

Guidelines for Fitting Hearing Aids to Young Infants

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Main changes from the previous version

1. The guidelines have been re-written to give greater detail and improved clarity.
2. The information given on programming advanced features has been updated.
3. More detailed guidance on the use of ABR thresholds in hearing aid prescription has been included.
4. Specific advice on verification when using the Aurical REM system has been removed as this is no longer applicable.

Introduction

5 These guidelines summarize the steps involved in the fitting of air conduction hearing aids to very young infants with permanent childhood hearing impairment (PCHI) identified through newborn hearing screening. They build on the Modernising Children's Hearing Aid Services (MCHAS) guidelines for children's hearing aid services, and should be read in conjunction with the MCHAS guidelines¹ and with other guidelines and good practice documents given in the References section. These guidelines assume a basic knowledge and understanding of hearing aid fitting and real ear measurement techniques, and assume that PCHI has been identified, and the degree and type of hearing loss confirmed, as discussed in the NHSP 'Guidelines for Early Audiological Assessment'². The fitting of bone conduction hearing aids is not covered in these guidelines.

15 Hearing aid technology is rapidly evolving, and research on the use of some advanced features with young infants has so far been limited. We have attempted to summarize current thinking at the time of publication, but guidance is likely to change with further advances in technology and understanding. The clinician should critically review any technological advance or manufacturers' recommendation, considering the available evidence base, before incorporating new technologies or procedures into clinical practice.

20 For bilateral hearing loss, binaural hearing aid fitting should be the norm, unless there are contraindications.

Guidelines for Hearing Aid Fitting

25 1. Estimating the audiogram

Estimated hearing levels will normally have been obtained by means of frequency specific Auditory Brainstem Response (ABR) assessment. A minimum of one high frequency (e.g. 4kHz) and one mid-to-low frequency (e.g. 1kHz) threshold should be obtained in each ear. Ideally thresholds at 3 or 4 frequencies would be available to improve the accuracy of fitting. There should also be an indication of the type of hearing loss (conductive, sensorineural or mixed). This will usually have been obtained by measuring bone conduction ABR thresholds at one or more frequencies, with additional information provided through high frequency tympanometry.

35 ABR thresholds measured in dB nHL should be converted to estimated behavioural hearing level (dB eHL) using the NHSP recommended correction values, as described in the Early Audiological Assessment guidelines². This nHL to eHL conversion is performed automatically by the eSP database^{a,b}.

^a DSL version 5 provides the option to enter ABR thresholds into the hearing aid prescription software as dB nHL values. However, it is recommended that eHL values (as calculated by the NHSP correction values and eSP database) are entered into the software, to avoid possible differences that may arise due to differences in the nHL to eHL conversion between different manufacturers' versions of DSL, and/or due to different types of transducer.

^b The DSL approach assumes that ABR thresholds have been measured with insert earphones. However, NHSP provides nHL to eHL correction values for ABR thresholds measured with headphones as an option if these are used instead of insert phones. Current NHSP guidance is that if the eHL values entered are based on

40 “Clinical judgment” needs to be applied when using an estimated audiogram based on ABR
measures to fit hearing aids to young infants. As discussed in the NHSP ABR³ and early
audiological assessment² guidance, dB eHL levels entered into software to prescribe hearing
aids may be slightly different from the levels shown in eSP. Judgement needs to be based
on professional experience taking into account all that is known about the individual case, for
45 example: type of hearing loss, possibility of temporary conductive overlay, prematurity and
any ‘inconclusive’ ABR results. ABR traces classed as ‘inconclusive’ when determining
threshold for reporting purposes may be useful when programming hearing aids. The
possible range of true thresholds based on the 5 to 95% confidence intervals at each
frequency, and the potential consequences of over- or under-amplification at each
50 frequency, should be borne in mind. To facilitate this approach, it is essential that there is
good communication between the audiologist carrying out the diagnostic testing and the
audiologist programming the hearing aids. Full information about the test, not just the
threshold levels entered into eSP, needs to be available to the audiologist programming and
fitting the aids; it is good practice for this information to include copies of ABR traces.

55 Note that when reliable ABR thresholds have been obtained, these thresholds should be
used in the hearing aid fitting. A ‘conservative’ approach, where an audiogram less severe
than that measured by ABR is entered into the software, should not be used unless there are
specific reasons (such as those discussed in section 8), as such an approach risks giving
sub-optimal amplification.

60 Where measured hearing thresholds are available at fewer than 4 frequencies, a prediction
of the estimated hearing levels at additional frequencies needs to be entered into the
audiogram to be used for hearing aid fitting. This prediction should be based on the available
measured thresholds and the most likely audiometric configuration for that type of hearing
65 loss. It needs to take into account the possible effects on the young infant of potential under-
or over-amplification at that frequency. For example, where a sensorineural hearing loss
has been measured at 1 and 4 kHz and testing has not been conducted at 500Hz: A ‘typical’
sensorineural loss would be expected to show somewhat better hearing at 500Hz than at
higher frequencies. A potential consequence of over-amplifying low frequency sound would
70 be upward spread of masking reducing the clarity of speech signals in the mid- and high
frequencies. When entering an audiogram for hearing aid fitting, it would therefore be
reasonable to enter a predicted threshold at 500Hz that is better^c than those measured at 1
& 4 kHz.

