ADMITTANCE IN GERIATRICS : NORMATIVE DATA

REG.NO.M9322

AN INDEPENDENT PROJECT SUBMITTED AS PART FULFILLMENT FOR THE FIRST YEAR M.Sc. (SPEECH AND HEARING) TO THE UNIVERSITY'OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE 570 006.

MAY 1994

DEDICATED TO
AMMA &
ACHHAN

CERTIFICATE

This is to certify that the Independent Project entitled: ADMITTANCE IN GERIATRICS NORMATIVE DATA is a bonafide, work done in part fulfilment for the First Year Degree of Master of Science (Speech and Hearing), of the student with Reg. No.M9322,

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MAY:1994

CERTIFICATE

This is to certify that the Independent Project entitled ADMITTANCE IN GERIATRICS : NORMATIVE DATA has been prepared under my supervision and guidance .

Mysore
May 1994

Dr.(Miss) S.Nikam
GUIDE

DECLARATION

This is to certify that the Independent Project entitled ADMITTANCE IN GERIATRICS : NORMATIVE DATA the result of my own study under the guidance of Dr. (Miss) S.Nikam, Director, and HOD-Audiology Department, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore
May 1994

Reg. No.M9322

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INTRODUCTION

The progress in science and technology has yielded beneficial results which has made rapid progress in all the spheres of audiology such as rehabilitation, management and the diagnostic aspects. Acoustic-immlttance measures have especially proven valuable in a variety of diagnostic applications. For instance, tympanometry and acoustic reflex measures are routine test procedures in most audiology clinics (Martin and Slides, 1985). These same measures form the basis of test protocol recommended by American-Speech-Language-Hearing Association for the screening of Middle Ear functions (ASHA, 1979).

Inspite of clinical popularity of acoustic immittance measures, there are surprisingly few reports of the normal confidence limits and variances for such measures. Furthermore the previous reports of normative acoustic immittance data have been limited in their application. For instance, Zwislocki and Feldman (1970) reported static acoustic immittance measures for a population of normal subjects. These data, were however obtained with an instrument (Grason-Stadler Zwislocki bridge) that is no longer commercially available.

Although there are other reports of tympanometric and static acoustic immittance findings in normal ears, the comparison and clinical ability of these data are limited due to -

a) installation differences

b) the typical absence of reported calibration measures or standards

c) the lack of reported variance measures associated with sample means

d) differences in the variances and units of measurement (Wiley, Oviatt and Block, 1984).

Advances with respect to immlttance audiometry have concentrated not on only one aspect. The roots have gripped all the aspects, be it the equipments, accessories or the testing parts. One of the recent developments is the Grason-Stadler Middle Ear Analyzer Version 2 which 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.

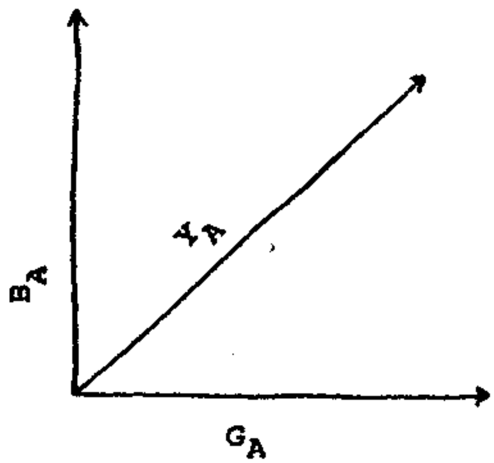
Acoustic immittance is a general term used to refer to acoustic energy transfer to the eardrum regardless of the manner it is measured. When sufficient sound pressure is applied, the middle ear and inner ear are set into motion. The middle ear system is not a perfect transducer of energy and so not all of the energy that impinges on the tympanic membrane actually flows through the middle ear transmission system. The middle ear system opposes the transfer of energy to some extent. This opposition to the transfer of acoustic energy is termed acoustic impedance (Z_A). In the same manner, the resulting energy flow or transfer of air pressure changes at the eardrum into movements within the cochlear fluids is termed acoustic admittance (Y_A). Since either measurement system can be used, the term acoustic immittance refers to either acoustic impedance or acoustic admittance.

