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Test-Retest Differences and Assistive Function in Detecting Conductive Hearing Loss of Impedance Audiometry

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Impedance audiometry requires physical modifications during the test, which might influence retest data. Therefore, in order to interprete retest data meaningfully, the range of variation should be identified in each measure of impedence audiometry. The present study obtained data on the retest variation of peak pressure, acoustic reflex threshold, static compliance and earcanal volume in impedance audiometry. In addition, the authors wanted to know whether or not impedance data would assist otolaryngologists in the detection of conductive hearing impairment. The variation of the retest data was not clinically nor statistically significant in the measurement except for those of ear canal volume. The data on ear canal volume also suggested that the ear canal increases in size during the teenage period and that male ear canals are larger than those of females in ears over 20 years of age. The impedance data assisted the otolaryngologist in the detection of conductive hearing impairment.

Key Words: Peak pressure, static compliance, acoustic reflex threshold, ear canal volume

Impedance audiometry, as a noninvasive technique, offers objective information on the status of the tympanic membrane, middle ear cavity, ossicular chain, Eustachian tube, stapedius muscle, the 7th and the 8th cranial nerves and brainstem as well as on the type and degree of hearing loss. Since the introduction of Metz' mechanical bridge in 1946, impedance audiometry has improved greatly through much research and modification of the instruments and of test procedures, so that since the 1970's, it has been used routinely in most otologists' and audiologists' clinics.

When impedance audiometry is performed, retests are often necessary in cases such as when the probe tip slips out during the test, to confirm the test results or to observe treatment results. In order to rely on the retest data, however, it requires that the retest data are not affected by the test procedures. Since impedance audiometry undergoes physical modification during the test, varying the air pressure in the sealed ear canal, it might influence the test results to some extent if this kind of physical modification is repeatedly performed. Another possible factor that might cause variation in test results is the size and/or location of the probe tip. That is, the distance from the tympanic membrane to the probe tip and the volume size of the sealed ear canal might be changed in retests, hence the test results as well.

According to Lewis *et al.* (1975), a high rate of discrepancy was observed in retest data when he used the most popular -100mm H_2O criterion. Therefore, it is important to know the test-retest variations in each measure in impedance audiometry in order to validate the retest data and in order to interprete retest data meaninfgully and with confidence. On the other hand, McCandless and Thomas (1974) reported that the otoscopic findings agreed with impedance findings in 93% of the cases. Cooper (1975) reported it as 94%. Fox *et al.* (1974) observed that impedance data exceed otoscopic findings in 13% of the cases in diagnosing conductive hearing loss.

The purposes of this research are first to obtain data on the test-retest differences in tympanograms and acoustic reflex thresholds and, second to obtain age related data and data of variability in ear canal volume for reference. The third purpose is to find out

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if impedance audiometry would assist resident doctors more in detecting conductive hearing loss than when examination of the eardrums using an otoscope only is performed.

MATERIALS AND METHODS

Subjects

34 young normal adults ranging in age from 20 to 26 years who were medical students in Yonsei Medical College and 213 patients between 3 and 68 years of age were tested. The age distribution of the patient group is given in Table 1.

Procedures

Otoscopic examinations were performed before and after pure tone and impedance audiometry. For impedance audiometry, tympanograms and acoustic reflex thresholds (ARTs) were measured three times in each patient: twice with the probe tip unchanged and once with the probe tip taken out and reset.

The instruments used were GSI 1704 pure tone audiometer and Teledyne Avionics 3D/3P Impedance Meter/Plotter. Both instruments were calibrated with Bruel & Kjaer Sound Level Meter (2203)/Octave Filter (1613) Set, and ARTs were computed in dB SPL (0.002 dynes/cm^2) as measured by the Sound Level Meter.

