



ABR AUDIOMETRY: SUMMARY OF MANDATORY, CONDITIONAL MANDATORY, AND DISCRETIONAL PROCEDURES

GENERAL

General Reporting and Documentation	
Mandatory Protocol Elements	<p>Mandatory elements are always completed except under exceptional circumstances. When mandatory elements are not fulfilled, a brief explanation is entered in the clinical record. Exceptions are evaluated as part of the ABR CQI process.</p> <p><i>Note that while the mandatory procedures in this section satisfy the minimum information needed for each type of hearing outcome, further testing beyond the mandatory minimum is often possible within a test session, and often provides valuable clinical information.</i></p>
Clinical Records	<p>Print/electronic copies/PDFs must be available for all test procedures completed (i.e., ABR waveforms, recording sheets, clinical summary of ABR threshold interpretation, etc).</p>

ABR Audiometry – General Aspects

ABR audiometry testing is preceded by cursory otoscopy.

ABR threshold is defined by findings of “Response” at given stimulus intensity and “No Response” at an intensity not more than 10 dB below the lowest intensity with “Response”. The exception is finding of “Response” at a BCEHP minimum (“normal”) stimulus intensity.

The grand average waveform must be provided for any threshold bracketing condition (upper and lower bound) or any condition where response presence/absence is not clear.

Averages at the threshold bracket intensities (or the minimum stimulus intensities) are replicated.

All individual averages must include at least 1000 accepted sweeps per average.

Unless clearly contraindicated, initial testing begins with 2 kHz AC at the BCEHP minimum stimulus intensity.

With a few exceptions, mandatory minimum stimulus intensities for ABR are: (i) AC: 35, 35, 30 and 25 dB nHL at 0.5, 1, 2 and 4 kHz, respectively, and (ii) BC: 20 dB nHL at 0.5 kHz and 30 dB nHL at 2 kHz and 4 kHz, respectively. Maximum AC tone intensities are 100 dB nHL; maximum AC click intensity is 90 dB nHL.

To determine rapidly the hearing status of both ears, it is strongly recommended that the test ear be switched, regardless of the result in the initial test ear. To facilitate this, a determined effort to place inserts in both ears initially should be made.

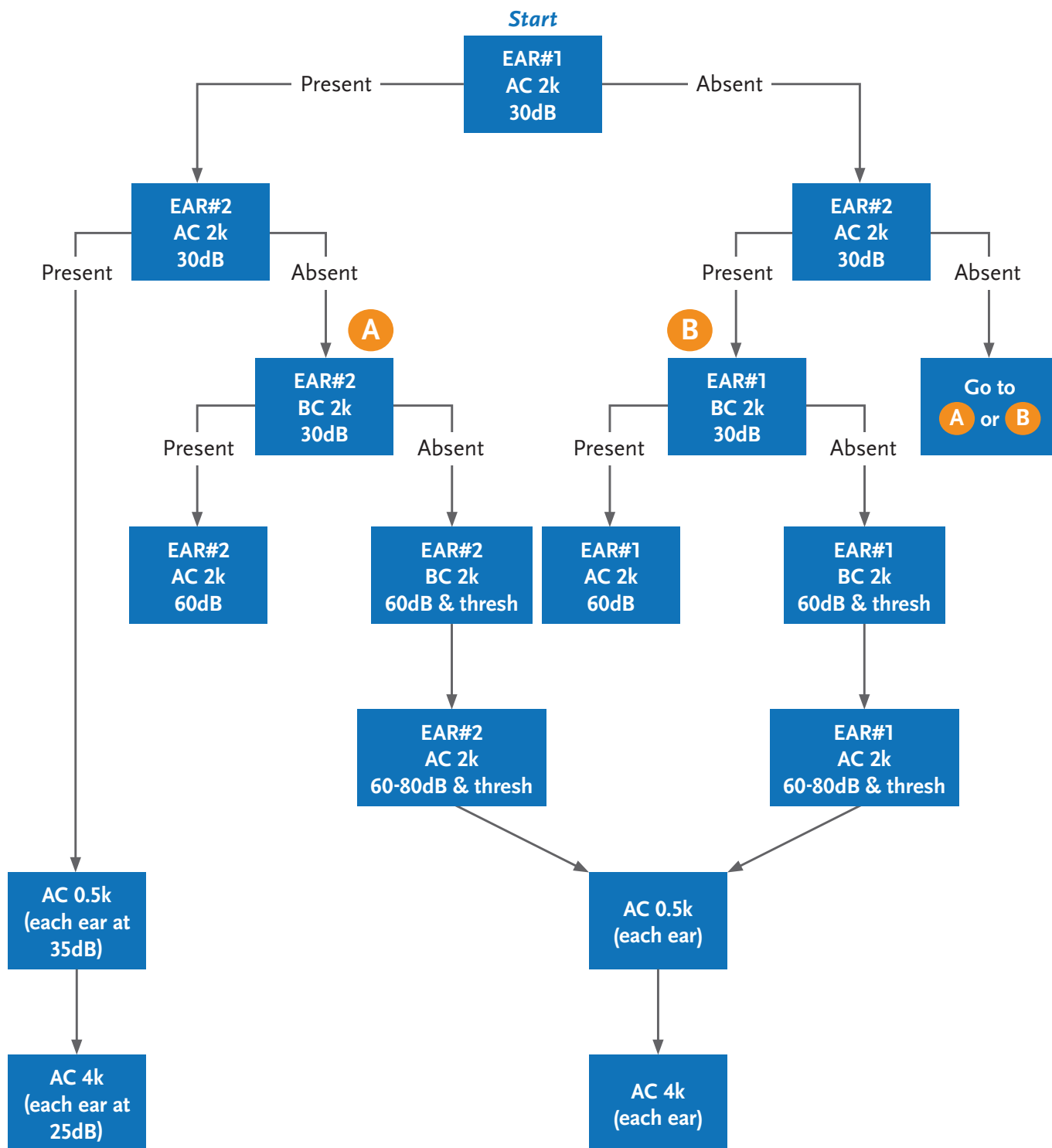
If the AC threshold is elevated in one or both ears, 2 kHz BC testing is initiated immediately after determining presence of elevation (i.e., before AC threshold determination).