75 If the ABR threshold at a particular frequency was recorded as ‘response absent’ (RA) at the
maximum stimulus level tested, it is suggested that an estimated hearing threshold of 5 dB
above the corresponding dB eHL level is used as a basis for the initial hearing aid
prescription. This can be carefully increased over the early months after fitting, following
monitoring and observation of behavioural responses (aided and unaided), if the infant does

headphone measures, transducer options specifying *inserts* (e.g. “insert-tip or ABR-tip”) should still be selected
in the DSL software, rather than selecting the “TDH phone” option. This guidance provides a consistent
workaround for this situation; it is possible that guidance may change in the future. A detailed explanation of
this is given in Appendix 1.

^c A slope of 10 dB per octave would be an appropriate ‘rule of thumb’. Any clear and consistent behavioural
responses from the infant should also be taken into account.

80 not appear to be responding with the aids. It is important to test up to the maximum recommended stimulus level^{d 2} (masked if appropriate) if ABR responses are absent at lower levels, to reduce the risk of under-amplifying.

2. Hearing Aid Selection

85 An appropriate digital signal processing hearing aid should be selected, taking the following factors into consideration:

- Size and shape – the aid must be practically wearable for a small baby.
- Paediatric features – e.g. tamper proof battery drawer (essential for safety with young infants), paediatric earhook, ease of operation of on/off switch and other controls, compatibility with FM or equivalent systems
- 90 • Suitable response range to match the generated prescription target, with appropriate advanced features if required.

For very young infants with more severe/profound hearing losses it may not always be possible in the first few weeks to achieve sufficient amplification to match the target without unacceptable acoustic feedback. Therefore it may occasionally be necessary to consider, as a short-term measure, fitting a smaller aid with slightly less than optimal power that is wearable on the very small ear. If such compromises have to be made, the infant's fitting must be upgraded to the optimal hearing aid model as soon as is practical. Every effort must be made to adjust the programming in order to achieve optimal amplification as quickly as possible after fitting. If the issue is feedback rather than actual size of the aid, alternative measures such as use of feedback management strategies or frequency lowering may be indicated (see section 4.2 for further discussion of these features). In occasional cases it may be appropriate to consider alternative options such as the use of an external FM microphone or a bodyworn aid.

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3. Prescription and Real Ear Measures^e

The predicted audiogram, as discussed in section 1, should be entered into the real ear measurement software using a prescription formula recommended by MCHAS¹ for paediatric use, i.e. DSL²⁴ or NAL-NL²⁵, and targets for hearing aid fitting should be generated. Ensure that the correct parameters are selected in the software, including the transducer used for measuring the hearing thresholds^b. For binaural fittings, current versions of both prescription techniques include a correction to allow for binaural loudness summation which the clinician can choose to apply. Ensure that the desired option for this is selected^f. For unilateral fittings, the full prescription, without any reduction, should be used.

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^d The Early Assessment Guidelines² allow the 'normal maximum recommended stimulus levels' for ABR to be exceeded by 5dB in cases of severe/profound hearing loss where ANSD has been ruled out. In these cases, if a 'RA' is obtained at the higher level, the suggestion to enter a threshold for hearing aid prescription of 5dB above the 'RA' eHL still applies.

^e These guidelines assume the use of an occluding earmould. Issues around the use of vented and open earmoulds are outside the scope of this document, but guidance is available from manufacturers and in the literature (for example on the DSL website²⁴).

^f See the individual techniques' literature for more guidance on this. At the time of publication of these guidelines, guidance from the DSL website⁴⁵ is that the decision to apply the binaural correction (a 3dB reduction in targets in DSL v5) for binaural fittings should be at the clinician's discretion, in view of lack of clear evidence about the benefits of this in the literature and the concerns of some clinicians about the risk of reducing the audibility of speech cues.

115 A real ear to coupler difference (RECD) should be measured using the baby's own earmould
(or a foam insert earphone tip)^g. This is used to correct the audiogram and hearing aid
output for the differences between the acoustics of the baby's ear canal and those of a 2cc
coupler, and to generate target values for hearing aid output in the coupler. See MCHAS¹
120 and BSA/BAA guidance⁴ and other references^{10,11} for details of this technique. Every effort
should be made to obtain a measured RECD, as differences between the acoustics of the
ear canal and the coupler and the individual variation between patients are particularly
marked for young infants. For binaural fittings, the RECD should be measured separately for
each ear; however, if necessary, the same measured RECD may be used for both ears as
125 the difference in RECD between the two ears of the same subject has been found to be
relatively small^{h,11}. Bagatto¹⁰ gives helpful tips for obtaining a successful RECD
measurement.

