

NEWBORN HEARING SCREENING AND ASSESSMENT

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Guidelines for Cochlear Microphonic Testing

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Version 2.0

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NHSP Clinical Group

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This document supersedes Appendix 2 of the Assessment and Management of Auditory Neuropathy / Auditory Dys-synchrony, May 2008 and its addendum

Amendment History:

Version	Date	Amendment History
1.0	Oct 2004	Version 1 as Appendix 2 of the NHSP Guidelines on Assessment and Management of Auditory Neuropathy / Auditory Dys-synchrony,.
1.1	Sept 2005	Version 2 with changes to calibration standards. Reissued May 2008 with an addendum
2.0	September 2011	Major review and revision led by Guy Lightfoot on behalf of Clinical Group.

Forecast Changes:

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Approvals:

This document requires the following approvals:

Name	Signature	Title / Responsibility	Date	Version
Adrian Davis	by email	Director NHSP	20/9/11	2.0

BACKGROUND

65 The cochlear microphonic (CM) is a pre-neural response from the cochlear outer hair cells which is thought to follow the waveform of the stimulus - it is as though the cochlea is acting as a microphone, hence the term. Like the oto-acoustic emission (OAE), when reliably present, it can be taken as evidence of hair cell function but cannot be used to estimate hearing threshold.

70 Auditory Neuropathy Spectrum Disorder (ANSD) is characterised by an absent or abnormal auditory brainstem response (ABR) in the presence of evidence of outer hair cell function. This is thought to arise when there is a failure to transmit hair cell activity to the auditory nervous system or when there is abnormally poor temporal synchronisation of the signals. Either an OAE or CM may be taken as evidence of outer hair cell function. The presence of an OAE or a CM (using a stimulus at or below a level that does not evoke a recordable ABR) is usually suggestive of ANSD. A reliably present OAE is evidence of
75 outer hair cell function and CM testing is usually not necessary. However, an OAE may be absent for a number of reasons (e.g. a conductive component) so it is important to consider CM testing when the OAE is absent and the ABR is absent or abnormal as defined below. An absent OAE cannot exclude ANSD. The CM is known to be less vulnerable to the effects of a conductive component than the OAE (since a conductive component affects sound both on the way into the ear and on the way out).

80 Where the AC 4kHz tpABR threshold is significantly raised ($>75\text{dBeHL}$) and there are no recordable BC 4kHz tpABR responses for that ear it is recommended to switch to ckABR (i.e. a broad band stimulus) to determine if any AC responses can be recorded up to the maximum recommended stimulus level available. This is because absent tpABR responses at 4kHz cannot exclude an island of better hearing
85 which could generate an ABR and CM in a "conventional" cochlear hearing loss. However in some cases it may be possible to record a low frequency (e.g. 1kHz) tpABR and this must be considered when interpreting the CM (see the notes in the section on interpretation, below). In practical terms therefore if CM testing is being considered it is necessary to first perform a ckABR up to the maximum permitted stimulus level (if required) in addition to tpABR.

90 ANSD should be considered when a click ABR is not present at the maximum permissible stimulus level or is present but abnormal at or above 75dBeHL . ABR waveforms should be considered abnormal if they have unexpected (even for a baby with hearing loss) latencies, amplitude or morphology (e.g. missing peaks).

95 It is worth noting that the label ANSD merely indicates the pattern of results, not a single pathology: accordingly among these cases will be babies with auditory maturational delay which may resolve, as well as those with a permanent condition.

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METHOD & TEST PARAMETERS

105 When present, the CM is usually easy to record from babies (but less so from adults in whom the CM is often small and less well defined) using the same surface electrodes and methods for recording the more familiar ABR. General NHSP guidelines for ABR tests should therefore be followed although some important differences are required if the CM is to be successfully recorded.

