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THE EFFECT OF EAR CANAL PRESSURE ON PURE-TONE THRESHOLDS, ACOUSTIC CONDUCTANCE AND ACOUSTIC TRANSMITTANCE

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ABSTRACT

Changes in pure-tone thresholds induced by static pressure changes in the ear canal were estimated from shifts in acoustic transfer functions for 19 young adults with normal hearing. Pure-tone thresholds at 500 and 2000 Hz were measured at ambient pressure, and at ear canal pressures of ±200 daPa using a 2 up 1 down-3AFC procedure. When averaged across pressure conditions, at 500 Hz there was a 6.6 dB elevation in threshold compared to a 5.0 dB shift in conductance. At 2000 Hz the average elevation in threshold was 3.5 dB compared to 2.4 dB for conductance. These differences were significant for an alpha level of 0.05. Individual differences between behavioral and physiological measures showed high variability such that individual shifts in behavioral threshold could not be well predicted by shifts in conductance. The results of this study suggest that for the conditions of this study, average changes in middle-ear conductance and transmittance are generally in agreement with behavioral measures at 500 and 2000 Hz. However, individual threshold elevations could not be predicted from shifts in conductance or transmittance. Further studies are needed to explore the predictive value of these physiologic measures in ears with reversible hearing loss such as in otitis media with effusion.

INTRODUCTION

A number of studies have examined the effect of ear-canal pressure or middle-ear pressure on hearing thresholds (Loch, 1942; Finkelstein et al., 1992; Rasmussen, 1946; Small, 1988; Truswell, Randolph & Snyder, 1979; Wever et al., 1948) or middle-ear mechanics (Huttenbrink, 1988; Kringlebotn, 2000; Murakami, et al., 1997; Rabinowitz, 1981). Ear canal and middle-ear static pressures result in increased middle-ear impedance such that thresholds for frequencies below about 2000 Hz are elevated and there is a reduction in middle-ear energy absorption (e.g., reduced stapes and umbo vibration).

New acoustic methods of assessing middle ear function using wideband transfer functions have been successful in predicting ears with conductive hearing loss (Keefe & Simmons, 2004; Piskorskski et al., 1999). The purpose of the present study was to examine the relationship between the pure-tone threshold elevation and changes in conductance and transmittance in human adults using ear canal pressure changes. Changes in conductance and transmittance in dB were compared to pure-tone threshold changes at 500 and 2000 Hz.

METHOD

Subjects

Nineteen young adults, 13 women and 6 men, participated in this experiment (mean age = 24 yrs.). Each had a negative history of middle ear disorders; a normal audiogram, and a normal 226 Hz admittance tympanogram with peak pressure within ± 10 daPa on the day of the test.

Procedure

- Subjects were seated in a sound-treated booth. A prototype Welch Allyn Diagnostic Middle Ear Analyzer (DME) was used to generate wideband click stimuli for the measurement of transmittance (1-energy reflectance) and conductance. The probe from the DME was inserted in the subject's ear and remained in place for reflectance testing. The probe was connected to the air pressure pump of a Grason Stadler model GSI-33 immittance instrument for ear canal pressure changes under computer control.
- For pure-tone threshold testing, 500 and 2000 Hz tones were digitally generated from a desktop PC using Tucker Davis Technologies (TDT) PsychoSig software. The tones were routed through a TDT PA-4 programmable attenuator to an ER-3A earphone coupled to the ear with an impedance probe tip assembly. The probe tip was coupled to the air pressure pump of a Grason Stadler model GSI-33 immittance instrument for ear canal pressure changes.
- Thresholds were obtained using a 2 up 1 down-3AFC procedure. Thresholds, transmittance and conductance measurements were obtained at ambient pressure and with ±200 daPa of pressure in the ear canal in random order. Subjects were trained in the psychometric procedure until stable performance was obtained prior to testing.
- The difference between ambient and pressure conditions in transmittance and conductance in dB were compared to the change in pure-tone threshold for these conditions.

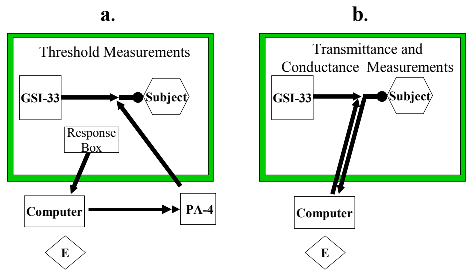


Figure 1 a. The experimental setup for pure-tone threshold testing at the three middle ear pressures. **b.** The experimental setup for transmittance and conductance obtained using the Welch Allyn DME.

