

# **Measurement of Tympanometric Gradient in Conductive and Mixed Hearing Loss**

**Register No. M 9507**

**An Independent Project submitted as part fulfilment for the  
First Year M.Sc. (Speech & Hearing)  
to University of Mysore.**

**ALL INDIA INSTITUTE OF SPEECH AND HEARING**

**MYSORE - 570 006**

**May-1996**

## CERTIFICATE

*This is to certify that the independent project entitled  
"Measurement of Tympanometric Gradient in Conductive and Mixed  
Hearing Loss" is a bonafide work done in part fulfilment for the  
first year degree of Master of Science (Speech & Hearing), of the  
student with Register No. M9507.*

Mysore  
May 1996




Director

All India Institute of Speech and Hearing  
Mysore - 570 006

## **CERTIFICATE**

*This is to certify that the independent project entitled*  
**"Measurement of Tympanometric Gradient in Conductive and Mixed**  
**Hearing Loss"** *has been prepared under my supervision and guidance.*

Mysore  
May 1996

  
Dr. (Miss) S. Nikam  
Guide

## **DECLARATION**

*I hereby declare taht this independent project entitled "Measurement of Tympanometric Gradient in Conductive and Mixed Hearing Loss" is the result of my own study under the guidance of Dr. (Miss) S. Nikam, Professor and Head Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for any other Diploma or Degree.*

Mysore  
May 1996

Register No. M 9507

## **ACKNOWLEDGMENTS**

*I would like to express my deep gratitude to my guide Dr. S. Nikam, Director and HOD - Audiology Department, All India Institute of Speech and Hearing, Mysore for her valuable suggestions and guidance.*

*My sincere thanks to **Mrs. Vanaja** and **Mrs. Manjula** for their precious suggestions and patient listening.*

*My special thanks to **my parents** and **family members** without whose love and support I would never have reached this stage in my life.*

*I would like to thank all **my friends** and classmates for being of source of constant support throughout.*

*My thanks to "Spaceage" for typing the manuscript.*

*Reg No. M9507*

## TABLE OF CONTENTS

	<i>Page No.</i>
I INTRODUCTION & REVIEW OF LITERATURE	1-7
II METHODOLOGY	8-9
III RESULTS & DISCUSSION	10-11
IV SUMMARY & CONCLUSION	12-13
V APPENDIX	14-16
VI BIBLIOGRAPHY	17-18

## **Measurement of Tympanometric Gradient in Conductive & Mixed Hearing Loss.**

Impedance Audiometry offers much to the practice of audiology and otology in the diagnosis of clinical problems, the impedance audiometer is an indispensable tool when fully utilized by an experienced clinician. This instrument was originally developed to evaluate conductive hearing impairment; but its utility has now been extended so that evaluations of Inner ear/Retrocochlear and brainstem problems are common practice (*ref: James W. Hall III & David Chandler (1994)*)

The operational impedance audiometer are relatively simple and the technical manipulation of the test procedures are not particularly complex. It consists of tympanometry, static compliance, acoustic reflex tests and the physical volume test. The technique is meaningful when the overall configuration of the entire impedance battery is available.

Tympanometry is the measurement of the mobility and the condition of the tympanic membrane and the middle ear during variation of the air pressure in the ear canal.

Tympanometry measures the TM compliance change as air pressure is varied in the external canal. It reflects the change in the physical properties of the middle ear system and tympanic membrane as air pressure in the external ear canal is varied. Compliance of the tympanic membrane is measured as the relative change in the sound pressure level in the entrapped ear canal cavity as the air pressure is increased and decreased. When sound waves strike the tympanic membrane some energy is reflected back, identical in frequency, to the

probe tone frequency but differing in phase and amplitude between the probe frequency and the reflected wave depends upon the impedance characteristics of the tympanic membrane and the middle ear system.

Acoustic Reflex Threshold is the sound intensity level at which the acoustic reflex occurs. Acoustic reflex is the reflexive contraction of the stapedial muscle that occurs when the ear is stimulated with a loud sound. This is measured as a sudden change in sound pressure caused by decrease in compliance of the middle ear system as the muscles contract. The presence or absence of acoustic reflex gives important information concerning the status of the ME system.

