedius reflexes, otoacoustic emissions. Contradictory or inconclusive results must be considered and clarified.

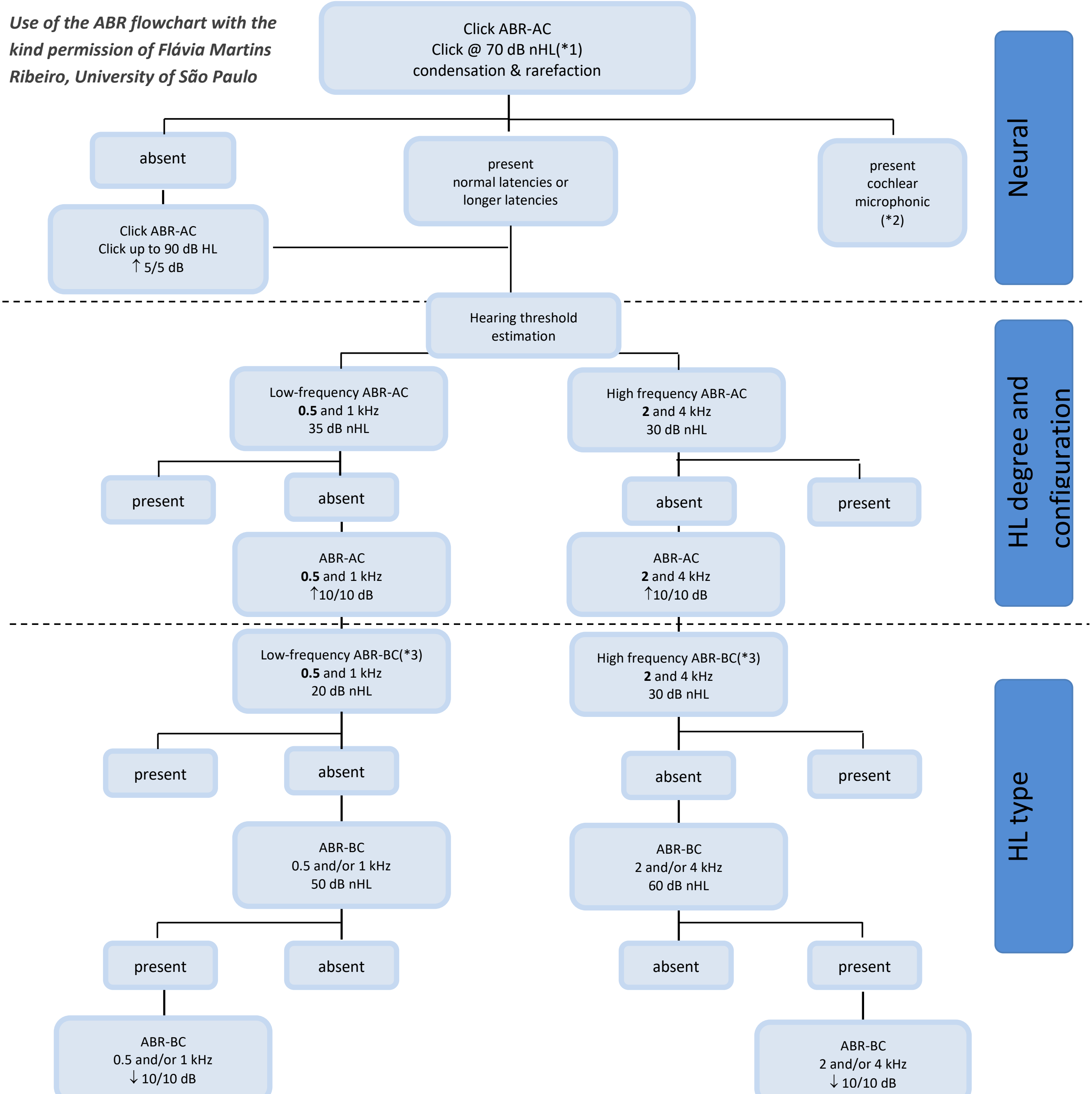
The frequency-specific hearing threshold values provide the data on which the programming of the hearing aid is directly founded. It is therefore essential to communicate the hearing threshold estimation to the professionals responsible for hearing-aid fitting and the early intervention in a way that can be understood by the professionals easily and without the risk of misinterpretation. This includes an agreement between the professionals on which correction factors are already used for their threshold estimation and which correction factors still have to be applied. Especially in countries with a variety of makes of ABR equipment or different stimulus approaches, the interpretation of the ABR results has to be done by the paediatric audiologist who did the ABR and who can take into account all the factors that might have affected the ABR outcome. One format that may leave less room for misunderstanding is an estimation of the hearing threshold as if it were the result of a reliable standard tone audiometry in dB_{HL}, plus the information on which kind of headphones was used for the ABR. With this information, the professional who fits the hearing aids can enter the threshold numbers into the fitting software and add the corrections for the smaller ear canal volume of the baby through the rear-ear-to-coupler values (RECD). Any doubts about the interpretation of the communicated hearing threshold should lead to a personal exchange of information by the professionals involved.

Any hearing threshold of a baby or young child should be re-evaluated regularly!

ABR Flow chart as part of the early hearing assessment of neonates and infants.

The flow chart may help the clinician to select the appropriate sequence of tests for the hearing assessment of neonates and infants. Additionally the clinician has to take into account prior existing test results and the condition of the child (e.g. Down syndrome, seizures, sleeping patterns ….)

Use of the ABR flowchart with the kind permission of Flávia Martins Ribeiro, University of São Paulo



AC – air conduction

BC – bone conduction

(*1) To test for neural integrity it is necessary to use a click at 70 dB or 80 dB. But at 70/80 dB a child in natural sleep, whether with normal hearing or a mild/moderate hearing loss with recruitment, may wake up immediately, thereby terminating the whole measurement. For these children the starting level must depend on the sleeping condition of the child and it may be necessary to start with the frequency-specific threshold estimation at 50 dB, instead of testing the neural integrity with a higher intensity click. The measurement with the click at 70/80 dB must then be done at the end of the measurement.

(*2) Presence of cochlear microphonic without neural response – indicative of auditory neuropathy – unable to perform frequency-specific ABR.

(*3) The necessity of a bone conduction ABR measurement depends on the prior assessment (see rec. 12-8.1.1, 12-8.1.2, 12-8.1.5) such as ear microscopy, high frequency tympanometry, behavioral audiometry.

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This recommendation was created and approved in a multidisciplinary cooperation between professionals of all audiophonologic disciplines, which are medicine, audiology, pedagogy, speech therapy, psychology and hearing instrument audiology.

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