The evaluation of patients with partial deafness by transiently evoked otoacoustic emissions

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Introduction

Otoacoustic emissions (OAEs) are well established in clinical practice and are a valuable tool in basic research (Probst et al., 1991). The most commonly used OAEs are click-evoked OAEs (CEOAEs) and distortion product OAEs (DPOAEs), which are evoked by two tonal stimuli. OAEs are believed to be good predictors of hearing status, particularly in the 1-4 kHz range. However, while DPOAEs perform more satisfactorily at higher frequencies, CEOAEs are better indicators of cochlear function at lower frequencies.

OAEs are known to be frequency-specific. In most cases, OAEs do not occur when hearing loss is greater than 35 dB HL. However, if hearing is preserved at a certain frequency, there is then the possibility of recording OAEs at this specific frequency (Kemp et al., 1986). It is the basal region of the cochlea that is most prone to damage. That is reflected in OAEs that tend to have a lower amplitude or even disappear first at the higher frequencies associated with hearing loss. Transiently evoked OAEs can also be elicited by so-called 'tone bursts', which are short stimuli centered at a certain frequency. Several studies have shown that the spectral content of a sum of tone burst-evoked OAEs (TBOAEs) centered in the 1-4 kHz corresponds to CEOAE. It is nevertheless the case that for tone bursts, the same level of stimulus as the equivalent click gives a higher level of OAE. Therefore those stimuli can give an advantage over standard clicks in some difficult cases.

The OAE is absent in a majority of patients who undergo standard cochlear implantation. However, as it will be shown below, by using tone bursts as a stimuli it is possible to measure OAEs in some of the partial deafness subjects.

Methods

Standard click stimuli and 0.5 kHz tone bursts (average amplitude - 80±3 peak dB SPL, nonlinear averaging protocol) were used to evoke a total of 520 OAE responses. The tone bursts were four cycles long with equal rise/fall times and no plateau. The initial part of the response was windowed automatically by the system to minimize the artifact of stimuli. The onset of the window was 2.5 ms for click, and 10 for 0.5 kHz tone bursts. All recordings were performed in two acquisition windows: the standard, ending at 20 ms and a longer, ending at 30 ms. All measurements were performed for a control group of normal hearing subjects (40 ears) and partially deaf patients (10 ears).

Results

Fig. 1A shows typical OAEs evoked by 0.5 kHz tone burst for a subject with normal hearing. It may be seen that in this case, part of the response exceeds 20 ms, which is the standard window in most measurement protocols. Fig. 1B shows average reproducibility values for a group of normally hearing subjects. Reproducibility is defined as the correlation between the two buffers of the sub-averages of the single responses (Kemp et al., 1986). It is the most common method of detecting the presence of OAEs and assessing the quality of their measurement. In Fig. 1B it can be seen that click evoked OAE reproducibility at 0.5 kHz is much lower than for 0.5 kHz TBOAE.

An example of the signal measured after a 0.5 kHz tone burst for one partially deaf subject is presented in Fig. 2 together with the pure tone audiogram. The response to the click is not shown as it contains mostly noise. The responses to the 0.5 kHz bursts are similar to those for subjects with normal hearing. However the amplitude of signals is usually lower than for the normally-hearing. The reproducibility values for clicks and 0.5 kHz bursts for 10 partially deaf subjects are summarized in Fig. 3. The reproducibility of the responses to clicks for partial deafness is very low, which indicates that these stimuli did not produce OAEs in these subjects. In contrast, the reproducibility of the responses to the 0.5 kHz bursts is only slightly lower than that obtained for normal subjects. This difference is probably due mainly to the fact that the high-frequency responses in partially deaf subjects consist mostly of noise. In Jedrzejczak et al. (2009) it was shown that after octave band filtering around the frequency of stimulus, the reproducibility of the 0.5 kHz TBOAEs for normal and partially deaf subjects was similar.