The response of the ME system to an acoustic stimulus such as the probe tone may be measured as a total response or as the response of each component which contributes to the total response. A measurement of the total response provides an "Overview" of how the ME system responds to the probe tone without providing any information about the status of each component. If the tympanic membrane is normal, a measurement of the total response at 226 Hz provides sufficient data to assess middle ear function. However, if a tympanic membrane abnormality exists, it masks the true status of the middle ear. In this case, measurement of each component yields more information regarding the total state of ME system.

The parameters of Tympanometry which are useful in determining the presence or absence of middle ear pathology are the static compliance, ear canal volume (ECV), the middle ear pressure and the tympanometric gradient.



Although static compliance and middle ear pressure interpreted along with ear canal volume measurement are quite sufficient for identification and differentiation of middle ear disorders, it has been proved that the gradient measurement contributes information not available from these simple measure.

### **Tympanometric Gradient**

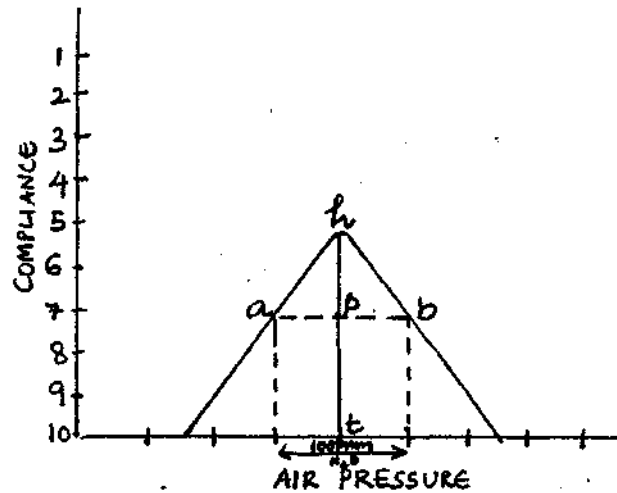
Brooks (1969) was the first person to introduce the concept of tympanometric gradient. He defined gradient as "the change in compliance from peak value to the value obtained at a pressure interval of 50 daPa on either side of the peak".

The tympanometric gradient may either be calculated as relative or obsolete gradient. Most of the studies on the tympanometric gradient have employed relative electroacoustic Immitance devices. Mangolis & Shanks recommended the use of electroacoustic Immitance devices for the measurement of tympanometric gradient. Fiellau - Nikolajsen (1983) contended that it is of little significance whether relative or absolute electroacoustic Immitance devices are employed, despite the fact that the type of device affects the tympanometric shapes, since the gradient is a ratio.

### **Calculation of Tympanometric Gradient**

The most widely used method for the computation of tympanometric gradient was given by Brooks (1969). The tympanometric gradient is obtained as the ratio of 'hp' to 'ht' where 'hp' is the distance from the tympanometric peak to the horizontal line intersecting the tympanogram such that the distance

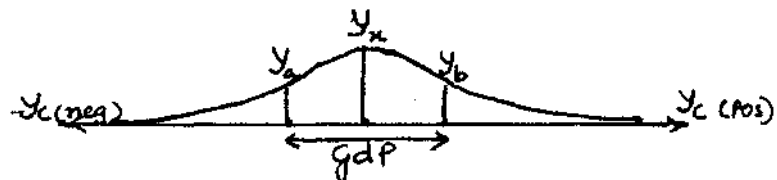
between the points of intersection (a & b) is 100 daPa and 'ht' is the peak height of the tympanogram.



The higher the gradient the steeper is the tympanogram and vice versa. Therefore, gradient is inversely proportional to the degree of flatness of the tympanogram.

Another method of computation reported by Koebshell and Margolis (1986) and de Jonge (1986) is as follows:-

A half amplitude admittance point is obtained on each side (+ve and -ve pressure directions) by dividing the total amplitude on each side by 2.



$$\left[ Y_b = Y_n - Y_c(\text{pos})/2 \quad ; \quad Y_a = Y_n - Y_c(\text{neg})/2 \right]$$

The difference in air pressure between each of these two points on the slope of the tympanogram ( $P_a$  and  $P_b$ ) is referred to as Delta pressure or gradient pressure (Gdp) and is expressed in daPa.