- Time base: 8 to 10ms. The CM will end long before 10ms and this short time base allows a rapid stimulus rate to be used and allows the region of interest to be examined in greater detail.
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- Stimulus repetition rate: typically 87.1/s. Being a pre-neural response, the CM (and OAE) is not subject to neural fatigue and may be recorded as fast as the timebase allows. This reduces acquisition time.
- Low (high pass) filter: 300Hz (if not available use the highest value available between 100Hz and 300Hz); This minimises recorded background myogenic and EEG activity.
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- High (low pass) filter: 3kHz to 5kHz.
- 120 • Data reject (artefact rejection) level: A value of $\pm 3\mu\text{V}$ is recommended where possible; a value of $\pm 10\mu\text{V}$ should not be exceeded. The recommended filters allow a strict artefact rejection to be used.
- 125 • Display scale: because of the large range of CM amplitudes the aspect ratio used for the display scale may need to be modified beyond that normally used for recording ABR responses. Use the normal ABR scale as the initial default but the more sensitive ABR scale may assist the interpretation of small or absent CMs; a less sensitive scale may be appropriate for large CMs. The scale should be chosen on the basis of most clearly demonstrating the presence or absence of a CM.
- 130 • The recommended method is to use separate replicated runs of condensation and rarefaction polarity clicks at 80 dBnHL^a. Many ABR systems have a facility whereby the responses evoked by rarefaction and condensation stimuli using an alternating polarity stimulus can be displayed simultaneously. This alternative approach is acceptable.
- 135 • Sweeps per waveform: typically 2000 (minimum 1500). If alternating polarity with simultaneous collection of responses to condensation and rarefaction stimuli is used then typically 4000 sweeps should be averaged.
- 140 • Tubal insert earphones **must** be used. These have a remote transducer coupled by an acoustic tube (eg ER-3A) This introduces a time delay (about 0.9ms) between the electrical signal at the transducer and the acoustic stimulus at the ear canal, enabling separation in time of the electromagnetic stimulus artefact from the cochlear microphonic. If conventional supra-aural earphones were to be used the CM and stimulus artefact would occur almost simultaneously and would therefore be difficult to distinguish. Tubal insert earphones have a further important advantage: the acoustic stimulus can be easily blocked during a control run by clamping the tube between the transducer and the ear tip. This forms an important element of the test procedure since in this condition the electrical artefact remains whilst the stimulus is effectively withdrawn, thus allowing a possible CM response to be validated or rejected as artefact.
- 145 • Use an ipsilateral mastoid electrode for the negative input to the amplifier rather than a nape of neck electrode which **cannot** record a CM. The mastoid electrode should ideally be sited as close to the meatus (and therefore cochlea) as practicable. The NHSP guidelines for ABR testing in babies¹ recommends a low mastoid position to allow room for a mastoid placement of the BC transducer and to maximise the ABR response. Placement of two electrodes, one for ABR and one for CM, is not practical and so it is recommended that the guidance for ABR testing is followed but that the 'low mastoid' position is interpreted as no more than 1cm lower than the meatal level of the ear.
- 150 • Be very careful to gather together (or twist) the electrode leads and physically separate them from the transducer cables and transducer to minimise the extent of stimulus or other electromagnetic artefact.
- 155 • When clamping the insert tube care must be taken not to move the transducer or its leads since this would change any stimulus artefact, introducing uncertainty into the interpretation of the presence of a CM. The initial positioning of the insert transducer therefore needs to allow the tubing to be clamped. In practice this is achieved by allowing the tubing to form a loop or curve rather than being straight. Nevertheless the transducer should not be placed close to the mastoid electrode or its lead.
- 160 • As with all insert measurements if a clear recording is not obtained check that the sound has been delivered to the ear canal at the desired level i.e. that the insert or tubing has not become blocked.
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^a Test level may be up to 85 dBnHL but note that the greater the stimulus level, the larger any stimulus artefact will be. Stimulus levels above 85 dBnHL in neonates may represent a noise hazard and **must not be used** – see the warning in the calibration section for details.

- Since the CM is a “near field response” there is no requirement to mask the non-test ear during CM testing, even if masking is needed when recording the ABR.

170 **INTERPRETATION**

The replicated waveforms should be superimposed and the separate polarities displayed immediately above & below each other without overlapping (Figure 1 provides an example) to look for the following characteristic features of the cochlear microphonic:

- 175 • A sinusoidal segment that has mirror image (inverts) in the two stimulus polarity waveforms, beginning within 1 ms of stimulus and possibly lasting up to 5 or 6 ms. If the polarity of the measured potential reverses with click polarity, this is consistent with cochlear microphonic basis for the potential. Note that tests using *alternating* clicks would yield a flat line if the potential was a genuine cochlear microphonic (due to cancellation of the response). If the response polarity does not reverse with changes in stimulus polarity and the response persists using alternating clicks, this is consistent with a **neural** (ABR) basis for the potential. For a CM to be regarded as “clear” its size should be substantially greater than the residual noise (as judged from the average gap between the replicates), preferably with a signal to noise $\geq 3:1$.
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- 185 • If a candidate CM potential is evident it is important to verify that it is not a stimulus artefact. Perform replicated additional runs (of either polarity; it is not necessary to obtain both) at the same stimulus level but with the tubing clamped. If the potential is clearly eliminated, it is a true biological potential. If the measured potential remains, it is due to a stimulus artefact: separate the transducer and electrodes as much as possible and retest. Carry out further replications of any test where there is any doubt over the presence of a cochlear microphonic or artefact.
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- If no potential CM is evident it is not necessary to perform a control run with the tubing clamped.