If it is not possible to measure an RECD, DSL software will make an age-related average
RECD correction. Ensure that the correct age of the child has been entered into the
130 software to enable an appropriate correction to be appliedⁱ. When this is the case efforts
should be made to obtain a measured RECD as soon as possible after the initial fitting.

4. Programming and Verification

135 4.1 Verification

Step 1 Initial programming

The hearing aid manufacturer's software should be used to generate an initial hearing aid
response based on the chosen prescription formula. RECD, where measured, should be
140 incorporated into the fitting software. Wide dynamic range compression should usually be
used. Advanced features (e.g. noise reduction) should initially be disabled^j.

*It may be preferable to run step 4 first, followed by steps 2 & 3, as adjusting the maximum
output may affect the output at lower input levels in some hearing aids.*

For binaural fittings, steps 2-4 should be repeated for each ear.

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Step 2 Verification of hearing aid response

In the 2cc coupler, predicted real ear aided response (REAR) curves for the hearing aid
should be run for input levels of 50, 65 and 80 dB SPL and compared to the generated

^g The DSL website²⁴ gives guidance on the difference between RECDs measured using a custom earmould and a foam tip. Ideally the same ear coupling would be used to obtain the ABR thresholds, to measure the RECD and to verify the hearing aid fitting. However in practice, the ABR will often have been carried out using a foam insert tip (or headphones) and the RECD and verification will be carried out with the custom earmould. The audiologist should be aware of the differences between these different transducers and ear couplings and the possible effects on the measures obtained.

^h As long as no middle ear condition is present in either ear.

ⁱ Note that this correction assumes an 'average' ear canal size for that age. This will be particularly inaccurate for infants with small/narrow ear canals relative to their chronological age (e.g. Down's syndrome; ex-premature infants) and it may be appropriate in such cases to adjust the age entered into the software accordingly to reduce the risk of over-amplification.

^j Seek the individual hearing aid manufacturer's guidance on when in the process certain features such as nonlinear frequency compression (NLFC) should be activated.

150 targets^k. A broad-band, speech-like signal should be used (e.g. modulated speech-weighted
noise, or a speech signal if this option is available).

Step 3 Modification of hearing aid response

155 The hearing aid programming at different frequencies/input levels should be adjusted and
the coupler-generated REARs re-measured until the hearing aid output at the different input
levels is as close as possible to the generated targets. The aim should be to at least meet,
and preferably improve on, the MCHAS recommended tolerances of +/- 5 dB at 0.25, 0.5, 1
& 2 kHz and +/- 8 dB at 3 & 4kHz. In addition the slope in each octave should be within +/-5
160 dB/octave of the target. It is important that young infants are provided with as close as
possible to optimal amplification of speech sounds, and therefore a 'conservative' approach
(i.e. providing less than the target amplification) should not be used (except in specific
circumstances as discussed in Section 8). In particular, evidence shows that high frequency
information is important for speech and language development in young children¹².

Step 4 Verification of maximum output

165 An RESR (real ear saturation response) curve for a 90 dB SPL input should be run. This
should be done using a pure tone sweep to provide maximum possible stimulation (unless
an alternative stimulus is recommended by the hearing aid manufacturer). The aid
programming should be adjusted as necessary so that the maximum output is below the
recommended target for a 90 dB SPL input. If adjustments are needed the REAR curves at
170 other input levels should be re-run as their match to target may have been affected.

Step 5 Finalising the programming

Activate any additional features as required, as discussed in Section 4.2.

175 **4.2 Programming features**

Modern digital hearing aids offer various advanced signal processing features. However,
much of the research for the benefits of such features has been carried out with adults or
older children, and for some features there is, as yet, little research on the benefits or
otherwise of their use with infants and young children. Current opinions and guidance on the
180 use of some of these features with young infants varies between different respected experts
and centres. The following is a brief summary of current thinking at the time of publication of
these guidelines. It is important to think through the possible effects of any advanced
feature on the individual patient and the possible benefits or disadvantages of its use. It is
also important to look at the details of what a particular feature from a particular hearing aid
185 or manufacturer is doing, since implementations can vary greatly from one aid or
manufacturer to another. The possible impact on the audibility of speech is a key factor, and
when activating such features the audiologist should consider how to verify their effects in
order to confirm that audibility is not reduced¹³.

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^k The exact input levels used for verification may need to be modified depending on the specific real ear measurement equipment and prescription formula used. The principle of checking the response to soft, average and loud speech sounds remains.

Number of programs

195 With infants and young children it is usually best to give just a single program for simplicity. If the aid has the option to select FM+M as the sole program, this may be appropriate, to enable a personal FM or equivalent system to be fitted.

Volume control

200 Deactivation of the volume control avoids accidental adjustment of gain. However, activation enables parents to reduce acoustic feedback, which can be a problem with rapid growth of the ear. It also provides flexibility for fluctuating conductive overlay. If the volume control is activated, it is wise to use a minimal range. A cover may be available to prevent inadvertent changes to the control.