The ASLHA(1989) states that the tympanometric gradient may be obtained as a 50% reduction in the static acoustic ME admittance.

### **Normative Values**

According to ASHA (1989) the 90% ranges for the tympanometric gradient of normal persons are 60-150 daPa in child and 50-110 daPa in adults (regardless of the pump speed). If the tympanometric gradient has a pressure interval wider than these values, ME effusion is suspected.

### **Tympanometric gradient in pathological ears**

There are not many studies which have studied the tympanometric gradient values in relation to middle ear pathology in adults. But quite a few studies have been done on tympanometric gradient values in children. Tympanometric gradient has been recommended as one of the criteria for detecting ME effusion in children by the ASHA committee on Audiologic Evaluation working group on Acoustic Immittance measurement. ASHA (1989) proposed a tympanometric gradient  $> 150$  daPa as consistent with ME effusion.

According to Fiellalt - Nikolajsen (1983), a value of absolute tympanometric gradient less than/equal to 0.1 could be an indication of ME pathology. They defined gradient as the ratio AG - the distance from the tympanometric peak to the horizontal line intersecting the tympanogram in such

a way that the pressure interval between the intersecting points is 100 daPa - to AC the maximal height of the tympanometric peak.

Jerger has proposed a classification of tympanometric patterns for detecting problem related to ME effusion in children (between 2 months to 10 years of age).

For an absolute acoustic - impedance device with a pump speed of 50 dapa/s and equivalent ear canal volume estimated at +200dapa, any one or more of the following is consistent with the presence of ME effusion, provided that tympanic membrane perforation, cerumen in the ear canal and technical factors are ruled out a) tympanometric gradient  $> 180$  dapa or  $< 55$  dapa or static acoustic ME admittance  $< 0.35$  mmho together with an absence of ipsilateral acoustic reflex at 1000Hz at 117 dBSPLO or b) tympanometric. peak pressure  $\leq -100$  dapa together with an absent acoustic reflex at 1000Hz at 117dB SPL

For a relative acoustic impedance device, a tympanometric gradient less than or equal to 0.1 is considered as consistent with ME effusion.

Very few studies have been conducted on tympanometric gradient in adults with ME pathology. One of the studies conducted by Fiellan and Nikolajsen (1983) concluded that abnormally wide tympanograms (i.e., with tympanometric width as high as 200daPa ) occur in certain stages of Otitis media and some patients with lateral ossicular fixation. They also reported that the Gdp values of cases with resolving otitis media were within normal limits.

Feldman (75) reported that gradient is decreased in ears with fluid and is increased in ears with healed perforations.

### **NEED FOR THE STUDY**

The normative data for tympanometric gradient is available in both children and adults. Many researchers speculate that the GdP may have more desirable sensitivity and specificity characteristics for detection of high impedance (low admittance) middle ear disease. Although this is theoretically sound documentation in patient population is not yet available. Hence, studies of the gradient measures carried out on clinical population are required to verify its actual clinical value.

### **AIM OF THE STUDY**

To study gradient values of adults with middle ear pathology and compare them with those of normal adults.

## METHODOLOGY

The methodology of the present study is described under the following headings.

### **I) Subjects :** Criteria for selection of subjects.

Adults : Totally 25 adults whose audiological evaluation in the octave frequencies from 250 Hz to 8 KHz reveal a conductive or mixed hearing loss.

Subject include those whose age is in the range 18-35 yrs.

In order to meet the criterion for selection, the subjects should have an 'A' type tympanogram on an impedance audiometer

### **II) Instrumentation.**

The Grason Stadler ME analyzer 33 will be used for the present study. It is a microprocessor based admittance audiometer has facilities for complete automatic or manual diagnostic testing for analysis of ME function. [APPENDIX A]

An audiometer, (Madsen OB 822) equipped with the ear phones (TDH - 39) and vibrator radio ear B - 71 calibrated according to ISO standards will be used to check the AC and BC thresholds at octave intervals. (From 250 Hz to 8000 Hz).

