

Correlative changes of medial olivocochlear reflex and electroencephalographic activity during sleep

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ABSTRACT

There is a projection of efferent nerve fibers called the olivocochlear bundle connecting the brainstem to the outer hair cells (OHCs). It is said that the olivocochlear system protects the inner ear by responding to sounds and suppressing the OHC amplification. Therefore, measuring the reaction (medial olivocochlear reflex; MOCR) strength is expected to be an applicable method of evaluating the possibility of noise-induced hearing impairment in advance. Since the MOCR strength fluctuates with each measurement, there is a problem that it is difficult to evaluate the function of the MOC system stably. In this study, we examined the influence of fluctuation of awareness during sleeping on MOCR. The awareness was evaluated objectively using electroencephalogram, and MOCR strength was evaluated by measuring otoacoustic emissions, which reflect the OHC amplification. There was a significant positive correlation between MOCR strength and α wave amplitudes, which reflects awareness. This result indicates that MOCR strength, and hence the inner ear protective function become weaker as awareness decreases. Therefore, exposure to loud sounds during a decline in awareness may increase the risk of causing noise-induced hearing impairment.

Keywords: Medial olivocochlear reflex, Sleep, Electroencephalogram

1. INTRODUCTION

From the brainstem to the outer hair cells (OHCs), there is a projection of efferent nerve fibers called the olivocochlear bundle. It acts to suppress the amplification of OHCs in response to acoustic stimulation, and this reaction is called medial olivocochlear reflex (MOCR) (1). MOCR is thought to protect the inner ear from loud noises via this suppressing the OHC amplification (2). Therefore, measuring MOCR strength is expected to be an applicable method of evaluating the possibility of noise-induced hearing impairment in advance (2, 3). However, since MOCR strength fluctuates with each measurement, there is a problem that it is difficult to evaluate the function of the MOC system stably. For example, it has been reported that the MOCR becomes weaker during sleep (4,5). Therefore, it is possible that MOCR strength depends on awareness. Despite this possibility, no studies have evaluated awareness level quantitatively and examined its relationship with MOCR. In this study, each stage from awakening to sleep was objectively evaluated using electroencephalogram (EEG) and their relationship with MOCR strength was investigated.

2. METHOD

The following measurements were taken during two hours of sleep in seven participants with normal hearing (one female, six males, average age 22.3 years, standard deviation 1.23 years).

2.1 MOCR MEASUREMENT

Otoacoustic emissions (OAE) is a weak sound generated on the basement membrane and is

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considered to reflect the amplification function of OHCs. It is known that when noise is presented to the contralateral ear on the OAE measurement side, the amplitude of the OAE is suppressed (1, 3). The amount of suppression is considered to reflect the MOCR strength (3). In this study, we measured the OAE evoked by a click in the right ear, when the contralateral noise for inducing the MOCR was presented to the left ear. Ear canal sound pressure was recorded using an Etymotic Research ER-10B low-noise microphone system inserted in each ear. The click had a duration of 100 μ s and was presented at 60-dB peak-equivalent sound pressure level. The noise was band-pass filtered between 100 and 1000 Hz and had a duration of 0.5 seconds including a 10-ms raised-cosine ramp. The noise was presented at sound pressure level of 60 dB. During the two-hours measurement session, the click and the noise were presented at intervals of 25 ms and 5s, respectively. The OAE waveforms measured from one minute before and one minute after each time point were extracted, and then the waveforms measured in the interval with and without contralateral noise were averaged respectively. The pressure levels of the OAEs for each condition were defined as RMS values in the region of 8–18 ms and are denoted as P_{with} and P_{without} (in Pa). MOCR strength was defined as $20\log_{10}(P_{\text{with}}/P_{\text{without}})$.