Warning beeps, power-on delay

205 Any audible warning beeps should be disabled (if possible). If available, power-on delay can be helpful to some parents if they find it easier to switch the aid on before inserting it in the ear.

Data-logging

210 This provides a means of monitoring hearing aid usage, and can be useful in identifying and addressing any difficulties the parent/carer may be experiencing in establishing and maintaining hearing aid use. If the data-logging feature is enabled parents should be made aware of this.

Feedback management

215 Feedback management strategies vary from one aid to another, and it is important to be aware of any effect on the hearing aid output, match to target, and thus audibility, particularly of high frequency sounds important for speech. In general, it is preferable to reduce feedback by doing everything possible to provide good-fitting earmoulds. However, the
220 dynamic feedback cancellation available in many digital aids may be helpful.

Digital noise reduction (DNR)

225 Recent reviews of the evidence¹⁴⁻¹⁶ have shown a wide variation in implementations between different manufacturers and different hearing aid models. Studies of DNR in school-age children and adults indicate a lack of significant improvement or degradation of speech understanding in noise. There may be an improvement in listening comfort and subjective sound quality, which may lead to reduced listening effort. There is, however, a lack of studies in younger children acquiring speech and language, where it is vital to know whether speech recognition is preserved. It is suggested that DNR be applied with caution
230 in younger children until more evidence is available.

Directional microphones (DM) and adaptive directionality

235 The potential benefit from directional microphones depends on the child's ability to turn their head towards the speaker of interest. Studies by NAL¹⁷ with children aged 11 months to 6 years have indicated that they are able to do this a proportion of the time, and gave some evidence for directional benefit. The authors of this study¹⁷ advocate the use of DM with young children, particularly if the automatic switching of the aid between omnidirectional and directional modes is accurate. However, others¹³ have expressed concerns about the

possible loss of ‘incidental learning’ as a result of ‘overhearing’ conversations, as well as the
240 potential harm from not detecting important signals from other sources, such as warning
signals. A study by Ricketts¹⁸ with school-aged children showed that although there were
benefits from DM use in some situations, there were also directional decrements when there
were sources of interest behind as well as in front of the child. A review of evidence by the
245 University of Western Ontario¹⁹ concluded that there is not yet sufficient evidence to support
the routine use of DM with very young children. It should be noted that directional
microphones may not work optimally once debris or moisture get into the microphone ports.
Because infants are unable to report on function, there should be some system for the
regular checking of any DM function by the ToD or Audiologist.

250 *Frequency lowering*

Frequency lowering strategies, such as nonlinear frequency compression (NLFC), aim to
address the problem of providing access to important high frequency information by shifting
these sounds to a frequency with better audiometric thresholds. For NLFC there is
increasing evidence of benefit, and of the lack of a negative effect, in children with moderate
255 as well as severe/profound hearing losses²⁰, although research to date has mainly been with
school-aged children. Respected centres such as the DSL and NAL teams now tend to
encourage the use of this feature with young children; other experts have expressed more
caution¹⁶. Note that the manufacturer’s default settings for NLFC may not be the most
appropriate ones for the child, and careful verification should be carried out, including use of
260 live voice stimuli (if possible) and listening checks, particularly looking at the distinction
between /s/ and // (‘s’ and ‘sh’) sounds²¹.

5. Fitting the aid

Sufficient time should be allocated for the fitting appointment to allow for detailed counselling
265 of the family, with time to answer questions and discuss concerns, as well as to ensure the
aid is fitted as optimally as possible. Consideration should be given to the location and
timing of the appointment to help the baby and family to be as relaxed as possible. It is good
practice for the teacher of the deaf/early interventionist¹ to be present at the fitting, to provide
a “joined up” approach for the family.

270 Following the measurement of RECDs, most of the programming and verification procedure
can be conducted without the baby and family present.

The family should be counselled about their expectations for the fitting, including responses
275 that may or may not be expected from the baby at this stage in their development. They
should be advised about when the aids are to be worn and how to establish hearing aid use.

The fit of the earmould and of the aid behind the ear should be checked to ensure that there
is no unacceptable feedback. Modifications to the initial programming or activation of the
280 volume control may be needed to achieve this.

¹ Early intervention (EI) services provide support for young hearing impaired children and their families in the development of language and communication. In England this support is primarily provided by the Education service, and the key early intervention professional working with the family is usually, but not always, a Teacher of the Deaf (ToD). References to the ToD in the remainder of this document apply to the key EI professional/s working with the child and supporting their hearing aid use.

285 The baby's response to high intensity sounds should be carefully checked for signs of loudness discomfort (e.g. excessive blinking or distress with intense "b-b" sound and/or narrow band noise across a range of frequencies). The hearing aid programming (maximum output / response to high level inputs and/or low frequency amplification) should be adjusted if indicated.

