

(iv) Auditory Steady State Response Test Protocol

**Provisional Guidelines for using Auditory Steady State Responses (ASSR) in
Babies- A Recommended Test Protocol.**

**Suggested parameter values for recording frequency-specific ASSR using Natus
Biologic MASTER / GSI Audera / ICS Chartr EP 200/ Interacoustics Eclipse
systems**

ASSR**(iv) Auditory Steady State Response Test Protocol****Provisional Guidelines for using Auditory Steady State Responses (ASSR) in Babies- A Recommended Test Protocol.****Suggested parameter values for recording frequency-specific ASSR using Natus Biologic MASTER / GSI Audera / ICS Chartr EP 200/ Interacoustics Eclipse systems*****INTRODUCTION***

At present there is no NHSP protocol for ASSR testing. This interim advice is provided by NHSP pending a full protocol for adaptation to clinical practice within the Healthy Hearing program. Use of ASSR in assessment following newborn hearing screening is described in the NHSP Early Assessment Guidelines Protocol¹ which should be read in conjunction with this document. In particular it is important to consider how ASSR fits with the overall hearing assessment process in babies.

The advice is based on experience with the Natus Biologic MASTER and GSI Audera systems but also covers the Otometrics ICS Chartr EP 200 and Interacoustics Eclipse systems. The advice is not intended to imply any relative merit of these systems over any others that are commercially available.

EQUIPMENT**Transducer:****Air conduction**

For air conduction insert earphones or supra-aural headphones can be used. However at high stimulus levels inserts are recommended as they are less likely to produce stimulus artefact.

Bone conduction

Bone conduction transducers have been shown to produce sufficient stimulus artefact to affect some ASSR results. Technical improvements have been made in equipment to overcome this but any responses should be checked for artefact. This is done by repeating the test with the vibratory stimulus blocked.

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To achieve this, the bone conductor should be lifted away from the head by a few millimetres to prevent transmission of the BC stimulus and should also be acoustically shielded to prevent stimulation by air conduction. A true bone conduction response should disappear.

Maximum stimulus levels

Care should be exercised when using high levels of stimuli. This is particularly the case for multi-frequency stimuli where the overall intensity will be higher than the level set for each single frequency. Some systems e.g. MASTER system and ECLIPSE warn the user when a single frequency should be used rather than multiple frequencies.

Electrodes:

Two ear testing

Two ear testing has the potential advantage of reducing the test time significantly. Details of this are beyond the scope of these guidelines and the reader is referred to Picton².

- Positive: High forehead (as high as possible but avoiding the fontanelle)
- Negative: Nape
- Common: Shoulder or site at least 4cm from other electrodes.

NB for the ECLIPSE (2 channel) - left channel negative electrode to the left mastoid, and right channel negative electrode to the right mastoid.

One ear testing

- Positive: High forehead (as high as possible but avoiding the fontanelle)
- Negative: Nape or ipsilateral mastoid
- Common: Shoulder or site at least 4cm from other electrodes.

STIMULUS PARAMETERS

Multi-frequency testing:

This has the potential benefit of reducing the test time when the ASSR threshold to more than one frequency is required. The reader is referred to Picton et al³.

Modulation parameters- NB in some equipment these are fixed

Amplitude Modulation Depth:	100%
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Frequency Modulation Depth:	20% ($\pm 10\%$)
FM to AM Phase:	-90° ($+270^\circ$)
Modulation Type:	Enable exponential modulation (if available) Enable FM modulation
Carrier frequencies:	500, 1000, 2000, 4000Hz
Modulation rates:	
MASTER:	MASTER version II variable, can be set by user. Recommendations on spread of rates are given in the manufacturer's information. This is particularly important to consider when carrying out multi-frequency testing.
Audera:	74Hz for 500Hz, 81Hz for 1000Hz , 88Hz for 2kHz, 95Hz for 4kHz.
Chartr:	Use 'child asleep search protocol default'. Default rates. Right ear :88Hz for 500Hz, 80Hz for 1000Hz, 96Hz for 2000Hz and 92Hz for 4000Hz. Left ear: 90Hz for 500Hz, 82Hz for 1000Hz, 98Hz for 2000Hz and 94Hz for 4000Hz. These rates can be modified but the default rates are recommended.
Eclipse:	Select 90Hz range
Stimulus levels:	Normally record responses in 10dB steps.
Initial intensity level:	Provisional recommendation is 50dBHL,

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	where expected threshold (e.g. from ABR results) is unknown.
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CALIBRATION

Contact a calibration specialist in your area for further information if required.

HEADPHONES

These can be calibrated in dBHL using pure tones as follows. The method is similar to the peak-to-peak calibration of transient tone burst or tone burst stimuli.

1. The transducer is placed on a suitable coupler connected to a sound level meter. The output of the sound level meter is displayed on an oscilloscope.
2. An amplitude-modulated tone from the ASSR system (with no exponential or frequency modulation) is fed to the transducer at a known stimulus level and displayed on the oscilloscope.
3. The peak-to-peak amplitude of the modulated tone is equated (on the oscilloscope) with a pure tone from a suitable source. The frequency of this reference tone is not critical but should be within the recording bandwidth of the sound level meter. A 1 kHz pure tone is a suitable choice or the frequency of the ASSR carrier.
4. The pure tone is then calibrated in dBHL using RETSPL data for pure tones (ISO 389-1)
5. This value in dBHL will be the output of the ASSR system at the set stimulus level. The ASSR system should be adjusted until they are the same value.

NB The ECLIPSE uses a chirp based stimuli and requires a slightly different procedure.

Insert earphones

These can be calibrated in dBHL in the same way as earphones using a suitable coupler for the insert and the appropriate reference levels (RETSPL in ISO389-2). However although this will calibrate the equipment for use in adults, allowance needs to be made for smaller ear canal volumes in babies, which will increase the stimulus level. See reference 1 for more details on this.

Bone vibrator

These can be calibrated in dBHL in the same way as for headphones, substituting an artificial mastoid for a coupler in (1), using a pure tone of the ASSR carrier frequency in (3) and using RETFL (ISO 389-3) reference data in place of RETSPL data in (4).

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HEALTHY HEARING AUDITORY STEADY STATE QUICK SUMMARY PROCEDURE

- Both ears must be assessed
- A “phase-locked” response down to 40 dB nHL is considered “functionally normal”, and can exclude all but a mild hearing loss at this frequency. Ideally, testing down to 30dBnHL is preferable where possible.

QUICK GUIDE: RECOMMENDED RECORDING PARAMETERS FOR ASSR

Filter settings:	Fixed by system except for Chartr. Use default rates for Chartr.
EEG Reject levels:	Closest equipment setting to $\pm 10\mu V$. A lower value than this can be used if the baby has very low EEG down to about $\pm 5\mu V$.
Recommended maximum recording time:	4 minutes for each run at one stimulus level.
Stop criteria for presence of a response:	A stop criteria of $p < 0.02$ (98% confidence) is recommended to accept the presence of a response. Times to reach $p < 0.02$ vary between test frequencies: e.g. it can often take longer to reach this criteria for 500 Hz. Use clinical judgment to decide whether there is time to wait for all frequencies to reach this target or whether available time is better spent on determining ASSR threshold at a limited number of frequencies.
MASTER:	Stop when $p < 0.02$. NB the MASTER system May have a default green light at $p < 0.05$. The More stringent criteria is recommended to take determination of threshold more robust. On MASTER II software the value can be changed to $p < 0.02$.

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Audera:	Fixed at >97% (p<0.03)
Chartr:	User settable: Set response confidence to 98%
Eclipse:	Set to accuracy option (p<0.01)
Noise floor for good recording condition:	Where this data is available the provisional recommended value is <10nV root mean square to accept that good recording conditions were achieved. Where noise is higher than this a result needs to be considered as inconclusive.
Minimum recordings:	30 dBnHL preferable 40dBnHL essential Threshold seeking for babies suspected of hearing loss- the following are required; Threshold – 10dB Threshold Threshold + 10dB

Definition of Threshold

In the AC click ABR protocol⁴ the definition of ABR threshold is “the lowest level at which a clear response is present, with the absence of a recordable response at a level 5 or 10dB below the threshold, obtained under good recording conditions”. The provisional Healthy Hearing definition for the ASSR threshold, for each frequency tested, is the equivalent to this, i.e. the lowest level at which the target response criteria value of p<0.02 is obtained, with the absence of a recordable response at a level 5 or 10dB below this threshold, obtained under good recording conditions (defined as p >0.02 with the noise floor <10nV). There should also be a response meeting the p<0.02 criteria at 5 or 10dB above threshold. If threshold is at the maximum stimulus level there should be a further run at the maximum stimulus level meeting the p<0.02 criteria instead of the run at 5 or 10dB above threshold.

REFERENCES

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2/ Picton TW (2006). Audiometry using ASSR. In Auditory evoked potentials basic principles and clinical application. Burkard RF, Eggermont JJ, Don M (Eds). Lippincott, Williams and Williams, Baltimore.

3/ Picton TW, van Roon P, John MS (2009). Multiple Auditory Steady State Responses (80-101Hz): effect of ear , gender, handedness, intensity and modulation rate. Ear Hear 30(1) 100-109.

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Further reading

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6/ Picton TW, John MS, Dimitrijevic A, Purcell D (2003). Human steady-state responses. Int J Audiol 42 177-219.

**(v) Transient Evoked Otoacoustic Emissions Test
Protocol**

(v) Transient Evoked Otoacoustic Emissions Test Protocol***INTRODUCTION***

Otoacoustic emissions are sounds, which appear in the ear canal as a by-product of sensory cell activity in the inner ear in response to sound. They are conducted through the middle ear. Their successful stimulation and detection indicates a high degree of normality in the functioning of the middle ear and inner ear. In particular the environment of the inner ear is shown to be healthy. This is a necessary but not in itself a sufficient condition for normal hearing. The signals detected by the cochlea also need to be transmitted effectively through the auditory nerve pathways and to be interpreted correctly by the higher auditory centres. The value of OAE testing for hearing screening is based on the fact that in a very high proportion of congenital hearing impairments it is the environment and the sensory cells of the inner ear which are affected and which will result in no OAEs being produced. OAE screening has therefore been shown to be very effective in screening the well baby population. In the at risk population it has been shown that some babies exhibit retrocochlear disorders which are not identified by OAEs testing alone.

Historically TEOAEs have been the most used method for newborn hearing screening both in the USA and Europe. All the major trials and longest running programmes (Rhode Island, Wessex Project, Whipps Cross programme) have employed TEOAEs and the majority of literature refers to TEOAE. However in recent years DPOAE technology has evolved to provide a viable alternative to TEOAE screening. TEOAE has been selected as the method to be used in the Healthy Hearing Diagnostic Audiology Protocols due to strengths in hearing loss identification and noise rejection. However, an Audiologist may use their discretion regarding when to use DPOAEs supplementary to TEOAEs to enhance the test battery.

SCOPE

The document firstly describes the types of OAE and recording technologies. It then focuses on the choice of parameters to be used in the recording of TEOAEs in the first few months of life. In addition, it proposes pass/refer criteria to be used in the Healthy Hearing Diagnostic Audiology Protocol (HHDAP). It only briefly looks at the practical aspects as these are covered elsewhere.

TYPES OF OAE AND RECORDING TECHNOLOGY TEOAEs and DPOAEs

Two forms of OAE technology have been used for newborn screening. These are known as Transient or click-evoked Otoacoustic Emissions (TEOAEs) and Distortion Product Otoacoustic

TEOAEs

Emissions (DPOAEs). The differences stem from the choice of stimulation and the technology subsequently used to extract the response. TEOAEs employ click stimulation and averaging similar to screening ABR. DPOAEs employ a series of tonal stimuli (in pairs). As TEOAEs have been chosen as the method to be used in the HHDAP program the remainder of this document will cover TEOAE only.

Automated and Operator Controlled instruments

For the purposes of diagnostic assessment of a neonate, operator controlled testing rather than automated testing is recommended (i.e. the use of diagnostic programs is in preference to automated TEOAE screening programs).

PRACTICAL ASPECTS

With OAE testing it has been found that probe fitting is the single most important aspect of the test. Probes need to be fitted well in the ear canal to collect the most sound and to exclude the most external noise. Problems are typically caused by debris in the ear canal, blocking sound tubes, by debris and fluid immobilising the eardrum or by the ear canal itself being collapsed between the probe and the eardrum. The most successful OAEs are recorded and obtained from a well sealed ear canal¹.

CRITERIA FOR DIAGNOSTIC TESTING

For the purposes of this protocol it is necessary to set pass-criteria for testing such that there is a negligible probability that moderate or greater bilateral hearing impairment, present at birth, will be missed consistent with an acceptable pass rate. Three conditions need to be met before an ear is judged to have passed an OAE test.

Firstly there must be a high probability that the ‘response’ seen is a true cochlear response and not due to artefact. For TEOAE this is usually achieved by careful control of the stimulation, by use of the non-linear (saturated) component extraction and by the selection of a delayed analysis window which excludes any expected stimulus artefact. With TEOAEs, to minimise stimulus artefact from contaminating the waveform the analysis window for data collection should start 2.5-4 milliseconds after delivery of the stimulus. The proposed start-time for is 4ms. The effective start time will depend on the gate function used in the analysis window. The start time should be 4ms taking this into account. The length of the data collection time, following the

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stimulus, varies dependant upon the stimulus rate used. The proposed end of the data collection and analysis window is between 10 and 12.5 ms.