### **iii) Calibration:**

The GSI 33 version II MEA was calibrated according to the standard specified in the manual. The audiometer was calibrated using a SLM (B and K

2230) and a microphone (B and K 4144). The calibration of earphone (TDH 39 Phones) output has been accomplished with the help of an artificial ear (B and K 4152) along with the sound level meter and microphone (B and K 4144)..[APPENDIX B]

**iv) Test environment:**

The test was conducted in air conditioned sound treated room. The environmental conditions namely temperature (85°F) and the humidity condition were in normal limits. The noise levels were measured using a SLM ( B and K 2209) an OFS (B and K 1613 and a condenser mice (Band K 4165) and the noise levels were within the permissible limits as given in ANSI standards.[APPENDIX C]

**v) Test procedure:**

The patient will be seated comfortably. The probe box is attached to the Velcro strip on the shoulder mount and position on the patient the correct size of ear tip is then selected and positioned on the probe. Then, it is securely inserted into the ear canal to obtain an airtight seal. A probe tone of 226Hz is selected and the pump speed selected as 200 daPas. The direction of the pressure change is always from +200 daPa to - 400 daPa. Then the 'start' button is pressed after instructing the patient not to talk or move their heads or swallow when the test is in progress.

The gradient value will be displayed on the screen along will the tympanogram and other parameters such as physical volume static compliance and peak pressure.

## Results and Discussions

The purpose of the present study was to study gradient values of adults with middle ear pathology and compare them with those of normal adults.

The data was collected based on the methodology given in the previous chapter. These data were subjected to statistical analysis. The mean, standard deviation and the range were calculated. Further the t test was used to find out the significant difference at 0.05 and 0.01 level between the following parameters:

- 1) Physical volume
- 2) Peak volume
- 3) Static compliance
- 4) Static compliance
- 5) Gradient

The values obtained for the cases with conductive and mixed loss were compared with the normative values reported by Sashidharan in 1994.

Parameters	Mean	standard Deviation	Range
Physical Volume (cc)	1.384	0.39	0.3 to 2.3
Peak pressure (daPa)	-7.6	27.9	-75 to +20
Static Compliance (cc)	0.724	0.303	0.3 to 1.7
Gradient pressure (daPa)	81.2	51.6	20 to 265

From table (a) it can be seen that

- i) The mean physical volume is 1.384 and has range of 2.3 to 0.3. These are within normal limits and the t - test did not reveal any significant difference between the physical volume of normal and pathological cases.
- ii) The mean peak pressure in pathological cases is -7.6 and the standard deviation shows a very high value of 27.9. The peak pressure falls within the normal range and the t - test did not reveal



any significant difference between the normal and pathological cases.

**iii) The Static compliance** has a value of 0.724 and a static deviation of 0.359. It falls within the normal range (0.3 - 1.7 cc). t - test did not reveal any significant difference between normal and pathological cases for the values of Static compliance.

**iv) Gradient:** The gradient pressure values (Gdp) of normal and pathological cases were compared in terms of mean, standard deviation and range measures.

The mean gradient pressure value in normal cases is 78.16 daPa while that in pathological cases is 81.2 daPa. Thus, there is not much difference in the mean gradient pressure although the standard deviation in case of pathological cases is very high (51.6) when compared to the normal standard deviation of 25.29.

The range of tympanometric gradient pressure shows a larger value of 20 - 265 daPa where as in normals it varies from 15-150 daPa.

In this study, the type of middle ear pathology affecting the cases was not considered. Thus, both the lower values around 20 daPa and values as high as 265 daPa could have occurred due to varying ME pathology. The abnormally high values may have been due to lateral ossicular fixation or otitis media as reported by Fiellau - Nikolajsen [(1983) cited in Silman and silverman].

The t - test was administered to find out the presence/absence of significant difference between gradient pressure values of normal and pathological ears. It did not reveal any significant differences.

Thus, the gradient pressure values of these cases with ME pathology with A type tympanograms are not significantly different from those from those in normal..

## Summary and Conclusions

The aim of the study was to determine whether the tympanometric pressure gradient (Gdp) values can predict the presence of middle ear pathology when all other parameters such as static compliance, peak pressure physical volume are within normal limits.

