NEONATAL HEARING SCREENING AND ASSESSMENT

TRANSIENT EVOKED OTO-ACOUSTIC EMISSION (TEOAE) TESTING IN BABIES

RECOMMENDED TEST PROTOCOL

Editor: John Stevens
Contributors: David Kemp, Roger Thornton, Lindsey Kimm, Mark Lutman, Pete Watkin

INTRODUCTION

With the publication of the systematic review on Neonatal Hearing Screening [1] a national group has had meetings to discuss some of the issues of implementation of Universal Neonatal Hearing Screening. Several workshops on technical issues have been held at which it was felt that it would be useful to produce consensus documents on test methodology where this was possible. This document aims to produce a consensus protocol for the use of TEOAE in the national UK pilot in newborn hearing screening. The editor wishes to acknowledge the work of David Kemp in producing a draft protocol covering wider application of OAE in babies on which this document is based. This document is specifically for the national UK pilot newborn hearing screening program whose aim is to detect moderate bilateral hearing impairment present at the time of the neonatal screen.

Otoacoustic emissions are sounds, which appear in the ear canal as a by-product of sensory cell activity in the inner ear in response to sound. They are conducted through the middle ear. Their successful stimulation and detection indicates a high degree of normality in the functioning of the middle ear and inner ear. In particular the environment of the inner ear is shown to be healthy. This is a necessary but not in itself a sufficient condition for normal hearing. The signals detected by the cochlea also need to be transmitted effectively through the auditory nerve pathways and to be interpreted correctly by the higher auditory centres.

The value of OAE testing for hearing screening is based on the fact that in a very high proportion of congenital hearing impairments it is the environment and the sensory cells of the inner ear which are affected and which will result in no OAEs being produced. OAE screening has therefore been shown to be very effective in screening the well baby population. In the at risk population it has been shown that some babies exhibit retro cochlea disorders which are not identified by OAEs testing alone. In the UK UNHS pilot AABR has therefore been chosen as the prime method for screening the at risk group.

Historically TEOAEs have been the most used method for newborn hearing screening both in the USA and Europe. All the major trials and longest running programmes (Rhode Island[2], Wessex Project[3], Whipps Cross programme[4] have employed TEOAEs and the majority of literature refers to TEOAE. However in recent years DPOAE technology has evolved to provide a viable alternative to TEOAE screening. TEOAE has been selected as the method to be used in the UK pilot in newborn hearing screening .

SCOPE

The document firstly describes the types of OAE and recording technologies. It then focuses on the choice of parameters to be used in the recording of TEOAEs in the first few months of life. In addition it proposes pass/refer criteria to be used in the UK UNHS pilot program. It only briefly looks a the practical aspects as these are covered elsewhere.

TYPES OF OAE AND RECORDING TECHNOLOGY

TEOAEs and DPOAEs

Two forms of OAE technology have been used for newborn screening. These are known as "Transient or click-evoked Otoacoustic Emissions" (TEOAEs) and Distortion Product Otoacoustic Emissions (DPOAEs). The differences stem from the choice of stimulation and the technology subsequently used to extract the response. TEOAEs employ click stimulation and averaging similar to screening ABR. DPOAEs employ a series of tonal stimuli (in pairs)

As TEOAE has been chosen as the method for screening in the UK new born hearing screening program the remainder of this document will cover TEOAE only.

Automated and Operator Controlled instruments

Instruments for OAEs screening differ greatly in the level of information they provide and in the level of involvement of the screening in the decision making. This parallels the division between automated screening ABR – where the machine decides both when conditions are right for testing and also whether the infant has passed the test, and diagnostic ABR where the tester is in complete control of ever aspect of the test.

PRACTICAL ASPECTS

With OAE screening it has been found that probe fitting is the single most important aspect of the test. Probes need to be fitted deep into the ear canal to collect the most sound and to exclude the most external noise. Problems are typically caused by debris in the ear canal, blocking sound tubes, by debris and fluid immobilising the eardrum or by the ear canal itself being collapsed between the probe and the eardrum

At the 'setting up' stage of OAEs ' probe fitting' requires operator skills. So far it has not been possible to automatically detect certain problems with fitting and/or the infant ear canal status.

This stage of the OAE test cannot therefore be totally automated. The recognition of normal OAE activity and the pass/refer decision can and has been successfully automated.

CRITERIA FOR SCREENING

For the purposes of this protocol it is necessary to set a pass criteria for screening such that there is a negligible probability that moderate or greater bilateral hearing impairment , present at birth , will be missed consistent with an acceptable screen pass rate.

Three conditions need to be met before an ear is judged to have passed an OAE test.

Firstly there must be a high probability that the 'response' seen is a true cochlear response and not due to artefact. For TEOAE this is usually achieved by careful control of the stimulation, by use of the non-linear (saturated) component extraction and by the selection of a delayed analysis window which excludes any expected stimulus artefact. With TEOAEs, to minimise stimulus artefact from contaminating the waveform the analysis window for data collection should start 2.5-4 milliseconds after delivery of the stimulus. The proposed start time for this the UK national pilot protocol is 4ms. The effective start time will depend on the gate function used in the analysis window. The start time should be 4ms taking this into account. The length of the data collection time ,following the stimulus ,varies dependant upon the stimulus rate used. The proposed end of the data collection and analysis window is between 10 and 12.5 ms.