The components of acoustic impedance are resistance and reactance. Acoustic resistance refers to the amount of sound energy dissipated within the middle ear system due to friction and cochlear consumption. Reactance refers to the amount of energy stored and then reflected to the middle ear system. The reactive component is composed of mass and stiffness.

Acoustic admittance ($^{Y}{}_{A}$), which is reciprocal of acoustic impedance (Z_A) consists of two components namely acoustic susceptance (B_A) and acoustic conductance (C_A) which are the reciprocals of reactance and resistance respectively. Susceptance is a measure of flow of energy through reactance while conductance is a measure of flow of energy through resistance. The relationship between admittance, susceptance and conductance can be represented as follows:

The susceptance B_{AS}(flow associated with -ve reactance)

-ve susceptance B_{AM} (flow associated with +ve reactance)



Applying Pythagorean Theorem,

$$Y_A = \sqrt{B_A^2 + G_A^2}$$

Acoustic admittance = $\sqrt{\text{(acoustic susceptance)}^2 + \text{(acoustic conductance)}^2}$

Admittance of sound energy from the earcanal to the cochlea is influenced by physiological factors:

a) Ossicular (bone) mass in the middle ear.

b) Elasticity of compliance of the tympanic membrane.

c) Stiffness of ligaments and muscular attachments.

d) Mass and friction effects resulting from the flow of sound through the middle ear.

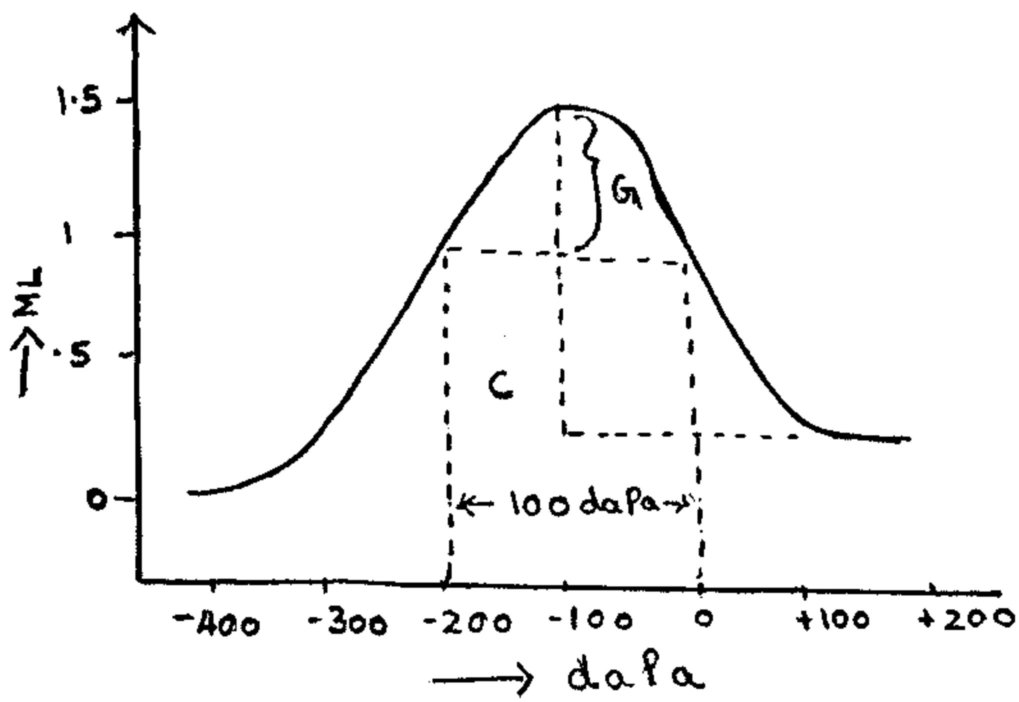
e) Interaction of the mass of fluid in the cochlea and stiffness of the basilar membrane.

From an instrumentational and computational point of view, it is often easier to measure acoustic admittance (Y_A) or energy flow. It is not possible to measure impedance directly because it is an intangible quantity that must be arrived at interentially. Hence admittance is generally measured instead.

