



Recommended Procedure

Assessment and Management of Auditory Neuropathy Spectrum Disorder (ANSD) in Young Infants

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General foreword

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Declarations of interests

- Declaration of interests by the authors: ERA Training & Consultancy Ltd offer training courses in ABR & CM testing, training and accreditation in ABR peer review and offer clinical support for centres performing ABR testing.

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Shared Decision-Making

It is implied throughout this document that the service user should be involved in shared decision-making when undertaking audiological intervention, receiving subsequent information and understanding how it will impact on the personalisation of care. Individual preferences should be taken into account and the role of the clinician is to enable a person to make a meaningful and informed choice. Audiological interventions bring a variety of information for both the clinician and the patient which can be used for counselling and decision-making regarding technology and anticipated outcomes.

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Contents

1. INTRODUCTION	7
2. BACKGROUND	7
2.1. Definitions and Terminology	7
2.2. Prevalence	8
2.3. Risk Factors	8
2.4. Aetiologies	9
2.5. Sites of Lesion	10
2.6. Natural History and Prognosis	10
3. ASSESSMENT	11
3.1. Core Assessment	11
i. ABR	11
ii. Tests of Outer Hair Cell Function	12
iii. Tympanometry	12
iv. Bone Conduction Assessment	12
v. Stapedial reflexes	12
3.2. Transient ANSD	12
3.3. Order of Testing and Interpretation of Results	13
3.4. Report Writing	
4. MANAGEMENT	17
4.1. Information and Support	17
4.2. Ongoing Audiological Assessment	18
4.3. Monitoring and Assessment of Communication Development	19
4.4. Intervention / Aids to Communication	19
i. Modes of Communication	19
ii. Conventional Hearing Aids	20
iii. Radio Aids	21
iv. Cochlear Implants (CIs)	21
4.5. Aetiological Investigations	22
4.6. Management of Unilateral ANSD	23
4.7. Management of Transient ANSD	23
5. REFERENCES	24

6.	Appendix A: What Constitutes an Abnormal ABR?	30
7.	Appendix B: Delayed Maturation and the Timing of Repeat ABR Testing	32
8.	Appendix C: Additional Tests	34
9.	Appendix D: Medical Assessment	36
10.	Appendix E: Case Scenarios.....	37
	i. Case example 1:Delayed Maturation.....	37
	ii. Case example 2:Bilateral ANSD, Rehabilitated with Hearing Aids.....	39
	iii. Case example 3:Bilateral ANSD Rehabilitated with CIs	42
11.	Appendix F: Document Revision History	44

Abbreviations

ABR	Auditory Brainstem Response
AC	Air Conduction
ANSD	Auditory Neuropathy Spectrum Disorder
BOA	Behavioural Observation Audiometry
BC	Bone Conduction
BSA	British Society of Audiology
BSA	British Society of Audiology
CAEP	Cortical Auditory Evoked Potentials
CI	Cochlear Implant
ckABR	Click Auditory Brainstem Response
CM	Cochlear Microphonic
dBeHL	Decibel estimated Hearing Level (Estimated PTA from electrophysiological thresholds)
dBHL	Decibel Hearing Level
dBnHL	Decibel normal Hearing Level
eABR	electrically evoked ABR
ECochG	Electro-cochleography

kHz	Kilo Hertz
MCHAS	Modernising Children's Hearing Aid Service
NDCS	National Deaf Children's Society
NHSP	Newborn Hearing Screening Programme
NICU	Neonatal Intensive Care Unit
OAE	Otoacoustic emission
SNHL	Sensorineural Hearing Loss
SR	Stapedius Reflex
ESIG	Electrophysiology Special Interest Group
tpABR	Tone Pip Auditory Brainstem Response

1. INTRODUCTION

This document is a revision of the previous recommendations of the Newborn Hearing Screening Programme (NHSP) in England for the assessment, diagnosis and management of infants suspected of having Auditory Neuropathy Spectrum Disorder (ANSD). In more recent years these guidelines have been adopted by the British Society of Audiology (BSA). The current document should be read in conjunction with the BSA Recommended Procedure for Cochlear Microphonic Testing January 2019.

This document has been updated in the light of recent work and other published guidelines. Many controversies and areas of uncertainty remain in the diagnosis and management of ANSD. These guidelines will be subject to further revision in the light of new evidence in the future.

2. BACKGROUND

2.1. Definitions and Terminology

This document addresses the practical issues in the identification, assessment, diagnosis and management of infants presenting with the following pattern of test results at the initial audiological assessment after the newborn screen:

- Auditory Brainstem Response (ABR) absent or with grossly abnormal morphology at high stimulus levels (Sininger 2002) (see [Appendix A](#) for further explanations), with
- Otoacoustic emissions (OAEs) and/or cochlear microphonic (CM) present.

These test results demonstrate the presence of pre-neural responses but absent or abnormal neural responses. This suggests relatively normal activity in the outer hair cells, but disruption of transmission at some point from the inner hair cells along the neural pathway to the brainstem. There are two proposed disruption mechanisms. One is when the neural synchrony is compromised and the other is when there is a reduction of the activated nerve fibres (Rance and Starr 2015).

Children with absent ABR, might at first sight be thought to have severe/profound sensorineural (cochlear) hearing loss until tests of cochlear function are carried out. It is important to differentiate between ANSD and 'cochlear' sensorineural loss or conductive hearing loss as prognosis and management can be substantially different.

The term 'Auditory Neuropathy' was originally described by Starr and colleagues in 1996 (Starr et al 1996). Other workers have preferred terms such as 'Auditory Dys-synchrony' (Berlin et al. 2002), 'Auditory De-synchrony' or 'Auditory mismatch', 'Peri-Synaptic Audiopathy', 'Persistent Outer Hair Cell Function', 'Neural Hearing Loss' feeling that these terms better attempt to describe what is happening in the auditory system without implying a particular locus of pathology (Rapin et al. 2003). To encompass these different opinions, the term 'Auditory Neuropathy/Dys-synchrony (AN/AD)' came into use and was used in previous versions of the NHSP guidelines.

At the International Guidelines Development Conference at Como, Italy, in 2008 (Northern Ed. 2008), a consensus was reached to adopt the term 'Auditory Neuropathy Spectrum Disorder' (ANSD). This is a blanket term to include various possible aetiologies described in a later section. The term ANSD was also considered helpful as it expresses the wide range of presentations, prognoses and underlying aetiologies associated with the disorder. However, the abbreviated term Auditory Neuropathy is still used by some.

2.2. Prevalence

Sininger (Sininger 2002) estimates that ANSD occurs in about 1 in 10 children with permanent hearing loss. A large Australian study confirms this estimate (Ching et al. 2013).

Although the majority of ANSD cases occur among infants who have spent time in special care / neonatal intensive care unit (NICU), some studies have indicated that a significant number may occur in the well-baby population (Sininger 2002). Many newborn hearing screening programmes, including the UK NHSP protocol, currently only screen for evidence of ANSD in infants admitted to NICU¹, and do not offer ABR screening to all well babies. Cases of ANSD occurring in the well-baby population may therefore remain undetected. Cases of ANSD may be referred at a later stage, likely due to parental or professional concerns. Therefore, these referral routes should be maintained for audiological assessment. The assessment and management of these older cases is outside the scope of this document.

2.3. Risk Factors

Below are listed some of the perinatal factors that are associated with ANSD.

Risk factors for ANSD from the neonatal history include: (Sininger 2002, Berg et al. 2005, Madden et al. 2002, Rance et al. 1999, Berlin et al. 2010)

- Extreme prematurity <28 weeks gestation.
- Low birth weight / intrauterine growth restriction.
- Severe hyperbilirubinaemia otherwise known as kernicterus, at levels requiring exchange transfusion.
- Hypoxic ischaemic encephalopathy / intraventricular haemorrhage (as is likely to occur in infants with prolonged assisted ventilation / severe sepsis).
- Anoxia.
- Artificial ventilation.
- Respiratory distress.
- Ototoxic drugs.

¹ In this document 'SCBU/NICU' means those infants classified as such by the NHSP screening protocol –*i.e.* those who are admitted to special care / neonatal intensive care for over 48 hours.

Due to the above, children with ANSD usually have a history of extensive neonatal intensive care unit stay (Norrix et al. 2014).

2.4. Aetiologies

ANSD is a label for a pattern of test results as defined above. It is not a diagnosis and further investigation is needed to ascertain this. It can also be transient (see sections 3.2, and [Appendix B](#)). ANSD may arise from a diverse range of aetiologies. Both genetic and acquired factors can result in ANSD. Genetic causes can be syndromic or nonsyndromic.

If a diagnosis of the underlying condition that gives rise to ANSD results is made it will be useful for the management of the child to include the comment 'ANSD pattern of subjective test results associated with...' alongside the diagnosis.

