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"Diagnostic implementation of impedance audiometry as an OPD procedure in patients with conductive deafness : An overview"

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ABSTRACT

Impedance audiometry is an objective technique which evaluates middle ear function by three procedures: Static immittance, Tympanometry and the measurement of acoustic reflex threshold sensitivity. The study aims to demonstrate the clinical implementation and usefulness of impedance audiometry in diagnosis of pathology involving the middle ear causing conductive hearing loss. The study was conducted in the department of ENT Muzaffarnagar medical college for a period of 18 months (i.e from Jan-2015 to June-2016), comprising 232 ears of 125 patients.

The patients were divided in 2 groups:

1. 75 patients (Male = 39, Female = 36 with conductive deafness aged between 10-60 years) - 139 ears
2. 50 normal control cases (Male = 42, Female = 8, Aged between 10-60 years) - 93 ears.

Impedance audiometry was done to evaluate the type of middle ear pathology in patients with conductive deafness and for establishment of type of deafness additional methods - Tuning fork test's and Pure tone audiometry were done.

The results were interpreted according to the parameters of impedance audiometry i.e static compliance, tympanometry (tympanogram type) and acoustic reflex.

Based on the clinical study results we could estimate the tympanometry as an objective and informative method for diagnosis of type of conductive hearing loss.

KEYWORDS: Conductive hearing loss, Pure tone audiometry, Middle ear pathology, Impedance audiometry

INTRODUCTION:

For proper hearing, we require the perfect transmission of sound from our surrounding environment (i.e air) to the fluid inside the cochlea and the process of hearing begins with a simple interaction between the mechanical energy of the sound wave and the hearing analyzer. Clinical audiology uses different methods of testing and techniques for the accurate diagnosis of the hearing function. Acoustic impedancemetry gives us information about the functional capacity of the hearing analyzer and abnormalities in hearing due to various middle ear pathologies. The concept of acoustic immittance is introduced to connect the changes in the middle ear, which occur on the transfer of sound energy and the moving of the system, which consists of several different mechanical components, which react in different ways to the forces applied in the external ear canal. The term acoustic immittance is used to present admittance or impedance, or both of them together (ANSI,1987)[1]. The sound pressure of the tone, which is applied in the outer ear canal (SPL) is an indirect expression of acoustic immittance. The acoustic immittance of the tympanic membrane in a normal ear changes inadvertently, when the air pressure to the outer ear canal deviates up or down from the normal surrounding level and the standard connection between the changes in air pressure and the immittance level is an expression of deviations, caused by diseases of the middle ear. In 1990[2] ASHA (American speech language hearing association) recommended immittance testing to screen middle ear diseases. Silman et al. 1992[3] created an immittance protocol for the early detection of otitis media with effusion in children, in which the main focus was: Tympanometry width, the absence of a counter-lateral acoustic reflex, peak pressure recorded in tympanometry, and static admittance of the middle ear. Katz 1994[4] defines this study as a routine, objective and sensitive method for determining pathologies in the middle ear, while Harrison et al. 2005[5] apply this for quantification of the hearing function. The interpretation of the results is part of the entire audiological assessment, combined with other hearing tests. Tympanometry is the measurement of acoustic immittance and the eardrum's mobility, as a function of the air pressure in the ear canal, when the air pressure varies from + 200 to - 200 daPa. The results obtained are represented graphically, as the 'X' axis represents the air pressure, while the vertical 'Y' axis represents the immittance or compliance, in other words - the conductance. It is a true fact that impedance meter measures the admittance (compliance) rather than the impedance. Compliance- the conduction of the eardrum is measured in cm^3, while the pressure in the ear canal is measured in daPa. The obtained data is routinely used in the audiological assessment and is an accurate reflection of the changes occuring in the mechano-acoustic characterstics and the ear function caused by various middle ear diseases and lays the fundamentals of differential diagnosis of conductive deafness while the tympanogram is a graphic expression of these interdependencies. Thus, tympanometry measures the energy of the reflected sound, while the tympanometer automatically shows the volume of the ear canal. In the following study our aim was to exploit the use of impedance audiometry to the maximum to define the topic of damage of the hearing analyzer system by various middle ear pathologies, we used data from the the tympanometry for accurate diagnosis of the state of the middle ear, the deviations in sound conduction. This eases clinical diagnosis and helped us to determine the adequate means of treatment: surgical or conservative.