Secondly there must be a high probability that a response-like signal is present at the frequency expected. This is usually determined by the degree of reproducibility or the signal to noise ratio although other statistical methods can be applied. With TEOAEs this assessment is typically made either in each of several half octave frequency bands. Using the proposed time window given above, the proposed criteria for this part is ≥ 6 dB signal to noise ratio in 3 or more of half octave bands from half octave bands centred at 1/1.5, 2, 3, and 4 kHz. It is essential for a response to be present in the 1/1.5 and 4 kHz bands to ensure normal hearing across the frequency range. Where different bandwidths and/or centre frequencies are used the pass criteria should be at least as stringent as one of these options. A response should be reported as present within a particular half octave band if the signal to noise is ≥ 6 dB.

NB This is a minimum criteria and where equipment permits and there is no significant increase in test time the test may be continued to higher pass criteria e.g. 10dB signal to noise ratio.

Thirdly the intensity of the validated response obtained must be large enough to be within the normal physiological range. The proposed minimum response level is -10 dB rms SPL.

Other criteria

In addition there should be a minimum amount of good data (below the reject level) of 50 sweeps at the low (aka quiet) stimulus level in the non linear mode. Stimuli are often presented in packets e.g. groups of 8 (2 stimuli at the high level to 6 at the low level). Where possible, collecting a larger number of sweeps (i.e. 260) at the low or quiet level is encouraged.

Maximum test time

The recommended maximum test time is 6 minutes. If more than 6 minutes actual testing time is required:

- a) The baby is usually too unsettled to test; continuing to test may lead to parental anxiety.
- b) The testing conditions are unsatisfactory for successful testing.

Data rejection level

The data rejection level should be set as low as possible and not above 55 dB peak SPL.

TEOAEs***RECORDING DETAILS*****Environment**

OAE screening in noisy environments is time consuming and inefficient. Every effort should be made to screen in a room without continuous background noise such as air-conditioning, ventilation or road traffic noise. Occasional voices and other noises are less of a problem since they are rejected by the instruments artefact rejection system. Noise can also be minimised by ensuring the cord is not rubbing against clothing.

State of baby and probe fitting

Fitting the probe need not disturb the baby who should be quiet during the test. The practical aspects of baby handling, patient preparation, probe fit and equipment care are covered elsewhere. It is MOST IMPORTANT that good probe fitting be achieved BEFORE in the ear calibration - since is impossible to overcome the effected of poor fitting by correcting the stimulation drive. Instruments must therefore provide a clear indication of the insertion and coupling achieved by the operator who should confirm probe fitting is optimised BEFORE they activate any in-the-ear calibration.

Stimulation and in the ear calibration

Unlike audiometry and ABR the level of stimulation is not critical to the interpretation of OAEs. Too high a stimulation will increase the chance of artefactual responses. Too low a stimulation, with a smaller expected response, will increase the testing time excessively. The recommended stimulus level for the TEOAE click stimulus (lower level) is 80 +/- 5dB peak equivalent sound pressure level (pe SPL) as measured in the neonatal ear canal or an equivalent sized cavity. Instruments should provide a means of achieving the target stimulation levels in the ear. Some instrumentation allows the click stimulus waveform to be viewed. The ideal is a clean, clear, positive and negative deflection lasting no longer than 1 ms and followed by a straight line indicating no or very limited 'ringing', or oscillation of the waveform.

Signal processing

TEOAE systems use signal averaging and frequency analysis to enhance and display the response. The instrument must use a numerical assessment of the confidence that a true OAE response has been observed. The instrument must also use a numerical assessment of the level of NOISE contamination present in that band since only by knowing this can it be decided an OAE was not seen because it was too small – or because it was probably obscured by noise. TEOAE

TEOAEs

instrument may additionally give an overall wide band signal to noise ratios of response reproducibility index. While useful in assessing the quality of the test environment – overall wide band quality indicators should not dominate the assessment over frequency specific measurements. Filtering to remove noise below 1 kHz is highly desirable particularly when viewing the result in the time domain. High pass filters at around 1.2 kHz and falling at 12 or more dB/octave have little effect on the TEOAE response from infants and greatly improve response quality.

Probe Checks

It is advised that the probe is regularly checked for sound output and microphone sensitivity at least:

- a) Every 50 babies
- b) Once per week
- c) After any changes are made to the probe.

After performing an acoustic loop back test with the probe in a cavity tester, the user should carry out a ‘biological’ TEOAE check on their own ears prior to each testing session.

Failure to observe an OAE

A recordable OAE indicates the presence of a normal cochlear function at or near the frequencies present in the emission. Absence could be for one of many reasons e.g. poor recording conditions, bad probe fitting, the presence of outer ear or middle ear disease, absent cochlear response, or an amplitude too small to record. Normally hearing ears produce a wide range of TEOAE intensity and waveforms. Some healthy ears may only produce emissions strong enough to be visible above the infant and background noise in only a narrow range of emission frequencies whilst others will produce a broad range of emission frequencies. Where TEOAEs are unexpectedly absent or below the minimum amplitude requirement (particularly at 1, 1.5 or 4 kHz, in the cases of rising or sloping hearing losses), TBABR or ASSR should be used to establish whether hearing at that frequency is normal or abnormal.

HEALTHY HEARING TRANSIENT EVOKED OTOACOUSTIC EMISSIONS QUICK***SUMMARY PROCEDURE***

- Stimulus of 80 dBpkSPL +/-5dB is required for testing
- Good “checkfit” – minimal stimulus ringing and appropriate broad, relatively flat ear canal response

TEOAEs

Pass criteria must be met as outlined below:

Minimum 6dB SNR across at least 3 frequency bands (including at least 1 or 1.5 kHz, and 4 kHz).

Minimum reproducibility of 80%

Minimum stimulus stability of 80%

QUICK GUIDE: RECOMMENDED PARAMETERS AND SETTINGS FOR TEOAEs:

Probe fitting:	Well fitted probe with no significant change in fit over recording interval
Stimulus:	Click between 75 and 100 p.p.s
Stimulus level (ppe) :	80 +/- 5 dBpeSPL into neonatal ear canal or equivalent volume cavity
Variation of stimulus level between probes:	+/- 2 dB
Data reject level:	At or below 55 dB peak SPL
High pass filter to remove low frequency noise:	Around 1.2 kHz
Bandwidth:	Able to record between 1000 and 5000Hz
Data collection / analysis window :	Start 4 ms. End 10 to 12.5 ms
Minimum number of responses:	Averaged 50 sweeps at low stimulus level equivalent
Maximum recording time:	6 minutes
Present response criteria:	<ul style="list-style-type: none"> • \geq 6dB signal to noise ratio in 3 or more of half octave bands from half octave bands centred at 1/1.5, 2, 3, and 4 kHz. • It is essential for a response to be present in the 1/1.5 and 4 kHz bands to ensure normal

TEOAEs

	hearing across the frequency range.
Minimum level to accept as an amplitude response:	0 dB rms SPL

FOOTNOTES

¹ OAEs are just air pressure fluctuations in the ear canal caused by vibration of the ear drum driven by the cochlea. It is wrong to think of OAE as sounds “emitted” by the cochlea itself, because sound pressure is not produced in any measurable quantity until the eardrum, driven by the cochlea, vibrates against the adjacent air in the ear canal. The physical construction of the middle ear positively helps us to observe OAEs. The efficient coupling that the middle ear provides between the low impedance of the thin light eardrum and the high impedance of the closed fluid-filled capsule that is the inner ear operates equally well in reverse. It matches cochlea to eardrum just as well as eardrum to cochlea. A horn can be used either to enhance hearing or in reverse as a trumpet to strengthen the voice. In the same way, the middle ear works in reverse as a kind of stethoscope, helping us to record vibrational activity deep inside the cochlea.

But with an open ear canal the air displaced by eardrum motion would just slide in and out of the ear canal. Very little actual sound pressure would result except at the highest frequencies (> 8 kHz for human ears), where the ear canal begins to act like a horn. Sealing the ear canal provides a small confined volume of air that the eardrum vibrations can work against to produce sound pressure right down to the low frequencies. Sealing the ear canal is an essential part of the OAE recording technique. It is achieved in humans by inserting the OAE measurement probe into the ear canal using a soft plastic tip to ensure a good seal. The probe either contains or is coupled to the recording microphone and acoustic stimulator. An additional practical benefit of sealing the ear canal is that it attenuates room noise. This is particularly valuable in clinical applications when testing is done outside of a sound booth.

REFERENCES

Kemp, D. T. (2008). Otoacoustic emissions: Concepts and origins. In G. A. Manley, R. R. Fay & A. N. Popper (Eds.), *Active processes and otoacoustic emissions*. New York: Springer (pp 3-4).

**(vi) High Frequency Tympanometry (1000Hz Probe
Tone) Test Protocol**

(vi) High Frequency Tympanometry Protocol (1000 Hz)***INTRODUCTION***

The use of 1000 Hz probe tone tympanometry is recommended to test babies less than 6 months corrected age. Tympanometry using 226 Hz should not be used. A simple classification scheme is proposed in which there are only two possible clinical outcomes – normal or abnormal, indicative of middle ear dysfunction absent or present respectively. This is based on a reliably recorded trace. Traces with positive peaks indicate that middle ear dysfunction is absent even when the positive peak is at a negative middle ear pressure (MEP); flat traces or traces with negative peaks indicate middle ear dysfunction is present.

The sensitivity and specificity of the method is good but not perfect as a small number of traces are not easily classified. Therefore in determining the management of an individual infant, tympanometry needs to be considered in the context of other audiological test procedures. This protocol is consistent with the recommendations of the US Joint Committee on Infant Hearing (JCIH) 2007 Position Statement for the audiological evaluation of infants aged from birth to 6 months of age.

SCOPE AND AIMS

The aim of the document is to provide recommendations for accurately determining the middle ear status of young infants who have been referred for diagnostic audiological assessment following Newborn Hearing Screening. The accurate determination of middle ear function is required for both audiological and medical management, and oto-admittance testing (tympanometry) is important in this.

The aims of this document are:-

- 1) To summarise the evidence base for high-frequency tympanometry.
- 2) To provide guidance as to the interpretation of test results. It assumes an understanding of conventional tympanometry (typically carried out using a probe tone of 226 Hz) and only attempts to cover those aspects that may differ for the assessment of middle ear function in young infants.

HFT**MEASUREMENT****Why are adult protocols inappropriate?**

There are anatomical and acoustical differences between the adult and neonatal middle ear which means that adult protocols for tympanometry are not appropriate. The mean adult middle ear resonant frequency is 900 Hz with considerable variability (650 Hz – 1400 Hz). The middle ear system is stiffness controlled below its resonant frequency and mass controlled above it. The 226 Hz probe tone has been used successfully to measure the stiffness-controlled component of the admittance (known as compliance) of the adult middle ear system as it is below the resonant frequency where the effects of mass and friction are negligible. The resonant frequency of the neonatal middle ear is much lower than in adults (Weatherby & Bennett, 1980; Holte 1991) and increases to adult values at around 4 months (Meyer et al. 1997). The maturational changes which occur in the first few months of life transform the middle ear from a mass-dominated to a stiffness-dominated system. Early studies predicted difficulties in using low frequency probe tones in early infancy because of the different acoustical properties of the neonatal middle ear compared to the adult (Himmelfarb, 1979; Weatherby & Bennett, 1980).

It has been suggested by some that there may be effects due to the greater flexibility of the neonatal ear canal walls, but this is unclear. Keefe et al. (1993) commented, “.....*the frequency range from 220 to 660 Hz is the worst possible range to use for tympanograms on infants. Not only is there significant ear-canal motion, but in fact there is a resonant amplification of the wall motion in this frequency range*”. Contradicting this, Holte et al. (1990) demonstrated that tympanogram shape was unrelated to ear canal wall movement in this age group.

For an extensive review of the literature about high frequency tympanometry in early infancy and for a more detailed explanation about the choice of a 1000 Hz probe tone see Purdy et al. (2000), Petrak (2002, and Lantz et al. (2004).

Choice of two component (B and G) or single admittance (Y) tympanograms

The measurement of the flow of acoustic energy through the ear canal and middle ear can be measured either in terms of acoustic impedance (the opposition to the flow of energy) or its reciprocal, acoustic admittance. Both impedance and admittance have two equivalent components. For admittance (Y) these are conductance (G) and susceptance (B) relating to frictional and stiffness/mass components respectively (such that $Y = G + jB$).

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For a comprehensive explanation of the theory of immittance and its application to the assessment of middle ear function in early infancy see Lantz et al. (2004).

Contemporarily admittance (Y) is the measurement of choice (Sutton et al. 1996; Kei et al. 2003; Baldwin 2006; Mazlan et al., 2007) but susceptance tympanograms have also been usefully applied in early infancy (Marchant, 1986; Williams et al., 1995).

Choice of probe tone

The validity of low frequency tympanometry in early infancy was questioned when normal tympanograms were observed in babies with middle ear effusion (MEE) confirmed by myringotomy (Paradise et al., 1976; Shurin et al., 1977). However high frequency tympanometry in early infancy has been difficult to validate with an adequate “gold standard” and traces have proven difficult to interpret and classify.