2.2 ELECTROENCEPHALOGRAM (EEG) MEASUREMENT

The dominant component of EEG changes depending on sleep stage: β waves (13-30 Hz) at rest with opened eyes, α waves (8-13 Hz) at rest with closed eyes, θ waves (4-8 Hz) in light sleep, and δ waves (0.5-4 Hz) in deep sleep. To assess sleep stage objectively, the amplitude of each EEG component was monitored during the two-hours measurement session. The spectrum of EEG at each time point was calculated by applying Fast Fourier Transform (FFT) for a duration of 2 minutes at 1-minute intervals within the 2-hours EEG measurement session. The strength of each EEG component at each time point was calculated by averaging the spectral amplitude in the frequency range corresponding to each EEG band. EEG was recorded using an amplifier (Nihon Kohden Corp. MEG-2208). The reference electrode was attached to the left earlobe (A1), the different electrode to the right parietal region (C4), and the ground electrode was set to intercostal space (Fz).

3. RESULT

Figure 1 shows the averaged correlation coefficient between the time variation of OAE suppression (MOCR strength) and the time variation of each EEG component. The correlation coefficient between the time variation of the amount of OAE suppression and the α -wave activity was statistically significantly greater than 0 ($p = 0.0488$), but the correlation coefficient between other EEG components was not significantly different from 0 ($p > 0.05$). Furthermore, the time variation of OAE amplitude did not have a significant correlation with the α -wave activity.

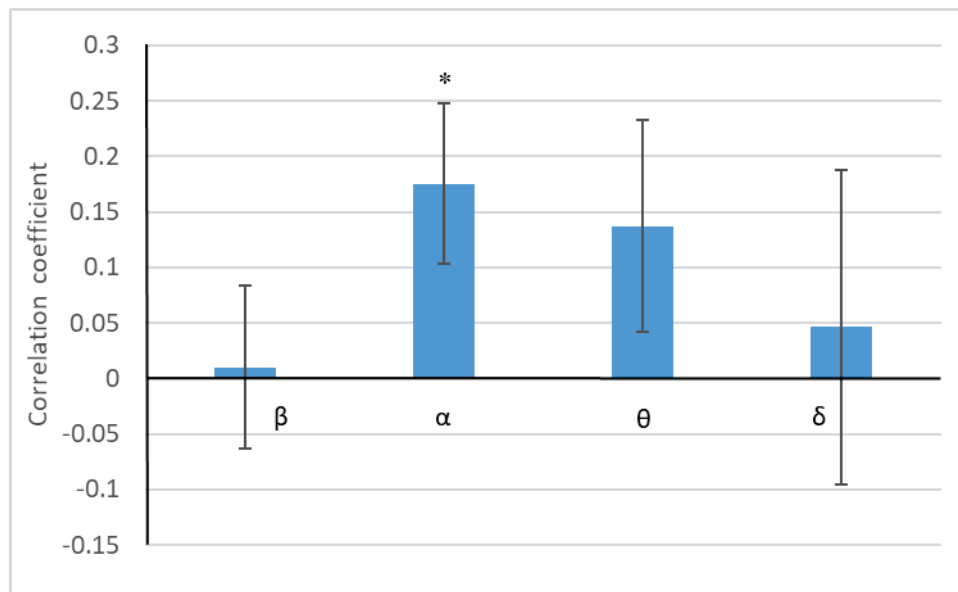


Figure 1 – Average value of correlation coefficient between β wave, α wave, θ wave, δ wave and the amount of OAE suppression. Error bars represent standard variation of the mean. * $p < 0.05$.

4. DISCUSSION

The amount of OAE suppression (MOCR strength) had a statistically significant positive correlation with the time variation of α -wave activity (appearing mainly from awakening to sleep onset). This result indicates that MOCR strength becomes weaker at a relatively early stage of sleep onset, which has a large change in awareness level, regardless of the depth of sleep. No correlation was found between the OAE amplitude and the α -wave activity. This result indicates that the inner ear function itself is not affected by the awareness level, but the activity of the MOC activity is affected by awareness level. Consequently, it is inferred that the inner ear protection function provided by MOCR also decreases when awareness level decreases. Therefore, being exposed to loud noise while awareness levels are decrease might increase the risk of causing noise-induced deafness.

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