RESULTS

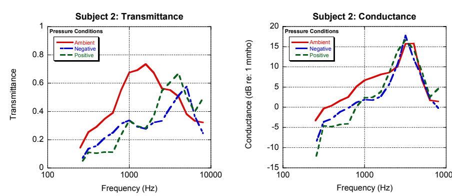


Figure 2. Mean 1/3 octave transmittance and conductance as a function of ear canal pressure for one subject (ambient, -200 daPa and +200 daPa).

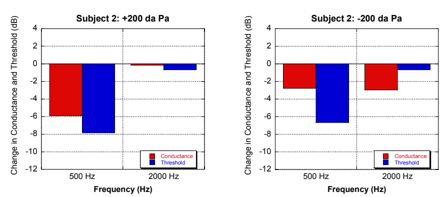
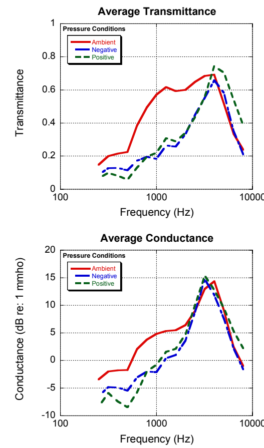
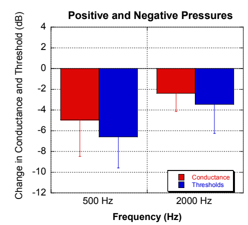


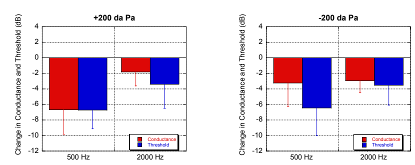
Figure 3. Mean data from one subject showing the change in conductance and pure-tone threshold for +200 daPa (left panel) and -200 daPa (right panel) pressure changes.



Figures 4. Average transmittance and conductance for 19 subjects for all pressure conditions.



Figures 5. Mean data for 19 ears for the change in conductance and pure-tone threshold for the ±200 daPa conditions. The error bars represent 1 standard deviation. The differences between the conductance shift and threshold shift were significant for an alpha level of 0.05 for both frequencies.



Figures 6. Mean data for 19 ears for the change in conductance and pure-tone threshold for +200 daPa (left panel) and -200 daPa (right panel) pressure changes. The conductance shift was significantly different from the threshold elevation for positive pressure at 2000 Hz, and negative pressure at 500 Hz for an alpha level of 0.05.

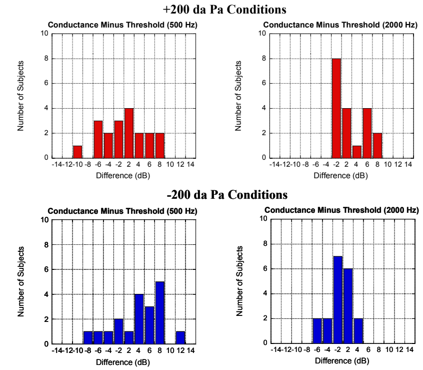


Figure 7. Data from 19 subjects reflecting the range of differences between the conductance shift minus the pure-tone threshold change as a function of frequency and ear canal pressure (red = positive pressure and blue = negative pressure).

CONCLUSIONS

Consistent with most previous studies, the change in threshold and middle ear function with static ear canal pressure was greater at 500 Hz than at 2000 Hz. There was a small (<1.5 dB) but significant difference between the average elevation in threshold and the conductance shift at 500 and 2000 Hz when averaged across ear canal pressure conditions (Fig. 5). When positive and negative ear canal conditions were examined separately, there was less agreement between threshold and conductance shifts, especially for the 500 Hz condition for negative ear canal pressure (Fig. 6).

Individual differences between conductance shifts and pure-tone threshold shift were quite variable, such that threshold shift could not be predicted from the change in conductance (Fig. 7).

The results of this study suggest that the average change in middle-ear conductance may provide an objective measure of conductive hearing loss for the conditions in this experiment. However, individual threshold elevations could not be predicted from shifts in conductance or transmittance. Further studies are needed to explore the predictive value of these physiologic measures in ears with reversible hearing loss such as in otitis media with effusion.

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