Classification of tympanograms by pattern

Low frequency tympanograms have been successfully classified by pattern in adults and the Jerger/Liden classification system is a familiar scheme (Liden, 1969; Jerger, 1970). However more complicated patterns are produced when the probe frequency increases towards the middle ear resonant frequency. Multi-peaked or “notched” tympanograms occur when the probe tone is close to the resonant frequency.

Classification of tympanograms by quantitative measures

Classifying high frequency tympanograms by a quantitative measure such as peak susceptance or peak compliance has been usefully applied to infants under 6 months of age (Marchant et al 1986, Williams et al 1995, Sutton et al 1996).

a) Marchant et al (1986) compared peak susceptance using a 660 Hz probe tone in ears with MEE confirmed by myringotomy and “normal” ears. The tympanograms were analysed by drawing a baseline between +300 daPa and -400 daPa and measuring peak susceptance above the baseline. Peak susceptance ≤ 0 mmho (i.e. no discernible peak) was highly associated with otoscopic diagnosis of MEE and evidence of MEE at myringotomy with a sensitivity of better than 0.94. Marchant et al.’s methodology influenced the recommendations of the earlier version of this protocol.

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b) Baldwin (2006) used an adaptation of Marchant's methodology to classify admittance tympanometry using 226, 678 and 1000 Hz probe tones undertaken on 211 babies aged 2 to 21 weeks. Tympanograms recorded from babies with normal ABR thresholds or robust TEOAEs were compared with those recorded from infants who had evidence of temporary conductive hearing impairment (attributed to MEE) based on the findings of a test battery, which included air and bone conduction ABR. There were no significant differences between the two groups using the 226 Hz probe tone and the majority of tympanograms were "normal" Type A. The sensitivity of the 226 Hz probe tone in correctly identifying the presence of MEE was only 0.02. There were significant differences between the 2 groups using the higher frequency probe tones with the majority of traces from the pathological group being typically "trough-shaped" as shown in Figure 1. The sensitivity of the 678 Hz and the 1000 Hz probe tone in correctly identifying the presence of MEE was 0.95 and 0.99 respectively. The specificity was 0.83 and 0.89 respectively. This methodology forms the basis of the current protocol.

Low frequency probe tones are invalid in early infancy. The choice between 678 Hz and 1000 Hz is based on its sensitivity and ease of interpretation. McKinley et al (1997) reported that 1000 Hz results were less straightforward to interpret; however if the data are re-classified into 'flat' vs. 'all other' (which seems more appropriate), then the relationship to OAE results is better for 1000 Hz tympanometry than for 678 Hz. Baldwin (2006) reported fewer difficult to classify traces when using the 1000 Hz tone compared to 678 Hz. Using the 1000 Hz tone, 5% of traces were 'difficult to classify' in the "normal" group and only 0.6% in the MEE group. The use of 1000 Hz is therefore recommended in early infancy.

Problems with normative data studies

Conventional adult tympanometry uses normative values and certainly objective pass/fail criteria would also be useful in the infant population. Normative data has emerged with 5th to 95th percentile data for a variety of test parameters which the authors believe may serve as pass/fail criteria for 1000 Hz tympanometry (Kei et al., 2003; Margolis et al., 2003; Swanepoel et al., 2007; Mazlan et al., 2009). However there are differences in the choice of criteria and also in choice of test parameters (eg. pump speed) which could influence this data (Calandruccio et al., 2006). Care would need to be taken to ensure the same parameters had been adhered to. Thus, this protocol does not include published normative data but is based on clinical studies that have directly demonstrated the effectiveness of a simple 'normal / abnormal' classification of 1000 Hz tympanograms for babies less than 6 months of age.

HFT**Up to what age is it necessary to use higher frequency probe tones?**

Meyer et al. (1997) predicted that valid low frequency tympanometry would only be possible when the adult middle ear resonant frequency was reached. This occurred at around 4 months in one longitudinal case study (Meyer et al. 1997). However, low frequency tympanometry can remain invalid up to 5 months of age and variability is currently unknown (Baldwin, 2006). Alaerts et al. (2007) recommended 1000 Hz below 3 months and 226 Hz above 9 months but there was uncertainty about the appropriate choice in the intermediate period. Differences between the neonatal and adult ear in energy transmission (Keefe & Bulen, 1993) and admittance phase measurements (Holte, 1991) which were evident at 4 months had disappeared by the age of 6 months. Tympanometry using the 226 Hz probe tone is used clinically to differentiate pathological ears in babies over 6 months old and further longitudinal studies would be necessary to establish the variability in the age at which it became valid. Until this is known we advise that high frequency tympanometry should be used and 226 Hz tympanometry be avoided up to the corrected age of 6 months. After 6 months of age it is advisable to consider using both 226 and 1000 Hz tympanometry.

EQUIPMENT**Calibration**

Equipment should be calibrated regularly according to IEC 61027:1991. Before use, a simple check on functioning should be carried out by testing one's own ear or in a cavity.

Precautions against cross infection

Local procedures should be adhered to. It is recommended that local advice be sought regarding best practices for cross-infection control.

Practical considerations in testing

- Otoscopy should be carried out before tympanometry as a general inspection of the external ear for obvious signs of disease, blockage or malformation such as atresia or stenosis. Care should be taken not to insert the otoscopic speculum deep into the ear canal of young babies.
- Conical tips, or those with a flange designed to seal against the entrance to the external auditory canal may be used for the tympanogram measurement. The pinna should be pulled gently to straighten the ear canal and position the tip.

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- Movement of the infant and crying can result in a false peak in the tympanogram. The baby does not need to be asleep but should definitely be resting quietly during the test.
- Traces should usually be repeated, if possible, to check that the result is replicable and not due to artefacts such as baby movement. It is especially important to retest any ear with an abnormal or difficult-to-interpret tympanogram.
- The direction of pressure change should be from positive to negative. The range should be at least from +200 daPa to –400 daPa. A fast screening mode speed of up to 400 daPa/sec should be used.
- The precise value of ‘Ear Canal Volume’ should be disregarded when high frequency probe tones are used, although it still is useful to indicate a blockage.

TYMPANOGRAM (TRACE) INTERPRETATION

The system recommended for interpretation is that of Baldwin (2006), adapted from Marchant et al. (1986) which improved intra-tester agreement significantly. Admittance is used in this scheme and one should check that the equipment is set to measure this. It differs from the previous recommendation in that MEP is no longer considered. A positive peak at negative or positive MEP was more likely to occur in the “normal” group and was not a feature of the MEE group (Figure 1): the MEE group typically had no discernible peak and the tympanograms were characteristically “trough shaped”.

In future developments, normative data based on peak compensated Y values may come into use. This will be addressed in future versions of this protocol.

Recommendation for middle ear measurement and trace interpretation in babies under 6 months

- Use a 1000 Hz probe tone and admittance (Y) measurement.
- Draw a baseline between points on the trace at pressure extremes (+200 to –400/-600 daPa). If the trace disappears below the x axis the baseline should be drawn to the x axis as shown in Figure 1.
- Identify the main peak which can occur at any middle ear pressure.
- Draw vertical line from this baseline to the peak of the trace.
- If the peak is above the baseline it is a positive peak; if it is below the baseline it is a negative peak.
- Positive peak is normal, negative peak is abnormal.

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- If there is a positive and a negative peak the trace should be classified as positive.
- If the conditions are good and the outcome is clear, repetition is not always necessary to draw a conclusion. However traces should usually be repeated if possible to check for reliability. Repeated traces should be classified in the same category of positive or negative. If the outcome is not clear the trace should always be repeated.

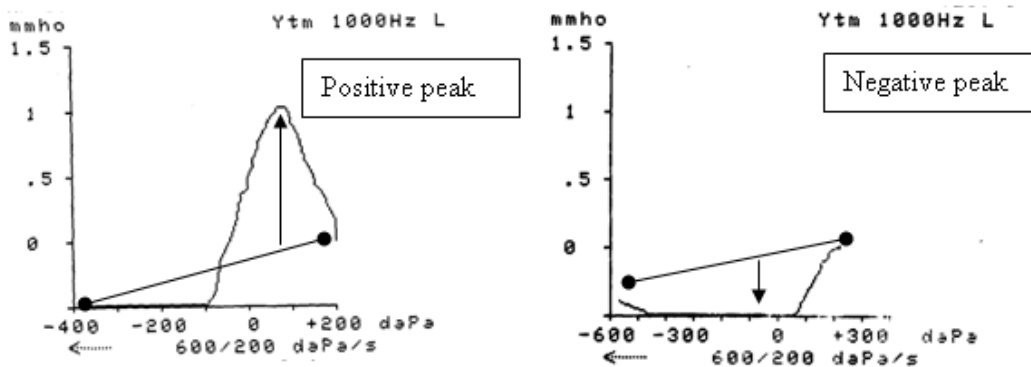


Figure 1. Examples of a positive and negative peak (adapted from a method used by Marchant et al 1986).

Further examples of normal and abnormal traces are given in the Tympanometry Appendix Figures 2 and 3.

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QUICK GUIDE: RECOMMENDED PARAMETERS AND SETTINGS FOR TYMPANOMETRY

Probe tone:	< 6 months (corrected for prematurity) – 1000 Hz (226 Hz is not recommended). > 6 months (corrected for prematurity) – 226 Hz (with additional 1000 Hz testing advisable)
Pressure Range:	The direction of pressure change should be from positive to negative. The range should be at least from +200 daPa to –400 daPa.
Pump Speed:	A fast screening mode speed of up to 400 daPa/sec should be used.

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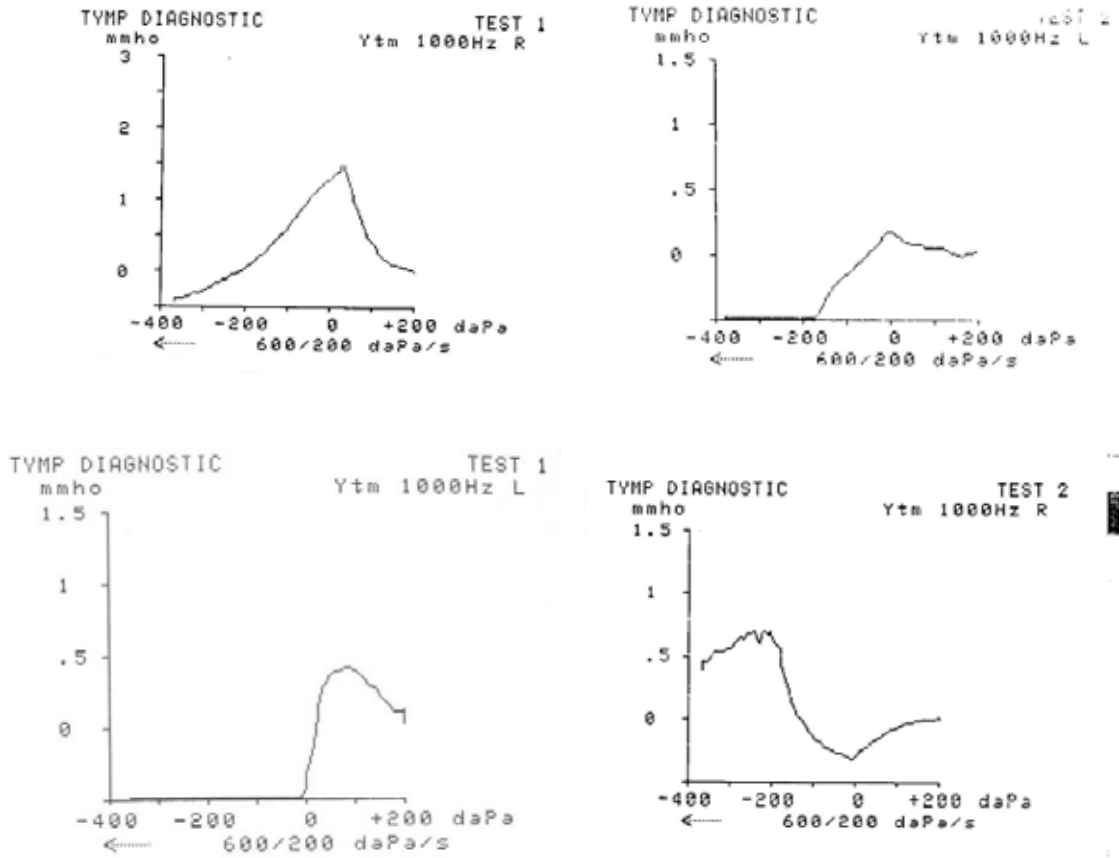
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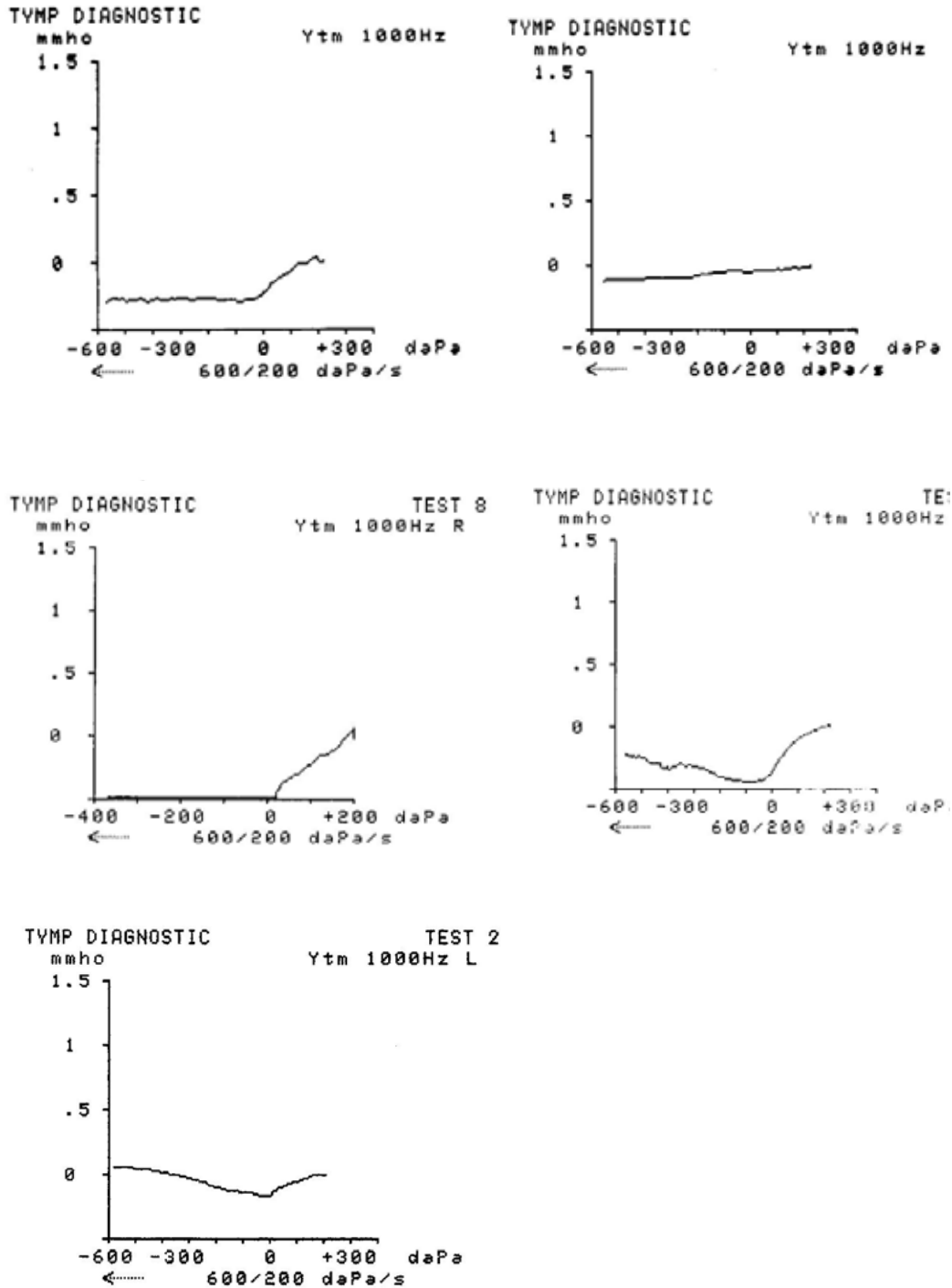
TYMPANOMETRY APPENDIX

Figure 2: Examples of tympanograms with positive peaks classified as “normal”.



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Figure 3: Examples of tympanograms classified as “abnormal”.



(vii) Behavioural Observation Audiometry

A Recommended Test Protocol

BOA**(viii) Behavioural Observation Audiometry*****INTRODUCTION***

Behavioural Observation Audiometry (BOA) involves presenting sounds to a baby and observing their responses. In the context of this paper, it is restricted to the responses before the developmental age at which babies can localise sound to the side.

A variety of types of stimuli, responses, and test protocols have been employed (Wharrad 1988). The behavioural responses have ranged from internal autonomic (e.g. heart rate) to body movements (e.g. the face and eyes), from excitatory or reflexive to inhibitory or attentive.

BOA is known to be a test of limited reliability: some babies will appear to respond even though they may not have heard, and others will have heard but not demonstrated any observable response.

Even in favourable circumstance, very young babies do not respond to the quietest sounds that they can hear. They only demonstrate responses to supra-threshold levels of stimuli. It follows that babies with cochlea deafness with recruitment may demonstrate responses to supra-threshold levels while being unable to hear quieter sounds.

The battery of physiological tests of hearing such as ABR, bone ABR, tone ABR, ASSR, TEOAEs and DPOAEs are considerably more objective and reliable. However, it is not always possible for physiological tests to be performed. In addition, BOA may be used as a demonstrative tool for parents whose children are diagnosed with hearing impairment. Some parents may have difficulty acknowledging the results of the physiological objective tests of hearing. It might be expected that most parents would be carrying out their own hearing tests at home when their baby is suspected of being hearing impaired or deaf.

Aims of BOA

- to determine age appropriateness of response to sound
- to confirm existence of behavioural response to sound
- to identify children at risk of significant hearing impairment
- to provide estimation of degree and configuration of hearing impairment

BOA

- to allow comparison of aided vs. unaided response

BOA may therefore have place in contributing to;

- a) provide information about low frequency hearing (in the absence of being able to obtain tone ABR or ASSR),
- b) provide more information about the hearing of neurologically immature babies where there may be doubts about the accuracy of the ABR, and
- c) demonstrate the hearing levels, the benefit of hearing aids, and giving indications of uncomfortable loudness levels.

The following recommendations aim

- to provide general guidelines only,
- to allow reasonable individual practice, but
- to exclude inappropriate practice.

1. Parents should receive a full explanation of the difficulties and pitfalls when observing a small baby's responses to sound.
2. Some children's audiology centres may include BOA to their battery of tests. Others may wish to avoid it.
3. Where it is used, the following recommendations are made:

SUGGESTED PROCEDURE:

Sticking rigidly to protocols should be avoided as the state of the baby will change within the test (Wharrad 1988).

Test environment:-

- sound-proof room
- minimal ambient noise
- minimal visual distractions
- dim lighting
- be aware of reflections/shadows

BOA*Noise-maker suggestions*

- Maracas
- Castanets
- Cellophane
- Woodblock
- Tambour
- Sleigh bells
- Small bell
- Chime bar
- Spoon in cup
- Horn
- Popcorn/batteries in jar
- Rattle
- Manchester rattle
- Drums

Suggested infant activity state:-

- The state of arousal is critical to obtaining responses.
 - For younger babies (maybe under 3 months), testers should aim to catch the ideal state between light sleep and quiet awake (Bench 1975, Bench 1976). The moment when the eyelids are half-closed can be particularly sensitive.
 - For older babies, "stilling" or attentive responses can be observed when they are more awake, but care must be taken to avoid states of strong internalised attention, or strong visual fixation. (Sonksen 1983)
- maintain complete quiet for few minutes prior to commencing test
- advise parents to have baby fed, bathed & changed
- best to be reclining in bassinet/bouncer, not in caregiver's arms

Tester / Observer:-

- one member to present noisemaker and observe SLM
- another member to observe infant response, record details

BOA

- both members to comment on response observation, if possible
- observers record more responses to louder stimuli
- observer bias reduced if infant is in light sleep state
- The observer can be "blind" to the presence of the stimuli. This may be achieved by video recording, or observing from an adjoining sound-treated room, or viewing the behaviour in the presence of masking through earphones (Gans 1987). The use of insert phones to present the test stimuli will attenuate audible sound to observers, and will provide ear specific information. The observer will require some pre-stimulus warning.

Stimulus Presentation suggestions:-

- The behaviour of the baby in the quiet must be observed for a short period prior to the presentation of any stimuli (Bench 1975).
- The duration of the stimulus needs to last several seconds, as the alerting and response time is longer in younger babies (Sonksen 1983).
- start with softer high frequency sounds
- move to lower frequency soft sounds
- if no response, check infant not too deeply asleep and gradually increase intensity
- present at 20° behind head, 30-45cm away from ear and out of sight
- present for 2-5 sec
- with at least 10 sec interstimulus interval to avoid habituation
- Habituation occurs rapidly when the stimuli are supra-threshold. The setting of stimuli levels should move quickly with the aim to identify the lowest level at which responses can be observed.
- choose presentation period carefully, wait until baby is settled again
- be aware of tactile cues (air from voice or horn etc.)
- use non-stimulus trials to check observer bias. Stimuli below the level of responsiveness could act as the equivalent of "catch" or no-sound-trials.
- ideally require two agreed responses per stimulus per ear/side of presentation
- don't present same stimulus more than twice in a row
- rapid rise time will produce better response
- startle response noisemaker last

BOA

- Test stimuli can be generated by loudspeakers, as this will reduce the possibility of baby responding to other non-auditory stimuli.

Interpreting responses:-

- The wider the frequency band of the test stimuli the more likely the baby will be to respond (Bench 1975, Bench 1976, Trinder 1990). Broad and narrow band noise must be available. Narrow band noise at low and high frequencies should be included in the range of stimuli.
- Responses are most likely to speech and broadband noise, then low frequencies, then warble and pure tone, then high frequencies
- Little interest in high frequencies before 3 months of age
- Probability of eliciting response increases with stimulus intensity, bandwidth and duration (up to 3sec), decreasing fundamental frequency and decreasing rise time
- Response must be observed no more than 2-3sec after stimulus presentation
- Acceptable responses:-
 - Arousal from sleep state: eye blink, whole body shudder, eye opening, head turn, marked limb movement, any combo
 - Changes in behaviour: cessation of movement, ceasing/commencing crying or vocalization, altered sucking rate, eyelid activity, Moro's response, breathing changes, eye widening, grimacing, Auropalpebral reflex

BOA - Result Interpretation:-

- Be careful of over interpreting results
- Always consider infant's activity state during test
- Consider whether developmental age is commensurate with chronological age
- Able to exclude all but a mild hearing impairment in the better ear
- In general, true thresholds will be 15-20 dB less than response to noisemaker
- Retest all children referred for BOA (usually with VROA) at 7-9mths, regardless of test outcome
- Refer for ABR/ASSR testing to confirm/enhance results if BOA is failed

BOA

Suggestions for reporting:-

- Record during testing:
 - ear/side of presentation
 - stimulus type: name (be specific) and frequency composition (broadband, low/mid/high frequency)
 - stimulus intensity level
 - observed response (in detail) or lack of response (NR) per presentation of each stimulus
 - additional comments regarding general infant state or test conditions
- Specific BOA Report Considerations:
 - include state of child during test
 - frequency range of stimulus and response levels
 - examples of types of responses observed
 - comment on reliability of test results
 - what can/cannot be excluded in terms of hearing impairment
 - avoid the term 'normal hearing'

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**(viii) Visual reinforcement audiometry testing of
infants**

A recommended test protocol

VRA**(viii) Visual reinforcement audiometry testing of infants*****INTRODUCTION***

This document has been prepared as part of the advice and guidance from the Newborn Hearing Screening Programme (NHSP) in England. Opportunity has been taken to incorporate the latest evidence-based knowledge on this procedure and provide more practical guidance on key issues, particularly around utilisation of the test and interpretation of results.

Visual Reinforcement Audiometry (VRA) is a key behavioural test for young children. It is central to completion of the diagnostic process for those hearing-impaired infants identified by newborn screening. Furthermore, contemporary paediatric amplification fitting methods rely on solid foundations of measurement to ensure the validity and reliability of hearing aid fitting. Also, it is hoped that the standardised VRA technique described here will facilitate training of Audiologists and be of use in research studies.

There were many points of debate relating to set-up and methodology for this test technique. For some features of the technique, it is recognised that alternative approaches exist. However, for the purposes of standardisation a decision to adopt the one described approach has been made. It is advised that only experienced Audiologists (or those led by such colleagues) should consider deviating from this protocol.

SCOPE

The document sets out to provide guidelines for testing babies with a minimum developmental age of 5-7 months. The test is suitable for infants who are able to sit unsupported or with minimal support and who have good head control. It is assumed that the reader of this document is familiar with the principles of VRA. This protocol covers only VRA, including the defining feature of one-sided reinforcement (rather than two-sided reinforcement of the conditioned orientation response test).

The document covers the technical procedure of carrying out a manual VRA test, equipment/environment considerations, basic interpretation of the results, reporting and patient handling procedures relevant to the test.

VRA***FACILITIES & PREPARATION*****Test Environment - Maximum Ambient Noise Levels**

The maximum levels of ambient noise, and reverberation time in the test room should meet the requirements defined in ISO 8253 for testing down to 0 dB HL, relevant to the stimuli and transducers employed. For soundfield and bone conduction testing it is pragmatic to relax the specification so as to permit testing of thresholds down to 10 dB HL. This entails adding 10 dB to the ambient noise values given in ISO8253 for sound field testing. Audiologists using the test facility and reporting on results should be aware of the limitations of the test environment relevant to the stimuli and transducers employed (i.e. the lowest stimuli levels that can be reliably used).

A high quality sound level meter (conforming to type 1 of IEC 60651) should be used to measure ambient noise against those levels specified in ISO 8253-2. It is also important to be aware of the limitations of the sound level meter at low sound levels. For these reasons, centres are advised to commission noise measurement specialists to survey new or modified test facilities.

Note that a simple test is if a person with normal hearing can hear signals of 10dB below the minimum presentation levels.

Test Environment - Other Considerations

The test should be performed in a room which is of adequate size to accommodate parent(s), child and 2 testers comfortably. As a guide, a minimum floor area of 12m² is ideal. Note, this specification assumes that the room is dedicated to VRA testing. More space will be required if the room is multi-use. The room should have adequate ventilation and air conditioning is recommended for patient comfort – babies who are uncomfortable are less likely to respond well to testing. The room should offer minimal visual distraction to the child. It is advised that room lights should be capable of being dimmed, in order to permit enhancement of illuminated visual rewards – this is particularly useful for children who have a visual impairment or who are just distractible.

The preferred arrangement is for control of stimuli and reward to be operated from a second (observation) room. Such an arrangement allows for discreet communication/instructions to the tester controlling the child's attention, reduces the potential for distraction, and allows for optimum (frontal) observation of the child's behavioural responses. The test and observation room should be separated by a one-way window (or alternative arrangements provided, e.g.

VRA

image on a monitor screen) such that the child is not distracted, yet allowing the observer (Tester 1) a clear view of the child. There should also be the facility for the observer to hear sounds made in the room (for appropriate timing of stimulus) - see below.

Where an observation room is not available (e.g. as might be the case at a more basic test centre), another possibility is to use a monitor screen linked to a camera positioned to observe the front of the child. Tester 1 must also be out of view of the child, perhaps behind a screen.

Test Equipment and Set-up

It is recognised that a variety of test room arrangements can be employed for VRA. However, the test protocol described below will be based upon the preferred test equipment and set-up described here. The single speaker and single reinforcement unit arrangement as described is the basis of the test procedure presented below. The arrangement also allows Tester 1 to present live speech to the patient through the sound-field speaker, via a microphone with presentation level controlled by the audiometer intensity attenuator.

The two speaker stimulus presentation level and reinforcement method may also be used if the facility can accommodate this technique it and if the clinician has significant experience to perform the method.

Type of Reinforcement: Illuminated and animated toys

These should be located within a cabinet, obscured by smoked perspex screen such that the toys are not visually attractive without illumination. A switch in the observation room should control animation and bright illumination of the toys. Ideally, at least two independently controllable toys should be provided for of testing. Alternatively, a variety of equivalent video images may be used.

Positioning of Reinforcers

A 90° azimuth (or as close to 90° as possible), with facility to re-position, to reduce the angle if required. A 90° azimuth is used in order to elicit the clearest head turn, while a lesser angle may be appropriate if the child is not developmentally ready for full head turn. The reinforcers should be located approximately level with the child's head at a distance of 1-2m. Facility should exist to move the reinforcers closer to the child if their developmental readiness is uncertain.

VRA**Positioning of Loudspeakers**

A 90° azimuth (RETSPLs are only available for these angles of presentation). The speakers should be positioned at least 1m from the test position. Speakers should be positioned adjacent to reinforcement apparatus and approximately level with the child's head.

Positioning of Child and Tester

A younger infant (eg age 5-12 months) may be seated on the parent's knee, gently supported at the waist and facing forward. Alternatively, the infant may be placed in a secure 'high chair'. An older child can be seated on a low chair, with parent seated on the opposite side to reinforcement, and slightly behind the child. The child should be at a point determined and marked during calibration of the sound field. A low table is placed in front of the child to provide a surface for the distracting activity. Tester 2 is either seated on a low chair or kneels in front of the table facing the child and distracts the child from that position.

Position of Tester in Observation Room

The tester should have a clear view of the child's face and tester 2.

Communication between testers

Good two-way communication between testers is essential requirement for the test. Communication from Tester 1 to Tester 2 should be direct and discreet so as to avoid auditory distractions for the subject for exam.

Hearing Protection

The Control of Noise at Work Regulations (2005) stipulate the daily personal noise exposure levels beyond which hearing protection should be used. If daily noise exposure is above the first action level of 80 dB(A) but below the second action level of 85 dB(A), hearing protection should be available to the employee. If daily noise exposure is beyond the second action level, or if any peak levels exceed 137 dB SPL then hearing protection must be used.

Calculations for a VRA system with a maximum output of 115 dB(A) indicate that the second action level could be exceeded when testing a child with severe or profound hearing loss. As well as this, some of the sound levels used may be uncomfortable and for this reason also hearing protection (muffs and /or plugs) should be available for parents and observers as well as testers. The maximum output at each frequency should be measured and this information used to

VRA

calculate likely noise exposure levels according to Queensland Legislative requirements. This information can be used to specify local hearing protection policy.

¹ An alternative approach is to dispense with Tester 2. This option could be considered if the child is shy and the parent is able to understand the test requirements.

² If a single tester arrangement is adopted, the observation room tester may communicate with the parent via headphones.

STIMULI**Stimulus Type**

Frequency-modulated (warble) tones and/or narrow-band noise should be employed. If the child is unresponsive to one of the above stimulus types use of the alternative should be considered. For insert earphones, pure tones are acoustically acceptable as a stimulus. For inserts used with a child's ear moulds, actual levels will differ from standard calibration.

Stimulus Delivery

There are advantages and disadvantages/limitations related to each method of stimulus delivery, which will not be explored here. However, a comprehensive range of transducers should be available for use (to facilitate comprehensive assessment of hearing losses): supra-aural earphones (e.g. TDH39/49), insert earphones (e.g. EAR3A coupled with immittance tip, foam tip or ear mould), speakers for soundfield presentation and a bone conductor.

Precautions Against Cross-Infection

Local procedures should be adhered to. If insert ear phones are used disposable tips are required. It is recommended that local advice be sought regarding best practices for cross-infection control.

Calibration

Stimuli presented through 'closed circuit' transducers (headphones, bone vibrator or insert-earphones) should be calibrated in accordance with the relevant ISO standards in dB HL or dB SPL (see below). Calibration of stimuli presented in the sound field is less straightforward. Most test environments do not provide the ideal anechoic condition and a number of measures have to be taken to ensure that the sound delivered to the patient's ear is accurate and stable.

Soundfield calibration requires a considerable knowledge of the use and limitations of sound level meters and soundfield acoustics. It is recommended that expert help is sought. The reader is referred to the British Society of Audiology Guidelines for Soundfield Audiometry in Clinical Applications (BSA, 2007) particularly as they relate to use of static systems as employed in VRA.

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Whatever the range of stimuli, a weekly visual examination and listening test should be carried out (Stage A check). Such checks are particularly important for VRA given the variety of stimuli and transducers typically employed and routing of signals between rooms often via additional cable connections. Aside from the requirement for initial and 5-yearly interval full calibration against the standards, an intermediate annual calibration should be carried out, and also when any major changes are made (e.g. to room layout) or changes in external noise levels occur. The BSA guidelines state that the test environment should be clearly documented with a defined layout of furniture, furnishings, equipment and positions for people in the room during testing. It also recommends that marks be provided to floors and ceilings to ensure that layout and positions remain consistent as any deviation may compromise calibration.

TEST PROCEDURE**Preliminaries**

Following equipment checks, parent(s) and child are brought into the room, seated and introductions made. History taking provides an opportunity for the child to settle in an unfamiliar environment and for the audiologist to make some preliminary observations about the child. If the child is becoming restless it may be appropriate to cut the history short and begin testing.

The test procedure is explained to the parent with suitable cautions about cueing the child to the presence of an auditory stimulus, and the need to minimize distracting noise. If a 'Tester 2' is not used, particular attention must be paid to instructions to parents remaining in the test room with the child. Information should be obtained about the child's developmental and visual status before starting the test. However, a two tester procedure is recommended at all times unless in extraordinary circumstances. If there is any doubt about the child's ability to respond in the desired manner (i.e. with a head-turn) this can be discussed with the parent. If necessary, head control and turning can be checked by having the child visually track an object of interest through an arc of 180°.

Any others present are best invited to sit in the observation room (preferred) or directly behind parent and child. The child will be placed in the test position with reference, and care should be taken when positioning parent and child to ensure that soundfield calibration (if relevant) is not compromised. The transducer should be fitted to the child, insert-earphones by clip to clothing on the child's back. The fitting of insert earphones should be preceded by otoscopy or if it is not done this is on the basis of an assessment of risk and benefit for individual subjects. An

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elasticised headband may be used to position the bone conductor in place as a more comfortable alternative to a conventional 'Alice Band'. If the child is resistant to either method of placement the bone conductor could be held in place by the parent. Whatever the means of placement Tester 2 should be alert to ensure that the conductor remains appropriately placed throughout the test procedure.

³ Another frequency may be selected if it is judged that the child is likely to be more responsive, e.g. a lower initial frequency would be appropriate if there is suspicion that the child has a severe high frequency hearing loss. If sounds other than warble tones and narrow-band noise are to be used, a biological calibration will have to be carried out. This is outside the scope of this document.

Procedure for Measurement of Minimum Response Levels (MRLs)**Initiation of Test and Role of Tester 2**

Tester 2 will choose a suitable table-top activity (e.g. playing with small toys). The toys selected and manner employed will be the minimum necessary to encourage the child to adopt a midline forward position and maintain alertness. Importantly, Tester 2 should provide no change in activity linked to stimulus presentation which could serve as a cue for signal presentation (e.g. distinct and rhythmical phasing should be avoided). Tester 2 will avoid noisy play, and refrain from engaging with the child too fully, save for praising a correct response.

Familiarisation/Conditioning

Before testing it is essential to establish conditioning. Some children will give a clear and repeatable head-turn to an auditory stimulus without any formal conditioning while others will require a number of conditioning trials.

The following sequence is suggested:

A 2 kHz³ stimulus is presented at a level judged adequately supra-threshold (as a guide, 60-70 dB HL is suitable for routine purposes, although consideration should be given to the type and degree of hearing impairment anticipated). If the child gives a clear head turn within 2-3 seconds visual reinforcement is provided, in combination with the sound, for a further 2-3 seconds. Conditioning can be considered to be established and the test sequence begins.

If the child does not respond spontaneously with a head turn a more formal conditioning procedure is needed. Initially stimulus and reward are presented simultaneously and if necessary the child's attention directed towards the reward. A number of such paired presentations may be required. When a head turn response is reliably elicited to the combined stimulus conditioning is checked by presenting the auditory signal alone and presenting the visual stimulus as a reward

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after the head turn response. Once the child is responding to sound alone testing can begin. If the child responds to the combined stimulus/reward but fails to demonstrate a response to the stimulus alone it may be that the stimulus is insufficiently interesting or is not audible. This can be checked by changing the stimulus type e.g. to narrow band noise, changing the frequency and/or level of the stimulus and ultimately by using a vibrotactile stimulus (e.g. around 50 dB HL at 500 Hz) generated from the bone conductor with reconditioning using the paired presentation.

If the child is not responding to the stimulus/reward combination it may be that the reward is insufficiently visible or interesting. This may be remedied by lowering the room lighting, changing the reward, using two or more rewards in combination or moving the visual reward closer to the child. Alternatively it may be that the child is not developmentally ready for the procedure or is not sufficiently motivated by the reward in which case other test procedures will be required.

Testing

When conditioning is secure (at least two consecutive correct responses), Tester 1 will proceed to the test trials proper. Here sound only will be presented for 2-3 seconds. If Tester 1 judges that the child has turned in response to the sound, then visual reinforcement will be presented for 1-2 seconds. The desired response is a clear head-turn to view the reinforcer. Eye glances or small movements should be interpreted with more caution and be reported as such.

False 'checking' responses will be managed by using variable inter-trial intervals, some of long duration – additionally, use of deliberate control trials may be employed. Withholding the visual reinforcer for a moment or two after the child turns also may help to distinguish checking glances, which are often short-lived, from real responses.

A '10 dB down, 5 dB up' rule for stimulus presentation should not be rigidly applied through threshold measurement. Once responses have been established to the initial high level, the level should be dropped as rapidly as possible (perhaps 20 dB steps) as long as responses are still observed. Tester 1 should determine presentation level based upon age of the child, attention state, and other factors concerned with time. However, around the estimated threshold a '10 dB down, 5 dB up rule' should be adopted. The criteria for threshold will be 2 out of 3 responses at any level. The minimum response level at one frequency should be defined before moving to another frequency where possible.

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The initial and subsequent test frequency will vary for each patient according to information obtained by previous methods and the need for further information. When changing stimulus frequency, present the initial stimulus at a level judged to be above threshold. It may also be helpful to present clear supra-threshold stimuli or re-condition a child who has become distracted. For a child who is restless or bored, it may be possible to maintain/restore interest by: using a combination of warble tones and narrow-band noise; randomly changing frequency; and increasing or varying the visual reward (e.g. changing toys or multiple toys).

It may be useful to measure speech detection thresholds using live speech, in order to provide some validation of the information obtained from electronically generated stimuli. Tester 1 should talk to the child through the sound-field speakers, using their name frequently, while slowly raising the level from around 20 dB(A) (using the audiometer intensity attenuator), until a response is seen. The recorded level, in dB(A), can be compared with the average minimum response level for the child.

For soundfield VRA, once thresholds have been defined at the required frequencies, the child's localisation ability for narrow band noise or voice (supra-threshold, up to 30 dB above the minimal response level) may be assessed, using both low and high frequency narrow-band noise. It may be necessary to recondition the child using loudspeakers on both sides. Difficulty with localisation may indicate an asymmetric hearing impairment and warrant testing each ear individually with insert earphones.

The selection of transducer to use will not be covered in depth in this protocol - as with selection of frequencies for testing, this will depend upon the profile of information previously obtained on the child and that required for further management. However, use of insert earphones is strongly preferred for those suspected or known to have a permanent hearing loss, in order to obtain reliable ear-specific information.

Tips for Effective VRA Testing

- The procedure relies on continued cooperation of the child, in particular their ability to stay in the required test position – time will therefore be limited. To avoid delay/disruptions ensure that all required equipment is checked in advance (stage A calibration checks are completed, reward system operating and communications equipment ready for immediate use).

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- Some children may be upset by certain animated toys. If so, reward through simple illumination rather than animation or switch to alternative toys.
- To extend interest in responding, switch reward toys and/or use in combination. Also be prepared to take a break from testing and return to complete the assessment, or switch testers. The interest of older children in particular may be extended by praise/encouragement of correct head turn, provided by Tester 2.
- Towards the end of the test procedure, return to the first frequency tested and present at MRL (or 5 dB above that dial level) - does the child still respond? This information will help the tester judge validity of later responses.

The Most Common Pitfalls of VRA Testing

- Inadequate test set-up and communication between testers.
- Attempting conditioning to sub-threshold stimuli.
- Not establishing clear responses at supra-threshold levels before descending to threshold.
- Incorrect scoring as true responses i.e. scoring of movement other than a clear head-turn, or false positive (checking) responses.
- Distinct and/or rhythmical phasing of attention by Tester 2 such that response cues are given to the patient.
- Use of toys or behaviour by Tester 2 (or parent), that are too distracting for the child and so inhibit responses.
- Overemphasis on quantity of results (number of thresholds obtained) rather than quality (reliability) of those thresholds obtained.
- Not using time efficiently, often spending too long at high intensities.
- Inaccurate interpretation and reporting of results due to inadequate consideration of differences in infant MRLs compared to adult normative (threshold) values (see below).

Testing Children with Vision Disorders, with other Disabilities or at an Early Age.

Visual disability may interfere with conditioning and responses. Consider bringing the reward closer to the child. Alternatively use of more visually contrasting rewards (e.g. bright flashing light), or removal of the smoked perspex cover to the reinforcer unit should be considered. Dimming the room lights will also increase the contrast. For the more severely visually impaired, use of other sensory reinforcement such as air puffs, vibratory stimulation or music may be needed to bring children under stimulus control.

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General developmental delay may not interfere with VRA. However, motor difficulties may obscure head-turn responses. A more flexible approach to response reward and interpretation may be appropriate. However, any deviations from the standard approach should be described when reporting.

Although VRA is generally reliable in assessment of normally developing children from age 30 weeks (corrected age), some infants may be testable at younger ages, from age approximately 20-26 weeks. Testing at this age may be required because of parental or professional concern and of particular value to early diagnosis and habilitation. However, for younger children it should be recognised that a sequence of test appointments may be required to incrementally gain the information required (e.g. a series of frequency and ear specific MRLs).

For children with disabilities or where VRA is used speculatively at an early age, a realistic appraisal of the likelihood of test success should be presented to parents/carers before testing. Testers should also seek the advice of parents/carers in advance of assessment to determine the appropriate test strategy. For more detailed information on conducting VRA for children with disabilities, clinicians are advised to refer to Coninx & Lancioni (1995).

Sequence and Objectives of Assessment

The sequence of assessment should be adapted depending on the objectives of the Audiologist and the status of the child. However, the testers must be aware that the cooperation/interest of the child may fail at any time and this should be reflected in the sequence of assessment – the clinically more important information should be obtained first. As a guide the following sequences are suggested for an initial formal behavioural assessment commencing with stimuli presented in the soundfield:

2 kHz → 500 Hz → 4 kHz → 1 kHz or

1 kHz → 4 kHz → 500 Hz → 2 kHz

Soundfield testing could be followed by delivery of stimuli through insert earphones where ear specific information will be of use (e.g. where the possibility of significant asymmetry is indicated by the history) or where results will be used to guide amplification. Likewise BC testing may be indicated, albeit with awareness of increased likelihood of vibrotactile responses at the lower frequencies compared to adults. If ear-specific thresholds are desired and use of insert

VRA

earphones is contra-indicated (e.g. due to wax) use of a hand held single TDH earphones could be considered.

The timescale for acquisition of MRLs should be considered carefully. On the basis that quality of results takes prominence over quantity (of MRLs) consideration should be given to arranging a sequence of appointments particularly where a large quantity of information is required and/or where the child is only just at sufficient developmental age or has relevant disabilities. A duration of 30 minutes would be typical for an assessment appointment that included soundfield VRA.

INTERPRETATION OF RESULTS

The process described above provides calibration to adult norms for a conventional audiometric technique. There are no specific international standards on the RETSPL values for stimuli used for VRA. Audiologists should be mindful of the influence of age of subject and the test method employed when interpreting and reporting results. Consideration should also be given to the use of MRL information, whether to inform others (e.g. ENT medical colleagues) of hearing status or for use by the Audiologist to guide effective amplification to a prescriptive target.

There are numerous factors contributing to the known difference between infant VRA MRLs and adult normative thresholds. These include sensory and non-sensory factors (including ear canal size) and other factors such as the effects of subject generated noise. The effect of these contributory elements is complex and not fully understood. However, the sum of these effects is that normally hearing infants performing VRA require a higher intensity stimulus to induce a response (e.g. a head turn) than that required for normally hearing adults performing pure tone audiometry. Although some studies have investigated and reported on the difference between MRLs obtained by VRA in infants and adult threshold normative data, the data set (relating to test frequency, age of subject and type of transducer) is far from complete. Further studies are required to confirm and build upon this knowledge base before we can endorse a series of specific correction factors for VRA (as is the case for Auditory Brainstem Response testing of newborn babies – see relevant NHSP guidelines). With due consideration of the above, the materials presented below (and in the references) represent current information on the scale of infant-adult correction factors based upon the mode of stimulus delivery, stimulus type and age. Consequently, the correction values indicated are provisional at this time.

VRA**Soundfield**

Information available on the relationship between adult thresholds and MRLs for soundfield VRA test indicates that normally hearing infants (ages 7-12 months) present mean thresholds at approximately +10dB relative to the adult normative RETSPLs (from 0.5 kHz to 4 kHz). A child responding at say 45 dB HL might therefore be considered to have equivalent hearing to an adult responding at 35 dB HL. The BSA descriptors for results of pure tone audiometry define thresholds at ≤ 15 dB HL as being within normal limits (based upon the adult normative scale). **Therefore, it is provisionally suggested that when testing by VRA in the soundfield, hearing should be tested down to at least 25 dB HL (equivalent to adult 15 dBHL) and that responses at this level are accepted as indicative of hearing within normal limits. Such guidance should not discourage testing down to lower levels subject to the ambient noise limitations of the test environment.** Those interpreting and reporting results should be mindful that sound field assessment only indicates the hearing status of the better hearing ear at each test frequency. If a hearing loss is suspected then testing with insert headphones and a bone conductor should be pursued.

Insert Earphones

For insert earphones the frequency specific correction factors are equivalent to the MRLs measured in studies on normally-hearing children, examples of which are presented in Table 1. The Parry et al study employed a VRA protocol similar to that described here and was conducted on 8-12 month old infants.

Table 1. Comparison of infant MRLs in dB HL between insert earphone VRA studies.

Reported Studies	Infant MRLs dB HL (std.dev.)			
	500Hz	1kHz	2 kHz	4 kHz
Nozza (1995)	14.8			
Nozza & Henson (1999)		17.2		6.8
Parry et al (2002)	16.4 (5.9)	13.3 (6.1)	7.1 (5.5)	6.4 (6.2)
RECOMMENDED PROVISIONAL VALUE (SUBTRACT)	15	15	5	5

VRA

The normative values presented above may be used as correction factors to convert MRLs into values that are more comparable to an adult audiogram, say for interpretation by medical colleagues. Correction of raw MRLs achieved by insert earphone VRA may also be appropriate when estimating the audiometric profile, required when using prescription formulae to fit hearing aids.

Bone Conduction

No studies have been identified relating to bone conduction VRA MRLs.

REPORTING OF RESULTS

Reporting of results should be clearly accompanied by a description of the type of transducer, the dB scale used, and the reliability of assessment. Where recorded results represent the MRLs (dial settings) this should be indicated. Similarly, the nature of any MRL threshold corrections applied (to guide interpretation or to provide an estimated audiogram for the purpose of prescription for amplification) should be indicated. The Audiologist leading the VRA procedure should be responsible for ensuring that results are appropriately documented and reported upon.

Finally, guidance on the matter of MRL to adult threshold corrections may change with the outcome of further research. The use of this (standardised) VRA protocol in further research studies around VRA MRLs is encouraged in order to facilitate future transferability of findings.

STAFF TRAINING AND EXPERTISE

Staff engaged in performing VRA testing should have received specific training associated with documented assessment to demonstrate their competency to perform this test. The level of competency should be at least adequate for the role performed (whether supporting or leading the assessment). Those leading the assessment should be competent in briefing/debriefing carers, use of the equipment deployed, and the correct interpretation of results to ensure appropriate recording/reporting of results for use by oneself and others. To ensure correct reporting of results for interpretation by others, it is particularly important that the difference between MRLs obtained by VRA and adult normative thresholds are recognised and understood.

QUICK GUIDE: RECOMMENDED PARAMETERS AND SETTINGS FOR VRA

VRA

Position of Reinforcers	90° azimuth
Positioning of Loudspeakers	90° azimuth At least 1m from the test position and approximately level with the child's head.
Stimulus type	Free Field – Warble tones and/or narrow band noise Other transducers – Pure tones
Suggested order of stimulus delivery	2 kHz → 500 Hz → 4 kHz → 1 kHz or 1 kHz → 4 kHz → 500 Hz → 2 kHz

GLOSSARY

Azimuth Direction of a sound source measured in angular degrees in a horizontal plane in relationship to the listener; e.g. 0° azimuth is directly in front of the listener, 180° is directly behind.

MRL Minimum Response Level – the lowest level to which a child will respond behaviourally to sound.

NHSP Newborn Hearing Screening Programme (England)

RETSPL Reference equivalent threshold sound pressure level

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CASE HISTORY

SAMPLE QUESTIONS

1. Presenting problem:-

Previous Examinations and evaluations:

Parent's thoughts on baby's hearing:

2. Pre-Natal History:-

Exposure to viral diseases during pregnancy:-

Which Virus?

At what month of pregnancy?

Exposure to drugs during pregnancy:-

Which Drugs?

At what month of pregnancy?

Exposure to trauma during pregnancy:-

Nature of trauma:-

At what month of pregnancy?

3. Birth Event:-

Delivery:-

Gestational Age at birth:-

Birth weight:-

APGAR Scores: - @ 1 Minute, @ 5 Minutes

Jaundiced?

Maximum SBR

Asphyxia?

Meningitis?

Other Issues?

4. Family History:-

History of hearing loss in a close family member (parent, grandparent or sibling)?

Kidney disease in either family?

Thyroid problems in either family?

Progressive blindness in either family?

History of previous stillbirth or miscarriages?

History of birth defects or abnormalities in either family?

Other issues?

5. Maternal Factors:-

Drugs or medications used during pregnancy:-

Name / usage

Exposure to chemicals during pregnancy:-

Amniocentesis:-

Rh immunoglobulin given?

Rh or ABO incompatibility?

Maternal illness during pregnancy?

Bleeding

Anaemia

Diabetes

Toxaemia

During pregnancy, was mother exposed to:-

Measles?

Mumps?

Chickenpox?

German Measles (Rubella)?

Has mother been diagnosed with:-

Syphilis?

Herpes virus?

Influenza (during pregnancy)?

Cytomegalovirus (CMV)?

Toxoplasmosis?

Other:-

6. Neonatal Risk Factors:-

Birth weight < 1500 gm

Low APGAR

SCN > 48 hrs

Extended Oxygen

High SBR (> ...)

CMV titre > ...

Congenital Rubella

Defect of ear, nose or throat

Congenital heart disease

Extended drug therapy

Exposure to chemicals

SUMMARY CRITERIA FOR DISCHARGE FROM THE HEALTHY HEARING PROGRAM

Children with functionally normal hearing must have the following performed prior to discharge;

(i) Normal hearing:

- Case history.
- Otoscopic Examination bilaterally.
- Click Evoked ABR:
 - Repeatable wave V responses down to 30dBnHL bilaterally.
 - Clearly identifiable I, III and V at suprathreshold levels bilaterally.
 - Normal wave V latency-intensity function bilaterally.
- 1 and 4 kHz Assessment:
 - Repeatable wave V responses down to 30 dBnHL bilaterally on tone burst ABR, or;
 - ASSR threshold down to 40dB bilaterally (which corrects to 30 dB), or;
 - TEOAEs present bilaterally including a response at 1/1.5 and 4 kHz.
- High Frequency Tympanometry (1000Hz probe tone):
 - Repeatable peak with normal middle ear pressure bilaterally.

If all of the above are met, and there are no **High Risk Indicators** identified in the child's history, then the child must be discharged from the Healthy Hearing Program.

If all of the above criteria are met, and the child has identified **High Risk Indicators**, then they are placed on “**Surveillance**” – see Surveillance Protocol.

If child has “functionally normal” thresholds on ABR/ASSR/TEOAEs bilaterally, but some conductive element appears present (i.e. tympanometry results are abnormal only), the child is discharged into the care of their GP and follow up only occurs if parental/doctor concerns arise.

(ii) Sensorineural Hearing Loss:

If the child continues to show a loss, either unilaterally or bilaterally, full diagnostic work-up is immediately commenced and continued until degree and type of loss are ascertained for both ears. A hearing loss must be confirmed with a second appointment. **No child should be referred on or discharged from the program until a diagnosis is confirmed with a minimum of a second click evoked ABR.** The repeat ABR is imperative for reasons such as neuromaturation and Hypoxic Ischaemic Encephalopathy, whereby thresholds have shown improvement over time.

Children suspected of having a sensorineural hearing impairment have the following assessments, at a minimum, performed prior to discharge;

- Case history
- Otoscopic examination bilaterally
- Click Evoked ABR:
 - Repeatable wave V responses down to threshold.
 - Clearly identifiable I, III and V at suprathreshold levels bilaterally (if possible).
 - A repeat ABR to confirm the loss (to be performed as soon as possible).
- Bone Conduction ABR
- Frequency Specific Assessment (500Hz, 1000Hz, 2000Hz and 4000Hz) including:
 - Tone burst ABR, or;
 - ASSR, and;
 - TEOAEs absent bilaterally.
- High Frequency Tympanometry (1000Hz probe tone):
 - Repeatable peak with normal middle ear pressure bilaterally.

Be sure to consider the possibility of delayed auditory neuromaturation and auditory neuropathy in this population– see Auditory Neuropathy Protocol.

While every attempt should be made to have testing complete prior to the referral to AH, it is recognised that some testing may not be able to be completed in a time frame that would not significantly delay hearing aid fitting. Some conditions negate the possibility of obtaining information across the full frequency spectrum (eg a poorly sleeping baby). Additional appointments should be made until as much frequency specific information can be gained to assist hearing aid fitting. If this is not possible for any reason, the clinician must document why deviation from Protocol has occurred. Where all results cannot be obtained immediately, the aim is to provide as much information as feasible to the AH audiologist to allow hearing aid fitting to occur as soon as possible. The following information is highly desired by Australian Hearing (AH);

- Case history
- Otoscopic examination information
- Click-evoked air conduction ABR results (first assessment and confirmation assessment)
- Click-evoked bone conduction ABR results
- ASSR / Tone burst ABR results
- High Frequency Tympanometry (1000Hz probe tone) measures
- Acoustic reflexes (ear specific) measures
- Transient Evoked Otoacoustic Emissions Testing
- Behavioural Orientation Audiometry results (if possible)

In obtaining frequency specific information, 1 and 4 kHz are considered priority, followed by 500Hz and finally 2000Hz. These frequencies are in the most important order required for the Australian Hearing Audiologists to guide the fitting of hearing aids in neonates and young babies.

Please note: If ASSR testing is performed, the Audiologists at AH require both the “Estimated Audiogram” as well as the “ASSR Thresholds Audiogram” for the purposes of hearing aid fitting.

It is the responsibility of the diagnostic audiologist testing the child to ensure that AH has the ASSR results in both formats.

(iii) Conductive Hearing Loss:

If the loss appears to be conductive, reassessment is arranged to occur within 6 to 8 weeks of the child’s first assessment.

If a conductive hearing loss is identified, a report is sent to the patient’s GP advising of the result and any recommendations. An ENT referral is recommended if the identified conductive involvement is worse than mild or is likely to be permanent (eg. CHARGE syndrome, craniofacial abnormalities). Furthermore, referral to Australian Hearing may be considered particularly when the hearing impairment is likely to extend over a 6 month period.

Children suspected of having a prolonged or permanent conductive hearing impairment must have the same assessments performed prior to discharge as per sensorineural hearing impairments.

REPORTING

Reporting results from Diagnostic and Surveillance assessments are considered high priority. Reports for assessments should be aimed to be completed and distributed within 2 weeks of having conducted the initial assessment. This may vary should a child return for assessment within that time frame.

Provision of Reports

Recognising that each service requirements vary, the following are a minimum for reporting;

Copies of reports are to be sent to:

1. The team leader of the Healthy Hearing Screening Hospital
2. The family’s General Practitioner and/or paediatrician
4. The assessing Audiology department/service
5. The Queensland Hearing Loss Family Support Facilitator
6. Other as requested by parent (eg. Paediatrician, AVT etc)

7. If a loss is diagnosed, copies of all reports are also to be sent to Australian Hearing, and the ENT surgeon if the parent elects to seek private ENT consultation.
8. Parents

Example Report/ Assessment Summary

To be developed prior to future review and in conjunction with eSP system capacity.

GUIDE TO DIAGNOSING A SIGNIFICANT HEARING IMPAIRMENT (PERMANENT / CHRONIC HEARING LOSS)

Aims

1. To allow consistency of information and clinical pathways offered to parents of children diagnosed with a significant permanent hearing impairment.
2. To provide effective, consistent and timely informational counselling to parents of children diagnosed with a significant permanent hearing impairment.
3. To establish networks with other allied health professionals in order to best identify and meet parent and child need.

Process

If a hearing impairment is suspected following the initial appointment, follow up appointments are made to further investigate and confirm the impairment and obtain necessary site of lesion information. At the time of diagnosis and confirmation of the impairment, the following information is to be consistently provided by the audiologist:

- Information about the degree of hearing impairment and implications of hearing impairment.
- Information regarding the nature of hearing impairment and best possible indications as to whether it is permanent.
- Information about the need for a series of events to be planned in the short term in order to assist the child to access sound for speech and language development.
- Acknowledgment to parents that it is a stressful time and that it is normal for families at such times of crisis not to remember all the information presented and that there will be other opportunities to talk and written information will be provided.
- Parents are to be advised that an urgent appointment (within two weeks for bilateral losses) will be recommended for their child to see an Ear, Nose and Throat Specialist (ENT). The audiologist will clarify whether the family wishes to continue to use public ENT services or access ENT services privately. The audiologist should remain in contact with the family to ensure progression to required medical services (see “fail to attend” section for further information).
- A further audiology appointment (in person or by phone) will occur on the same day or subsequent to the ENT appointment, **if appropriate**, to further discuss issues associated with the hearing loss and address any other questions that may have arisen. Wherever possible this appointment will be with the same audiologist who made the original diagnosis.
- The diagnosing audiologist will also contact the Queensland Hearing Loss Family Support Facilitator to assist families (should they have previously provided consent) through this stage of diagnosis and to

guide the family through communication options and Australian Hearing appointments. Families not already receiving support from the QHLFSF service will be referred, should they consent.

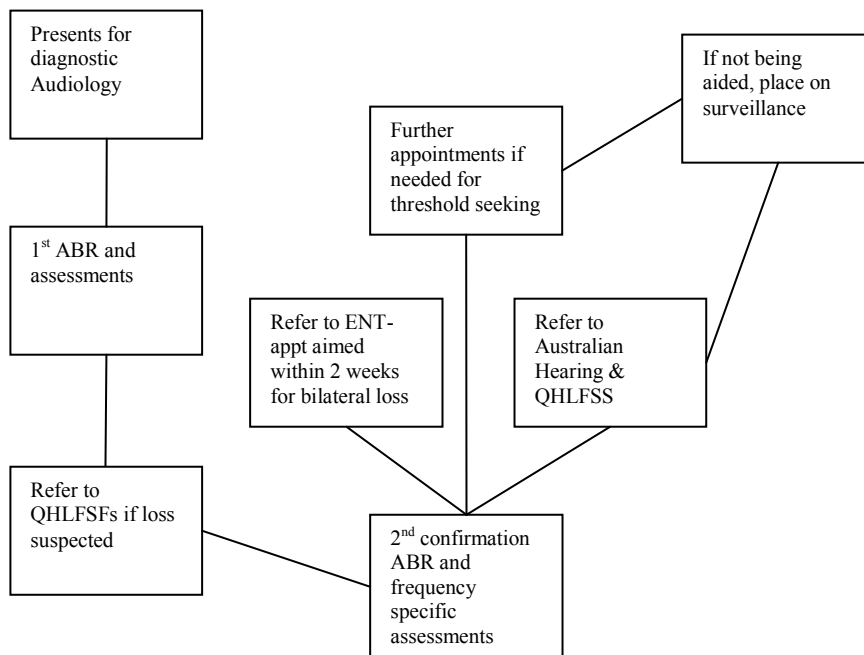
- Written information is to be provided to the families. Timing of the provision of the “Possibilities” pack should be negotiated with the QHLFSS if they are involved. Other Healthy Hearing material such as DVDs should also be given at the appropriate time.
- Parents are to be encouraged to write down questions to ask the Audiologist prior to the next appointment.
- Parents are to be encouraged to phone the Audiology Department with urgent concerns.
- **NOTE: Siblings of children diagnosed with PCHI without a specifically identifiable and known cause should also be audiotologically assessed.** It is also worthwhile offering hearing assessments to the parents of the newly diagnosed child. These assessments should be negotiated through Australian Hearing or the diagnosing clinic with referrals arranged as appropriate (i.e. requested from GP). Family hearing tests are an important part of the medical guidelines for investigating hearing loss, and the successful completion of these tests should be monitored.

Checklist prior to the confirmation (second ABR) appointment

- Contact the QHLFSFs and inform them of the impending diagnosis and of the need for them to contact the family.

Following the confirmation appointment the Audiologist is to:

- Obtain an urgent ENT appointment for the child (within 2 weeks for bilateral losses). Prior to arranging the ENT consult, it is the audiologist’s responsibility to ensure that adequate audiological information has been obtained to assist in guiding the appropriate management for the child (as outlined in the previous table).
- Make phone contact with parents within 5 days following diagnosis to monitor response of parents and confirm appointment times. Contact is to be documented in the patient’s chart.
- Liaise with Australian Hearing to facilitate the transition of the child to their service for hearing aid fitting.
- Ensure all results have been forwarded to the relevant agencies (eg. Australian Hearing, AVTs, referral source).

PATHWAY FOR DIAGNOSIS OF PERMANENT HEARING IMPAIRMENT- Diagnostic refers:**RECOMMENDED PRACTICES**

Reference: “Working with Children with Development Disorders – A Life Course Perspective”

(Presented by: Child Development Program, 15th November 2002)

Best practice in breaking news to parents of children with impairments involves consideration of the setting and structural procedures of the appointment, affective aspects of the Audiologist in breaking news and the content necessary in any information provided. The following are imperative in breaking news effectively to families;

Setting or Structural Procedures

- Give news soon after completion of assessment
- Give news in person
- Both parents are preferably present or alternatively a support person is present.

- Remember that the family have a right to privacy. Including a quiet room free from interruptions, unhurried and sufficient time from the Audiologist, and a limited number of professionals within the room.
- Have a colleague present to interpret information differently and to provide support.
- Facilitate a follow up interview in short space of time (eg within 2 days).
- Provide written information.
- Be available for parents that may require repeated opportunities to discuss child/information.
- Offer contacts with support groups.

Affective Aspects

- Communication of hope is important.
- Characteristics of the Audiologist should include; warmth, interest, tolerance of expression of emotion, patience, tolerance of non acceptance of information and a respectful attitude.

Content of Information

- Information should be clear and direct – what is known, what is not known.
- Language is simple and non technical.
- Labels should be applied thoughtfully.
- Information should be given at the parents' pace.
- Acknowledgment and discussion of parental reaction should occur eg. "How does that make you feel?"
- Consider the direction of the interview and evaluate the appointment afterwards.
- Continue to provide a supportive relationship.
- Check with parents "Have I explained this well enough".

ROLE OF THE MULTI-DISCIPLINARY TEAM

Although there will be some overlap in the communication which occurs with the family by different professionals, it is important that professionals only provide information directly relevant to their own area of expertise.

Given the level of stress facing families in this situation consistency and clarity is important in the messages they receive.

It is critical that any questions asked of a professional that are outside their domain are referred back to the relevant professional. This can be achieved in two ways:

1. By suggesting the parent ask the relevant professional directly and;
2. By professionals informing the relevant other professional of the questions they were asked, so that direct follow up with the family can occur by the correct professional.

ROLE OF THE AUDIOLOGIST

- Determine the degree and nature of the hearing impairment.
- Provide informational counselling to the child/parents regarding all relevant aspects of hearing impairment.
- Discuss communication options with the family.
- Discuss educational options for children with hearing impairment (this will also be done by Australian Hearing at the time of hearing aid fitting and a copy of “Choices” will be provided).
- Provide written information regarding the above details.
- Arrange ENT consultation at the time of confirmation of the hearing loss.
- Liaise with Australian Hearing to facilitate the provision of hearing aids / amplification as appropriate.
- Ensure that families are referred to a rehabilitation pathway.

ROLE OF THE QUEENSLAND HEARING LOSS FAMILY SUPPORT FACILITATOR:

- To support the family through the time of initial diagnosis of the hearing loss by providing counselling support, assessing the families support networks and if required making referrals to community agencies for ongoing support and or assistance.
- Ensure that Families are accessing a rehabilitation pathway.

HANDLING OF PATIENT FAILURE TO ATTEND AND DECLINE OF SERVICE**Failure to attend resulting in direct decline of service;**

If a family fails to attend a diagnostic audiology appointment every effort should be made to discuss the urgency of the appointment and to encourage the family to reschedule the appointment. Implications regarding the negative impact of an undiagnosed hearing impairment on speech and language development should be thoroughly discussed. The family may choose (and has the right to choose), to decline the appointment despite a refer from screening and subsequent discussions with an Audiologist. If a family declines service a letter advising the decline of the service should be sent to:-

- The family
- Their family’s general practitioner
- The Healthy Hearing screening site

The letter should contain information advising the family that their baby is discharged from the Healthy Hearing Program, implications of an undiagnosed hearing impairment and that the baby will require a GP referral for a hearing assessment at a later date.

If a family attends a preliminary diagnostic appointment and a hearing loss is suspected and the family then fails to attend the confirmation appointment every effort should be made to discuss the urgency of the appointment and to encourage the family to reschedule the appointment. Implications regarding the negative

impact of a permanent hearing impairment on speech and language development should be thoroughly discussed. If the loss is unilateral and normal speech and language development is likely a letter should be sent to the family, their general practitioner and the Healthy Hearing screening site advising them of the decline of service despite a suspected permanent unilateral hearing impairment. The letter should contain information advising the family that their baby is discharged from the Healthy Hearing Program, implications of a suspected unilateral hearing impairment, and that the baby will require a GP referral for a hearing assessment at a later date.

For families who decline an appointment and their baby is suspected of having a bilateral hearing impairment, every effort should be made to discuss the urgency of the appointment and to encourage the family to reschedule the appointment. Implications regarding the negative impact of a permanent hearing impairment on speech and language development should be thoroughly discussed. The GP and the QHLFSF should be contacted in person to discuss the possibility of encouraging and supporting the family to attend the appointment. Failing all attempts to reschedule the appointment, the Child Advocacy Service should be contacted and a report lodged. A suspected permanent bilateral hearing impairment will potentially significantly affect the child's speech and language development and access to communication. Every child has the right to access a form of communication and as such referral to CAS is imperative.

Failure to attend and unable to contact;

Three consecutive points of contact should be made with the family. This should occur by phone, mail and/or through the alternative contact listed. Each point of contact should be documented. Following no response from a third point of contact the patient should be discharged from the Healthy Hearing program. A letter should be sent to the family, their general practitioner and the Healthy Hearing screening site advising them of the decline of service. The letter should contain information advising the family that their baby is discharged from the Healthy Hearing Program, implications of an undiagnosed hearing impairment and that the baby will require a GP referral for a hearing assessment at a later date

SURVEILLANCE REFERRALS- MINIMUM TEST BATTERY FOR SURVEILLANCE

- Children referred for surveillance are seen for their first assessment after screening between 3 and 12 months of age, depending upon the risk factors for each child.
- Refer to HH Surveillance Pathway on following page for protocol information

The minimum requirements, prior to discharge, for assessing a baby referred for surveillance includes normal results, for both ears, on the following assessments;

- (i) VRA or play audiometry
- (ii) TEOAEs
- (iii) Tympanometry (High Probe Tone- 1000Hz, if under 6 months of age)

Additional testing using alternate assessments may be performed at the clinician's discretion.

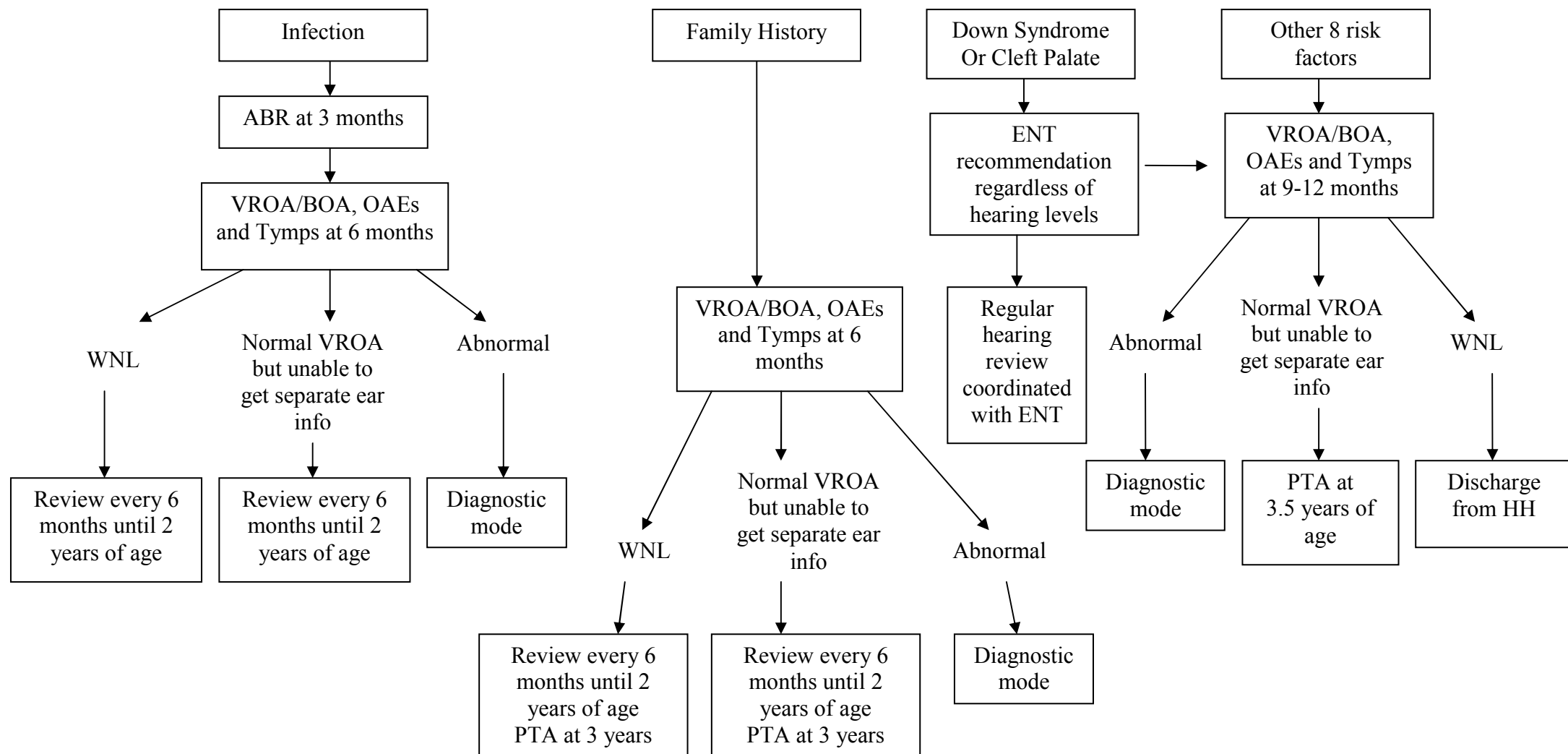
In terms of the aspects of diagnosis of permanent hearing impairment, reporting, referral and the handling of failures to attend appointments the procedures outlined in the above sections apply for children under surveillance. In addition, the following form should be completed and returned to Healthy Hearing.

NB: Children with a diagnosed unilateral hearing impairment should remain on annual review.

Children diagnosed with conductive hearing impairment should be re-tested in 6-8 weeks. Should a second test reveal continued middle ear involvement, the GP is to be advised that ENT referral is recommended. The outcome of this recommendation should be followed up. The decision to refer to Australian Hearing for rehabilitation should occur with any prolonged period of impairment (unilateral or bilaterally), particularly if the child is pre-lingual.

If a child with ongoing middle ear dysfunction returns for assessment following consultation with ENT or Australian Hearing (as appropriate), a new session of tests is opened for this child in the Healthy Hearing eSP database.

PATHWAY FOR SURVEILLANCE REFERS:



Monitoring the Risk of Progressive Hearing Loss:

Children who present with the following medical diagnoses or histories should be monitored for change in hearing sensitivity. Histories known to be associated with progressive hearing loss include:

1. Family history (parents or siblings with significant permanent hearing loss)
2. Congenital Infections:
 - Syphilis
 - Toxoplasmosis
 - Cytomegalovirus (CMV)
 - Herpes (HSV)
 - Rubella
3. Meningitis
4. Cochlear Aplasias:
 - Michel aplasia
 - Mondinis aplasia
 - Scheie aplasia
5. Syndromes associated with hearing loss:
 - Down's syndrome
 - Pierre-Robin syndrome
 - Treachery Collins syndrome
 - Noonan's Syndrome
 - Wartenberg syndrome
 - Oculo-Auriculo-Vertebrali (OAV) Spectrum
 - Branchio-oto-renal syndrome
 - Osteogenesis imperfecta
 - Pendred syndrome
 - Usher syndrome
 - Stickler syndrome
 - CHARGE Association
 - Morning Glory Syndrome
6. Craniofacial anomalies:
 - Cleft palate
 - Hemifacial microsomia
7. Neurofibromatosis type II
8. Mitochondrial disorders

Healthy Hearing Report of PCHI not identified by the newborn hearing screen

SUMMARY

This form is for use in initial reporting of false negative cases and other babies with confirmed PCHI of any degree not identified by the newborn hearing screen. The form should be completed by the audiologist and faxed to the Healthy Hearing Program team. Separate consent is required from a parent before returning this form to the Healthy Hearing Program.

1. Identifiers

Site name	
Patient UR	
d.o.b.	
Birth Hospital	
Screening protocol	Well baby/community/nicu*

*delete as appropriate

2. Contact details for reporting clinician

Name	
Designation	
Address 1	
Address 2	
Address 3	
Telephone	
E mail	

3. Screening information. Please list the results of each and every test and supply a copy of the Healthy Hearing referral form.

Test	Right ear		Left ear	
	date	result	date	result

4. Referral details. Please complete the following details in respect of the referral that led to the identification of hearing loss

Referral date	
Referral source e.g. GP, parent,	
Referral reason	

5. Identification and confirmation of hearing loss (this section may be omitted if the information has already been entered into eSP). Please supply a copy of the assessment report.

Date of 1 st audiological assessment	
Date of confirmation of hearing loss	
Right ear: degree and type of loss	
Left ear: degree and type of loss	

6. Management of hearing loss (this section may be omitted if the information has already been entered into eSP)

Date decision to aid	
Date of aiding-right ear	
Date of aiding-left ear	
Date referral to AH	

7. Clinical history. Please summarise the relevant clinical history including details of any risk factors and aetiological investigations. Include information about the parents’ opinion about the duration/onset of the hearing loss.

8. Category of hearing loss. If possible, please indicate, by circling the appropriate option, the category of hearing loss for each ear:-

Right	Left
Congenital	Congenital
Acquired-post meningitis	Acquired-post meningitis
Acquired-other	Acquired-other
Probable/possible late onset	Probable/possible late onset
Probable/possible progressive	Probable/possible progressive
Other-describe	Other-describe
Not applicable	Not applicable

9. Any other comments/relevant information

Please copy this form and send to Healthy Hearing, and place original on the patient’s file.

Appendix A

Check list for daily and monthly function check of auditory brainstem response systems

(Stage A check)

Appendix A

Check list for daily and monthly function check of auditory brainstem response systems

(Stage A check)

(Based on B700/701, BS EN ISO 8253-1:1998)

1. Clean equipment and examine for damage or wear.
Check headphones, bone conductor, insert earphones and leads for signs of damage.
2. * Switch on & adjust according to handbook.
3. * Earphone serial numbers or marking tally with equipment.
4. * Check battery state, if appropriate.
5. * Electrode impedance test correct with dummy load.
6. *# Threshold levels of stimuli to be used are subjectively correct for:
 - a) Air conduction (For all transducers used)
 - b) Bone conduction
- 7.* High level (max 80dBnHL) listening test with stimuli to be used satisfactory by:-
 - a) Air conduction (For all transducers used)
 - b) Bone conduction
 - c) Masking (including insert)
8. Attenuator sweep subjectively satisfactory.
9. Noise, hum and break-through levels are adequately low.
10. Radiated noise from instrument is acceptable at the patient's position.
11. Headbands are in good condition and tensions subjectively correct.
12. Amplifier: select calibration mode (or loop test mode), run test and check averaged waveform is of expected amplitude and morphology.
13. Connect amplifier inputs together, run test and check that the noise floor meets equipment specifications.
14. Check test parameters against the relevant departmental / NHSP protocol
- 15.* Reset all controls to normal operating positions for commencement of patient testing.

** Tests marked with an asterisk are recommended for checking at the start of a session when the equipment is used; other checks may be performed at monthly intervals. Additionally, it is vital that all checks are conducted prior to and following objective calibration and whenever the user has reason to question the correct function or adjustment of the system.*

Threshold levels may be tested at the rate employed in the ABR test but note that in theory, these levels are correct only when a rate of 20/s is used in a subjective listening check. If the stimuli appear too loud, repeat the check at a rate of 20/s.

Ongoing vigilance: Whenever an elevated ABR threshold is recorded, check that the stimulus is being delivered at the expected level; Monitor waveforms recorded in babies with normal ABR thresholds and report / investigate any unexpected artefacts.