Automated TEOAE Detection Methods for Neonatal Hearing Screening

Otoacoustic emissions (OAE) are byproducts of active processes in the inner ear and are known to be a good indicator of proper inner ear function. All OAEs are generated by the outer hair cells of the cochlea, which represent the first amplifier stage of hearing.

Types of OAEs
Otoacoustic emissions are commonly classified into spontaneous otoacoustic emissions (SOAE), and evoked otoacoustic emissions. The latter is divided into transient evoked otoacoustic emissions (TEOAE) and distortion product otoacoustic emissions (DPOAE).

Since SOAEs are not present in 100% of normal hearing people, their clinical use as a hearing screening technology remains uncertain. TEOAEs can most readily detect emissions and have advantages in hearing screening. DPOAEs are generated at defined parts of the cochlea, and can therefore detect frequency dependant hearing losses.

The Natus Echo-Screen® Hearing Screener incorporates proprietary AOAE® technology, which automates the hearing screening process using TEOAE and DPOAE detection methods.

Rationale for Automated, Objective Detection
Universal newborn hearing screening for early detection of hearing loss has dramatically increased the number of infants tested prior to hospital discharge. Personnel requirements to staff such programs have increased interest in objective screening procedures with "automated" results in order to allow existing staff and non-technical employees to operate screening equipment reliably and accurately. There has also been a need for, and recommendation from the JCIH for, systems that utilize standardized, objective criteria to minimize test variability and user error.

During the past decade, techniques have been developed to automate the OAE screening process such as Natus’ proprietary AOAE technology, which utilizes a patented binomial statistics algorithm. Other detection algorithms such as cross-correlation analysis, signal-to-noise analysis, frequency analysis and neuronal networks require knowledge of their individual features in order to evaluate their utility for newborn hearing screening.

AOAE® Technology: Automated TEOAE Detection Using Binomial Statistics
TEOAE technology is approved as a first stage screening method for well neonates, babies, and toddlers. TEOAE is more robust in neonates than DPOAE, and has higher specificity for mild hearing loss.

“The danger in using a normal averaging procedure is that any waveform can be produced by chance” (Hall 2000). The Echo-Screen TEOAE method is different than other TEOAE methods in that it uses a binomial statistical algorithm to give either an automatic PASS or REFER result. Although false negatives cannot be eliminated from any screening measure, the statistical criterion in the Echo-Screen system reduces the probability of a false negative result down to 0.3%. The binomial statistics algorithm presumes that the newborn is hearing impaired until enough click responses have been evaluated to conclude with a very high degree of probability that the baby has satisfactory inner ear function. Because the statistics of a non-response
condition are very well defined, this probability can be precisely controlled without requiring decisions or equipment adjustment by the user as described below. As opposed to other methods, the impact of non-random noise is very low. Modulated, narrow-band or tonal noise is often present in clinical environments and can easily lower the sensitivity of other detection methods.

In contrast to the signal averaging techniques typically applied to most TEOAE instruments, the Echo-Screen device calculates the statistical probability that the emission has been recorded, at a succession of sampling points ranging from 6 to 12 msec after the stimulus. If the assumption that each signal point is random can be rejected with 99.7% confidence, then the signal point is considered to be an emission. Each captured recording is filtered into one of eight quality buffers according to its amplitude, or "echo-level". The statistical analysis is carried out simultaneously in each of the eight quality buffers. Screening results depend on whether or not the statistical OAE trace exceeds the 99.9% confidence limit. Since no user adjustments are provided, high sensitivity of the Echo-Screen device cannot be altered by the user.

Noise is always present in the ear canal during OAE testing. Compared to other methods, the impact of non-random noise is very low with the Echo-Screen TEOAE method. Modulated, narrow-band or tonal noise is often present in the environment and can easily lower the sensitivity of other detection methods. The advantage to Echo-Screen system's technique over the other techniques is that measures based on signal statistics are more robust in noise than those based on signal averaging. Therefore, measurement time can be significantly reduced, especially under less than optimum noise conditions.

Since the optimum artifact rejection level is dependent on the emission strength as well as environmental noise, the Echo-Screen TEOAE method has the unique flexibility to automatically select the appropriate artifact threshold. For successful completion of the screen, the artifact rejection rate cannot exceed 20%. Prior to recording, a calibration run ensures a proper signal. The Echo-Screen system uses a nonlinear click sequence in the 1.5-3.5 kHz range presented at 60 dB nHL. For successful completion of a screen, the stimulus stability must reach 80%. Successful screening can take place in as little as 15 seconds.

Other Analysis Methods

Cross-correlation analysis compares two or more sets of measured TEOAE click responses with each other and attempts to identify the presence of a common, synchronous signal, which is assumed to be the TEOAE. The main drawback of this method is that the sensitivity can be extremely poor.

Signal-to-Noise analysis also compares two subsets of averaged data by assuming that the sum of these buffers represents signal and noise, while the difference only represents noise. The ratio between these two is used as a SNR estimation and a result is issued dependent on a defined value. Again, the sensitivity of this method strongly depends on the nature of background sound.

Black Box algorithms using neuronal networks or other self-learning or pre-trained algorithms are also used for TEOAE detection. Usually, the algorithmic parameters are tuned in training phases to provide maximum correlation to the classification that an experienced expert might give. The main disadvantage is that these methods act like a black box since the features used to detect TEOAEs are more or less unknown. Therefore, the behavior in certain noise or operating conditions cannot be predicted, possibly resulting in high false pass rates.
Clinical Efficacy
Independent clinical studies have compared the Echo-Screen device to other OAE and auditory brainstem response (ABR) equipment. Schorn and cohorts (1998) found sensitivity of the Echo-Screen device with ABR to be 100%, and that the Echo-Screen system has the highest specificity (>96%) when compared to other OAE systems. Grandori and cohorts (2002) compared the Echo-Screen TEOAE method with the ILO88 device by testing 8494 neonate ears. The test time using the Echo-Screen TEOAE method was 3-6 times faster, with a sensitivity of 98.72%.

Informed Choice and Quality Assurance
It is essential to understand that these differences in OAE detection methods mean that all TEOAE hearing screeners cannot be considered equal or truly automated. The ability to adjust screening parameters and the requirement for waveform interpretation by trained professionals may have a significant negative impact of performance reliability, consistency, and cost on newborn hearing screening programs.

The Echo-screen TEOAE detection algorithm uses a signal statistics method that reduces the original signal to binomial data that delivers well-known, low probabilities for erratic results. No user adjustments are allowed to ensure that this high sensitivity cannot be altered by the user.

References