Genetic conditions that may give rise to this pattern of test results include, among others:

- DFNB₉ gene mutations (autosomal recessive) (Varga et al. 2003), responsible for the coding of the protein otoferlin (OTOF).
- DFNB₅₉ gene mutations (autosomal recessive) (Delmaghani et al. 2006), responsible for the coding of the protein pejvakin.
- DIAPH₃ gene mutations, which is another protein coding gene, causing autosomal dominant non syndromic auditory neuropathy or AUNA₁ (Norrix et al. 2014).
- ATP1A3 gene mutations (Han et al. 2017). These mutations are linked with late onset ANSD.
- Familial delayed auditory maturation (Aldosari et al. 2004).
- Neurodegenerative conditions²: Charcot Marie Tooth, Friedreich's Ataxia (Starr et al. 1996).
- Metabolic conditions, *e.g.* Maple syrup urine disease (Spankovich et al. 2007).
- Mitochondrial disorders (Corley et al. 1999).
- OPA1 gene mutation, causing late-onset ANSD together with vision loss due to optic atrophy (Huang et al., 2009; Santarelli et al., 2015)
- Riboflavin transporter deficiency gene mutations (RFVT2 & RFVT3), causing late-onset sensorimotor neuropathy with ANSD (Menezes et al., 2016)

Some anatomical anomalies may also give rise to this pattern of test results. Management of such cases is outside the scope of this document.

Examples include:

- Hydrocephalus³ (Sininger 2002, Berg et al. 2005).

² These conditions usually give a delayed onset presentation

³ Note that hydrocephalus may interfere with the recording of the ABR so presenting with wave I only. ABR thresholds may improve after shunt insertion and it is therefore advisable to wait until after shunt insertion before performing the ABR assessment.

- Brainstem anomalies (Huang et al. 2010).
- Auditory nerve hypoplasia or aplasia (Buchman et al. 2006).
- Other anatomical brain anomalies, *e.g.* microcephaly, space-occupying lesions such as cerebellar tumours.

2.5. Sites of Lesion

Some researchers have attempted to categorise ANSD according to whether the lesion is pre- or post-synaptic or have tried to identify the structure affected. This holds promise in predicting outcomes and individualising management. For example better outcomes are expected with pre-synaptic (*e.g.*, OTOF, hypoxia) than with post-synaptic disorders (*e.g.*, kernicterus, OPA1, auditory nerve malformation) . When this becomes routine clinical practice, it may make the term ANSD redundant. These lesions have been categorised as follows (Rance and Starr 2015):

1. Presynaptic disorders affecting inner hair cells and ribbon synapses.
2. Postsynaptic disorders affecting unmyelinated auditory nerve dendrites.
3. Postsynaptic disorders affecting auditory ganglion cells and their myelinated axons and dendrites.
4. Central neural pathway disorders affecting the auditory brainstem.

2.6. Natural History and Prognosis

The impact of ANSD on a child's hearing ability varies amongst individuals and to a great extent is unpredictable. The possible outcomes are listed below.

Electrophysiology outcomes:

- The ABR may not change or may recover totally or partially. On some occasions it can be consistent with the behavioural threshold and has normal morphology (Psaromattis et al. 2006, Attias and Raveh 2007).
- ABR is a poor predictor of speech discrimination ability (Rance, 2013)
- OAEs which are present at initial assessment may disappear over time, whether or not the child is aided (Sininger 2002, Deltenre et al. 1999, Starr et al. 2000).
- ABR thresholds can fluctuate with fever (Starr et al., 1998)

Behavioural assessment outcomes:

- Behavioural thresholds may remain stable, fluctuate, deteriorate or improve. If they fluctuate they are usually consistent within a test session.
- Behavioural thresholds can fluctuate with fever (Marlin et al., 2010).
- In some cases, the behavioural thresholds may appear to be satisfactory, with age-appropriate speech development, but the child may exhibit features consistent with auditory processing difficulties (Starr et al. 1996) (Rance et al., 2012). There should be a local protocol for the ongoing monitoring of such cases.
- Speech discrimination may be poorer than the behavioural audiogram would suggest (Rance, 2013).

- Hearing aids may be of less benefit than the behavioural audiogram would suggest (Rance et al., 2002).
- Temporal processing and frequency discrimination is poorer compared to individuals with sensorineural loss and similar puretone audiogram results (Zeng et al., 2005).

Functional assessment outcomes:

- Speech discrimination may range from no difficulties to difficulties listening in noise to disrupted speech discrimination in quiet with difficulties ranging from mild to profound (Rance et al., 2007).
- Speech may develop normally or may be significantly delayed.

3. ASSESSMENT

3.1. Core Assessment

The assessment should include (refer to 3.3 and Figure 1 for interpretation and flow diagram of the assessment):

i. ABR

In the NHSP early audiological assessment protocol (Stevens et al. 2013), 4kHz tpABR assessment will usually be the first investigation for babies referred following the screen⁴. Note that with babies born prematurely, the initial ABR assessment should not be performed until the baby has reached 40 weeks corrected age, to allow some time for neural maturation. Where there is no ABR response at the normal maximum recommended stimulus levels⁵, or a grossly abnormal response, investigations to differentiate between ANSD and sensorineural hearing loss must be performed (see [Appendix A](#) for further notes on abnormal ABR).

In an infant, abnormal or absent ABR may be due to:

- ‘Conventional’ hearing loss – sensorineural, conductive or mixed
- Transient ANSD, possibly due to delayed neural maturation
- ANSD due to other causes.

It is preferable that ANSD should be excluded before proceeding to hearing aids which are programmed to a prescriptive formula on the basis of ABR results. However, see section 3.1.3 where clinical judgement may be required. The ANSD test protocol should be followed as part of the assessment of every suspected case of permanent hearing loss with absent/grossly abnormal ABR, whether or not

⁴ For well babies, current NHSP guidance is that it is acceptable to use TEOAEs as the first test. For babies admitted to NICU > 48 hours, and any baby where there is suspicion of, or a possible risk factor for, ANSD, ABR must be performed (Stevens, Sutton, Wood Eds. 2013).

⁵ Refer to the BSA-NHSP ‘Guidelines for early audiological assessment’ (Stevens et al. 2013) for guidance on maximum recommended stimulus levels. Please note that this guidance is due to be updated in 2019 under the BSA.

there are known risk factors for ANSD. Refer to BSA-NHSP guidance for the specific tests (www.thebsa.co.uk/resources).

ii. Tests of Outer Hair Cell Function

Diagnostic (NOT screening) OAEs– transient evoked (TEOAE) are recommended. OAEs are by-products of the active amplification processes in the cochlea. The presence of OAEs is taken as evidence of outer hair cell function.

Cochlear Microphonics: Cochlear microphonics are potentials that reflect the activity of both the outer and inner hair cells. As, however, outer hair cells are considerably more numerous than inner hair cells they are considered as the main contributors. Refer to the BSA-NHSP Guidelines for Cochlear Microphonic Testing (BSA 2019) for details. In brief: perform click CM with separate replicated runs of condensation and rarefaction click stimuli using insert earphones at 85 dBnHL, or, in cases of a grossly abnormal ABR, at the maximum level at which the cKABR is absent, providing this is no less than 70 dBnHL (see 3.3 for further details). A CM is present when it inverts with click polarity and disappears upon clamping the insert tubing. When a CM is present and there is still no later true neural ABR response (*i.e.* not inverting with click polarity) at the same intensity level, this is taken as evidence of ANSD.

iii. Tympanometry

A significant overlying conductive loss may prevent the CM from being detected. Even milder conductive elements can cause OAEs to be absent. When abnormal tympanograms are present it is not possible to exclude the possibility of ANSD; however, in cases where there is no other evidence for ANSD this should not delay the management of the child's hearing loss. High frequency tympanometry should be carried out for babies under the age of 6 months.

iv. Bone Conduction Assessment

Bone conduction testing allows for the assessment of presence of conductive components.

v. Stapedial reflexes

Optionally include if possible stapedial reflexes (SRs) using 1kHz probe (Mazlan et al. 2009). Stapedial reflexes appear to be invariably absent or elevated in cases of ANSD (Berlin et al. 2005).

3.2. Transient ANSD

A key issue with ANSD is **distinguishing long-term ANSD from delayed maturation (or transient ANSD)** particularly in babies who have been in neonatal intensive care. To help differentiate neural maturation changes from other causes of ANSD, whenever possible ABR should be repeated before a definitive initial diagnosis is made; this should preferably be at around 8-10 weeks corrected age (*i.e.* usually around 2 months after the first ABR). A further repeat ABR at a later age may be helpful in order to confirm the diagnosis. If this is felt to be helpful for the management of the individual case, then a re-test at around 12-18 months of age should be considered. For a discussion of the issues around this decision, see [Appendix B](#). For advice on management, see section 4.7.