Secondly there must be a high probability that a response-like signal is present at the frequency expected. This is usually determined by the degree of reproducibility or the signal to noise ratio although other statistical methods can be applied. With TEOAEs this assessment is typically made either in each of several half octave frequency bands, or over a broad band encompassing the main speech frequencies. Using the proposed time window given above, the proposed criteria for this part is >=6dB signal to noise ratio in two or more half octave bands from half octave bands centred at 1.5,2,3 and 4 kHz. Alternatively where a single broader band is used the proposed pass criteria is >=6dB. Where different bandwidths and/or centre frequencies are used the pass criteria should be at least as stringent as one of these options.

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

Amplitude of response

Thirdly the intensity of the validated response obtained must be large enough to be within the normal physiological range. The proposed minimum response level is 0dB rms SPL .

Other criteria

In addition there should be a minimum amount good data (below the reject level) of 240 sweeps at the low stimulus level in the non linear mode. Stimuli are often presented in packets e.g. groups of 8 (2 stimulus at the high level to 6 at the low level), in this example the equivalent figure to be used is 40 sets of good data).

Maximum test time

The recommended maximum test time is 6 minutes. If more than 6 minutes actual testing time is required:
a) The baby is usually too unsettled to test; continuing to test may lead to parental anxiety
b) The testing conditions are unsatisfactory for successful testing

Data rejection level

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

Diagnostic testing

The results should be analysed in half octave bands centred at 1,1.5,2,3 and 4 kHz. A response should be reported as present within a particular half octave band if the signal to noise is >=6dB.

RECORDING DETAILS

Environment

OAE screening in noisy environments is time consuming and inefficient. Every effort should be made to screen in a room without continuous background noise such as air-conditioning, ventilation or road traffic noise. Occasional voices and other noises are less of a problem since they are rejected by the instruments artefact rejection system.

State of baby and probe fitting

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

Stimulation and in the ear calibration

Unlike audiometry and ABR the level of stimulation is not critical to the interpretation of OAEs. Too high a stimulation will increase the chance of artifactual

responses.
Too low a stimulation , with a smaller expected response, will increase the testing time excessively. The recommended stimulus level for the TEOAE click stimulus (lower level) is 80 to 88dB peak equivalent sound pressure level (pe SPL) as measured in the neonatal ear canal or an equivalent sized cavity. Instruments should provide a means of achieving the target stimulation levels in the ear.

Some instrumentation allows the click stimulus waveform to be viewed. The ideal is a clean, clear, positive and negative deflection lasting no longer than 1ms and followed by a straight line indicating no or very limited 'ringing', or oscillation of the waveform. This condition is much easier to obtain in a new-born ear than in an adult.

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

TEOAE instrument may additionally give an overall wide band signal to noise ratios of response reproducibility index. While useful in assessing the quality of the test environment – overall wide band quality indicators should not dominate the assessment over frequency specific measurements

Filtering to remove noise below 1kHz is high desirable particulary when viewing the result in the time domain. High pass filters at around 1.2 kHz and falling at 12 or more dB/octave have little effect on the TEOAE response from infants and greatly improve response quality.

Probe Checks

It is advised that the probe is regularly checked for sound output and microphone sensitivity at least:
a) Every 50 babies
b) Once per week
c) After any changes are made to the probe.

After performing an acoustic loop back test with the probe in a cavity tester, the user should carry out a 'biological' TEOAE check on themselves prior to each testing session. Detail on equipment checks used in the UK newborn hearing screening program will be produced separately.

Failure to observe an OAE

A recordable OAE indicates the presence of a normal cochlear function at or near the frequencies present in the emission. Its absence could be for one of many reasons e.g. poor recording conditions, bad probe fitting, the presence of outer ear or middle ear disease, or a absent cochlear response or one of too small an amplitude to record. Normally hearing ears produce a wide range of TEOAE intensity and waveforms.

Some healthy ears may only produce emissions strong enough to be visible above the infant and background noise in a only narrow range of emission frequencies whilst others will produce a broad range of emission frequencies.

SUMMARY: UK Pilot - Newborn Hearing Screening - Criteria

Probe fitting	Well fitted probe with no significant change in fit over recording interval.
Stimulus:	Click between 75 and 100 p.p.s
Stimulus level (ppe) :	80 to 88dBpeSPL into neonatal ear canal or equivalent volume cavity
Variation of stimulus level between probes	+/- 2 dB.
Data reject level:	At or below 55 dB peak SPL
High pass filter to remove low frequency noise:	Around I.2 kHz
Bandwidth	Able to record between 1000 and 5000Hz
Data collection / analysis window :	Start 4 ms . End 10 to 12.5 ms
Minimum number of responses averaged	240 sweeps at low stimulus level equivalent . E.g. 40 stimulus packets if 8 stimuli for each packet (6 low, 2 high).
Maximum recording time	6 minutes
Response present criteria	>= 6dB for 2 out of 4 half octave bands centred at 1.5,2,3,4 KHz or >=6dB for a single band.
Minimum level to accept as a response	0dB rms SPL

REFERENCES (details to complete)

1. Davis A, Bamford J M, Wilson I , et al. A critical review of the role of neonatal screening in the detection of congenital hearing impairment. Health Technology Assessment 1997 (1) (10).

2. Rhode Island Study

3. Wessex Study

4. Whipps Cross