Vestibology

Effect of eye lateralization on contralateral suppression of transient evoked otoacoustic emissions

Effetto della lateralizzazione oculare sulla soppressione controlaterale delle emissioni otoacustiche evocate transienti

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SUMMARY

Several studies have previously demonstrated that postural changes modify evoked otoacoustic emission. In order to evaluate a possible interaction between eye muscles and ciliated cells in the inner ear, we studied the effects of eye lateralization on the contralateral suppression of transient evoked otoacoustic emissions (TEOAEs). Thirty-eight normal hearing subjects with TEOAEs were recruited. Their TEOAEs at threshold level were recorded with contralateral suppression (white noise) via straight ahead fixation and right or left lateral fixation. Eye lateralization in the same direction of the white noise significantly decreased the suppression at 4 kHz (p = 0.003). The signal-to-noise ratio in the suppression condition with straight ahead was 1.54 (± 4.610) dB, while the ratio was 3.48 (± 4.631) dB in the suppression condition with gaze toward the white noise. Eye lateralization seems to reduce the contralateral suppression effect of TEOAEs at 4 kHz. However, further studies are necessary to investigate the possible mechanisms of this phenomenon.

KEY WORDS: TEOAE • Gaze • Contralateral suppression

RIASSUNTO

Alcuni studi hanno precedentemente dimostrato che i cambiamenti nella postura modificano le otoemissioni acustiche evocate. Per valutare una possibile interazione tra i muscoli oculari e le cellule ciliate dell’orecchio interno, abbiamo studiato l’effetto della lateralizzazione oculare sulla soppressione controlaterale delle emissioni otoacustiche evocate transienti (TEOAEs). Sono stati reclutati 38 soggetti normoaudiometrici con TEOAEs presenti. Le TEOAEs sono state registrate a soglia, con una soppressione controlaterale (rumore bianco), fissando lo sguardo al centro, a destra e a sinistra. La lateralizzazione oculare nella stessa direzione del rumore bianco riduceva significativamente la soppressione delle TEOAEs a 4 kHz (p = 0.003). Il rapporto segnale-rumore in condizione di soppressione con lo sguardo fisso al centro era 1.54 (± 4.610) dB e 3.48 (± 4.631) dB con lo sguardo omolaterale rispetto al rumore bianco. La lateralizzazione oculare sembra dunque ridurre l’effetto di soppressione controlaterale delle TEOAEs a 4 kHz, tuttavia, sono necessari ulteriori studi per fornire le possibili spiegazioni.

PAROLE CHIAVE: TEOAE • Gaze • Soppressione controlaterale

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Introduction

In 1946, Kekcheev hypothesized an interaction between posture and auditory perception. In particular, he reported a higher auditory sensitivity when the listener was in a seated position, but not when the listener was in a standing or horizontal position. This was the first of numerous studies that have attempted to evaluate the correlation between postural changes and auditory threshold. Some authors have reported a shift in the pure-tone threshold with different body positions (upright, seated, supine, inverted, right or left positions). Several hypotheses to explain this phenomenon include an increase in cochlear fluid pressure, a change in blood supply to the cochlea and direct contractions by the middle ear muscles. More recently, researchers have begun to pay attention to the correlation between position changes and transient evoked otoacoustic emission (TEOAEs) as it has been demonstrated that postural changes can modify TEOAEs. In fact, a reduction in the peak latencies was observed as well as a reduction in amplitudes and the form of a phase shift.
The interactions among visual, auditory and vestibular inputs are well known. Several studies have reported that the lateral movement of the eyes influences the ability to localize sound. These studies have also shown that changes in the body axes toward the source of optokinetic stimulation modified the orientation of sound localization, and that vestibular stimulation influenced the perception of auditory space. Moreover, Ferber-Viart et al. demonstrated that visual attention tasks inhibit outer hair cell (OHCs) activity, and that the combination of contralateral acoustic stimulation and visual attention tasks lead to significant reduction in TEoAEs via the medial olivocochlear efferent system.

In a previous unpublished pilot study, we observed no significant influence of direct gaze, i.e. with straight ahead, on TEoAEs. Therefore, the aim of this study was to evaluate the possible effect of eye lateralization on contralateral suppression of TEoAEs according to Collet’s protocol. The remaining subjects were submitted to contralateral suppression of TEoAEs according to Collet’s protocol. In this study, the subjects were approved by the Ethics Committee of the Fondazione IRCCS Ospedale Maggiore Policlinico Mangiagalli e Regina Elena.

Materials and methods

Subjects

Forty-seven healthy subjects were recruited. All subjects were right-handed and exhibited normal hearing. Pure tone audiometric thresholds were regarded as normal if the mean values for the 500, 1000, 2000 and 4000 Hz frequencies were between 0 and 25 dB hearing level (HL). None of the subjects had middle ear pathologies, as evidenced by normal tympanometry results and presence of acoustic reflexes to contralateral broad band noise and pure tones. Moreover, patients suffering from disorders of the visual, oculomotor or equilibrium system were excluded. TEoAEs were included in the study.

The first step was to evaluate TEoAEs in the basal condition (with a stimulus of approximately 80 dB peak sound pressure level – pSPL). Six subjects were excluded because either their TEoAEs levels were lower than 3 dB in at least 3 frequencies between 1 and 5 kHz, or because their reproducibility was less than 50%.

The remaining subjects were submitted to contralateral suppression of TEoAEs according to Collet’s protocol. Veuillet and colleagues suggested that an absolute decrease of less than 0.5 dB in TEoAEs could be taken as a sign of impairment in the crossed medial olivocochlear (MOC) system. Thus, only subjects who reported a suppression of 1 dB or more were recruited. As a result, 3 subjects were excluded. In the final cohort, there were 38 subjects (24 females and 14 males) aged 21-47 years. The mean age was 28.2 ± 8.45 years. This study was approved by the Ethics Committee of the Fondazione IRCCS Ospedale Maggiore Policlinico Mangiagalli e Regina Elena.