Discussion

The idea of making use of tone burst stimuli in clinical practice resurfaces in the literature from time to time. For example, Lichtenstein and Stapells (1996) compared hearing thresholds with OAEs evoked using tone bursts as well as clicks. They concluded that 0.5 kHz tone bursts could act as much better stimuli than clicks when searching for responses at this frequency. They also showed that OAEs evoked by 0.5 kHz tone bursts provide a better estimate of hearing status at 0.5 kHz than those evoked by clicks.

The results shown here revealed that clicks are not a reliable method of evaluating of OAE status at 0.5 kHz. This is probably a result of such factors as measurement-noise bias and the low-frequency filters used in most of the equipment (Hurley and Musiek, 1994). On the other hand 0.5 kHz TBOAEs can be measured in subjects with partial deafness even when they have a profound high frequency hearing loss. By performing this measurement together with standard CEOAE recording one can get additional information about the status of low-frequency area of the cochlea.

The global reproducibility values for 0.5 kHz TBOAEs are significantly lower than those obtained using standard wideband click stimuli. Therefore prolongation of the measurement time and lowering the detection criteria should be considered. The 30 ms recording window seems better suited to 0.5 kHz TBOAEs, given that its duration exceeds 20 ms in most cases.

Conclusions

The 0.5 kHz TBOAE is more reliable than CEOAE in the case of preservation of low frequencies. 0.5 kHz TBOAE is a promising tool for the detection of emissions in patients with profound high-frequency hearing loss when click stimuli do not produce OAEs.

The CEOAE is absent in a majority of patients considered for cochlear implantation. The presence of a 0.5 kHz OAE could be used as one of the tests in the qualification procedure for Partial Deafness Cochlear Implantation (as introduced by Skarzynski et al., 2003). The 0.5 kHz TBOAE test could be particularly helpful when pure tone audiometry is not possible.

References

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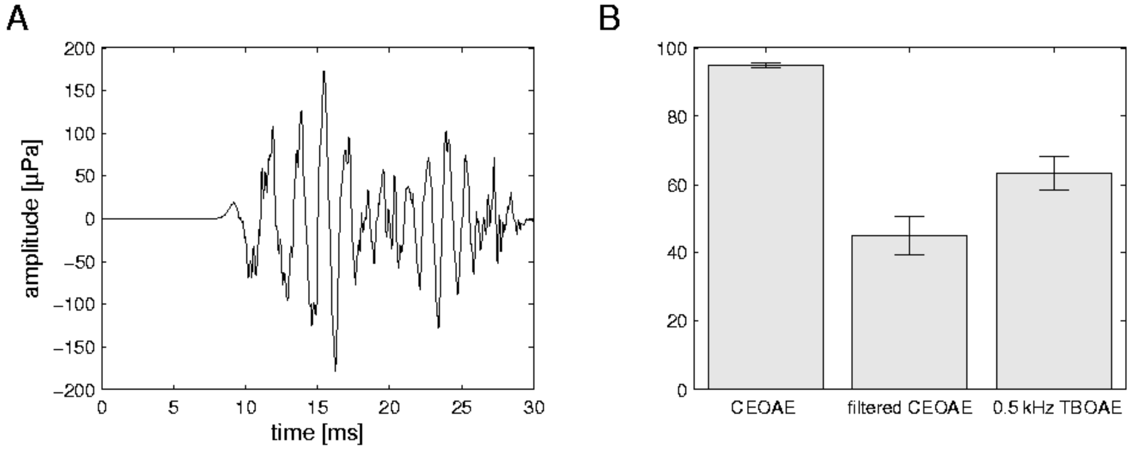

Fig. 1. A: Example of 0.5 kHz TBOAE for normal hearing subject. B: Average reproducibility values for 40 ears of normal hearing subjects, for click, click octave filtered around 0.5 kHz, and 0.5 kHz TBOAE. The bars represent standard errors.