3.3. Order of Testing and Interpretation of Results

This section describes a recommended order of testing and interpretation of results. The order of testing however may vary depending on practical considerations.

If 4kHz AC tpABR (see note 1 below) response is **absent** at the maximum permissible testing level (see note 2 below) then (refer to Figure 1 for the flow chart of the assessment process):

- Perform a 4kHz tpABR with a bone conductor at the maximum permissible testing level :
 - If an ABR is obtained of normal morphology, then this points towards a mixed hearing loss and ANSD is not indicated.
 - If bone conduction ABR yields a response absent, then:
- Perform a tp air conduction ABR at a low frequency (either 0.5 or 1kHz) to maximum permissible testing level.
 - If this is present and of normal morphology: this pattern is most likely associated with a sensorineural hearing loss (see Note 3 below).
 - If low frequency tpABR is absent, then:
- Perform a ckABR at the maximum permissible testing level:
 - If there is a normal morphology ABR this indicates a sensorineural hearing loss.

If ckABR is absent, then:

- Perform a cochlear microphonic at 85dBnHL and/or an OAE.
 - Studies show that a substantial proportion of patients with ANSD and present CMs do not have recordable OAEs. This could be due to middle ear conditions. It has also been demonstrated however that OAEs can disappear over time, with the reasons as to why not being clear as yet. ***Therefore, all children with absent OAE responses in the absence or grossly abnormal appearance of an ABR at maximum stimulus levels should be tested for a cochlear microphonic.***
 - If a robust diagnostic OAE has already been recorded, CM testing is not essential although it may be useful to try and record both OAEs and CM, for the following reasons:
 - i. CM appears to be more robust over time as mentioned above. Therefore, when testing for signs of maturation, a CM may continue to be recordable (and confirm the persistence of ANSD for example), although an OAE may disappear over time.
 - ii. OAEs and CM may provide different perspectives of the physiological processes of the cochlea and one does not guarantee the presence of the other (Buchman et al. 2006). Having the retrospective data of both recordings may help us investigate this further in the future.
 - iii. Some clinicians believe it is possible to have features of both ANSD and SNHL and this likelihood is greater when OAEs are absent and CM present (Picton 2011).

- If, in combination with the ABR results, a clear response on either the cochlear microphonic or the OAEs are obtained, then this should be taken as evidence of ANSD.
- The absence of OAEs and CM (with absent ckABR and no evidence of middle ear effusion), does not categorically rule out ANSD, but when both are absent it is reasonable to assume conventional hearing loss. There are anecdotal reports that in some cases of ANSD the OAE and/or CM can “burn out” with time.
- If both OAEs and CM are absent and there is evidence of middle ear effusion, then ANSD cannot be ruled out and further assessment is recommended. This is because both the cochlear microphonic and OAEs can be affected by the presence of middle ear effusion.
- It may not be necessary to conduct both a ckABR and a CM test if the patient does not have ANSD and the two tests do not have to be conducted in a fixed order. For example, where CM is performed prior to ckABR and it is absent (with absent OAEs), then there is no need to conduct the ckABR, as this makes ANSD unlikely.
- If initial or subsequent assessments lead to ANSD, repetition of the assessment may be necessary to rule out transient ANSD (refer to [Appendix B](#) for further guidance).

Note 1: Reference to 4kHz tpABR in this guidance should be read to include the use of 4kHz narrow-band CE-chirps as an acceptable alternative stimulus. However, only tone pips (not chirps) should be used at lower frequencies because the latencies of peaks for lower frequency chirps makes the identification of an abnormal morphology ABR more difficult. The definite decision regarding waveform abnormality should be based on the ckABR.

Note 2: Where the maximum recommended stimulus level with inserts fail to evoke an ABR, a switch to supra-aural earphones is suggested for threshold determination. Using supra-aural earphones the calibration uncertainty associated with neonatal ear canal volumes is not an issue. Using headphones allows a higher stimulation level to be achieved which may evoke a response to reveal a sensorineural hearing loss. Refer to the Early Assessment guidance for the maximum recommended stimulus levels.

Note 3: A pattern of results has been reported where both 4kHz and the ckABR are absent and with a present low frequency ABR at high stimulus levels and present CM. At this stage there is no consensus as to how best to categorise or manage this pattern of results. There are suggestions that it may be associated with a steeply sloping sensorineural hearing loss (Coates & Martin, 1977), or that features of both ANSD and sensorineural hearing loss may be involved. It is recommended that this pattern is treated as a sensorineural hearing loss, with close monitoring for signs of poor speech processing.

If ABR response is **grossly abnormal** (as described in [Appendix A](#)) at 4kHz or with clicks (see note 1 above), the following steps are suggested:

- a) Determine the maximum level where cKABR yields a response absent.
- b) If this level is ≥ 70 dBnHL then perform the CM at the level where ABR is absent. If CM is present, then this should be taken as evidence of ANSD.
- c) If this level is < 70 then a CM can be performed, but may not be recordable and its absence should prompt the tester to assess OAEs. If OAEs or CM are present, then this should be taken as evidence of ANSD.
- d) In any other situation, ANSD may or may not be present but cannot be excluded with confidence. Other tests such as stapedial reflexes or contralateral suppression of OAEs may help the differential diagnosis. It is then advised to wait until 10 weeks corrected age, where a repeat assessment should be carried out. If results remain the same, then the ANSD label can be adopted for management purposes.

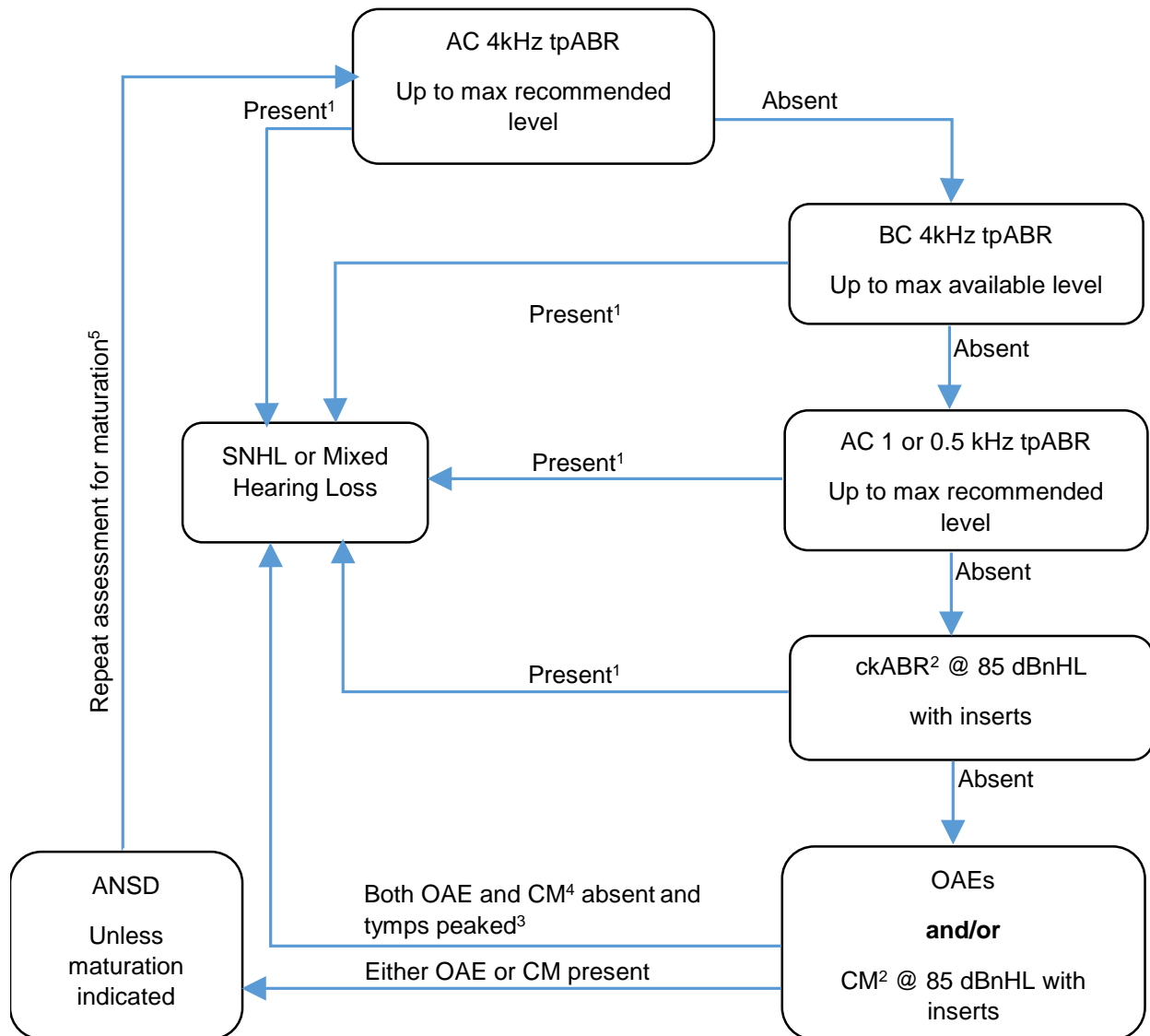
Note 4: Where a unilateral ANSD is suspected, effort should be made to rule out even a mild hearing loss on the other side, by testing down to 20 dB HL at both 4kHz and 1kHz. This is because the effects of ANSD cannot be predicted, the child may need to rely heavily on the non-ANSD ear for speech access. In this case, even a mild hearing loss or a reverse slope hearing loss could have a significant effect.

