Tympanometric Measures in Human Ears with Negative Middle-Ear Pressure

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Abstract. Tympanometry is a physiological measurement of the acoustic admittance in sound transmission through the ear canal and middle ear and has been widely used in audiology as an objective and non-invasive means to determine the function of the middle ear system. A graphic display of the measurement is called a tympanogram. Characteristics of tympanograms have been quantified with several measures, e.g., peak compensated static acoustic admittance (Ytm) and equivalent ear canal volume (Vec). In the past decades, numerous investigations confirmed the effect of several middle-ear pathologies on tympanometric measures. However, little effort has been made to specifically explore the effect of negative middle-ear pressure. The objective of the present study was to present the outcomes of two tympanometric measures (Ytm and Vec) in human ears with negative middle ear pressure. Data was obtained from 77 patients' records (96 ears) at the Wichita State University Speech-Language-Hearing Clinic. Results demonstrate that substantial overlap exists in both Ytm and Vec measures of tympanometry between the ears with negative middle ear pressures and those with normal pressure in previous studies. These measures are unlikely useful to serve as an index in the diagnosis of negative middle ear pressure in humans. The present study also suggests that both Ytm and Vec tend to decrease with decreasing negative middle ear pressure.

1. Introduction

The middle ear, serving as an impedance matcher between air and the inner ear fluid, is critical in effective transmission of sounds from the outside world into our inner ear. However, certain pathologies in the ear may compromise the function of the middle ear. A non-invasive electroacoustical procedure, tympanometry, has been developed to evaluate the function of the middle ear system in sound transmission. This technology is widely used by most audiologists today as part of a full diagnostic test battery and a screening tool of middle ear disorders in children [for review see 1].

In the administration of tympanometry, a microphone probe is placed in the ear canal. A probe tone, commonly 226 Hz, is presented through an earphone to measure acoustic admittance of the middle ear system as a function of air pressure in the ear canal, which is systematically varied from +200 daPa to -400 daPa. Acoustic admittance of the ear canal and middle ear system is determined at the probe tip by the ratio of the acoustic volume velocity to the acoustic pressure. A graphic display of the measurement is called a tympanogram. With increasing either positive or negative ear-canal air pressure, less acoustic energy travels into the middle ear system due to an increased stiffness of the system. As a result, the admittance decreases. Acoustic admittance is at its highest when pressure in the middle ear is equal to the ambient pressure, displaying a peak on tympanogram, which also indicates the resting pressure of the middle ear system, known as tympanometric peak pressure (TPP). In a normal functioning middle ear system, the TPP should be near 0 daPa.

Characteristics of tympanogram have been quantified with several measures, e.g., peak compensated static acoustic admittance (Ytm) and equivalent ear canal volume (Vec). Ytm is a measure of the admittance value in millimho (mmho) from the peak to the tail on tympanogram, representing the admittance of the middle ear only. Vec is a measure of the volume of air in the ear canal between the probe tip and the tympanic membrane, which is derived in cm³ from the admittance value at a tail for the positive or negative pressure extreme relative to the baseline on a tympanogram. There has been an abundance of research that focuses on effects of several middle ear diseases on these measures in tympanometry, but systematic examination of the effect of negative middle ear pressure alone on tympanometric measures has not been reported [for review see 1]. Although a minor problem in the ear, negative middle ear pressure may cause other major disorders. Acoustic admittance of the middle ear with negative pressure is definitely reduced because of an increased stiffness of the middle ear system. Although negative middle ear pressure is compensated at the peak of the tympanogram with the application of an equivalent amount of ear-canal pressure, air pressure in both middle ear and ear canal is still negative. The Ytm of the middle ear may not be the
same as that for a normal middle ear. Negative middle ear pressure most likely has little effect on $V_{ec}$ since the tail of a tympanogram theoretically is independent of middle ear pressure.

This study seeks to find effects of negative middle ear pressure without other disorders on the tympanometric measures, $Y_{tm}$ and $V_{ec}$. A retrospective study will be conducted using case files of patients who have been tested with tympanometry. The results may provide a clearer understanding of effects of negative middle ear pressure on tympanometric measures and implications regarding the reliability of these measures.

2. Experiment, Results, Discussion, and Significance

**Experiment:** Data used in this study was obtained from the case files of patients at the Wichita State University Speech Language Hearing Clinic. A total of 96 ears of 77 subjects were used in this study with various age ranges. Patient inclusion criteria included: 1) a negative TPP lower than -50 daPa; 2) no current sign of otitis media based on audiologist’s inspection; 3) negative history of frequently occurring otitis media. The GSI tympanometer was used to record tympanometric data for patients.

**Results:** To perform descriptive statistics, patients were divided into two groups: adults (15 to 99 years of age, n = 79 ears) and children (1 to 9 years of age, n = 17 ears). Negative TPP of the adults ranged from -50 to -320 daPa and the children from -50 to -280 daPa. The mean $Y_{tm}$ for adults was 0.68 mmhos (90% range = 0.2 – 1.5 mmhos) and children 0.44 mmhos (0.2 – 0.9 mmhos). The mean $V_{ec}$ for adults was 1.36 cm$^3$ (90% range = 0.7 – 2.8 cm$^3$) and children 0.79 cm$^3$ (0.6 – 1.3 cm$^3$). When correlation analysis was conducted, data for the two groups were combined. Although the results did not show a strong correlation between TPP and both $Y_{tm}$ ($r = 0.2$) and $V_{ec}$ ($r = 0.2$), trends were observable that both $Y_{tm}$ and $V_{ec}$ decreased with decreasing TPP.

**Discussion:** The mean $Y_{tm}$ values of both adult and child patients with negative TPP in the present study are slightly lower than those in normal human ears (0.72 to 0.84 mmhos for adults and 0.5 mmhos for children) reported by previous studies [2, 3, 4], but the 90% ranges of $Y_{tm}$ in this study are similar to those in the previous studies. Both mean and 90% range of the $Y_{tm}$ value of adult ears in this study are similar to those in a previous investigation with a large sample [5]. It seems that $Y_{tm}$ value may be reduced in some ears with a negative middle ear pressure due to an increased stiffness of the system, whereas the range of $Y_{tm}$ in ears with negative middle ear pressure largely overlaps the normal range. The mean $V_{ec}$ values as well as 90% ranges for both adults and children in the present study are slightly higher than those of normal ears in previous studies [2, 3, 4]. This suggests that the ear canal volume slightly increases as a negative pressure forms in the middle ear. The present data exhibits that both $Y_{tm}$ and $V_{ec}$ tend to decrease as the middle ear pressure becomes more negative, whereas correlations between TPP and both $Y_{tm}$ and $V_{ec}$ are weak, as shown in the data distribution. Overall, it is unlikely that either $Y_{tm}$ or $V_{ec}$ measure in ears with negative middle ear pressure is significantly different from that in normal ears because of large variability of these measures in humans.

**Significance:** To the best of our knowledge, a systematic investigation on tympanometric measures in human ears with negative middle ear pressure has not been conducted. The present study provides scientific evidence concerning the variability of these measures in human ears and the reliability of the measures applied in separating ears with and without negative middle ear pressure.

3. Conclusions

The present study demonstrates that substantial overlap exists in both $Y_{tm}$ and $V_{ec}$ measures of tympanometry between the ears with normal and negative middle ear pressures. These measures are unlikely useful to serve as an index in the diagnosis of negative middle ear pressure in humans. Results also suggest that both $Y_{tm}$ and $V_{ec}$ tend to decrease with decreasing negative middle ear pressure.

4. References