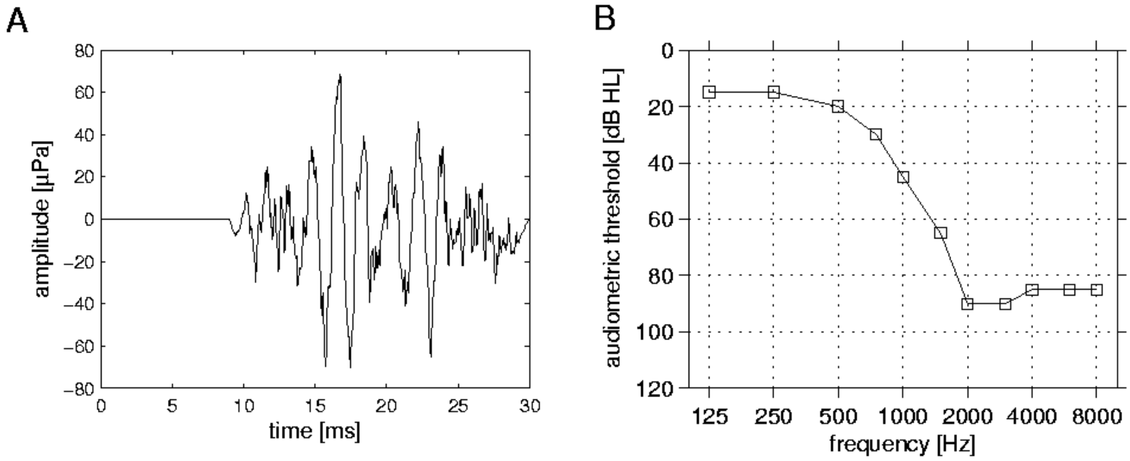

Fig. 2. A: Example of 0.5 kHz TBOAE for partial deafness subject. B: Subjects pure tone audiogram.

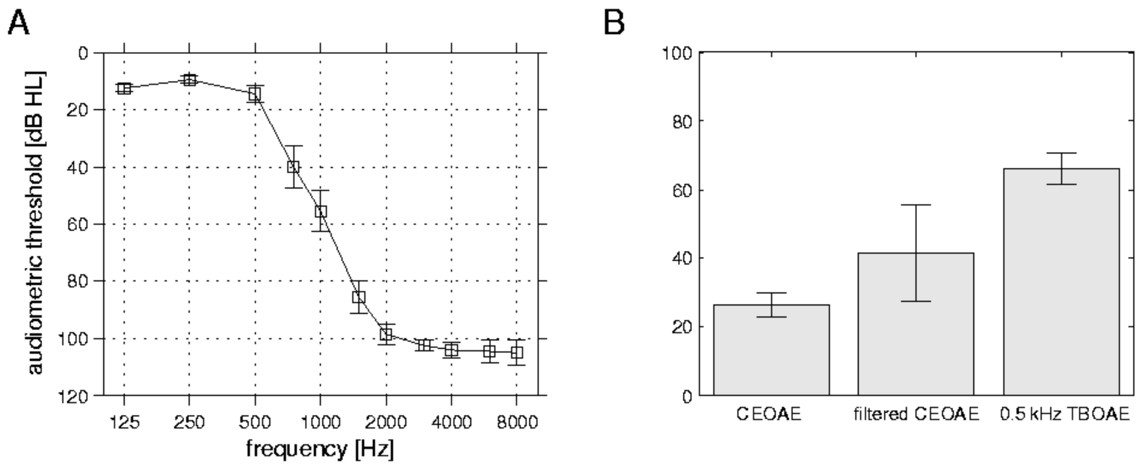

Fig. 3. A: Average audiogram for 10 partial deafness subjects. B: Average reproducibility values for 10 ears of partial deafness subjects, for click, click octave filtered around 0.5 kHz, and 0.5 kHz TBOAE. The bars represent standard errors.