Large step sizes are used initially to efficiently bracket elevated thresholds.

Prior BCEHP threshold ABR test results may alter the sequence indicated above.

Typical and Efficient Tone-ABR Test Sequence

(Adapted from Stapells, 2002)



ABR Response Determination

Response Present	<p>The response waveforms show visual (subjective) replicability.</p> <p>Peak-to-peak response amplitude should be at least 2.5-3x the actual residual noise level (on I.H.S. the p-p response amplitude should be at least 1.25-1.5x the SmartEP RN).</p> <p>The overall SNR for the grand average should be (but is not always) at least 1.0.</p> <p>There is no specific value of RN required for judgement of response presence.</p>
No Response	<p>The averages show “no response” visually (subjective).</p> <p>Averages appear quiet and flat at a display scale of 0.5 μV (25% plot size).</p> <p>The grand average RN is $\leq 0.08 \mu\text{V}$ (visually flat) OR $\leq 0.04 \mu\text{V}$ (if not visually flat but no apparent wave V).</p>
Could not Evaluate	<p>Neither “Response Present” nor “No Response” criteria above can be satisfied.</p> <p>If visually flat and grand average has an RN $> 0.08 \mu\text{V}$.</p> <p>If visually non-flat and no replicable wave V, the grand average has an RN $> 0.04 \mu\text{V}$.</p>

RESULTS NECESSARY TO INFER

Normal Hearing	
Mandatory Procedures	<p>Air conduction “Response Present” at:</p> <p>30 dB nHL at 2 kHz in both ears,</p> <p>35 dB nHL at 0.5 kHz in both ears, and</p> <p>25 dB nHL at 4 kHz in both ears.</p>
Discretionary Procedures	<p>Air conduction “Response Present” at:</p> <p>35 dB nHL at 1 kHz in both ears.</p> <p>Tympanometry: (i) younger than 6 months corrected age: probe tone of 1 kHz; (ii) age 6 months or older: probe tone of 226 Hz.</p> <p>DPOAE amplitude and noise measurements at 2, 3, and 4 kHz nominal f2.</p>

Presumed Temporary Conductive Hearing Loss

Mandatory Procedures	<p>Elevated AC ABR showing a threshold range at 2 kHz (or 0.5 kHz if it is the only AC threshold elevation) with normal BC at the corresponding frequency (i.e., at 30 dB nHL for BC 2 kHz; at 20 dB nHL for BC 0.5 kHz). For example, showing an AC threshold range between 40-70 dB nHL is often sufficiently informative. <i>Note that BC 0.5 kHz is only required if 0.5 kHz AC is the only elevation.</i></p> <p>Tympanometry: (i) younger than 6 months corrected age: probe tone of 1 kHz; (ii) age 6 months or older: probe tone of 226 Hz.</p>
Discretionary Procedures	<p>BC-ABR testing at 0.5 kHz and 4 kHz at the normal minimum intensity (i.e., 20 dB nHL for 0.5 kHz and 30 dB nHL for 4 kHz).</p> <p>10-dB final threshold bracketing for AC ABR at 2 kHz, 0.5 kHz, and 4 kHz (i.e., minimum requirement for purely conductive loss that is suspected to be transient in nature is demonstration of a reasonable range of AC threshold at one frequency with normal BC at the corresponding frequency).</p> <p>If AC elevation (at 0.5 kHz and/or 2 kHz) is only 10 dB above the normal minimum intensity and BC ABR is present at the normal minimum intensity, additional BC testing at 10 dB below the normal minimum intensity may be considered, in order to confirm conductive component.</p> <p>DPOAE amplitude and noise measurements at 2, 3, and 4 kHz nominal f2.</p> <p>4 kHz AC and 1 kHz AC are not required.</p>