Auditory screening

Pure tone audiometry was performed in a soundproof room using an Amplaid A321 audiometer according to ISO 6189 standards. Tympanometry and acoustic reflex recordings were performed in a soundproof room using an Amplaid 702 tympanometer hearing impedance audiometer.

TEoAE recordings

TEoAEs were recorded using an Otodynamics ILO-292 DP system with ILO-V5 software. TEoAEs responses were evoked by trains of non-linear clicks at a rate of 50/200/sec. Each click stimulus had a duration of 80 μsec. The analysis window was 20 msec, and responses were band-pass-filtered from 0.5 to 6 kHz. Each response was the average of 260 sweeps.

Contralateral suppression

Contralateral suppression was performed according to the Collet protocol: a white noise was delivered to the contralateral ear (left ear) by an ear phone (TDH 49). The suppressor noise was delivered at an intensity of 45 dB SPL. In order to evaluate the presence or the absence of TEoAEs in the right ear during contralateral suppression, all tests utilized the following criteria:

• stimulus stability no less than 65%;
• noise level no more than 40 dB;
• A-B difference (a measure of the noise contained within the response (in dB)) no less than 2 dB;
• whole-wave reproducibility no less than 50%;
• signal-to-noise ratio (SNR) no less than 60% in at least 2 frequencies.

Gaze

In a dark and silent room, the subjects sat on a chair with their heads fixed to a headrest. The tests were performed by asking the patients to look at a fixed red light dot on a light bar in front of them. This light was directed to the front, right and left sides of the subject at an angle of 40°. The corrected eye position was monitored by a nystagmography system (EOG amplifier by Nystar).

Procedures

Only the right ear was analyzed because the TEoAE magnitude for the right ear was statistically wider than that for the left ear. Furthermore, the level of TEoAEs suppression was significantly higher in the right ear than in the left ear.

The protocol was as follows:

1. Determination of TEoAE threshold: determined as the lowest stimulus intensity that evoked an otoacoustic emission of 2 dB or more for at least 2 frequencies, and with at least 49% reproducibility;
2. Recording of basal suppression condition: TEoAEs were recorded at threshold level with contralateral suppression and straight ahead fixation;
3. Recording the contralateral suppression test with lateral gaze (40°): TEoAEs were recorded at threshold level with contralateral suppression and lateral gaze;
Tests were conducted three times while the subjects looked at each light dot. The sequence of dot positions (straight ahead, right or left) was randomized to avoid bias. Each test was conducted after a pause of 30 sec to avoid fatigue.

Data analysis
The exact non-parametric two-way Wilcoxon signed-rank test was performed to compare the results obtained in basal condition with those in the contralateral suppression. The Friedman exact non-parametric ANOVA was used to determine the statistical significance of the variation of SNR obtained with the contralateral suppression with and without lateral gaze. When the Friedman test indicated significant differences, an exact non-parametric two-way Wilcoxon signed-rank test was performed to evaluate the different SNR.

The SPSS® (SPSS Inc., Chicago, IL) programme was used, and a p-value < 0.05 was considered statistically significant.

Results
Table I shows the mean values ± standard deviation as well as the p-values for whole-wave reproducibility, A-B difference, stimulus stability and noise level. There were no significant differences in the different parameters except for reproducibility, and the level of reproducibility was significantly lower in the basal suppression test than in the basal condition. The A-B difference, stability and noise level were the same in the different tests. The lack of different noise levels (p = ns) indicated the absence of environmental bias.

The mean TEOAEs suppression decreased from 11.00 ± 3.867 dB in the basal condition to 8.85 ± 4.103 dB in the suppression condition; the difference was statistically significant (Z = -4.910; p < 0.001). Table II shows the mean values ± standard deviation (dB) of the SNR by frequencies in the different conditions. Contralateral suppression reduced the SNR at 1 kHz (Z = -2.576; p = 0.009) and 4 kHz (Z = -2.322; p = 0.01). In particular, the mean reductions were 1.79 dB at 1 kHz, 2.30 dB at 2 kHz, 1.34 dB at 3 kHz and 1.25 dB at 4 kHz.

As reported in Table II, the mean TEOAE responses were 8.97 ± 3.960 dB with right gaze and 9.06 ± 4.180 dB with left gaze; neither condition was significantly different from the suppression condition with straight ahead (respectively, Z = -1.03 and Z = -1.565; p = ns). The Friedman test did not indicate significant differences in contralateral suppression among the different gazes (straight ahead, with right gaze or with left gaze) from 1 kHz to 3 kHz and to 5 kHz. Instead, the different gazes caused significant different suppression at 4 kHz ($\chi^2 = 9.053$, p = 0.010). Right lateralization of eyes (i.e., contralateral to the white noise) did not significantly modify the results obtained with contralateral suppression. Instead, left lateralization (i.e., in the same direction as the white noise) significantly decreased the suppression (Z = -2.860; p = 0.003) at 4 kHz; the mean TEOAE increase was 1.94 dB compared to the TEOAE level in the contralateral suppression with straight ahead.

Discussion
The results herein highlight the interaction between eye muscle activation and TEOAEs, which are the readouts for motile activity by the OHCs. In particular, we observed that the activation of extrinsic eye muscle with lateral fixation decreased the contralateral suppression of TEOAEs, and this difference only existed at the 4 kHz. Thus, the suppression was significantly decreased at 4 kHz if the fixation was homolateral to the noise.

The modifications in TEOAE due to the contralateral sound are mediated via the medial olivocochlear (MOC)
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