A total of 25 pathological ears consisting of cases with 'A' type tympanograms and with audiograms revealing conductive/mixed hearing loss were selected and their immittance characteristics were obtained.

Grason - Stadler Middle ear analyser 33 version 2 was calibrated and used for testing the subjects. The testing was done in a sound treated room.

Data were obtained and analyzed using appropriate statistical procedures. Means, standard deviation and range were obtained for each of the parameters. These were then compared to the values in the normal cases. t-test was administered to see if there are significant differences between the mean values of physical volume, static - compliance, peak pressure and gradient pressure.

The following results were obtained.

**I. Physical volume** : There is no significant difference between the physical volume values of normals and pathological cases.

**II. Peak pressure**: There is no significant difference between the peak pressure values of normal and pathological cases.

**III Static compliance** : There is no significant difference between the static compliance values of normals and pathological cases.

**IV. Gradient:** There is no significant difference in the gradient values of normal and pathological cases.

#### **Clinical implications**

This study was conducted on cases with ME pathology but the pathological conditions was not controlled and also the sample size was only 25. Thus, the results are not helpful to come to any definite conclusion regarding the significance of tympanometric gradient measurements. Thus, further study wherein there is a large sample size with controlled or known pathological condition is required to ascertain the utility of the gradient measurements in pathological cases

## APPENDIX A

The GSI 33 version 2 ME analyzer is a high tech microprocessor based admittance instrument designed to be used in a clinical or research setting. It contains total capabilities for complete automatic or manual diagnostic testing for analysis of Middle ear function. The extensive battery of test mode choices include diagnostic tympanometry, acoustic reflex threshold and decay instruments, eustachean tube function testing, screening tympanometry, acoustic reflex latency testing, acoustic reflex sensitization and multiple frequency tympanometry (250 Hz to 2 KHz). The operator has a choice of 3 mountings to support the probe box; the standard light weight shoulder mounting, standard clothes clip and an optimal operator wrist attachment. The probe box has 2 LEDs to indicate the test status and also a right and left switch to designate the ear to be tested. The GSI 33 calculates the gradient as an average of the compliance points at an interval of + or -50daPa. In GSI 33, the contralateral stimuli are presented through an insert receiver.

GSI 33 was calibrated according to the specifications given by ANSI S3 - 6 -1969 (R 1986), IEC 645 - 1979, IEC 126 - 1961 and UL 544 listed hospital and dental equipment (GSI 33 version 2 ME A, Instruction manual, 1989). The test data may be stored in instrument memory and recalled for review prior to being transferred via an RS 232 interface to a PC.

## **APPENDIX B**

### **Standard for calibration of puretone audiometry**

The following standards were used for the calibration of the audiometer.

AC (Ear phones) ANSI S3 - 6 1989

BC (BC vibrator) ANSI S3 - 26 1981.

The procedure used was as presented by the instruction manual of the audiometer.

### **Standard for calibration of Immitance Audiometer**

The immitance audiometer used for the study was calibrated using the following standards.

ANSI S3 1973

ANSI S3-39 1987

ANSI S3-6 1969

IEC 645 1979

IEC 126 1973.

## APPENDIX C

### **Ambient Noise Levels in Test Room**

The noise levels in the test room were measured using a Type 1 sound level meter with an octave filter set. The measurements were made in the 'C' scale in the slow mode. The obtained measurements were as follows:

## BIBLIOGRAPHY

**Basavaraj, V. (1973)** : Measurement of acoustic Impedance in Indians. A dissertation submitted as part fulfilment of M.Sc. degree (Speech and Hearing) to the University of Mysore.

**Beattie, R.C., and Leamy, D.P., (1975)** : " Otoadmittance : normative values, procedural variables and reliability", Journal of American Audiological Society, 21 - 27.

**Berry, Q.C., et.al., (1975)** : "Tympanometric pattern classification in relation to Middle ear effusion", Annals of Oto - Rhino laryngology, 84, 50 -64.