290 The parent/carer should be shown how to insert the earmoulds and operate the aid and understand how the aids work, the cause of feedback, and how to perform daily checks and troubleshooting. They should be provided with a paediatric care kit, including aids to retention (e.g. toupee tape, huggies); contact names/telephone numbers for support; and written information on hearing aid use. The review system should be explained, and arrangements should be made for provision of the next set of earmoulds.

6. Record keeping & reporting

295 Hearing aid test box curves for 50, 65 & 80 dB input levels should be recorded and shared with Early Intervention (EI), to enable subsequent checking of hearing aid performance by both Audiology and Early Intervention. All the relevant information on hearing aid settings etc should be shared with EI colleagues. Reports / individual management plans detailing the hearing aid fitting should be copied to parents/carers and other relevant professionals.
300 The amplification section of eSP should be updated.

7. Early audiological follow up

305 Following hearing aid fitting there should be a schedule of routine hearing aid reviews. At these reviews arrangements should be in place for behavioural testing, real ear measures (REMs)^m and adjustment of aid programming to be carried out at the same appointment, in line with family friendly practice.

310 In the initial months after fitting, frequent reviews will be required. Once hearing aids are established, accepted good practice is that routine reviews are carried out at least every 3 months in the first 1-2 years of life, then every 6 months until age 5. RECD measurements should be repeated at least every 3 months in the first year of life, and aids adjusted accordingly.

315 In addition to this schedule of routine reviews there needs to be an arrangement for taking impressions for replacement earmoulds^{5,6} which may be required approximately every 2-3 weeks in the early months, depending on the degree of hearing loss. It can be helpful to offer the parent/carer the option of setting up a series of impression appointments in advance.

320 Hearing aid review appointments should be for a minimum duration of 90 minutes, with 2 experienced audiologists, in line with MCHAS guidelines. These sessions should include:

^m This document has suggested that real ear measures are obtained through the measurement of RECDs. This is generally the most practical method with infants and young children, as the RECD measure is quick to perform and predicted REMs can then be generated in the 2cc coupler without the need for further co-operation from the child. With older children who are able to co-operate for longer time periods, in-situ REMs can be measured directly and this becomes the method of choice. 'REMs' in section 7 refers to either RECDs or in-situ REMs.

- Routine checking of hearing aid function
- Verification against prescription targets using real ear measures^m
- Unaided behavioural testing (as discussed below)
- 325 • Functional aided testing, once the child is old enough – e.g. Ling 6 Sound testⁿ and other age-appropriate speech discrimination tests.
- Evaluation of the fitting using age-appropriate questionnaires and monitoring tools. For young infants this would include use of the Early Support Monitoring Protocol for deaf babies and children²².

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There must be regular exchange of information between Audiology and Early Intervention about the audiological status, hearing aid prescription and fitting, use of aids at home and in other settings, observed responses to sound in the home environment, and early communication development. This may be achieved by the ToD attending the hearing aid review and/or by exchange of written information. Families should be encouraged to share the Monitoring Protocol record²² with the audiologist. An example of a proforma to enable ToDs to update audiology in advance of a hearing aid review is given in Appendix 2. This exchange of information will facilitate a joined up approach to the child's management.

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Unaided ear-specific air and bone conduction Visual Reinforcement Audiometry (VRA)⁷ thresholds^o should be obtained as soon as possible and used to improve the accuracy of the hearing aid fitting. This testing should be attempted from around 6 months of age^p (corrected for prematurity), and completed by 12 months at the latest (although this may not be possible with infants with substantial developmental delay). The timing of hearing aid reviews must facilitate these early attempts at behavioural testing, and a flexible system for arranging review appointments is needed.

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Notes

- The principal means of prescribing and verifying hearing aid responses should be through the use of unaided thresholds (behavioural when available, otherwise objective) and real ear measures.
- The use of sound field aided response measures can provide useful additional information on hearing aid benefit, and can help illustrate aided responses to parents/carers, but should not compromise time spent acquiring unaided thresholds and REMs at hearing aid review appointments.
- For infants under 6 months developmental age, behavioural observation audiometry⁸ (unaided and aided) may provide useful information to supplement objective test results and to give early indications about suprathreshold responsiveness to sound with aids.
- 360 • The use of electrophysiological measures such as cortical auditory evoked potentials, including sound field and aided electrophysiological testing, is beginning to come into

ⁿ The Ling 6 Sound stimuli can be used for functional aided testing of infants from around 6 months developmental age by means of distraction/VRA techniques

^o The VRA guidelines⁷ include a discussion of provisional corrections to VRA minimal response levels for young infants. However, note that the suggested corrections are for infants with normal hearing, and age-related corrections for infants with SNHL may differ. Further work is needed in this area.

^p It is possible to begin this from around 5 months of age with some infants

clinical practice and may in future have a useful role in providing early, objective measures of the infant's ability to detect and discriminate between different speech sounds before the age at which reliable behavioural measures can be obtained.