3.4. Writing reports

The Quality Standards in Paediatric Audiology (2000) state that all letters relating to the child's assessment results, diagnostic opinions and agreed management plan, should be copied to parents within 5 working days. Written clinic reports can also help parents with information retention, can raise any misunderstandings or errors. Effective communication with families via report writing can promote parental understanding and shared decision making. However below there are some points to consider when writing a report of a child with ANSD.

- Information should reflect the consultation and results should be discussed with parents before they are included in a report to avoid distress. Points to include in the report are tabulated in section 4.1
- In cases of unilateral ANSD it may be necessary to clarify why in one side ABR results give an estimation of the functional levels whereas on the ANSD side an absent ABR at maximum levels does **NOT** mean there is a severe-profound hearing loss when OAEs and/or a CM are present.
- If a diagnosis of the underlying pathology has been made, report should state the diagnosis along with a comment "...with ANSD pattern of subjective test results".

Fig 1. Schematic diagram of the assessment for ANSD



Notes:

1. ABR "present" means identifiable characteristic morphology with expected latencies. If ABR presents with abnormal morphology, refer to section 3.3 for further guidance.
2. An alternative testing order would be to perform the CM prior to the ckABR.
3. If there is evidence of middle ear effusion, ANSD cannot be excluded.
4. The absence of OAE and CM does not categorically rule out ANSD, but when both are absent it is reasonable to assume conventional hearing loss. There are anecdotal reports that in some cases of ANSD the OAE and/or CM can "burn out" with time.
5. See Appendix B for advice on repeat assessments.

4. MANAGEMENT

Sections 4.1 to 4.5 refer primarily to the management of bilateral ANSD. However, some of this guidance will also be relevant to the management of unilateral ANSD. Section 4.6 refers to specific considerations regarding unilateral ANSD.

The management of the child with ANSD requires a multidisciplinary team approach, working in partnership with the family. We suggest the team should include a Paediatric Audiologist, a medical professional (Audiological Physician, ENT consultant or Paediatrician), a Speech-Language Therapist, a Teacher of the Deaf, and a Neurologist. The timing and the necessity of involvement of these professionals will depend on the individual case and the wishes of the family. One member of the team should be designated to take ultimate responsibility for the management of the case. All the members should be familiar with and knowledgeable about the condition.

The management of ANSD presents great practical challenges, and the number of cases occurring in any one geographical area is small. While it is entirely feasible for departments that perform ABR to carry out CM and OAE testing and raise the initial suspicion of ANSD, we recommend that those with little or no experience of these cases should seek advice from centres with high levels of expertise and more experience, to obtain a firm diagnosis and start the management process. Such centres need to be able to offer support and guidance in diagnosis and management, ensure that families get the best information and advice, and build confidence in the local staff. In some cases, referral of the patient on to such centres may be appropriate.

4.1. Information and Support

The lack of certainty around prognosis can make ANSD a particularly difficult diagnosis for parents and families to deal with. In addition, many infants with ANSD will have other medical issues, meaning that hearing may not initially present a high priority for parents (Uus et al. 2012).

The confusion that parents are likely to feel may have a negative impact on the relationship between parents and professionals. **Ongoing communication, support, encouragement, and information for parents are critical to successful management.** It is important to provide written information⁶ regarding the condition to families as well as to other professionals involved with the child, such as Health Visitors, GPs and Paediatricians. ANSD should be described specifically, including what is known and not known about the condition.

⁶ Helpful sources of written information may include the relevant NDCS booklets 'ANSD-Information for families' and 'ANSD To Parents from Parents'.

Some families find it helpful to get in touch with other families that are in a similar situation. If this is not possible locally, this option can be explored via the NDCS website which provides various platforms for communications between families.

Hearing what ANSD sounds like may help parents' understanding. A simulation of what a person with various degrees of ANSD may be hearing has been created by Zeng et al. (1999) and can be found online.

During consultation with the family, it is helpful to cover the following points:

- The term ANSD is a label for a pattern of test results; it is not a label for a child.
- It is not immediately possible to predict the impact on the child or even the most successful form of treatment. However, by pooling test results and observations from parents, audiologists and other professionals will be able to do as much for the child as possible.
- An absent ABR does not necessarily imply a profound hearing loss.
- Close monitoring is required, as the child may not respond to sound in a typical way.
- Many children with ANSD are able to make good use of their hearing. However, the majority of children with this pattern of test results do turn out to have hearing problems of some degree which requires support and management.
- While the impact of ANSD on the child cannot be predicted at an early stage, establishing the child's early communication and language skills is important, and use of visual cues is advisable until the child's true hearing ability is known.

Families of children with ANSD should be offered referral for early support. Children with ANSD are at risk for communication difficulties and need to be monitored accordingly. The overall goal is to begin management as soon as the parents/carers feel ready to proceed (preferably by 6 months) and to establish a communication method for use by the child and family, and put in place a plan for continuing assessment of hearing and communication.

4.2. Ongoing Audiological Assessment

The audiological profile of children with ANSD may fluctuate. Therefore, ongoing and regular monitoring of auditory status (behavioural, functional, electrophysiological and middle ear) and hearing, speech, language and general development is required.

Audiological assessments should include:

Behavioural thresholds: in each ear determined by an developmentally appropriate method (VRA with insert earphones, Play Audiometry, conventional Pure Tone Audiometry). These can be acquired from a developmental age of around 6 months. Behavioural Observational Audiometry (BOA) and informal observation can start at an earlier age. Any BOA should be carried out and interpreted with extreme care (BSA-NHSP Guidelines).

Some children may have complex medical and developmental factors which present a challenge for behavioural testing. Such children must be assessed by suitably experienced and skilled professionals and results should be viewed in the context of the child's developmental status. If reliable results cannot be obtained because of significant developmental delay, BOA and informal observation may be useful in guiding management.

Electrophysiology: as discussed in [Appendix C](#).

Tympanometry/Stapedial Reflexes: Monitoring of middle ear status is important as the presence of fluid in the middle ear will affect other tests, and children with ANSD are as likely as any other to develop middle ear effusion. This should be done in conjunction with other testing. SRs (using both tonal and broad band stimuli) should also be measured.

Additional tests that may be appropriate in the ongoing assessment of children with ANSD are discussed in [Appendix C](#).

4.3. Monitoring and Assessment of Communication Development

Monitoring and assessment of language and communication development is the key determinant of management options. Close monitoring of communicative and developmental progress by parents and professionals together should be undertaken using the Early Support Monitoring Protocol for deaf babies and children (2013) or other appropriate monitoring tools. In addition, regular standardised assessments of language and communication should be undertaken by qualified Teachers of the Deaf and specialist Speech and Language Therapists. The development of more sophisticated monitoring tools would be helpful in the early monitoring and management of infants with ANSD.

Although specific questionnaires for ANSD have not been developed, existing questionnaires can be used from the first few months. Some modifications may be required, for example sections that are aimed to evaluate hearing aid usage. Examples of such questionnaires are:

- ELF: Early Listening Function
- IT-MAIS: Infant Toddler Meaningful Auditory Integration Scale
- CAP: Categories of Auditory Performance
- PEACH: Parent Evaluation of Aural/oral performance of Children
- LittleEARs auditory questionnaire.

4.4. Intervention / Aids to Communication

i. Modes of Communication

This should be determined by the needs and desires of the family, taking into account the observed progress of the child. For most children with ANSD, use of a combination of communication systems that incorporates visual support is appropriate (*e.g.* auditory/aural with lip-reading and natural gesture, total

communication, sign language). On the other hand, an auditory-only approach (such as auditory-verbal therapy) may not be successful.

