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Effect of Probe-Tip Placement on Impedance Audiometry

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Subjects, Material and Methods: The study was conducted on twenty normal hearing subjects (40 ears) with age range of 17 to 28 years. It included measurements of compliance, ear canal volume, middle ear pressure and acoustic reflexes. These parameters were studied for two probe-tip positions (i) $\leq$1mm; and (ii) 2mm inside the ear canal.

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Results: Significant differences were observed between the two probe-tip positions for ear canal volume. During acoustic reflex for 2000 Hz probe-tone, the change in compliance was significantly affected.

Conclusions: The results can be explained by ear canal resonance principles. Thus, the study verifies that the placement of probe-tip affects the measurements of tympanometry and acoustic reflex testing.

Aim and Objectives: To study the changes of tympanometric and acoustic reflex test measures with different placements of probe-tip.

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I. Introduction

Energy transfer in the human ear is initiated when sound waves are presented to the ear canal and sound pressure is applied to the tympanic membrane. Energy begins to flow and tympanic membrane vibrates with a characteristic amplitude and phase that depends upon the acoustic admittance of the entire system (Zwislocki, 1963). The transfer of energy from the ear canal to the middle ear and ultimately to the cochlea can be described from measures of sound pressure level (SPL) at the lateral Stoppenbach, 2002).

surface of the tympanic membrane (Wiley and Lucae (1867) was the first to measure tympanic membrane and middle ear characteristics in humans using an instrument called the interference otoscope, by presenting sound into both ears of a participant and listening to the level of sound reflected in each ear canal (cited in Feldmann, 1970). The term impedance was first introduced as an electrical term by Heaviside in 1886 (cited in Heaviside, 1892). Webster extended the principles of electrical impedance laws to the analysis of acoustical system (Webster, 1919). The first acoustic impedance measures made with an actual probe tube inserted into the human ear canal were reported by Troger in 1930 (cited in Metz, 1946). Martin in 1971 reported the first survey of audiologic practices where tympanometry or acoustic immittance measures were not mentioned among the procedures used by practicing audiologists. The recent survey of practicing audiologists reported by Martin et al in 1998 indicated that 96% of the respondents routinely used acoustic immittance measures in their daily practice. Acoustic immittance instruments and procedures are now commonplace in audiology, otolaryngology, pediatric and other diagnostic clinics. The most recent guidelines for screening middle ear function recommended by ASHA (1997) are based on the use of acoustic immittance measures. When it has become such an important tool for our clinical settings, then awareness of the variability in measurements becomes an essentiality for an audiologist. The error most likely to happen is by different placements of probe-tip in the ear canal leading to variability. To verify this hypothesis the present study was conducted.

The hypothesis proposed was based on the principle that accurate determination of the static compliance depends on an accurate estimation of the ear canal volume. If ear canal volumes are overestimated, then the static compliance will be underestimated that could lead to suspicion of middle ear effusion where none exists. Secondly, in the case of flat tympanogram, the estimation of equivalent volume can provide a clue to the cause of the flat tympanogram, whether it is due to artifact, tympanic membrane perforation or patent tympanostomy tube, or middle ear effusion (Fowler CG & Shanks JE, 2002).

II. Material and Methods

The study included twenty adult normal hearing subjects of either sex with age range of 17 to 28 years. Subjects' selection criteria were normal hearing, with no external and middle ear pathology on clinical examination. The impedance audiometry was carried out in sound-treated rooms of Speech and Hearing Unit of ENT OPD, PGIMER, Chandigarh. The equipment

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used for impedance audiometry was SD 30 tympanometer. The 226 Hz probe-tone was used for tympanometric measurements. The pressure in the external auditory canal was varied from +200 to -300 daPa at the rate of 200 daPa per second. The parameters noted were compliance, ear canal volume (or base volume) and middle ear pressure. The acoustic reflex testing was also conducted. The change in compliance denoted the acoustic reflex in the monitored ear with probe tip. The reflexes were elicited and recorded at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz at 90 dB HL. The change in compliance was also noted from 80 dB HL to 100 dB HL at 1000 Hz. All these parameters were studied in two placement positions of the probe-tip (i) ≤1mm; and (ii) 2mm inside the ear canal to understand the variability.

The data was subjected to appropriate statistical measures. The values of mean for central tendency and standard deviation for variability were computed. Paired t-test was administered for comparison of two positions of probe-tip in the ear canal. The significance tests were two-tailed and conducted at or above the 5% significance level.

The study was conducted in the Speech and Hearing Unit, Department of Otorhinolaryngology, PGIMER, Chandigarh. The investigations were carried out complying the ethics and were approved by the ethical committee of the institute. Each of the subjects was told about the purpose of the investigation and written informed consent was taken from the patients.

III. Observations and Results

A total of twenty subjects with normal hearing and healthy external & middle ear were included in the study. The subjects with age range 17 to 28 years of either sex were assessed for tympanometry and acoustic reflex test in both the ears. Thus total number of ears assessed was forty (40 ears). The table 1 shows that highly significant differences were observed between two positions of the probe-tip for ear canal volume. Differences were also observed for middle ear pressure in two positions but could not reach the statistical significance level. Similar results were seen for compliance differences.