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8. Special cases

8.1 Extremely pre-term babies (typically born at less than around 28 weeks gestation) and other infants with neurological conditions (without evidence of ANSD)

370 Caution should be employed when programming aids, as there is a risk of delayed maturation leading to a temporary elevation of ABR thresholds. In some ex-premature infants, this can occur even when the ABR is carried out post-term⁹. In such cases it is wise to initially amplify a little conservatively, i.e. below target, and there should be particularly careful checks for signs of loudness discomfort. Following the initial hearing aid trial and feedback from parents and the ToD, if there is no indication that the baby's behavioural thresholds are better than indicated from the ABR, the amplification should be gradually increased to meet target, with observation of the baby's responses. Consideration should be given to repeating the ABR after allowing some time for possible maturation to obtain an up-to-date indication of thresholds when the baby is not yet ready to give accurate behavioural thresholds.

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8.2 ANSD (Auditory Neuropathy Spectrum Disorder)

The decision to aid infants with test results consistent with ANSD needs to be based on behavioural responses, not on the ABR. As with all infant hearing aid fittings, it is important to achieve optimal audibility of speech. Therefore once behavioural thresholds are available the aids should be fitted to the targets generated by these thresholds, *not* conservatively. However, it is unclear how beneficial or detrimental low frequency information may be to these patients, and therefore it is particularly important to avoid over-amplifying low frequency sound. More work is needed on hearing aid fitting strategies with these patients. Refer to the NHSP ANSD guidelines⁹ for further information.

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8.3 Conductive hearing losses or fluctuating conductive overlay

For persistent conductive losses consideration needs to be given to prescribing some additional amplification to take account of the conductive component. This allowance is incorporated in some hearing aid prescriptions – DSL version 5 and NAL-NL2 have the option of applying a conductive correction. Temporary conductive overlay may need to be addressed by strategies such as use of a volume control or second program. Consideration should be given to whether or not to include the suspected temporary component when entering the audiogram on which to base the fitting, bearing in mind the possible effects on the child should the temporary component resolve before the next review appointment. Close monitoring and communication with the family and ToD are important.

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⁹ Improvement in ABR thresholds post-term in NICU graduates has been reported both anecdotally and in the literature²³, although in many reports it is unclear whether factors such as ANSD or temporary conductive overlay had been excluded.

405 **Glossary**

	ABR	Auditory brainstem response
	ANSD	Auditory neuropathy spectrum disorder
	BAA	British Academy of Audiology
	BSA	British Society of Audiology
410	DM	Directional microphone
	DNR	Digital noise reduction
	DSL	Desired Sensation Level
	eHL, dB eHL	Estimated Hearing Level (behavioural pure tone threshold predicted from electrophysiological threshold)
415	EI	Early Intervention
	eSP	e-Screener Plus (national NHSP database)
	MCHAS	Modernising Children's Hearing Aid Services
	NAL	National Acoustics Laboratory (Australia)
	nHL, dB nHL	Stimulus level on electrophysiological testing (measured relative to adult psychoacoustic threshold)
420	NHSP	NHS Newborn Hearing Screening Programme in England
	NICU	Neonatal Intensive Care Unit
	NLFC	Nonlinear frequency compression
	NOAH	Standard interface for hearing aid fitting software
425	PCHI	Permanent childhood hearing impairment
	REAR	Real ear aided response
	RECD	Real ear to coupler difference
	REDD	Real ear to dial difference
	REM	Real ear measure or Real ear measurement
430	RESR	Real ear saturation response
	SNHL	Sensorineural hearing loss
	SPL	Sound pressure level
	ToD	Teacher of the Deaf
	VRA	Visual reinforcement audiometry

435

References

1. Other relevant guidelines

- 440
1. Guidelines for the fitting, verification and evaluation of digital signal processing hearing aids within a children's hearing aid service. Modernising Children's Hearing Aid Services (MCHAS), revised Sept 2005. www.psych-sci.manchester.ac.uk/mchas
 2. Guidelines for the early audiological assessment and management of babies referred from the newborn hearing screening programme. NHSP Clinical Group. Version 3.1, July 2013. Available at <http://hearing.screening.nhs.uk/audiologyprotocols>
 3. Guidelines for Auditory Brainstem Response testing in babies. NHSP Clinical Group. Version 2.1, March 2013. Available at <http://hearing.screening.nhs.uk/audiologyprotocols>
 4. British Society of Audiology and British Academy of Audiology: Guidance on the use of Real Ear Measurement to Verify the Fitting of Digital Signal Processing Hearing Aids. July 2007. www.thebsa.org.uk
- 450