Regardless of communication method, it is important that parents become proficient in the method and use it regularly in the home. Such approaches can be put into place at an early stage, before behavioural thresholds and the child's 'true' hearing ability are known, in order to lay the foundations of communication and language development.

ii. Conventional Hearing Aids

There is increasing evidence that a substantial number of children with ANSD derive benefit from hearing aid fitting if there is a significant behavioural hearing loss (Ching et al., 2013). About 50% of the children in one study gained significant benefit (Rance et al. 1999), although this is variable with some clinics reporting much lower success rates (Berlin et al. 2010) and some much higher. Therefore, a trial of amplification should be undertaken. However, due to doubt as to the benefit in children where behavioural thresholds are near-normal, **the recommendation is to aid a child whose behavioural thresholds are reliably elevated**. A number of other considerations and complications apply – for further details and discussion please see reference (Northern Ed. 2008).

The decision on whether to aid should be based on behavioural results, cortical auditory evoked potentials (CAEP) results where available and observations from families and early interventionists regarding the child's responses to sound and early communication development. If reliable behavioural hearing thresholds are not yet available and there is significant concern from the family and early interventionist, hearing aid fitting can begin based on these concerns and behavioural observation audiometry (unaided and aided) in the test situation.

Where CAEP measurements are utilised, refer to the Australian protocol on how these measurements can be incorporated into the fitting protocol (Punch et al. 2016).

The fitting of hearing aids to children with ANSD should be based on a prescriptive method specifically developed for infants and young children (MCHAS 2003) (e.g. DSL). The behavioural thresholds (not ABR / electrophysiological thresholds) should be used to establish amplification targets. In order to provide the best chance of benefit, it is important that optimal audibility of speech sounds above threshold is achieved. Therefore, provided reliable behavioural thresholds are available, aids should be fitted to target based on these thresholds, rather than adopting a 'conservative' approach.⁷

⁷ If behavioural thresholds fluctuate from test to test, the lowest thresholds obtained should be used, to avoid risk of over-amplification.

Where there is a lack of reliable behavioural thresholds on which to base the prescription, a conservative approach should be adopted, beginning with low hearing aid gain and increasing the gain gradually if no responses from the child are observed.

Hearing aid benefit should be determined. Benefit is determined primarily based on the development of speech perception skills, not on aided detection thresholds. Monitoring of the child's hearing aid fitting is essential – refer to the appropriate MCHAS guidelines (2003).

Conventional fitting formulae have been developed mainly for individuals with sensorineural hearing loss. Individuals with ANSD have poorer temporal processing and reduced frequency discrimination especially at the lower frequencies. Therefore, their amplification needs may be different. Modified amplification using low frequency cut or reduction (Prashanth et al. 2017) or enhancement of temporal and spectral cues (Name and Vanaja 2012) and transposition of low frequencies to high have been proposed. There is no clear evidence at this stage however, whether any of these strategies have positive effects on speech intelligibility.

iii. Radio Aids

Radio aids (with or without personal hearing aids) may be beneficial for children with ANSD who have residual speech recognition in quiet but experience difficulty in noise (Hood et al. 2004). A trial with a radio aid should be considered as part of the hearing aid fitting process, particularly when the child is involved in a day care or educational setting in which poor acoustic conditions restrict access to spoken language.

iv. Cochlear Implants (CIs)

The literature has shown increasing numbers of children with ANSD who benefit from cochlear implants (Berlin et al. 2004, Northern Ed. 2008, Berlin et al. 2010, Shallop et al. 2001, (Ching, Day et al., 2013)), and this option should be considered when behavioural responses indicate the child is behaving like a child with a severe/profound hearing loss, and/or when the child is not making progress with hearing aids (i.e. they show no or very limited speech discrimination abilities). A trial of conventional amplification is important prior to cochlear implantation (this is an area where more research is needed). Behavioural pure tone thresholds are not a good guide to determine CI candidacy. Children with ANSD who have even relatively mild hearing losses on behavioural testing may be CI candidates if they do not show good progress with other interventions.

Infants identified with ANSD can be referred to a cochlear implant centre for assessment as soon as there are significant concerns about behavioural responses to sound and/or communication/speech/language development. It is not appropriate to refer infants with ANSD for cochlear implantation based purely on ABR results, and generally behavioural measures will need to have been obtained. Some cochlear implant centres however, would encourage early contact to initiate communication for advice and input. In view of the reports of significant improvement in auditory function in some infants with ANSD over time, **the final decision to implant should not be made until audiological test results are stable and demonstrate unequivocal evidence of permanent ANSD**

(Northern Ed. 2008). However, these tests can be carried out as part of the CI assessment to avoid delays. The exception to this is where there is a strong suspicion of a genetic cause for the ANSD known to be associated with profound deafness and good CI outcome (e.g. OTOF mutation); such cases can be referred and implanted in a similar timescale to infants with profound typical cochlear hearing loss. There is limited evidence that ATP1A3 mutations associated with late onset ANSD is also linked with good CI outcomes (Han et al. 2017).

Refer to [Appendix C](#) on how CAEP testing may help identify ANSD patients that may benefit from CIs.

Local centres should be able to discuss cases of ANSD with the CI team, and it is important that the CI team are able to accept referrals on the basis of assessment and advice, rather than on the assumption that they will be candidates for surgery. The approach and timescale for assessing such cases will be different from that for cases of conventional SNHL (except in the event of a known genetic cause as defined above), and assessment for possible delayed maturation must be carried out as part of the process of CI assessment. It is important to make clear to parents and involved professionals that the referral at this stage is for *assessment* and that it is not yet clear whether the child will turn out to be a candidate for implantation. Responsibility for the ongoing monitoring of hearing and communication development, with appropriate modification of management strategies, also needs to be clearly agreed between the CI team and the local service.

Guidelines for cochlear implant assessment of children with ANSD in the UK have been developed by the British Cochlear Implant Group (Ambler et al. 2013). Cochlear implant funding bodies in the UK have also reviewed their candidacy criteria for patients with ANSD (NHS England (2014) http://www.bcig.org.uk/wp-content/uploads/2010/10/SSC1442_ANSD.pdf).

In a large cohort study conducted in Australia (Ching et al. 2013), 451 children diagnosed with a permanent childhood hearing impairment (of which 44 had ANSD) were managed according to their national protocols. Results suggested that a delay in cochlear implantation had a significant effect in global outcomes (speech and language, functional and social measurements). This effect was not apparent for hearing aids. It is noted that all children had received amplification before the age of 3 years. Results likely suggest that the length of auditory deprivation is detrimental for speech and social outcomes in children with ANSD, who are candidates for cochlear implants.

However, the challenge for interventionist is how to identify the cases that are likely to benefit from CIs sooner and how to rule out transient ANSD prior to CI implantation. Gardon et al. (2013) found that a sensitive period for intervention for children with ANSD that receive CIs is around 2 years.

4.5. Aetiological Investigations

Ongoing medical (and neurological assessment if warranted) is essential. Some infants may already have an established neurological diagnosis. In others, ANSD identified by newborn hearing screening may be the first indicator of an underlying neurological condition. It is therefore recommended that all children

who are diagnosed with ANSD are assessed and investigated by an appropriately skilled and experienced Audiovestibular Physician, Paediatrician or Paediatric Neurologist. There are separate guidelines underway, that can provide more information regarding the aetiological investigation of children with ANSD (BAAP 2018). Key elements that should be included in the assessment are listed in [Appendix D](#). Also refer to section 2.4 for possible aetiologies for ANSD.

Diagnosis of the underlying aetiology may determine the most appropriate further management, including specific intervention if indicated. In some children however the underlying aetiology may remain unidentified.

4.6. Management of Unilateral ANSD

a) Neonatal tests indicating unilateral ANSD with SNHL in the contralateral ear

Cases where the contralateral ear has a severe/profound hearing loss (*i.e.* absent/grossly abnormal ABR with no evidence of outer hair cell function) should be managed with caution, as it is possible that they may in fact be cases of bilateral ANSD. Aiding of the “non-ANSD” ear is advised, but decisions about cochlear implantation of either ear should not be made until there is unequivocal evidence of permanent profound hearing loss or ANSD on behavioural testing. The above refer to cases where there is no evidence of middle ear effusion as this would complicate the picture.

b) Unilateral ANSD with normal hearing in the contralateral ear

There is little consensus about the management of unilateral ANSD in young infants. The effects of unilateral SNHL are fairly well understood, but the impact on speech/language and educational progress varies between individuals. The effects of unilateral ANSD are less well understood. As discussed above, monitoring of hearing, communication and speech/language development are important.