Table 1. Classification of patients

Type of hearing loss	Sex	Age (yr) 0-9	10-19	over 20	Total
Sensorineural	Male	9	33	51	93
	Female	6	12	42	60
Conductive or mixed	Male	15	0	18	33
	Female	6	9	12	27
Total		36	54	123	213

Table 2. Peak pressure, canal volume and static compliance of normal adults(N=34)

Statistic	Peak pressure (mm H_2O)	Canal volume (cc)	Static compliance (cc)
Mean	−3.5	1.3	0.55
SD	4.5	0.3	0.24
Range	−110±10	0.78−2.03	0.17−1.39

RESULTS

The mean, standard deviation, and ranges of peak pressure, canal volume and static compliance of the 34 normal adults are shown in Table 2. The mean peak pressure, canal volume and static compliance were -3.5mm H_2O, 1.30cc and 0.5cc, respectively. The test-retest differences in peak pressure were within ±30mm H_2O and there were no significant differences between the first and second retests (Table 3). The test-retest differences in static compliance were less than 0.2cc regardless of the type of hearing loses (Table 4). The mean acoustic reflex thresholds were 101 dB sound pressure level (SPL) (89.5 dB hearing level (HL) for 500 Hz, 95 dB SPL (88 dB HL) for 1000 Hz, 96 dB (87.0 dB HL) for 2000 Hz and 98 dB SPL (88.5 dB HL) for 4000 Hz for contralateral stimuli. The ipsilateral acoustic reflex thresholds were 91 dB SPL for 1000 Hz and 106 dB SPL for 2000 Hz. The test-retest

Table 3. Differences in peak pressure between the first and the retests

Type of hearing loss	No. of tests	Differences (mm H_2O) 0	10	20	30	Total(%)
Conductive	2	12	1	0	0	13
	3	11	1	1	0	13
Normal or sensorineural	2	46	4	1	0	51
	3	44	5	1	1	51
Total (%)		113 (88.2)	11 (8.1)	3 (2.3)	1 (0.4)	128 (100.0)
P>0.05						

Table 4. Differences in static compliance between the first and the retests

Type of hearing loss	No. of tests	Differences (cc) 0.1	0.11−0.20	Total(%)
Conductive	2	48	5	53
	3	50	3	53
Normal or sensorineural	2	13	0	13
	3	11	2	13
Total (%)		122 (92.4)	10 (7.6)	132 (100.0)
P>0.05				

differences were not significant statistically ($p>0.05$) (Table 5).

The ear canal volumes of the normal ears and of the ears with sensorineural hearing losses were as in Table 6. The ear canal volumes increased as age increased ($p<0.05$). There was no statistically sigificant difference between male and female subjects in each group under 20 years of age. However, male ear canal volumes were larger than those of females in ears over 20 years old ($p<0.05$). The range of ear canal volume overlapped each other in all groups so that the range of each group, instead of the mean and a standard deviation should be referenced when necessary. The test-retest differences were 0.3cc or less in all cases of conductive and mixed hearing loss. However, in sensorineural hearing loss, one ear exhibited difference of 1.2cc which occurred as time passed even when nothing was changed and the probe was not taken out and reset (Table 7). The test-retest variations of the third measurement were similar to those of the second measurement. The statistically significant increase in ear canal volumes between those of teenagers and those of the older group suggests that ear canals grow in teenagers' ears. The mean test-retest variation in each subject was 0.2cc in all types of hearing loss. The ranges were between 0.02cc and 0.98cc in sensorineural hearing losses and between 0.1cc and 0.36cc in conductive and mixed hearing loss.