**Bess, F.H. and Humes, L.B. (1990)** : " Audiology: The fundamentals " williams and Wilkins, Baltimore.

**Birch, Elbrond, O., and Kristiansen, L. (1986).**: " Impedance audiometric study of children ", Scandinavian Audiology. 15. 334 - 339.

**Brooks, D.N., (1971)** : " A new approach to identification audiometry." Audiology, 334 - 339.

**Creten, W.L., and Van camp, K.J., (1974):**, "Transient and Quasi - static tympanometry", Scandinavian - Audiology. 30, 139 - 142.

**Creten, W.L., and Vande Heyning, P., and Van camp, K., (1985)** : "Immittance, Audiometry". Scandinavian Audiology, 14, 115- 121.

**Feldman, A.S., (1967)**, " Acoustic Impedance study of normal ear", Journal of Speech and Hearing Research. 10,165 - 176.

**Feldman, A.S., (1974 b):** " Ear drum abnormality and the measurement of Middle ear funcions", Archives of Otolaryngolgy. 25, 202 - 209.

**Feldman, A.S., :** Tympanometry - procedures, interpretation and variables", Chapter 6, cited in A.S. Feldman, and L.A. Wilber (Eds.) "Acoustic Impedance and Admittance. - The measurement of ME function", Baltimore, The williams and Wilkins Co.,

**Jerger, J:** " Tympanometry:, " Cited in Jerger, J., "Impedance Audiometry", New York and London, Academic Press.

**Jerger, J., (1972)** : "Suggested nomenclature for Impedance Audiometry", Archives of Otolaryngology. 96, 1 - 3.

**Liden, G., Harford, E. & Hallen, O., (1974 A):** "Tympanometry For the diagnosis of Ossicular Disruption", Archives of Otolaryngology, 99, 23 - 29.

**Liden, G., Harford, E. & Hallen, O., (1974):** "Automatic tympanometry in clinical practices", Audiology, 24, 126 - 139.

**Liden, G., Peterson, J.L., and Bjorkman, G. (1970) :** "Tympanometry - A method for analysis of Middle Ear function", Archives of Otolaryngology Supplement (Stockholm). 263, 218 - 224.

**Malini, M.S. (1980) :** Impedance - Admittance measurement - A primer. Unpublished Independent Project, University of Mysore, Mysore.

**Margolis, R.H, and Poplka, G.R., (1977) :** "Interaction among tympanometric variables", Journal of Speech and Hearing Research, 20. 447 -462.

**Margolis, R.H., and Shanks, J.E., (1985) :** " Tympanometry", Katz - Hand book of clinical Audiology, Ed. 3, Willam and Wilkins, Baltimore.

**Poster, T.A., (1972) :** " Normative Otoadmittance Values for three populations," , Journal of Auditory Research. 12, 53 - 58.

**Poster, T.A., and Winstor, M.B. (1973) :** "Methodological aspects of admittance measurements of the middle ear", Journal of Auditory Research, 13, 172 - 177.

**Shanks, J.E., (1984) :** " Tympanometry", Ear and Hearing 5, 268 - 279.

**Shanks, J. and Shetton, C. (1991) :** " Basic Principles and Clinical applications of tympanometry in the otolaryngologic Clinics of North America, Osguthorpe", J.D. and Melnick, W., (Eds.) 24, 2, 299 - 328.

**Silman, S. and Silverman, C.A. (1991) :** "Acoustic admittance assessment", Auditory Diagnosis - Principles and Application, Academic Press, Inc., San Diego, 29, 71- 132.

**Swapna (1994) :** Admittance in Geriatrics. Unpublished Independent project, University of Mysore, Mysore.

**Terkildsen, K. and Nielsen, S.S. (1960) :** " An electracoustic impedance measuring bridge for Clincl use", Archives of Otolaryngology, 72, 339 - 396.

**Wiley, T.L., Oviath, D.L., and Block, M G. (1987) :** " Acoustic Immitance measures in normal ears", Journal of Speech and Hearing Research, 30, 2, 161 - 170.

**Wiley, T.L., and Block, M.G.,** "Over view and Basic principles of Acoustic Immitance measurements, Chapter 22, Katz - Hand book of clinical Audiology, Willam and Wilkins, Baltimore.