Children with unilateral ANSD should also receive a medical referral for aetiological investigation. There is high prevalence of cochlear nerve deformities in patients with unilateral ANSD (Mohammadi et al. 2015) although not all cases will present with an ANSD phenotype (Buchman et al. 2006). In a study of 17 infants with unilateral ANSD, 59% were found to have cochlear nerve aplasia. In about 17% of those, the condition was missed with a CT and confirmed with MRI imaging. It is therefore advised that an MRI should be the first line of imaging investigation for children with unilateral ANSD. A definite diagnosis of nerve hypoplasia/aplasia can inform management for the individual. Cases of cochlear nerve deficiency are expected to have poorer outcomes following cochlear implantation. For those diagnosed with nerve aplasia however, both cochlear implant or brainstem implant options can be investigated, as the condition is not necessarily associated with complete loss of nerve fibers.

4.7. Management of Transient ANSD

Children with transient ANSD should be monitored for their communication development at least until they reach school age (Uus K 2017). We recommend that the monitoring occurs annually by the Audiologist if there are no concerns.

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(last accessed Dec 2017)

6. Appendix A: What Constitutes an Abnormal ABR?

There is a lack of consensus about the definition of “severely abnormal ABR morphology” and different practices exist. We suggest that the following: Abnormal ABR at *or above 75dB HL* applies to click or tone pip ABRs and does not include waveforms having a waveform morphology that is typically consistent with elevated hearing thresholds. Rather, an abnormal waveform is one with grossly abnormal morphology (for example no wave V in the presence of wave I or wave III), latencies or amplitudes likely to be seen in cases of ANSD or neurological dysfunction.

In some cases of grossly abnormal ABR, early components may be recognisable, but no clear wave V at the expected latency, as in Fig 2. Furthermore, any ABR components that do not change in latency with stimulus level changes should be considered abnormal (Berlin et al. 2010).

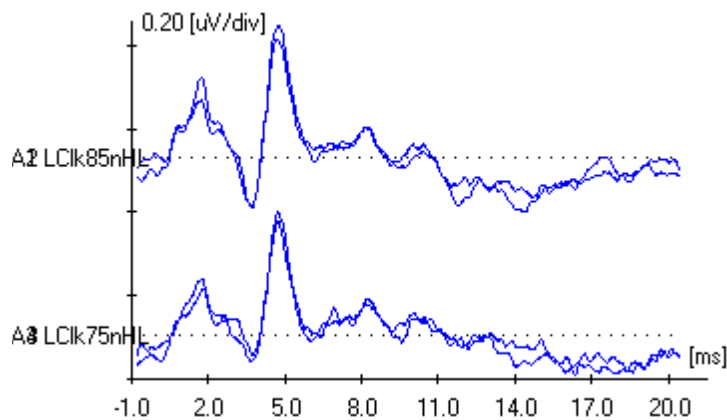


Fig 2 Example of a grossly abnormal ABR, which eventually matured to normal morphology at 11 weeks (corrected age). A possible small wave V can be seen around 8ms.

Below there is another example of a grossly abnormal ABR with an earlier and a later (possibly neural) component. Both components disappear with clamped insert earphone tube.

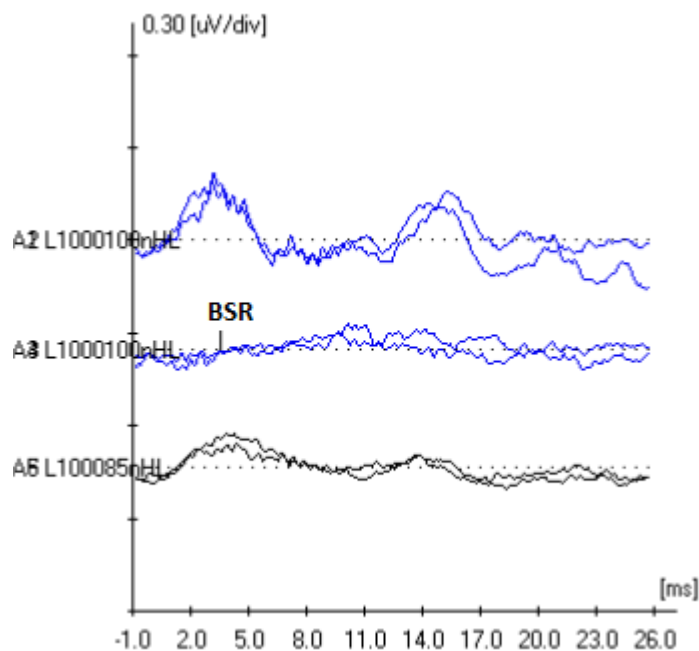


Fig 3 Example of a grossly abnormal ABR with an earlier and a later component but no clear wave V at the expected latency. “BSR”: a **blocked stimulus run** where the insert tube was clamped.

Occasionally, babies may present with more moderately raised ABR thresholds (of normal morphology) and TEOAEs present. Our current advice is that such cases should not be labelled as ANSD and that an expert paediatric audiology centre should be consulted.

7. Appendix B: Delayed Maturation and the Timing of Repeat ABR

Testing

For babies in whom their initial ABR/CM tests were performed at a corrected age of up to 6 weeks, it is recommended that the ABR is repeated at a corrected age of 8-10 weeks. We suggest that a re-test should be considered at 12-18 months of age. However, the decision whether or not to carry out this re-test should depend on the circumstances of the individual case. The practical difficulties of performing an ABR at this age are also recognised. In making this decision, the following factors need to be considered:

i) Age of maturation of ABR

Anecdotally, any maturation of the ABR occurs by around 18 months of age, but there appear to be few reported studies in the literature. Attias & Raveh (2007) reported 5 cases of high risk neonates being considered for cochlear implantation who showed full or partial recovery of the ABR on re-test 7-12 months after diagnosis. Madden et al (2002) reported improved behavioural thresholds 1-15 months after diagnosis, with a stable audiogram reached by 11-25 months, in 9 out of 18 infants, but do not report whether any changes in ABR were seen. Psaromattis et al. (2006) reported recovery of the ABR after 4-6 months in 12 out of 20 NICU babies diagnosed with ANSD although limitations of this study include no defined lower age limit for conducting ABR, lack of bone conduction testing and lack of CM testing.

ii) Practicalities of testing

ABR testing under natural sleep is often difficult to achieve in this older age group, and sedation may well be required. However, co-morbidities in many of these children may mean that sedation is contra-indicated. Sometimes the child may be undergoing sedation or anaesthesia for treatment of some other condition, and it may be possible to arrange to repeat the ABR at the same time.

iii) Parent counselling

Experience has shown that careful counselling of parents around the repeating of ABR tests is needed. As noted above, sleep can be difficult to achieve and the re-test session may prove to be a long and difficult one for parent and child. In the case of a child who is showing good behavioural responses to sound, it can be very discouraging to a parent if the repeat ABR still shows an abnormal response. It is important that parents understand that active monitoring of the child's behavioural responses and speech & language development is the key factor in determining their ongoing management and outcome. It helps if these issues have been discussed with parents to prepare them for the different possible outcomes of the re-test before this is carried out.

iv) Patient management

The practical issues outlined above need to be weighed up against the likely usefulness of the repeat ABR result in management of the patient. For example, if the child at this age is showing convincing and reliable behavioural responses consistent with a severe/profound hearing loss, and poor speech &

language development, then active audiological management (including consideration of CI referral) is clearly indicated and a further abnormal ABR test may not add to the picture. Conversely, if the child is showing good behavioural responses and good speech & language development, whilst it would be informative and encouraging to demonstrate an improved ABR, ongoing follow-up and monitoring of the child's speech & language development would still be recommended until more subtle auditory processing difficulties have been ruled out. However, ongoing use of the ANSD label in these cases may not be helpful.

8. Appendix C: Additional Tests

The following tests may be valuable in the ongoing assessment of infants and children with ANSD.

a) Speech discrimination testing

This should be attempted at as young an age as possible, including testing in noise. In addition to testing in the clinic, speech discrimination ability should also be evaluated in the child's natural environment (e.g. home, nursery) – this may be done in conjunction with education and/or speech-language therapy colleagues. Further work is needed on developing age-appropriate tools that are sophisticated enough to look in sufficient detail at early speech/language/communication development in order to inform the management of young infants with ANSD.

b) Advanced electrophysiological techniques

i) Electrocochleography (ECoChG) and Electrically-Evoked ABR (eABR)

Recent studies have indicated that these tests may have a role in narrowing down site of lesion and helping predict cochlear implant outcome (McMahon et al. 2008). Studies using trans-tympanic electrocochleography have identified two abnormal potentials in some ANSD patients: an “abnormal positive potential” (enlarged summing potential) which has been interpreted as indicating a pre-synaptic disorder and may give a good CI prognosis, and a “dendritic potential” which has been interpreted as indicating a post-synaptic disorder and therefore likely to indicate poorer CI outcome. There is some contradicting evidence on whether cases with normal eABR are associated with better outcomes following implantation, than those cases with an abnormal eABR. Furthermore, these are invasive techniques which are still at a research stage and further work is needed.

ii) Cortical Auditory Evoked Potentials (CAEPs)

There is emerging evidence (Rance et al. 2002, Cone-Wesson 2004, Sharma et al. 2011, Cardon & Sharma 2011) that the presence or absence of auditory cortical responses in patients with ANSD might provide an insight into the degree of an individual's dys-synchrony and whether hearing aids are likely to be helpful. The mechanism of this is unclear. Sharma and colleagues (Sharma et al. 2011, Cardon & Sharma 2011) suggest abnormal, or dys-synchronous, patterns of sub-cortical transmission, which occur in children with more disabling degrees of ANSD, have the potential to disrupt normal cortical development and it is this abnormal cortical development that explains the failure to evoke cortical responses. An alternative basis for the lack of recordable cortical responses in some patients with ANSD has been proposed by Neary & Lightfoot (2012): it requires only a modest degree of temporal dys-synchrony to “smear” the relatively short latency responses of the ABR but it takes a correspondingly greater degree of dys-synchrony to abolish the longer latency cortical response. So, if both the ABR and CAEPs are absent then it is reasonable to conclude the dys-synchrony is profound and the prognosis with amplification may be poor. However, caution should be exerted interpreting the absence of CAEPs. As it has been suggested that even when the stimulus is audible CAEPs are increasingly detectable with increasing sensation level and their detectability lies in the region of 70% (Van Dun 2012). If the ABR is absent but cortical responses are present the degree of dys-synchrony is likely to be modest and

therefore the prognosis for amplification is better. However, the latency of the response is likely to be significant as well. Sharma et al. (2013) found that the P1 latency was an indicator of the maturation of central auditory pathway and correlates well with outcomes. The delay of the latency prior to intervention and the improvement of the latency following intervention were both used to guide management.

Thus, cortical testing may have potential in informing patient management and could guide the expectations of patients or their parents. In Australia, a protocol has been devised that incorporates CAEPs into the management of infants with hearing loss (Punch et al. 2016).

iii) Contralateral OAE suppression

It measures the reduction in the OAE signal that occurs when a masker is presented contralaterally. It provides an assessment of the efferent pathway from the medial olivocochlear system to the outer hair cells. It can be abnormal in ANSD.

iv) Acoustic Change Complex (ACC)

ACC is an auditory event-related potential that can provide evidence of discrimination capacity. It can sometimes be recorded from individuals with ANSD despite the absent or abnormal ABR to assess temporal processing and is elicited by stimulus changes. It is a promising test in predicting speech perception performance in patients with ANSD and thus identifying individuals that require additional support (He et al. 2015).

9. Appendix D: Medical Assessment

Key elements in the assessment of infants identified with ANSD should include:

- CMV testing.
- Detailed history, including family history, neonatal factors e.g. gestation, hypoxia, assisted ventilation, hyperbilirubinaemia, intraventricular haemorrhage, hydrocephalus, convulsions.
- Examination, particularly focused on neurological and developmental assessment.
- Imaging – MRI brain and internal auditory meati to assess integrity of the VIIIth and VIIth nerves (refer to section 4.6 for unilateral ANSD).
- Ophthalmology assessment – particularly looking for evidence of visual cortical dysfunction, optic disc pathology.
- Peripheral nerve conduction studies –if generalized neuropathy suspected.
- Referral to a geneticist, particularly if a neurodegenerative condition is suspected. It has become possible recently to test for OTOF in the UK.
- Genetic sequencing:
- Metabolic studies as indicated by relevant clinical features – *e.g.* urine amino acids.
- Vestibular assessments as vestibular function can be abnormal in individuals with auditory neuropathy.

Acquired ANSD is particularly associated with a neurodegenerative or metabolic aetiology and these children especially require detailed neurological assessment and investigation. Neurodevelopmental history, speech and language development, and neurological abnormalities should be noted in detail.

10. Appendix E: Case Scenarios

i. Case example 1: Delayed Maturation

History summary:

Born at 26 weeks gestation.

Prolonged assisted ventilation; treatment for repeated episodes of sepsis; phototherapy for jaundice.

Home at 5 months on ambulatory oxygen.

Screen: NICU protocol

TEOAE: CR R&L AABR: NCR R&L

Initial Audiological Assessment:

8 weeks corrected age, shortly after discharge home. Parents unsure about responses to sound.

(R) ear:

4kHz tpABR: no response (**RA**) at 85 dBeHL

1kHz tpABR: no response (**RA**) at 100 dBeHL

Switched to ckABR using inserts: no response (**RA**) at 85 dBeHL.

CM recorded at same level.

(L) ear:

Started with ckABR in view of result obtained on (R) and screen result on (L).

1kHz tpABR recorded to check for low frequency response: No response (**RA**) at 100 dBeHL

No response (**RA**) to click at 85 dBeHL

CM recorded at same level.

No obvious behavioural responses observed.

Interpretation

- History: high risk for SNHL and ANSD
- ANSD pattern R&L
- Delayed maturation a possibility, though baby is now post-term.

Management

- Results discussed with parents, including explanation of ANSD and unpredictable outcome.
- Referral to ToD agreed. Encouraged visual input and close monitoring.
- For repeat ABR 8 weeks later, in view of possibility of delayed maturation.
- Results discussed with neonatal paediatrician.

Repeat ABR: 16 weeks Corrected age

TEOAE: present R&L

Started ABR with click in view of previous lack of response. Click ABR: repeatable responses present down to 60 dBeHL R&L though delayed waveforms.

4kHz tpABR: repeatable responses present down to 60 dBeHL though delayed waveforms.

BC 4kHz tpABR: no convincing response at 60 dBeHL.

High frequency tymps: normal R&L

Interpretation

- Some signs of maturation; need to continue monitoring.

Management

- Results discussed with parents: signs of improvement; still difficult to predict outcome
- Continue ToD support, visual support for communication, and monitoring
- Review in Audiology for behavioural testing.

Audiology review: 7 months corrected age (i.e. 10 months chronological age)

Seems to respond well to sound at home; babbling tunefully; good physical development – just sitting unsupported.

Conditioned well for insert VRA:

	Minimal response level (dBHL)			
Frequency (kHz)	0.5	1	2	4
(L) ear	30	30	N/T	25
(R) ear	30	25	20	30

Tymps: peaked R&L

Interpretation

- Satisfactory VRA responses for developmental age. In view of previous results, need to monitor to ensure good receptive & expressive speech & language development.

Management

- Discussed with parents: encouraging results; responding well to sound; too young to be sure how useful hearing is for speech
- Continued support & monitoring by ToD

Audiology review 6 months later

Seems to hear well at home; responds to quiet sounds.

Producing several recognisable words with meaning.

Insert VRA: Minimal response levels at ≤ 20 dBHL R&L at 0.5, 1, 2 & 4 kHz

Ongoing reviews

Repeat ABR successfully obtained under natural sleep at 21 months:

4kHz tpABR: CR R&L ≤ 20 dBeHL with normal waveform morphology (unable to attempt 1kHz recording as child woke up)

Hearing and speech development monitored at least annually until aged 6 years
Age-appropriate speech and language development.

Interpretation

- Was 'transient' ANSD due to delayed maturation. 'ANSD' label no longer appropriate.

Management

- Discharged at 6 years of age after successful start at school. Advised to re-refer if any concerns.

ii. Case example 2: Bilateral ANSD, Rehabilitated with Hearing Aids

History summary:

Born at term by emergency caesarean section due to reduced foetal movements.

Required intensive resuscitation, followed by assisted ventilation for 5 days.

Developed neonatal convulsions. Cranial ultrasound and MRI demonstrated cortical changes consistent with hypoxic ischaemic encephalopathy.

Home at 6 weeks.

Screen: NICU protocol

TEOAE: CR (R), NCR (L) AABR: NCR R&L

Initial Audiological Assessment: Aged 6½ weeks

Parents feel baby sometimes responds to loud sounds.

(R) ear:

4kHz tpABR: no response (**RA**) at 85 dBeHL

1kHz tpABR attempted to check for low frequency response: no response (**RA**) at 100 dBeHL

Switched to ckABR using inserts: no response (**RA**) at 85 dBeHL.

Cochlear microphonic recorded at same level.

(L) ear:

4kHz tpABR: no response (**RA**) at 85 dBeHL

No response (**RA**) to click at 85 dBeHL

Woke before 1kHz tpABR and CM recording could be attempted.

Clear TEOAE recorded.

No obvious behavioural responses observed.

Interpretation

- History: high risk for SNHL and ANSD
- ANSD pattern R&L
- Term baby, tested at 6 weeks, so delayed maturation less likely, but wise to repeat ABR to confirm initial diagnosis.

Management

- Results discussed with parents, including explanation of ANSD and unpredictable outcome.
- ToD referral offered but parents prefer to wait for now. Encouraged use of visual as well as auditory stimulation.
- For repeat ABR in 6 weeks
- Neonatal paediatrician informed of results.

Repeat ABR: 12 weeks

Clear TEOAEs recorded R&L

Started with ckABR (inserts) in view of previous results. No repeatable response R or L at 85 dB HL

Baby still sleeping, so CMs recorded R&L.

High frequency tymps: normal R&L

Interpretation

- Bilateral ANSD with no indication of maturation so far.

Management

- Discussed results with parents and re-iterated importance of support for early communication as it will be some time before we have an indication of true hearing ability
- Parents agreed to ToD referral
- For regular support & monitoring by ToD, with feedback to Audiology. Audiology review for behavioural testing.

Audiology review: 7 months

Parents & ToD feel child responds to some louder sounds at home, but little response seen to voices or quieter toys. Some vocalisations but no real babble. Some developmental delay – not yet sitting unsupported.

Unable to successfully condition to VRA. Repeatable responses obtained on a combination of behavioural observation audiometry & distraction testing, as follows:

	MRL to soundfield warble tones (dBA)			
Frequency (kHz)	0.5	1	2	4
Presented on (L)	70	80	85	85
Presented on (R)	70	75	80	80

Responded to voice at 60-70 dBA; no response to 's' or high frequency rattle at 60 dBA. Tymps: mobile R&L.

Interpretation

- Behavioural responses and parent/ToD observations consistent with moderate/severe hearing loss, though responses recorded may not yet be quite threshold

Management

- Discussed with parents. Agreed to trial hearing aids
- Aids fitted programmed to behavioural responses, slightly conservatively initially in view of lack of precision over thresholds and lack of ear-specific information. Alerted to sound with aids, but no sign of loudness discomfort when checked with loud sounds.

Audiology review 6 weeks later

Conditioned to insert VRA using earmoulds:

	Minimal response level (dBHL)			
Frequency (kHz)	0.5	1	2	4
(L) ear	60	60	N/T	70
(R) ear	65	60	70	70
BC	40	60	70	70

Aids re-programmed to these results – now fitted accurately to target.

Ongoing reviews: every 3 months over next year

Insert VRA thresholds confirmed on subsequent tests – similar to above, with some variation between assessments.

Parents report good responses to voice with aids. Wearing aids consistently.

Continued support from ToD and Speech & Language Therapist; signing introduced.

Child diagnosed with mild cerebral palsy – under care of paediatric neurologist.

Speech and language development delayed but showing steady progress.

At 2 years

Child had GA for orthopaedic procedure – opportunity used to repeat ABR.

No response R or L to 1 and 4kHz tp or ckABR at 85 dBeHL.

CMs recorded R&L at 85 dBeHL

Interpretation

- Bilateral ANSD confirmed.
- Moderate-to-severe loss on behavioural testing.
- Making good progress with hearing aids.

Management

- Continue with aids and ongoing monitoring.

iii. Case example 3: Bilateral ANSD Rehabilitated with CIs

History summary:

Born at 35 weeks gestation. Admitted to NICU for 10 days for temperature maintenance and to establish feeding.

Discharged home well. Discharged from further follow-up by neonatal paediatricians after first outpatient review.

1st child. No family history of deafness.

Screen: NICU protocol

TEOAE: NCR R&L AABR: NCR R&L

Initial Audiological Assessment:

0 weeks corrected age. Parents concerned about lack of response to sound at home.

Clear TEOAE recorded R&L.

ABR carried out as baby was in NICU > 48 hours:

(L) ear:

4kHz tpABR: no response (**RA**) at 85 dBeHL

1kHz tpABR: no response (**RA**) at 100dBeHL

Switched to ckABR: no response (**RA**) at 85 dBeHL.

CM recorded at the same level

(R) ear:

4kHz tpABR: no response (**RA**) at 85 dBeHL

1kHz tpABR recorded to check for low frequency response: no response (**RA**) at 100 dBeHL

Switched to ckABR: no response at 85 dBeHL.

CM recorded at same level.

No obvious behavioural responses observed.

Interpretation

- History: slightly premature and in NICU > 48 hours, but no major risk factors for ANSD
- ANSD pattern R&L
- Delayed maturation a possibility – baby only just term – though was only 5 weeks premature.

Management

- Results discussed with parents – fits with their concerns at home. Explained unpredictable outcome.
- Referral to ToD agreed. Encouraged visual input and close monitoring.
- For repeat ABR in 8 weeks.
- Referred to paediatrician and Audiovestibular physician:
 - Satisfactory general and neurological examination

- Neurological MRI, including internal auditory meati, performed without sedation (under 'feed and wrap' protocol). Reported as normal including VIII nerve.
- Possible genetic cause for ANSD considered and referral made to genetic service.

Repeat ABR: 8 weeks CA

No repeatable response to 1kHz tpABR at 100 dBeHL

No obvious behavioural responses to 4kHz at 85 dBeHL.

Still no repeatable response to ckABR at 85 dBeHL

CMs recorded R&L

Interpretation

- Bilateral ANSD with no evidence of maturation
- Possible genetic cause

Management

- Parents commenced home sign language tuition
- For close support & monitoring from ToD
- Review for behavioural testing as early as possible

Audiology review: 5 months CA

Parents & ToD report no observed responses to loud sounds at home.

VRA: Conditioned to vibrotactile stimulation. No response to warble tones using inserts at maximum levels – 100 dBHL at 0.5 kHz and 120 dBHL at 1,2 & 4 kHz R or L.

Tymps: normal R&L.

Interpretation

- Behavioural testing and parental/ToD observations are all consistent with severe/profound bilateral hearing loss
- Genetic cause suspected in view of lack of other risk factors

Management

- Discussed with parents and agreed to hearing aid trial. Aids fitted, programmed to behavioural responses.
- Cochlear implant referral discussed with parents.

At 7 months CA

Insert VRA continues to show profound bilateral hearing loss

Limited response to hearing aids

Producing vibrotactile vowel sounds only. Beginning to show understanding of sign.

Satisfactory developmental progress.

Interpretation

- Bilateral profound hearing loss with no evidence of maturation

- Genetic cause strongly suspected

Management

- After discussion, referred to cochlear implant programme
 - Appropriate to go ahead with CI referral without further delay.

11. Appendix F: Document Revision History

Version	Date	Amendment History
1.1	2008	First version
2.1	2012	<ul style="list-style-type: none"> • The name used for the condition was updated from 'Auditory Neuropathy / Auditory Dys-synchrony' to 'Auditory Neuropathy Spectrum Disorder', in accordance with recent international guidelines. • A section on Aetiology was added. • The section on 'Initial Assessment' was updated in line with the NHSP guidelines for Early Audiological Assessment (2011) and Cochlear Microphonic testing (2011). • Version 1.1 recommended a repeat ABR assessment at a corrected age of 9-15 months (to test for possible delayed maturation). In versions 2.1 & 2.2 the guidance is to <i>consider</i> a repeat ABR at 12-18 months corrected age, depending on the circumstances of the individual case. Appendix B discusses the issues around this decision. (Guidance on an earlier repeat ABR at 8-10 weeks corrected age is unchanged.) • Section 3.4 on Intervention was re-ordered to highlight the importance of early communication support, before the age at which decisions about amplification can be made. • A brief section on the management of unilateral ANSD was added. • Some example case scenarios, illustrating the diversity and spectrum of the disorder, are given in Appendix E. • Appendices on additional audiological tests (including recent work in electrophysiology) and on medical assessment were added. • Previous (version 1.1) Appendices 1 (timeline) and 2 (cochlear microphonic testing, plus addendum) were removed. This information is now incorporated into the main document and into the separate 'Guidelines for cochlear microphonic testing'. • The References section was updated.

2.2	2013	Minor changes have been made to clarify some points. In particular, issues around the definition and initial diagnosis of ANSD in sections 1&2 and the timing of possible cochlear implant referral in section 3.4d have been clarified. Slight changes to section 2 ('Initial Assessment') have also been made for consistency with the 2013 revision of the NHSP Early Assessment guidelines.
3.0	2019 (this version)	<ul style="list-style-type: none"> • Advice on testing and interpretation updated • Expansion of testing and interpretation section with specific advice when ABR has abnormal presentation • Aetiologies and Risk Factors expanded • References have been updated • A new appendix has been added explaining the definition of abnormal ABR • Sites of lesion section added • Initial and ongoing assessment sections merged and a flow chart incorporated. • Advice to attempt both OAEs and CM if possible