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IPSILATERAL STIMULUS INTENSITY AND TYMPANOMETRY IN MAN*

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The tympanometric characteristics of a human eardrum are studied under the influence of various intensities of the ipsilateral stimulation for the acoustic reflex. Emphasis is placed on the position of the tympanograms relative to atmospheric pressure, at the different stimulus intensities. The results indicate that there is no deviation of the notch of the tympanogram in the intensity range from 40 to 75 dB SPL, but there is an increase in the relative shift of the notch above 75 dB SPL. The change in deviation is caused by the suppression of the elicitation of the stapedius muscles in man. The ratio of the deviation, with and without the stimulus, is found to be 2.35 at 1000 Hz, 115 dB SPL, the highest intensity used in this work. The results reported are the average values of six normal human ears.

Introduction

Tympanometry which is one of the techniques of measuring the acoustic impedance of the ear, is gaining in importance [1, 4, 7-10, 15]. This technique assesses the mobility, or compliance, of the tympanic membrane during variation of the air pressure in a hermetically sealed ear canal. A tympanogram, which is a graph relating the change in compliance of the eardrum to the variation of air pressure in the ear canal, is generated by this technique. In other words, the tympanogram is a pressure compliance function. The observed or recorded change of the sound pressure level of the probe tone in the ear canal is an expression of the relative change of the impedance of the tympanic membrane and the middle ear. This change is expressed either in decibels or in cubic centimeters.

An electro-acoustic impedance bridge is generally used for tympanometry and intra-aural muscle reflex measurements [4,8]. A number of other measure-

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ment techniques have been developed using the acoustic reflex as the basis of the test. These tests include estimation of the hearing loss using filtered white noise and, perhaps more importantly, using ipsilateral stimulation. Recently, Madsen Electronics Oakville, Ontario, Canada, has developed a modified version of the electro-acoustic impedance bridge with the facility of presenting an ipsilateral stimulus, in addition to the contralateral stimulus. The availability of this ipsilateral bridge has made the present investigation possible.

The aim of the present work is to study tympanometry in man at various intensities of ipsilateral stimulation. The position of the tympanograms with respect to atmospheric pressure is examined.

Material and method

Apparatus. The equipment used in this investigation consisted of an electro-acoustic impedance bridge (Madsen, ZO-72I) and a chart recorder. This bridge had a probe tone frequency of 220 Hz. Only two tones of 1000 Hz and 2000 Hz at intensities of 40 to 115 dB SPL were available in the instrument used for the presentation of ipsilateral stimulation with the probe tone. A tone of 1000 Hz at 40 to 115 dB SPL was selected for the present work.

Subjects. Three male subjects in the age range 20-30 years were examined. None of them could recall having suffered from any middle ear infection. The outer ear and the tympanic membrane had a normal appearance. Both of the ears of each person were used in this work.

Procedure. The *I/C* switch of the impedance bridge was kept at *I* for presentation of ipsilateral stimulation at 1000 Hz. Tympanograms were recorded at different hearing levels in the range 40 to 115 dB SPL. The air pressure control of the impedance bridge was adjusted to sweep smoothly through a pressure range from $-$ 200 to $+$ 200 mm (H_2O) in a period of 45 seconds. This unit monitors the actual changes in air pressure in the ear canal [16, 17]. The sensitivity of the graphic recorder was held constant for all measurements. The recorder speed was set to 5 mm/sec for each test.

Results

The tympanograms were obtained at various intensities of the ipsilateral stimulation for three male subjects. Table 1 shows the average results of the six normal ears. The deviation of the notch, i.e. peak of each tympanogram

relative to atmospheric pressure was examined at various stimulus intensities. It was found that there was no effect of the ipsilateral stimulus intensity on the tympanometry in the intensity range from 40 to 75 dB SPL. However, an increase in the deviation, was found beyond 75 dB SPL. The ratio of deviation with and without presentation of ipsilateral stimulus, was found to be 2.35 at 1000 Hz, 115 dB SPL, the highest stimulus intensity used in the present investigation.

Table 1. Position of the tympanograms relative to atmospheric pressure at different intensities of the ipsilateral stimulation

Ipsilateral stimulus intensity [dB]	Deviation from zero pressure [mm H_2O]	Ratio of deviation with and without stimulus
Without stimulus	−20	1.00
40-75	−20	1.00
80	−30	1.50
85	−32	1.60
90	−35	1.75
95	−37	1.85
100	−40	2.00
105	−42	2.10
110	−45	2.25
115	−47	2.35

Pure tone = 1000 Hz.

It was observed that the individual differences were great, but all the subjects showed results which demonstrated that the position of the notch of the tympanogram was affected, deviated or shifted, by the presentation of different intensities above 75 dB SPL. It was verified that this deviation in the tympanograms was not due to any inherent noise, delay or any other cause arising from the equipment used. Thus the results were due only to the physiological behaviour of the ear, as has been indicated by several other investigators [2, 11].

Discussion

The results in Table 1 indicate that the shift in the position of the tympanogram is due to the activity of the tympanic muscles. The activity of these muscles is not affected by the ipsilaterally presented stimulus up to an intensity of 75 dB SPL for a pure tone of 1000 Hz. However, above 75 dB SPL, the relative shift of the notch of the tympanograms indicates that the muscle activity is suppressed by the pressure variation in the middle ear. It may be mentioned here that at the peak (i.e. notch) of the tympanogram, the pressure in the ear

canal is the same as in the middle ear. At this point the eardrum has its maximum mobility [7]. As has been reported earlier [3, 13], the compliance of the eardrum is found to be decreased during acoustic stimulation which, in man, is due primarly to the effect of the stapedius reflex [14]. Our results agree well with these findings. The middle ear reflex (stapedius) contraction, is changed upon the application of an ipsilateral stimulus (above 75 dB SPL), which is thus responsible for the relative shift of the position of the notch of the tympanograms.

It is known that the acoustic reflex to pure tones occurs at a sensation level (SL) of approximately 85 dB in the average normal ear, but the reflex SL is reduced by the presence of loudness recruitment [3, 5, 6, 12]. This occurs because the reflex is apparently mediated by the loudness of the sound signal. In the normal ear, this loudness level is reached for pure tones at sensation levels of 70 to 100 dB [3]. In an ear with loudness recruitment, however, the loudness level required to elicit the reflex is reached at a much lower level above the impaired threshold. From Table 1, it is also clear that the ipsilateral stimulus is effective only above 75 dB SPL, in shifting the position of the tympanograms with respect to atmospheric pressure. Generally, the loudness level [12] for normal human beings is 75 dB SL. Thus, from the above, it is quite clear that an ipsilateral sound stimulus has an effect on the position of tympanograms only above a loudness level for pure tones corresponding to a sensation level of 75 dB.

Conclusion

The effect of varying intensity of ipsilateral stimulation for the acoustic reflex, on the tympanometric characteristics of human eardrums, has been studied. It has been found that there is no effect from ipsilateral stimulation in the intensity range from 40 to 75 dB SPL, on the position of the tympanograms relative to atmospheric pressure. An increase in the relative shift, caused by the suppression of the elicitation of the stapedius muscle has been found above 75 dB SPL. The average value of the ratio of the deviation, with and without the stimulus, has been found to be 2.35 at 1000 Hz, 115 dB SPL, the highest stimulus intensity used in this investigation.

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