Among the 45 cases of conductive hearing loss, the detectability of otoscopic findings increased by 24.4% when the doctors consulted impedance data than when they did not. Among the detected cases

Table 5. Comparison of ARTs in dB SPL of the three tests in normal adults(N=34)

Side	Freq	Statistic	Tests 1	Tests 2	Tests 3	Total
Contra-lateral	500	Mean	101	100	99	100
		SD	6	6	5	6
	1000	Mean	95	94	95	95
		SD	5	4	5	5
	2000	Mean	96	96	95	96
		SD	5	4	5	4
	4000	Mean	98	97	96	97
		SD	5	6	6	6
	500-2K	Mean	98	97	97	98
		SD	4	4	4	4
	WB	Mean	87	86	88	87
		SD	6	6	6	5
	LO	Mean	82	81	81	82
		SD	7	7	8	7
	HI	Mean	84	83	84	83
		SD	7	6	7	7
Ipsila-teral	1000	Mean	91	91	90	91
		SD	5	5	6	5
	2000	Means	106	104	106	106
		SD	4	4	5	4

$p>0.05$

Table 7. Differences in the ear canal volumes between the first and the second tympanograms of normal and ears with sensorineural hearing loss(N=153)

Age (yr)	Differences (cc) <0.30	0.31–0.50	0.51–1.00	>1.01	Total
0–9	15				15
10–19	42	3			45
over 20	87	3	2	1	93
Total (N)	144	6	2	1	153
(%)	(94.1)	(3.9)	(1.3)	(0.7)	(100.0)

$P>0.05$

Table 6. Comparison of ear canal volumes in cc According to age and sex(N=153)

Statistic	Sex	Age (yr) 0–9**	10–19**	over 20*	Total
Mean	Male	0.64	0.96	1.36	1.06
	Female	0.63	0.91	1.04	0.98
Range	Male	0.42–0.83	0.72–1.25	0.72–2.20	0.42–2.20
	Female	0.45–0.85	0.60–1.20	0.45–1.90	0.45–1.90

* $P\leq0.05$ ** $P>0.05$

by impedance audiometry were 6 ears with abnormally colored tympanic membranes, three ears with retracted eardrums, one perforated eardrum and one case of tympanosclerosis.

DISCUSSION

The air pressure where the peak compliance occurs in normal ears was reported as occurring within +50 mm H_2O by Alberti and Kristensen (1970), −80 mm H_2O or less by Renval *et al.* (1973), and −100 mm H_2O or less by many scholars (Bluesone *et al.*, 1973; Harker and Wagner, 1974; Jerger, 1970; Jerger *et al.*, 1972; McCandless and Thomas, 1974). The normal peak pressures of the present study were within ±10 mm H_2O except for one ear exhibiting −110 mm H_2O. The test-retest variations were within ±30 mm H_2O in hearing loss group and there was no significant difference between the three measurements. The ARTs of the present study were somewhat smaller than those of the two other studies on normal Korean adults. Noh and Min (1975) reported them as 96, 97, 99 and 96dB HL and Wang (1980) as 95.3, 89.2, 92.3 and 90.7 dB HL at 500, 1000, 2000 and 4000 Hz, respectively.

The mean and standard deviation of the ear canal volume of normal adults were 1.3cc and 0.3cc, respectively, which were similar to those of normal American adults (Northern and Downs, 1978). The ear canal volumes increased as age increased. The ranges, however, were superimposed in all groups so that the use of ear canal volume for diagnosis should be interpreted with caution.

The mean static compliances of normal adults were reported as 0.61cc, 0.67cc, 0.69cc and 0.53cc and the ranges as between 0.36cc and 0.79cc, between 0.30cc and 1.65cc, between 0.20cc and 1.40cc, and between 0.14cc and 1.49cc by Terkildsen (1960), Jerger *et al.* (1972), Noh and Min (1975), and Chun (1979), respectively. The mean static compliance of the present study was 0.55cc and the range was between 0.17 and 1.39cc. The test-retest differences of the static compliances were 0.2cc or less regardless of the type of hearing loss, which are not clinically significant.

CONCLUSIONS

1. The variations in retests were not clinically nor statistically significant in peak pressures, static compliances or acoustic reflex thresholds.
2. However, variations in ear canal volumes were clinically significant in retests. Therefore, interpretation of ear canal volume requires caution. The possibility of the growth of the ear canal during the teenage period is suggested according to the data on ear canal voume.
3. The impedance data aided otolarngologists in the detection of conductive hearing loss.

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