Microtia/Atresia: For ear(s) where insert earphone/probe placement is not possible	
Mandatory Procedures	<p>Elevated AC ABR (TDH headphones) showing a threshold range at 2 kHz (e.g., showing a range between 40-70 dB nHL is often sufficiently informative). In the rare case that 2 kHz is normal, test 0.5 kHz.</p> <p>BC-ABR testing at 2 kHz and 0.5 kHz. Note that both BC 0.5 kHz and 2 kHz are required because amplification options are limited to BC devices.</p>
Discretionary Procedures	<p>BC-ABR testing at 4 kHz.</p> <p>10-dB final threshold bracketing for AC ABR at 2 kHz, 0.5 kHz, and 4 kHz.</p>

Permanent Hearing Loss (includes Sensorineural, Mixed & Permanent Conductive)	
Mandatory Procedures	<p>AC-ABR testing at 2 kHz, 0.5 kHz, and 4 kHz, with 10-dB final threshold bracketing.</p> <p>BC-ABR testing at 2 kHz if AC 2 kHz threshold is elevated; 10-dB final threshold bracketing when BC shows a “no response (NR)” at the minimal stimulus intensity (up to and including NR at 60 dB nHL).</p> <p>Tympanometry: (i) younger than 6 months corrected age: probe tone of 1 kHz; (ii) age 6 months or older: probe tone of 226 Hz.</p> <p>DPOAE amplitude and noise measurements at 2, 3, and 4 kHz nominal f2.</p>
Conditional Mandatory Procedures	<p>BC-ABR testing at 0.5 kHz <i>if AC 0.5 kHz threshold is the only elevation</i>; 10-dB final threshold bracketing when BC is absent at the minimal stimulus intensity (up to and including NR at 50 dB nHL).</p> <p>AC-ABR testing at 1 kHz (10-dB bracketing, if elevated), <i>if the difference (in dB nHL) between AC 2 kHz and AC 0.5 kHz exceeds 20 dB.</i></p> <p>AC 2 kHz at 20 dB nHL <i>if AC 4 kHz threshold is the only elevation</i> (this is an exception to the minimum stimulus intensity rule).</p> <p>AC Clicks if AC ABR at 2 kHz has severely delayed or absent wave V ≥ 80 dB nHL (see ANSD sub-protocol for details about clicks).</p> <p>If unilateral/asymmetric hearing loss, 2-channel AC recordings are required when responses in one ear are at the normal minimum intensity and the other ear threshold are greater than or equal to 60 dB nHL, or (ii) thresholds are elevated in both ears with at least a 40-dB threshold difference (in dB nHL) between ears.</p>
Discretionary Procedures	<p>The application of contralateral masking is always discretionary. However, if AC/BC 2-channel ipsi/ contra asymmetries are unclear or abnormal, application of contralateral masking may be necessary to determine responding ear.</p> <p>BC 4 kHz (especially if AC 4 kHz is the only threshold elevation).</p> <p>If AC-ABR thresholds are greater than 70 dB nHL, 5-dB AC threshold bracketing may be pursued, but <i>only after all mandatory measurements are completed.</i></p> <p>Ipsilateral acoustic reflexes (Broad-band noise or 1 kHz).</p> <p>Real-ear-to-coupler difference determination, where non-ANS D PHL is confirmed.</p>

ANSD or Retrocochlear Disorders: Sub-protocol Required

In addition to the requirements specified for permanent hearing loss, if there is no clear tone-ABR wave V-V' for any 2 kHz intensity tested ≥ 80 dB nHL, the sub-protocol for ANSD or retrocochlear disorders should be initiated (after all tone ABR has been completed).

