Effects of Negative Middle-Ear Pressure on Auditory Steady State Responses: A Preliminary Study

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Abstract. The auditory steady-state response (ASSR) is a type of auditory evoked potentials, which are electrical activities of the auditory system in the presence of sounds and recorded with electrodes from the scalp. Research has suggested that the ASSR is a useful tool for evaluating the function of the auditory system and is superior to conventional techniques in estimating hearing thresholds in certain special populations. Negative middle ear pressure (MEP) is one of the most common pathologies in humans, particularly among young children. A negative MEP causes retraction of the eardrum which affects the transmission of sounds. However, impact of this condition on the ASSR has never been investigated. The purpose of this study was to make a preliminary observation on ASSR recordings in ears with negative MEP. In 25 human subjects, a positive ear canal pressure (200 daPa) was applied to simulate a negative MEP. The effect of negative MEP is expressed by the change of ASSR amplitude caused by the air pressure. Results show that ASSR amplitudes for all four frequencies were reduced by approximately 12% to 51%, which became larger with increasing frequency from 500 to 4000 Hz.

1. Introduction

Auditory evoked potentials (AEPs) are electrical potentials of the brain in response to sounds received by the ear. Various types of AEPs have long been used in audiology as tools for evaluating the function of the auditory nervous system and estimating hearing sensitivity. Recently, a new type of AEP, auditory steady-state responses (ASSRs), has gained considerable attention due to the growing need for more precise physiological measurements (for a review, see [1]). Investigations in the past decade have established that the ASSR measurement has a good potential to be used in clinical applications such as predicting hearing thresholds in the so-called difficult-to-test populations, e.g., newborns, infants, and patients with mental retardation or developmental disability. The advantages of ASSR over other AEP measurements include the ability to test for frequency-specific data, testing both ears simultaneously, and response detection with a more objective method.

The middle ear system plays an important role in our hearing because sounds must go through the middle ear to reach the inner ear for processing. Problems with the middle ear adversely affect sound transmissions. Negative middle ear pressure (MEP) is one of the most common pathologies of the middle ear, especially in children. When the middle ear functions properly, the air pressure in its cavity is the same as the ambient air pressure. The Eustachian tube, a small passage connecting the middle ear to the back of the throat behind the nose, maintains the pressure balance. Obstruction or blockage of the Eustachian tube gives rise to a negative MEP, resulting in a retraction of the tympanic membrane. A stiffer middle ear apparatus causes an increase in the acoustic impedance of the system. The condition may lead to substantial reduction of sound transmission through the middle ear and thereby likely affects the ASSR measurement.

Literature review shows that a limited amount of studies have been done pertaining to the effect of negative MEP on other types of electrophysiological tests in humans. For example, Ferraro et al [2] studied the effect on electrocochleography using the ear canal pressure (ECP) change to simulate negative MEP. Sun and Shaver [3] investigated the effects of actual negative MEP on otoacoustic emissions, a physiological measurement of the inner ear function. To develop the ASSR technique into a reliable clinical tool, we must document the extent to which ASSRs are influenced by negative MEP. To the best of our knowledge, research on the effect of negative MEP on ASSRs has never been carried out. The objective of the present study was to conduct a preliminary experiment of the effect of negative MEP on ASSR recordings. In this study, the negative MEP was simulated with a positive ECP.

2. Experiment, Results, Discussion, and Significance

A total of 25 young adults (18 to 35 year old) were recruited based on the following inclusion criteria: (1) negative history of otologic disease; (2) no positive findings in the ear canal and tympanic membrane in otoscopic inspection; (3) normal hearing defined by pure-tone thresholds of 25 dB HL or better for the octave frequencies from 250 to 8000 Hz; and (4) type A tympanogram with the tympanometric pressure within ±50 daPa. An IHS SmartEP system (Intelligent Hearing System, Inc.) was used to measure the ASSR and a GSI TympStar Middle-Ear Analyzer (Grason-Stadler, Inc.) to adjust the ECP in the experiment. The air pump portion of the tympanometer probe assembly was connected to the earphone tube of the ASSR system.

For each subject, the ear with better hearing and/or better middle-ear function was used as the test ear. Through the insert earphone placed in the ear canal, four tone bursts at frequencies of 500, 1000, 2000, and 4000 Hz were simultaneously presented with a presentation rate at 77, 85, 93, and 101 Hz, respectively. For recording ASSRs, three electrodes were placed on the scalp (one on the forehead and one behind each ear). The stimulus sounds were presented at 80 dB SPL. The ECP was set manually at +200 daPa to simulate a -200 daPa MEP and monitored on the tympanometer's LCD screen. ASSRs were repeatedly measured three times: two baselines under normal MEP and one under the introduced ECP. The second baseline ASSR was measured after the ECP was released in the first fifteen subjects and measured before the ECP was applied in the last ten subjects.

Valid data was collected in 22 ears. The effect of negative MEP is expressed by the change of ASSR amplitude caused by ECP, which was calculated by subtracting the ASSR amplitudes measured under the ECP from the amplitudes of the first baseline. Compared to those in the first baseline, ASSR amplitudes for the four frequencies were reduced by ECP by approximately 12% to 51% on average (Fig. 1). The reduction increased with frequency from 500 Hz to 4000 Hz. Large variability among subjects is evident for the ECP effect (Fig. 1) and ASSR measures (not shown), particularly for 4000 Hz. A minimal difference was noticed between the two baselines for all frequencies (Fig. 1) except for 4000 Hz (18% change), which may be due to the large individual variability. The change of recorded background noise in the ASSR measurement under the ECP was minimal (not shown). Statistic test will be performed to examine the significance of the change of ASSR amplitudes.

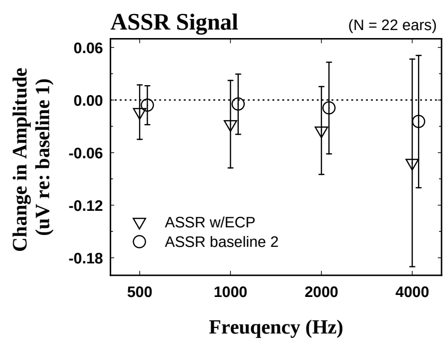

Fig. 1. Change of ASSR amplitude as a function of frequency when measured unde +200 daPa ear canal pressure and for a repeated baseline measurement.

3. Conclusions

This is the first study aiming at the effect of negative MEP on ASSRs. Results of the present study show that, as a positive ECP is applied, the ASSR for all frequencies from 500 to 4000 Hz noticeably decreases in amplitude with a larger change for high frequencies. This reduction in ASSR amplitude may result in an inaccurate estimation of the hearing sensitivity of patients when a negative MEP is present. Further investigations in this line with a larger sample size need to be conducted to confirm the findings from the present study.

4. Acknowledgements

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References

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