MATERIALS AND METHODS:

The Present study was conducted in the Department of ENT & HNS, Muzaffarnagar Medical College and Hospital, Muzaffarnagar, Uttar-Pradesh.

STUDY DURATION:

Total duration of study was 18 months (i.e from Jan 2015 to June 2016).

STUDY POPULATION:
Study was conducted on 125 Patients who attended the ENT outpatient department with some complaints in Ear, Nose, Throat & Head and Neck area or were referred from other departments of the same hospital and were divided in two groups:
1. Control cases = 50 in number and comprised 93 tested ears.
2. Patients = 75 in number. (They were the patients of Conductive deafness confirmed so by doing Otoscopy, Tuning Fork Tests & Pure tone Audiometry) and comprised 139 tested ears.

INCLUSION CRITERIA:
All the patients satisfied the following criteria -

FOR PATIENTS:
1. Age between 10 to 60 years
2. Patients having conductive hearing loss as was evident in Tuning fork tests, Otoscopy & Pure tone audiometry.

FOR CONTROLS:
1. Age between 10 to 60 years
2. Healthy persons having no clinical middle ear disease
3. Subjects given consent for the test

EXCLUSION CRITERIA:
FOR PATIENTS:
1. Patients having Tympanic membrane perforation
2. Patients having history of recurrent ear discharges
3. Patients having Sensorineural hearing loss as was evident in PTA.

FOR CONTROLS:
1. Non consenting subjects
2. Subjects having discharging ear or previous ear disease

SELECTION OF CASES:
During this period75 cases of conductive deafness as subjected on clinical examination which included otoscopy and Tuning fork tests (Rinne's, Weber's and Absolute bone conduction test) were subjected to Pure tone audiometry and like normal cases these too were subjected to impedance audiometry which included :
1. Static compliance
2. Dynamic compliance i.e Tympanometry
3. Stapedial reflex

An attempt was made to include a variety of ears like Otosclerosis, Secretory otitis media, Adhesive otitis media, Eustachian tube blockage etc and the patient belonged to both sexes and were of different age groups.

Another 50 normal cases were taken after a detailed ENT examination, Tuning fork tests and Pure tone audiometry.

If there was no abnormal finding then each ear of these cases was subjected to impedance audiometry, these subjects served as an index of the normal impedance values in indian population.

INSTRUMENTS USED:
FOR EAR EXAMINATION:
1. Jobson - Horne Probe with Ring Curette
2. Bull's Eye Lamp
3. Forehead Mirror
4. Riester Ri-scope Pneumatic Otoscope
5. 0° Rigid Rod Endoscope with Camera
6. Carl - Zeiss Microscope
7. Tuning Fork of 512 Hz
8. ALPS AD 2100 two channel diagnostic audiometer system with TDH -49 Telephonic Supraaural headphones and Radioear B – 71 Bone vibrator
9. Interacoustics AT 235 Impedance Audiometer

FOR NOSE EXAMINATION:
1. Thudicum nasal speculum
2. St.Clair Thompson Posterior Rhinoscopic Mirror
3. 0°Endoscope

FOR THROAT EXAMINATION:
1. Lac's Tongue depressor
2. 70°Endoscope
3. Laryngeal Mirror.

OBSERVATIONS:
IN CASES OF CONDUCTIVE DEAFNESS:
75 cases of conductive deafness as suspected by clinical examination, Tuning fork tests and Pure tone audiometry were subjected to impedance audiometry. These cases ranged in the age group of 10 to 60 years and a maximum i.e 76% of cases fall between the age group of 11 to 40 years with Males 52%(39 cases) and Females 48%(36 cases).

These 75 cases of conductive hearing loss included in the study comprised of 141 ears.

These cases were of Secretory otitis media, Adhesive otitis media, Otosclerosis, Scarred drum and Eustachian tube blockage.

Impedance audiometry was successfully done in 139 ears i.e all the three parameters were successfully recorded, in 2 ears a proper seal could not be obtained and in rest 9 ears no abnormality of any sort was detected.

TABLE 1: Showing distribution of 139 ears on the basis of clinical examination

Diagnosis	No. of Ears	No. of Cases	Percentage (%)
Otosclerosis	77	40	55.00
Secretory Otitis Media	30	16	21.00
Adhesive Otitis Media	22	12	16.00
Eustachian Tube Blockage	5	4	4.00
No definite Diagnosis Made	5	3	4.00
Total	**139**	**75**	**100.00**

TABLE 2: Showing distribution of Tympanograms in 77 ears clinically suspected as having Otosclerosis:

Type of Tympanogram Noted	No. of Ears	Percentage (%)
A_s	64	83.10
A	11	14.30
B	1	1.30
C	1	1.30
Total	77	100.00

As depicted in the above table 'As' type of Tympanogram was present in 83.1% of ears suspected as having Otosclerosis.

In 14.3% ears Type 'A' tympanogram was seen and in all these cases acoustic reflex was absent.

TABLE 3 : Showing distribution of Tympanograms in 30 ears clinically suspected as Secretory otitis media:

Type of Tymparnogram Noted	No. of Ears	Percentage (%)
B	26	86.67
As	4	13.33
Total	30	100.00

From the above table it is clear that type **'B'** Tympanogram was commonest **(86.67%)** in cases of Secretory otitis media.

TABLE 4 : Showing distribution of Tympanogram in 22 ears suspected clinically to be of Adhesive otitis media:

Type of Tympanogram Noted	No. of Ears	Percentage (%)
A	1	4.54
B	13	59.10
C	4	18.18
As	4	18.18

Total	22	100.00

It is evident from the above table that Type 'B' Tympanogram was commonest in cases of Adhesive otitis media.

TABLE 5 : Showing distribution of Tympanograms in 5 ears of Eustachian tube dysfunction:

Type of Tympanogram Noted	No. of Ears	Percentage (%)
B	2	40.00
C	3	60.00
Total	5	100.00

Above table shows that Eustachian tube blockage gives rise to either 'B' or 'C' type of tympanogram.

TABLE 6: Showing distribution of Tympanograms in 5 ears in which no definite clinical diagnosis was made:

Type of Tympanogram Noted	No. of Ears	Percentage (%)
A_s	3	60.00
A	1	20.00
A_d	1	20.00
Total	**5**	**100.00**

As shown above one case had 'Ad' type of Tympanogram.

Static compliance in this case was 1.5 c.c and this was the only case in this series with compliance more than 1.2 c.c (the upper limit of normal range in this series).

TABLE 7 : Showing ranges of Static compliance in normal ears and various middle ear disorders:

Type of Cases	Range of Static Compliance Noted	No. of Ears
Normal	0.3-1.2 c.c	93
Otosclerosis	0.2-1.0 c.c	77
Secretory otitis Media	0.2-0.3 c.c	30
Adhesive otitis Media	0.2-0.7 c.c	22
Eustachian tube blockage	0.3-0.4 c.c	5

The above table illustrates that values of static compliance overlap with normal but in general are on the lower side of normal range. Acoustic reflex was absent in all cases of conductive deafness.

TABLE 8: Showing comparative study of findings of impedance audiometry in cases of unilateral conductive deafness.

Left half of the table is showing the results of impedance studies of ears with conductive deafness while right side shows the impedance audiometry results of normal ear in the same case.

Ear with Conductive deafness					Normal Ear		
AC-BC Gap	Diagnosis	Tympanogram Type	Static Compliance	Acoustic Reflex	Tympanogram Type	Static Conpliance	Acoustic Reflex
25dB	Secretory Otitis media	B	0.2	Absent	A	0.6	Present
30dB	Eustachian Tube blockage	B	0.3	Absent	A	0.5	Absent
30dB	Adhesive otitis media	C	0.3	Absent	A	0.4	Present
15dB	Secretory otitis media	B	0.3	Absent	A	0.6	Present

As shown in the above table the acoustic reflex is present in 3 out of 4 normal ears and it was absent in all the ears with conductive deafness.

OPERATIVE FINDINGS:

Out of 77 ears of 40 patients suspected to have Otosclerosis, 16 cases gave the consent for the Tympanotomy and out of these 16 cases. In 15 ears in which diagnosis was confirmed by impedance audiometry, tympanotomy was done.

In 14 stapes was found fixed. In one ear tympanotomy revealed ossicular disruption. One case of clinical otosclerosis revealed Type 'A' tympanogram and tympanotomy revealed the fixation of stapes in this particular case as shown in table 9.

TABLE 9: Showing distribution of operative findings in 16 cases ofOtosclerosis:

Tympanogram type Noted	No. of Ears	Diagnosis confirmed at Operation	Wrong Diagnosis
A_s	15	14	1
A	1	1	0
Total	**16**	**15**	**1**

Out of 16 cases of Secretory otitis media, 14 cases had bilateral secretory otitis media and 2 cases had unilateral secretory otitis media. Out of these 12 cases had given a consent for Myringotomy and all these 12 cases were subjected to impedance audiometry pre-operatively.