Mandatory Procedures	<p>Slow-rate (19.1-21.1/s), separate recordings of RC and CC clicks at 90 dB nHL (at least 2 replications for each polarity), for assessment of cochlear microphonic potentials (CM), cochlear summing potentials (SP) and neural components (ABR waves I to V presence, morphology, latency, amplitude).</p> <p>No-stimulus recordings to either RC or CC by clamping insert earphone tube (if clamp tube recording is not clearly flat in the first 0-3ms post-stimulus, then testing of both polarities is required).</p> <p>Specific analyses are required for the above data: (i) RC and CC grand averages, (ii) the alternating polarity replications and their grand average (calculated by averaging sets of RC and CC averages), (iii) RC grand average and the CC grand average “butterfly plot”, (iv) either the RC-CC or CC-RC subtraction (from the RC and CC grand averages), and (v) grand average of the RC or CC clamped-tube no-sound condition.</p> <p>Determination of ANSD requires low-noise recordings. Specifically, when both CM and wave V amplitudes are very small ($< 0.1 \mu\text{V}$ p-p), the SmartEP RN amplitude must be no more than 50% of the CM and wave V p-p amplitudes. If not, additional trials/replications should be obtained to reduce the waveform RN (with $\text{RN}=0.04 \mu\text{V}$ being the practical limit; i.e., no need to try to get RN lower than $0.04 \mu\text{V}$).</p> <p>For all cases for which ANSD is considered “probable” or “definite”, the PSA(s) must be consulted, and referral made via BEST for further testing at BC Children’s Hospital.</p>
Conditional Mandatory Procedures	<p>If cochlear (CM and/or SP) potentials cannot be differentiated from wave I, then separate recordings using a very fast rate (91.1-101.3/s) of RC and CC at 90 dB nHL (at least 2 replications for each polarity), are required to help tease out cochlear from neural responses. For example, stimulating at this fast rate will often substantially reduce or remove neural potentials (especially wave I), but not the CM or summing potential, SP (both cochlear potentials).</p> <p>For unilateral hearing loss, 2-channel recordings are required. Masking may also be helpful.</p>
Discretionary Procedures	<p>Click-ABR <i>threshold</i>, as part of the ANSD sub-protocol. In very rare cases, the tone-ABR protocol may miss an island of better hearing that the broadband click-ABR reveals (i.e., NR to tones but clear wave V to clicks).</p> <p>Acoustic reflex measurements: They have some value as a crosscheck when ABRs are absent at high stimulus levels, in that reflex presence contradicts inference of both ANSD and profound conventional cochlear hearing loss. In general, reflex presence may be clinically informative, whereas reflex absence is rarely so. Acoustic reflex measures should only be obtained after all mandatory components have been completed.</p>

ANSD Classification (based on relationship between CM and ABR V-V' amplitudes, Table 5.10.1)

- If DPOAEs present at 2, 3 or 4 kHz and click ABR V-V' $\leq 0.1 \mu\text{V}$: **Definite ANSD component**
- If DPOAEs present at 2, 3 or 4 kHz and click ABR V-V' $0.1 - 0.2 \mu\text{V}$: **Probable ANSD component**
- If DPOAEs absent at 2, 3, and 4 kHz and CM is $< 0.1 \mu\text{V}$: **ANSD not suspected**
- If DPOAEs absent or unreliable at 2, 3 and 4 kHz, apply table below:

CM μV	Click ABR V-V' μV			NS = ANSD Not Suspected
	< 0.1	$0.1 - 0.2$	> 0.2	
< 0.1	NS	NS	NS	*If CM/V-V' amplitude ratio > 1.5 = Probable ANSD component
$0.1 - 0.2$	Probable	See Ratio*&	NS	*If CM/V-V' amplitude ratio ≤ 1.5 = ANSD not suspected
> 0.2	Definite	Probable	See Ratio*	&Meeting RN requirements especially important when comparing small-amplitude waves

SUPPLEMENTARY INFORMATION FOR ABR AUDIOMETRY

Masking

The following masking levels are recommended for infants under 12 months old (modified from Lau & Small, 2020):

Air-Conduction Noise Masker Levels for BONE-CONDUCTION Stimuli (in dB SPL)

BC STIM LEVEL (dB nHL)	BC 0.5 kHz	BC 2 kHz	BC 4 kHz ^{&}
20	75	55	55
30	85	65	65
40	*85	75	75
50	*85	85	85
60	N/A	*85	*85

[&]Masking levels for BC 4kHz stimuli are provisional, pending further investigation.

*85 dB SPL is the maximum allowed masker level thus responses may not be fully masked.

Air-Conduction Noise Masker Levels for AIR-CONDUCTION Stimuli (in dB SPL)

AC STIM LEVEL (dB nHL)	0.5 kHz	1 kHz	2 kHz	4 kHz	CLICKS
**60	65	65	45	60	55
70	65	65	45	60	55
80	75	75	55	70	65
90	85	85	65	80	75
100	*85	*85	75	*85	N/A

*85 dB SPL is the maximum allowed masker level thus responses may not be fully masked. Levels are derived from Stapells (1984) and assume 30-dB of interaural attenuation. *Levels are only for AC stimuli, not BC stimuli.*

**Not recommended to reduce masking noise below the level suggested for 70 dB nHL.

Even if contralateral masking cannot fully mask a response from the contralateral ear, comparisons of masked and unmasked waveforms often give a clear inference about which cochlea is responding, *especially because ipsilateral/contralateral response asymmetries are also assessed.*