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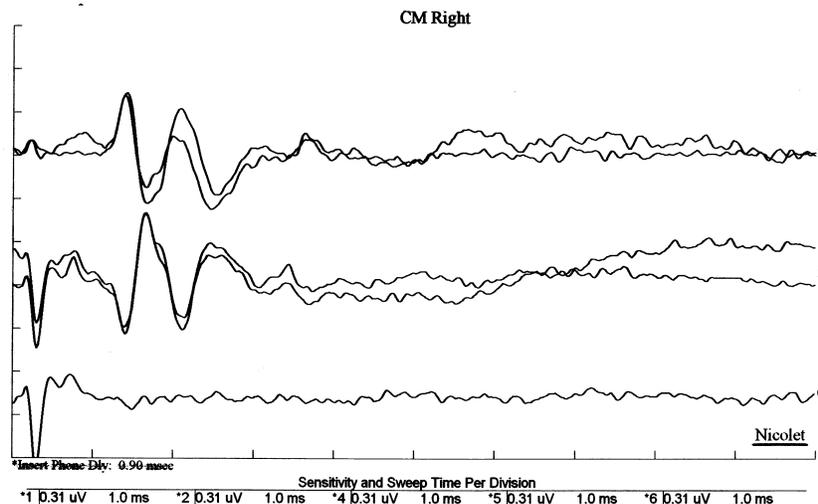
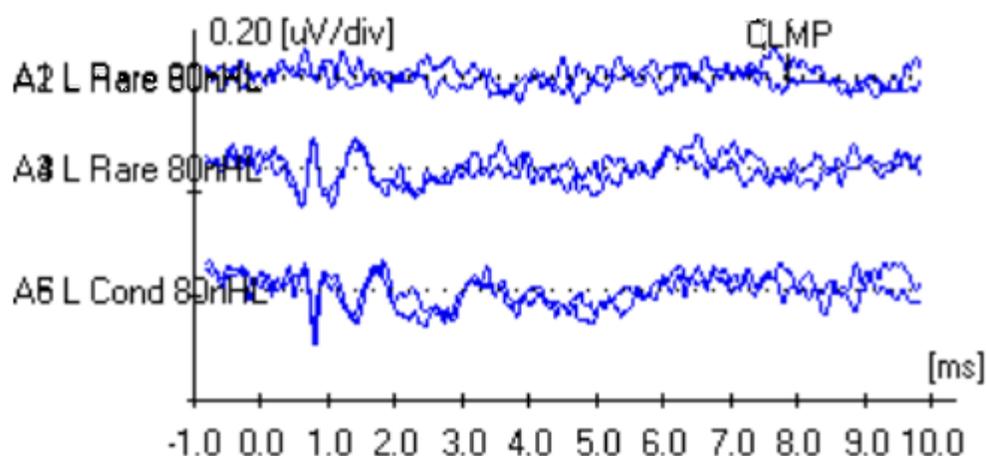


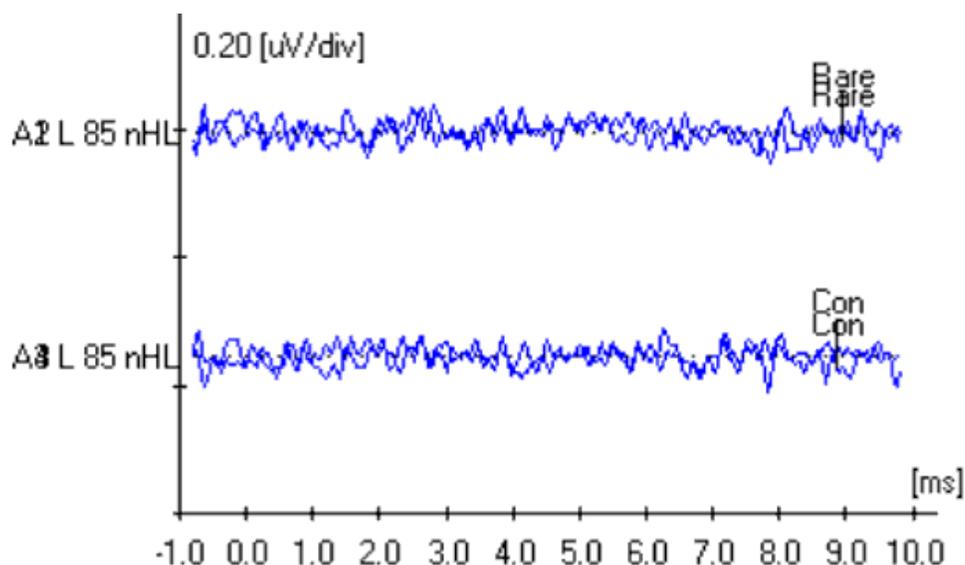
Figure 1 A clear and large (about 0.8µV) CM in a case of a baby with ANSD. Top: Rarefaction click. Centre: Condensation click. Bottom: Condensation click, with tube clamped. Note that the initial deflection in the condensation waveforms is the stimulus artefact. The CM is not present in the clamped waveform. Ideally the clamped waveform should have been replicated but in such an obvious case the lack of replication does not introduce uncertainty. Because of the large size of this CM a display scale beyond that recommended for ABR has been used.