The response of the middle ear system to an acoustic stimulus such as the probe tone may be measured as a response of the system as a whole, or measured as the response of each component Which contributes to the total response. A measurement of the total response provides an "overview" of how the middle ear 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, a measurement of each component will yield more information regarding the total state of the middle ear system. This is particularly true with probe tone frequencies of 678 Hz or above. This is because at low frequencies, the normal middle ear system acts as a stiffness controlled system.

but: at frequencies above resonance, it acts as a mass controlled system Whereby notching appears on the tympanogram. Middle ear pathologies affect the resonant point of the system. A measurement of the contribution of each component at the higher probe tones provide valuable information about the status of the middle ear system. Admittance in such cases is measured in acoustic mmhos (1 acoustic mmho = $10^{-8} m^3$ /Pa.s)*

Tympanometric gradient is a quantitative description of the shape of a tympanogram in the vicinity of the peak. There are two methods of calculating the tympanometric gradient. The first method is by changing in ' compliance' from peak value to the value obtained at a pressure interval of 50 dapa on either side of the peak.



The second method is based on determining the width of the tympanogram in dapa at one half or 50% of the amplitude (height) of the tympanogram. The new gradient value is a positive integer pressure value.

According to the American Speech-Language-Hearing Association (1989), the 90% ranges for tympanometric width of normal persons are 60-150 dapa in children and 50-110 dapa in adults.

The volume of the ear canal (physical volume) is estimated when the admittance value is measured at a high positive pressure such as 200 dapa. If the eardrum is intact, the volume estimate at 200 dapa is of the ear canal only and should average 0.7 cm in children to $1.1 cm^3$ in adult males.

Clinical measurement of complex acoustic admittance has been directed recently towards the explanation of empirical factors that affect the test's diagnostic power. One of the factors is the effect of advanced age on the tympanic acoustic admittance. The most common cause of hearing loss in the adult population is presbyacusis which is a descriptive term used to denote a common but not universal deterioration of auditory function coincident with aging. There have been studies indicating that there is an increase in acoustic admittance with respect to age (Sweitzer, 1964; Beattie and Leamy, 1975). The studies on establishing a normative data of admittance in the geriatric population have been very limited. A few are quoted here.

Beaty and Lemy (1975) reported a mean static admittance of 3.43 mmho for the younger (17-29) group and 5.25 mmho for the older group (60-78) for a 660 Hz probe tone.

Blood and Greenberg in 1976 collected acoustic admittance data at 220 Hz probe tone. The result indicated that the mean of acoustic admittance for the age group of 50-59 years was 0.85 mmho, 0.81 mmho for 60-69 years age group and 0.60 mmho for 70 years and over.

Anatomical studies have suggested specific variations in the ossicular joints, stapedius muscle and tympanic membrane with advanced age (Covel, 1952; Harty, 1953; Rosen Wasser, 1964). But the influence of these changes on measures of static acoustic admittance is unknown.

There is a lack of normal confidence limits for acoustic - admittance measures which severely limits the clinical application of such data. These normal limits are diagnostically critical not only for contrasting measures in normals and pathologic ears but for monitoring changes in the status of the auditory system associated with progressive disease process, treatment or surgery.

Accordingly the purpose of the present study is to provide a preliminary database (normative data) for acoustic admittance measures and its components namely the susceptance and conductance, and the tympanometric gradient in the geriatric population using the Grason-Stadler Middle Ear Analyzer 33 version 2.

NEED FOR THE STUDY :

Recent reports have indicated that the aging process alters the selected aural acoustic irranittance characteristics of the middle-ear transmission system (Alberti and Kristensen, 1972; Handler and Margolls, 1977; Jerger, Hayes, Anthony and Mauldin, 1972; Silman, 1979 (b); Silman and Gelfand, 1979; Jerger, Jerger and Mauldin, 1972; Thompson, Sills, Recke, Bui, 1979, 1980). The results of the study revealed that static immittance changes are minimal upto approximately 60 years. Moreover, Nerbonne et al. (1978) presented a study on variation of static compliance with age. He found a slight but not significant tendency for static compliance values to reduce with age. The present study is aimed at validating the results obtained with respect to Indian geriatric population.