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Table 1 : Findings of tympanometry (N= 40)

	1st position (≤1mm)		2nd position (2mm)		‘t’
Parameters	Mean	SD	Mean	SD	
Compliance(cc.)	0.788	0.427	0.778	0.480	0.639
E C Vol.(cc.)	1.443	0.398	1.147	0.307	**5.989*****
ME Press. (daPa)	-8.13	20.50	-6.25	16.28	1.292

**p<0.05; **p<0.01; ***p<0.001.*

Table 1 depicts mean, standard deviation (SD) and ‘t’-value of compliance, ear canal volume (E C Vol.) and middle ear pressure (ME Press.).

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Table 2 : Findings of Acoustic Reflex Test (N= 40)

d	1st position (≤1mm)		2nd position (2mm)		t’
Frequency	Mean	SD	Mean	SD	
500 Hz	-6.825	9.142	-6.15	6.100	0.514
1000Hz	-8.975	8.368	-9.400	4.986	0.354
2000Hz	-2.400	3.350	-5.250	9.190	**2.119***
4000Hz	-1.350	2.887	-2.250	4.490	1.630

**p<0.05; **p<0.01; ***p<0.001.*

Table 2 shows mean, standard deviation (SD) and ‘t’-value of ‘change in compliance’ during acoustic reflex at 90dB SPL for different frequencies tested.

As seen from the table 2 statistically significant difference was found between two positions of the probe-tip at 2000 Hz. It means that change in compliance during acoustic reflex for 2000 Hz probe-tone was affected by position of the probe-tip in the ear canal. Differences were observed for 4000 Hz probe frequency but could not reach the statistical significance. For 500 Hz and 1000 Hz probe frequencies, the compliance shift with acoustic reflex was again not significantly different in two probe-tip positions.

IV. Discussion

Tympanometry is a measure of the acoustic admittance or compliance in the ear canal as a function of changing ear canal pressure (Wiley TL and Stoppenbach DT, 2002). Tympanometric measures include contributions offered by the volume of air between the probe-tip and the tympanic membrane as well as the entire middle ear system. The obtained measures will vary with individual ear canal characteristics (e.g. shape and volume) (Wiley TL and Stoppenbach DT, 2002). The probe-tip position thus determines the volume of air in the external ear canal. If the placement of probe-tip is deep in the ear canal the volume would be less and with lateralized placement volume of the ear canal would be greater. Similar findings were found in the present study that when the placement of probe-tip was ≤1mm the ear canal volume was large and with placement position of probe-tip 2mm deep the ear canal volume was smaller. To overcome these differences the compensated measures were recommended by ANSI (ANSI S3.39-1987) that eliminates the contribution of the ear canal to the overall acoustic admittance or compliance (ASHA, 1990). The ear canal volume is not the direct measure but it is the estimate of the admittance or compliance offered by the volume of air between the probe-tip and the tympanic membrane. The measure is based on the principle that under specified conditions, a given volume of air has a specified admittance or compliance (Shanks & Lilly, 1981).

The differences of compliance in two positions were not found statistically significant. The probable reason for this might be the instrument used (Siemens SD 30) where the compliance measured with 226 Hz probe-tone at 200 daPa serves as an approximation of the compensated acoustic admittance of the ear canal.

Similarly there were no significant differences observed for middle ear pressure in two probe-tip positions. Middle ear pressure is an indirect estimate made from the tympanometric peak pressure (TPP) (Wiley TL and Stoppenbach DT 2002), and ANSI defined TPP as the pressure in deca-Pascals at which the peak of the tympanogram occurs (ANSI S3.39-1987). As the subject included in the study were with normal middle ear on examination, thus the middle ear pressure measured should be normal showing non-significant differences in two positions of the probe-tip.

Significant differences were obtained for change of compliance in acoustic reflex testing at 2000 Hz frequency but the differences observed at 4000 Hz could not reach statistical significance. These results can be explained by ear canal resonance principles. The resonant frequency is based on the tube length and is assumed independent of diameter in the normal ear (Goode RL, 2001). The resonant frequency is calculated by the formula F0 = 1/4th wavelength of sound (∂) multiplied with ear canal length. In a normal average ear canal the resonant frequency is about 3500 Hz (= 10cm wavelength) (Goode RL, 2001). In tympanometry the probe-tone used is 226 Hz with longer wavelength hence the F0 would be occurring at ¼th wavelength of sound. Secondly modification in length of ear canal also affects the resonant frequency. As explained by Goode RL et al, 1977 that lengthening the canal lowers the resonant frequency and decreasing the length raises the frequency. In such situation the placement of the probe-tip would either underestimate or overestimate the SPL measured. It would also affect the change in compliance during acoustic reflex.

V. Conclusions

The present study based on data of 40 ears, shows that placement of probe-tip affects the measurements of tympanometry and acoustic reflex testing to some extent. The change of compliance during acoustic reflex is the most affected parameter by shift of probe-tip position during impedance audiometry.

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