5. Guidelines for the taking of impressions and provision of ear moulds within a children's hearing aid service. MCHAS, revised Sept 2005. www.psych-sci.manchester.ac.uk/mchas
6. British Society of Audiology: Recommended Procedure (Supplement): Taking an Aural Impression: Children under 5 years of age. February 2013. www.thebsa.org.uk
- 455 7. Visual Reinforcement Audiometry testing of infants: A recommended test protocol. NHSP Clinical Group. Version 2.0, June 2008. Available at <http://hearing.screening.nhs.uk/audiologyprotocols>
8. Behavioural Observation Audiometry: A recommended test protocol. Ed. Williamson, 2002. Available at <http://hearing.screening.nhs.uk/audiologyprotocols>
- 460 9. Guidelines for the assessment and management of auditory neuropathy spectrum disorder in young infants. NHSP Clinical Group. Version 2.2, August 2013. Available at <http://hearing.screening.nhs.uk/audiologyprotocols>

2. Additional references

- 465 10. Bagatto M (2001). Optimising your RECD measurements. *The Hearing Journal* 54:9, 32-36.
11. Munro K (2004). Integrating the RECD into the hearing instrument fitting process. *Phonak Focus* 33. (Available for download from the Phonak website: www.phonakpro.com)
12. Pitman A (2010). High frequency amplification: Sharpening the pencil. In: *A Sound Foundation through Early Amplification: Proceedings of the fifth international conference.* p179-185. (Available for download from the Phonak website: www.phonakpro.com)
- 470 13. McCreery R (2011). Pediatric Hearing Aid Fittings: Selection and Verification of Features. *Audiology Online.* <http://www.audiologyonline.com/articles/pediatric-hearing-aid-fittings-selection-797>
14. McCreery RW, Gustafson S, Stelmachowicz P (2010). Should Digital Noise Reduction be activated in pediatric hearing aid fittings? In: *A Sound Foundation through Early Amplification: Proceedings of the fifth international conference.* p153-165. (Available for download from the Phonak website: www.phonakpro.com)
- 475 15. McCreery RW *et al* (2012). An evidence-based systematic review of directional microphones and digital noise reduction hearing aids in school-age children with hearing loss. *Am J Audiol* 21 (2): 295-312.
- 480 16. Bentler R (2013). Evaluating hearing aid benefit. Presentation to the BSA Annual Conference, Keele University, UK
17. Ching T *et al* (2009). Directional Effects on Infants and Young Children in Real Life: Implications for Amplification. *Journal of Speech, Language and Hearing Research* 52:1241-54.
- 485 18. Ricketts T & Galster J (2007). Directional Benefit in Simulated Classroom Environments. *American Journal of Audiology* 16:130-144
19. Petlicka K (2010). Critical Review: Do Directional Microphones provide benefit for young and school-aged children compared to Omnidirectional Microphones? University of Western Ontario. Available at <https://uwo.ca/fhs/csd/ebp/reviews/2009-10>
- 490 20. Wolfe J (2010). Nonlinear frequency compression for children with moderate hearing loss. In: *A Sound Foundation through Early Amplification: Proceedings of the fifth international conference.* p217-225. (Available for download from the Phonak website: www.phonakpro.com)
- 495 21. Glista D & Scollie S (2009). Modified Verification approaches for frequency lowering devices. *Audiology Online.* <http://www.audiologyonline.com/articles/modified-verification-approaches-for-frequency-871>
22. Early Support Monitoring Protocol for deaf babies and children. Available at <http://www.ncb.org.uk/early-support/resources/developmental-journals/monitoring-protocol-for-deaf-babies-and-children>
- 500

23. Hof JR *et al* (2013). Auditory maturation in premature infants: a potential pitfall for early cochlear implantation. *Laryngoscope* 123 (8): 2013-18
24. DSL website: <http://www.dslio.com>
25. NAL website: <http://www.nal.gov.au>

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Appendix 1: Entering ABR thresholds into DSL software

Summary

510 **When entering ABR thresholds in dB eHL into DSL software, always select 'insert' as the transducer, even if TDH phones were used**

The purpose of this guidance is to achieve consistency across audiology departments in England in the way that ABR thresholds are interpreted and used in hearing aid prescription and verification.

515 The NHSP Guidelines for Early Audiological Assessment² give correction values to convert ABR thresholds measured in dB nHL using insert earphones or TDH headphones, and bone conduction, into estimated hearing levels (eHL). This conversion is done automatically in eSP. We recommend that these eHL values, calculated using the NHSP corrections, are entered into NOAH for hearing aid prescription (see section 1 in the main text for a detailed discussion on the determination of
520 appropriate threshold levels for this purpose).

The DSL software converts these entered eHLs into a predicted SPL at the tympanic membrane. In order to make this conversion, the software asks which transducer has been used to measure the eHL thresholds. Exact options available vary between equipment manufacturers, but may include
525 'TDH phone', 'ABR tip', insert tip' or 'insert foam'. **We recommend that one of the 'insert' options is selected, even if TDH phones were in fact used to measure the ABR.**

The reasoning behind this guidance is as follows.