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210 **Figure 2** An example of a small but clear CM in the centre and bottom waveforms, which is not evident in the clamped waveforms at the top. As with conventional ABR recordings, the superimposition of replicated waveforms provides an estimation of the residual noise thus allowing the significance of waveform features to be assessed. The display scale falls within the range normally used for ABR work.



215 **Figure 3** An example of an absent CM. The low level of residual noise (as judged from the average gap between replicates) confirms that recording conditions were good. There is no feature in the waveforms with the characteristics of a CM so no clamped waveforms are necessary.

220 **NOTES**

- The CM threshold level is **not** a useful predictor of behavioural threshold, as even in normally hearing infants it cannot be reliably measured at levels below 50 – 60 dBnHL.
- If there is no recordable ckABR or 4kHz tpABR at the stimulus level used to perform the CM test a recordable 1kHz tpABR (or tpABR at other frequencies) is unlikely but not impossible. In the event of a 1kHz tpABR being recorded the presence of a CM is not necessarily confirmation of ANSD since this combination of results might occur in a steeply sloping cochlear loss. Detailed inspection of the CM may reveal whether the CM has been generated by intact outer hair cells from lower frequencies in the cochlea. Expert advice should be sought in cases of doubt.
- Figure 1 shows a very large (about 0.75µV) CM. This is sometimes seen in ANSD and may be associated with abnormal efferent inhibition of hair cell activity. There have been anecdotal reports of similarly large OAE responses in some cases of ANSD. However large CM and OAE responses are not always seen in ANSD.
- Although not relevant to distinguishing between ANSD and SNHL, as with ABR testing, make a note of any behavioural response to the CM stimulus.

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CALIBRATION

The international standard (ISO 389-6, 2007²) gives the reference equivalent SPL for clicks and tone bursts/pips The reference levels for clicks and insert earphones are:

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Earphone	Coupler	dBppe RETSPL
ER-3A	IEC60126 (2cc) ³	26.5
ER-3A	IEC318-4 ⁴	35.5

ppe = peak to peak equivalent

245 The ER-3A earphone RETSPL values are recommended for the two respective couplers. It is recommended that expert help is sought if you are not familiar with the measurement of peak to peak equivalent values.

Warning: The above values were derived from normal adults. When inserts are used on neonates, the smaller canal volume has the effect of increasing the actual SPL of the stimulus by around 10dB - 20dB. This is the reason for limiting the stimulus level to 80-85dBnHL – a neonate may actually receive 100-105 dBnHL and higher stimulus levels are likely to risk cochlear damage.

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SUMMARY OF PARAMETERS FOR CM TESTING

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Electrode Location:	Positive Negative Common	High forehead (as close to vertex as possible, avoiding fontanelle) Ipsilateral mastoid Contralateral mastoid
Stimulus:	Separate runs of Rarefaction and Condensation clicks	Rate: typically 87.1/s Level: 80-85 dBnHL
Earphone:	ER-3A tubal inserts	Clamp tubing for control run
Coupler value for 0dBnHL	IEC60126 ^{A1} coupler IEC318-4 ^{A2} coupler	26.5 dBppeSPL 35.5 dBppeSPL
Amplifier reject levels:	±3µV to ±10µV	±3µV recommended
Filters:	Low (high pass) High (low pass)	100 – 300 Hz 3000 Hz – 5000 Hz
Window length:		8 -10ms
Number of sweeps averaged per replication :		Minimum 1500 Typically 2000
Display Scale:	Default: Small or absent CMs: Large CMs:	0.05 - 0.1µV (50 - 100nV) = 1ms 0.025 - 0.05µV (25 - 50nV) = 1ms 0.1 – 0.2µV (100-200nV) = 1ms

REFERENCES

- 260
1. NHSP Guidance for Auditory Brainstem Response testing in babies. Version 1.1 April 2010
 2. ISO 389-6 (2007). Acoustics - Reference zero for the calibration of audiometric equipment - Part 6: Reference threshold of hearing for test signals of short duration. International Organisation for Standardisation, Geneva.
 - 265 3. IEC 60126 (1973). IEC reference coupler for the measurement of hearing aids using earphones coupled to the ear by means of ear inserts (*will become IEC 60318-5. Also referred to as the 2cc coupler*)
 - 270 4. IEC318-4 Occluded-ear simulator for the measurement of earphones coupled to the ear by ear inserts. (was IEC 60711)