20 ears had a Tympanogram of 'B' Type & 4 ears had 'As' Type of tympanogram.

TABLE 10 : Showing operative findings in 24 ears of 12 cases of Secretory otitis media in which Myringotomy was done:

Tympanogram Type Noted	Effusion Present	Effusion absent
A_s	4	0
B	19	1
Total	**23**	**1**

The above table reveals that all ears with Type 'B' Tympanogram except one ear revealed fluid on Myringotomy.

All four ears in which 'A_s' Pattern was obtained also revealed fluid on Myringotomy.

IN NORMAL (CONTROL) CASES:

50 normal cases,ranged in the age group of 10 to 60 years with a maximum i.e 80% fall in the age group of 10-40 years. Number of Males = 84%(42 cases) and Females = 16%(8 cases). After thorough clinical examination and Pure tone audiometry were selected from ENT OPD of Muzaffarnagar Medical College Hospital.

All these patients had normal audiograms. 50 such cases comprised of 96 ears as in 4 ears unilateral ear disease was noted. Out of 96 ears, impedance audiometry was successively done in 93 ears. In 3 ears proper seal could not be obtained.

Static compliance in normal ears was in the range of **0.3-1.2 c.c** and the average compliance was **0.6 c.c.**

TABLE 11 : Showing distribution of compliance values in 93 normal ears:

Compliance	No. of Ears	Percentage (%)
0.3	6	6.45
0.4	18	19.35
0.5	19	20.43
0.6	15	16.13
0.7	14	15.05
0.8	10	10.76
0.9	4	4.30
1.0 or >1.0	7	7.53
Total	**93**	**100.00**

According to the above table more than 80% values fall between the range of 0.4 - 0.8 c.c of compliance.

Middle ear pressure of **± 50 mm of H_2O** was taken as normal.

Middle ear pressure of **≤ to 100.00 mm of H_2O** was taken as significant.

Taking the above criterion into account in most of normal ears middle ear pressure was normal except in 'C' type of curves where middle ear pressure was **≤ -100.00 mm of H_2O.**

Acoustic reflex was present in all cases except one in which tympanogram was type 'C'.

TABLE: - 12 Showing distribution of Tympanograms in normal ears which were divided into Types 'A', 'A_s', 'A_d', 'B'& 'C'.

Type of Tympanogram	No. of Ears	Percantage (%)
A	76	81.70
B	0	0.00
C	4	4.30
A_s	13	14.00
A_d	0	0.00
Total	**93**	**100.00**

In normal ears commonest tympanogram was **'A' Type (81.70%).** 'As' Type is similar to Type 'A' but is shallower and is noted in 14.00% of normal ears.'C' Type was observed in 4.30% of ears.

DISCUSSION:

Impedance audiometry is the objective measurement of middle ear function. In the present study the diagnostic significance of type of tympanogram is seen in ruling out the middle ear pathology as was also seen by Jerger (1970)[6] & Liden (1970)[7]. We have seen that Type 'A' tympanogram was seen in 81.70% of normal ears and 14.30% in cases of Otosclerosis, Type 'B' tympanogram was seen in 86.67% of cases of Secretory otitis media and 59.10% in cases of Adhesive otitis media and Type 'C' was seen in 18.18% cases of Adhesive otitis media. Our findings tally with those of Jerger (1970)[6] & Liden (1970)[7] who was of the view that Type 'A' tympanogram is seen in Normal cases, cases of sensorineural deafness and in cases of Otosclerosis and Type 'B' and Type 'C' was indicated in middle ear disorders of the nature of Secretory and Adhesive otitis media.

In the present study, the ear with the probe tip was considered to be the test ear for acoustic reflex and Jerger (1970)[6] too was also of the same view.In the present study the range of static compliance was 0.3-1.2 c.c in normal cases, mean static compliance was 0.6 c.c and the value noted is approximately similar to that of Brooks (1971)[8] i.e 0.71 c.c and Feldman (1976)[9] i.e 0.65 c.c. Feldman's range of static compliance was 0.28-1.72 c.c.