530 NHSP 'eHL' versus DSL 'eHL'

The NHSP nHL to eHL correction values include i) an age-related stimulus level correction to take account of the effect of average differences in ear canal volume (and skull mass for BC) at different corrected ages (0-12 weeks, 12-24 weeks, 24 weeks-2 years and over 2 years) with different transducers, and ii) a correction for the offset between ABR (electrophysiological) threshold (dB nHL)
535 and behavioural pure tone threshold (dB HL). These two corrections are combined into a single overall nHL to eHL correction factor for each transducer at each of the four age ranges. (The derivation of these corrections is described in appendices D1 and E1 of the 2013 guidelines.)

The nHL to eHL correction offered as an option in DSL version 5, on the other hand, is purely an allowance for the offset between ABR and behavioural threshold. The effects of individual ear canal acoustics are then allowed for as part of the conversion from eHL to predicted ear canal SPL, by measurement of an RECD (or REDD if headphones are used) or by use of an age-related average correction. In order to make the eHL to SPL conversion, the software asks which transducer has
540 been used to measure the eHL thresholds.

545 Air conduction ABR thresholds measured with insert earphones

The eHL values predicted by NHSP should be entered into DSL. (If using DSL5, the 'eHL' not the 'nHL' option should be selected.) One of the 'insert' options should be selected in the DSL software as the transducer used to measure the ABR thresholds. An RECD should then be measured to correct for individual ear canal acoustics in the prediction of ear canal SPL and in verification of the aided response[†].

[†] Note that the RECD is essentially used twice, once to predict the SPL at the tympanic membrane from the audiometric threshold and once to obtain the real ear to 2cc coupler transform for hearing aid verification. In practice, the same measure is generally used for both purposes although often different ear couplings will

In fact, for infants 0-12 weeks corrected age tested with insert earphones, the eHL value calculated by NHSP at 0.5, 1, 2 and 4kHz for a given ABR dB nHL threshold is numerically the same as the eHL value calculated by DSL5⁵. We can therefore be satisfied that it is appropriate to use the NHSP eHLs and then measure an RECD to correct for individual ear canal acoustics.

Air conduction ABR thresholds measured with TDH phones

The DSL approach, using RECD to convert audiometric thresholds from dB eHL to predicted ear canal SPL and to verify the aided response^r, assumes that insert earphones have been used in threshold measurement. If ABR thresholds have been measured with TDH phones, a workaround is needed to enable RECD to be used in hearing aid verification so that the effects of individual ear canal acoustics can be accounted for. If ‘TDH phone’ is selected in DSL as the transducer used to measure the thresholds, the software will apply an averaged REDD to the entered eHLs to account for the difference in average enclosed ear canal volume between inserts and headphones. However, this difference is already accounted for in the NHSP nHL to eHL correction values for headphones. We do not wish the DSL software to apply an additional REDD correction. Therefore when TDH phones have been used to measure the ABR thresholds, one of the ‘insert’ options (e.g. ‘insert tip’, ‘insert foam’ or ‘ABR tip’) should be selected as the transducer in DSL. Any of these ‘insert’ options, when used within the same REM software, will give the same estimated thresholds on the SPL-o-gram and therefore the same generated target for hearing aid fitting.

Example of the differences in predicted ear canal SPLs and generated targets:

Using the Aurical+ with age-related averaged RECD for a 1-month-old and entered eHL values of 40, 50, 60, 60 at 0.5, 1, 2 & 4 kHz:

Frequency (Hz)		500	1000	2000	4000
‘TDH-phone’ selected:	Estimated threshold, dB SPL	43	44	59	60
	(Target for 65 dB input, dB SPL)	(68)	(64)	(72)	(73)
‘ABR-tip’ or ‘Insert-tip’ selected:	Estimated threshold, dB SPL	42	47	65	66
	(Target for 65 dB input, dB SPL)	(67)	(66)	(77)	(77)

have been used for the two procedures (i.e. foam insert tip or headphones to measure thresholds and custom earmould for verification). The Audiologist should consider and be aware of the implications of this – see also footnote g in main text.

⁵ However the actual eHL value calculated may vary between different manufacturers’ implementations of DSL5, which is why we recommend always using the NHSP values.

Appendix 2: Example proforma for feedback from Early Intervention to Audiology

580 This proforma was designed to enable ToDs to supply an update to Audiology in advance of review appointments. It is reproduced with thanks to the Joint Local Authority Sensory Support Service in Bristol, South Gloucestershire, Bath & North East Somerset and North Somerset.

Hearing Support Team

Child Progress Summary

NAME:		D.O.B.	
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HEARING AIDS: Overall use, problems, concerns, loudness discomfort Benefit reported by parent Benefit observed by teacher Any changes	
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OBSERVED RESPONSES:	
Aided responses to environmental sounds / speech	
RESPONSES TO LING SOUNDS: AH OO EE MM SH SS (DETECT / IDENTIFY) Date assessed:	
Child's listening environments	

COMMUNICATION SKILLS		
Progress		
Monitoring Protocol Levels	Age range	Comment
Overall Communication (English/BSL) Receptive Language Expressive Language		
Attention		
Listening		
Vocalisation		

ADDITIONAL COMMENTS:

TEACHER:

DATE: