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Symposium

Otoacoustic emissions

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During this symposium five central questions were addressed:

I A review of OAEs; what is the current status in the clinic?
II What is the role (importance) of baby screening based on OAEs?
III What is the practical use of OAEs in newborn: special requirements?
IV How can middle ear dysfunction affect OAEs?
V What are the current methods and which new developments can be expected?

Otoacoustic emissions (OAE) are mechanical vibrations generated in the cochlea, that are transmitted by the lymphatic fluids in the cochlea and by the middle ear to the outer ear canal where they can be recorded as generally weak sounds with a microphone [1,4]. Two main classes of OAEs have been discovered: spontaneous and stimulated emissions. Spontaneous emissions (SOAE) are sounds continuously emitted by the ear consisting of one and often many more pure tones. Stimulated emissions only occur with and shortly after stimulation with any type of stimulus. In general it is technically difficult to separate the weak emitted sound from the about 60 dB stronger stimulus. For two stimulus types this problem has been solved to such a degree that clinical use became possible. The first and by far the most widely used stimulus is the click stimulus. By virtue of its short duration, the transient part of the emission lagging behind the stimulus can be rather easily recorded. This is called the transiently evoked OAE, TEOAE or click-evoked OAE (cEOAE). The second type of stimulus is a complex of two 'primary' pure tones. The inner ear, by distortion, generates in response a series of pure tones also at 'non-primary' frequencies, the strongest one being the cubic difference tone at the frequency $2f_1-f_2$. By recording the sound level in a very narrow frequency band

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around this exactly predictable frequency the distortion product OAE (DPOAE) is found. It seems obvious that with the DPOAE the cochlea frequency map can be scanned by tuning the frequency of the primaries appropriately, while with the cEOAE a 'whole-cochlea' response is acquired. However, it may well be that the frequency components of the cEOAE bear the same clinical frequency specific value as the DPOAE. Until now there is no proof for a higher frequency specificity of one type of OAE.

Neither the cEOAE nor the DPOAE strength can be used as a clinical measure of the ear's sensitivity to sound [3,9]. There is a clear and significant negative correlation between OAE-strength and ear-sensitivity, but the inter-individual variability of the strength is too large to yield a reliable sensitivity assessment by OAE-strength in the individual patient. In adults it has been shown that the OAE-strength decreases with increasing hearing loss and that the OAE disappears (remains undetectably weak) when hearing loss exceeds 25–30 dB for the EOAE, and exceeding 30–40 dB for the DPOAE is too large.

Because of this discriminating quality, at present both emission types are in evaluation and/or applied as method of hearing screening. The most widely applied type of OAE now is the cEOAE for screening in newborns in the general population [5,10] and in subgroups of babies which are at a high risk of hearing impairment [6], but screening by DPOAEs is in evaluation right now. With the present commercially available equipment one recording takes between 1 and 10 min per ear. As of now there are strong indications that OAE-screening will eventually serve as a high quality and objective hearing screening tool. However, essential knowledge on the exact performance of the screen and its dependence on factors as site of testing, training of the tester, etc. is still lacking. What is clear however is that neonates should not be screened too early in life. Below the age of 2 days the proportion of ears lacking an emission in normal newborns is still high ($>10\%$), due to vernix in the outer ear and incomplete clearance of amniotic fluid out of the middle ear.

If no stimulated emission is found then a sensitivity loss of the ear exceeding 25 dB is probable. The loss can be due to middle ear and/or cochlear dysfunction. The EOAE provides no clue to distinguish between these two. If middle ear dysfunction caused the sensitivity loss, then both the stimulus sound on its way to the cochlea and the emitted sound on its way to the ear canal are attenuated. It is obvious that this is most detrimental to the emission, because it is weak already. In these cases the emission very often becomes undetectably weak [8].

SOAEs are of course a very peculiar phenomenon: sounds continuously generated by the inner ear. When these were discovered around 1980, the prevalence in normal hearing was not reported to be very high, 20–40%. Although found in normal hearing it was judged to be not very specific for normal hearing, because normally not very prevalent and also found in pathological hearing, albeit rarely. In the past decade the detection limits have been lowering and nowadays the normal prevalence is reported to be considerably higher, especially in newborn. Both in normal and in high risk neonates the prevalence of SOAEs is reported to be about 80%. The clinical significance of SOAEs reported up to now is that they enhance

the strength of the cEOAEs, due to the fact that SOAEs do interact with a stimulus. SOAEs do generally become time-locked to the stimulus, they get entrained and synchronised with the click and by this they do show up in the cEOAEs and make these stronger ([2], Morlet et al., pers. commun.). In cases with hearing loss SOAEs disappear also in general, although some cases of pathological hearing with SOAEs have been described. Therefore, and because SOAE-prevalence in normal hearing is still considerably lower than cEOAE-prevalence, SOAE-absence cannot serve as reliable an indicator of ear function as the cEOAE.

As stated above the main clinical application of OAEs in the paediatric population is screening for ear dysfunction. With the current commercially available recording equipment, the acquisition time is between 1 and 10 min per ear, depending on the degree of relaxation of the infant or child. In laboratory conditions two methods to speed up EOAE-recording are developed. The first is based simply on the use of higher repetition rates of the stimulus [7]. At repetition rates over 50 stimuli per second and a post stimulus recording period of 20 ms, the responses to subsequent stimulus obviously overlap. A classical technique can be used to extract the original non-overlapped waveform of the response: a quasi random maximum length sequence of click-stimuli is presented with on average a very short inter-click period, down to 5 ms. Thanks to the exact knowledge of the sequence it is possible to deconvolve the recorded response to this MLS-sequence. Using this method it will be possible to reduce the TEOAE-recording time by an order of magnitude, so down to a couple of seconds. However, as before in this field, a patent on this method in relation to OAEs is slowing down commercial implementation and availability.

The second method is based on reduction of either the post stimulus recording period to 10 ms as opposed to 20 ms, giving a 50% gain, or restriction of the recording bandwidth to frequencies around 1.5 kHz. In the latter case the signal to noise ratio improves considerably. With only a low number of stimuli the averaged response has a good quality then and can be recorded in less than a second. This enables 'realtime'-recording of the OAEs: on the equipment display a repetitively updated OAE-waveform is shown. Presently the reduced post stimulus recording period is available commercially (ILO-QuickScreen, OtoDynamics, London). Real-time recording is commercially implemented and may be available soon.

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