Middle ear pressure in more than 80% cases was normal i.e 0.0 mm of H_2O, in some other normal cases it was ± 50.00 mm of H_2O and in case of some abnormality in middle ear with'C' type of tympanogram it was -100.00 mm of H_2O and these results tally with that of Jerger (1972)[10] who took -100.00 mm of H_2O pressure in middle ear as significant.

Overall 237 ears (Normal & Conductive deafness) were subjected to this test out of these in 5 ears (3 normal + 2 of conductive deafness) a proper seal was not achieved i.e we were unable to achieve a proper seal in 2% of cases and our findings tally with that of Jerger (1974)[11] i.e 2% and also with those of Jerger (1974)[12] in an another study on children of less than 6 years of age i.e 1.8%.

In the present study 77 ears were clinically diagnosed as having Otosclerosis. They ranged in the age group of 12 to 60 years, range of static compliance was 0.2 to 1.0 c.c which overlaps with the normal values. Tympanometric findings revealed that 'A_s' pattern which was seen in 83.1% of ears and 'A' Type in 14.3% and these findings tally with that of Jerger (1974)[11] who reported 95% cases of Type 'A' pattern as he did not use 'A_s' pattern.

Acoustic reflexes was absent in all of the cases in this series and the findings were approximately similar with that of Jerger (1974)[11].
In the present study 30 ears ranging in the age group of 10-25 years with clinical diagnosis of Secretory otitis media were subjected to impedance audiometry. In secretory otitis media, 86.66% ears the tympanogram noted was Type 'B' and in another 13.33% of ears it was 'A_s' Type, static compliance was 0.2-0.3 c.c which was significantly low and acoustic reflex was absent in all the cases. In 24 ears surgery was done in the form of Myringotomy and on myringotomy fluid was seen in all cases except one, in one case in whom only adenotonsillectomy was done, post operatively the patient on tympanometry showed a change from Type 'B' to Type 'C' tympanogram.

In the present study 22 ears of Adhesive otitis media of age range of 10-57 years. Static compliance was in the range of 0.2-0.7 c.c which is also overlapped with normal but in general was noted on the lower side. Commonest tympanograms noted were of Type 'B' i.e 59.1% followed by 'C' & 'A_s' 18.18% each and our findings matches with those of Jerger (1970)[6] and Liden (1970)[7] who also obtained Type 'B' tympanogram as the commonest.

Overall in the present study it is seen that absolute compliance values overlap with normal range, and hence do not appear to be of any diagnostic value in the differential diagnosis of conductive deafness.

In Secretory otitis media absolute compliance values were significantly low and in the present study it comes out to be 0.2-0.3 c.c and these findings matches with those of Bluestone (1973)[13].

In the present study 4 cases of unilateral conductive deafness were taken to compare the impedance audiometry results in the corresponding normal ears. They had conductive deafness of 15-30 dB in the affected ear. In all these cases, absolute values were low in the ear with conductive deafness as compared to normal ears. Reflex was absent in affected ear in all of the four cases and was present in normal ear in 3 out of 4 cases tested and this finding is in agreement with Jerger et al. (1974)[11] who was of the view, that amount of AC-BC Gap is necessary to abolish stapedial reflex in approximately 25 dB with sound in the ear with conductive deafness and approximately 5 dB with probe tip in bad ear.

Scar in the drum was noted as a finding in some of the cases but all these had conductive deafness of 20-40 dB and in these cases tympanogram were abnormal and other than Type 'A'.

Another 50 Normal cases ranging in the age group of 10-60 years were subjected to impedance audiometry. They comprised 96 ears and in this 81.70% of normal ears had 'A' Type of tympanogram and rest 18.30% ears had abnormal tympanogram with or without the presence of acoustic reflex and the reflex was present in all cases except one in which case tympanogram was Type 'C' and these findings tally with the findings of Jerger et al. (1972)[10] whose analysis of normal ears with normal audiograms, showed 18% abnormality either in tympanogram type or stapedial reflex or both.

CONCLUSION:

In the present study it has been noted that as a battery test comprising of Tympanometry, Static compliance and Acoustic reflex. Impedance audiometry is a very useful test in assessing the condition of middle ear and is a objective, quick and simple to perform as was also noted by Jerger (1974)[11], Ransome (1973)[14] & Feldman (1976)[9], Alberti&Krinstensen (1970)[15] and Jerger (1974,1975)[11,16].

Impedance audiometry has a definite edge over pure tone audiometry as far as children are concerned, as in this procedure patient's cooperation is not much required as it is an objective test.

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