Wiley, Oviatt and Block in 1984 did a comparative analysis of static values at 220 Hz for subjects with single peaked 660 Hz tympanograms and for subjects with notched 660 Hz tympanograms but single peaked 220 Hz tympanograms. They found that the static measures for both acoustic admittance components (acoustic susceptance and acoustic conductance) and both measurement conditions (peak pressure and ambient pressures) were slightly higher for subjects with notched 660 Hz tympanograms compared to static values of subjects with single-peaked 660 Hz tympanograms. The aim of the present study is to compare the physical volume, peak pressure and static admittance and its components at low and high frequency probe tones.

Jerger in 1972 reported that males show higher acoustic compliance than females at all ages, Osterhammel and Osterhammel in 1979 studied sex variations for the tympanometric compliance values on 286 persons in the ages of 10-80 years and reported that there was no dependency of compliance values on sex. Thus, this study is to validate the above obtained results in the geriatric population and find out the significant difference in values, if any, in the males and females.

Most of the studies concerning the relationship between acoustic irnmittance and interaural difference indicates that there is no significant differences in the immittances values obtained for both ears (Wilson, Shanks and Velda, *1981;* Creten, Van de Heyning and Van Camp, 1985). Osterhammel and Osterhammel in 1979 studied the right-left differences for the tympanometric compliance values on 280 person in the ages of 10-80 years. The results indicated a very small right-left differences in the absolute compliance values. The present study is to validate the results of above studies and to estimate the significant differences between the right and left ears in terms of admittance values.

There have been a lot of studies done to establish normative data for admittance, conductance and susceptance in adults and children (Wiley, Oviatt and Block, 1984; Brooks, 1971; Jerger et al. 1972; Porter, 1972). But the normative data on geriatrics for admittance, conductance and suceptance is very rare (Beaty and Leamy, 1975j Blood and Greenberg, 1976) and hence this study has been undertaken.

AIM OF THE STUDY:

1. To establish norms for admittance and its components, namely conductance and susceptance and for the gradient in the geriatric population (above the age of 50 years).

2. To study the effect of three different probe tone frequencies namely 226 Hz, 678 Hz and 1000 Hz on -

a) admittance tympanogram (peak pressure)

b) admittance at the tympanic membrane

c) ear canal volume.

3. To compare the above mentioned parameters in males and females and to estimate the significant difference between the two populations.

4. To find the significant difference between the above mentioned parameters in the right and left ear.

5. To find the significant difference between the gradient values at 226 Hz between males and females and the right and left ears.

REVIEW OF LITERATURE

Effects of aging on hearing

The gerentologists indicate that the aging process begins even before birth. The most recent studies of hearing in humans indicate that the sensitivity for puretones increases until puberty is reached after which there is a long, slow decline particularly for frequencies around 4000 cycles per second.

The process of aging in individual cells has been subject to extensive research but i3 still incompletely understood. The effect of aging on the sound conductive mechanism of the middle ear has been studied by Nixon et al. (1962). They found a slight impairment of transmission of sound in the f requenci es above 2 KHz with a maximum effect of 12 dB at 4 KHz. This inefficiency of sound transmission was due to alterations in the elasticity of the tympanic membrane and changes in the ossicular joints and tendons.

The most common cause of hearing loss in the adult population is presbyacusis which is a descriptive term used to denote a common but not universal deterioration of auditory function coincident with aging. It is probably the cumulative effect of a number of disorders or insults contributing to the anatomic and physiologic degeneration of the auditory system. Age related alterations of the auditory system include loss of elasticity of pinna and external auditory meatus, freckling of the auricle, excessive coarse hair growth in the pinna, increased pinna size, a stiffened and more translucent tympanic membrane, stiffening of the ossicular chain, degeneration of the sensory hair and support cells and stria vascularis, decrease in the number of functional spiral ganglia and the eighth cranial nerve fiber, loss of elasticity of the basilar membrane, reduced cochlear supply, reduction in the number of functional neurons in the central auditory system and cortical atrophy (Belal and Stewart, 1974; Calavita, 1978; Crowe, Guild and Palvogt, 1934/Hansen and Reske-Neilson, 1965; Kirikae, Sato and Shitara, 1964; Krmpotic-Nemanic, 1971; Nadol, 1981; Nerbonne, 1988; Rasmussen, 1940).

The hearing loss associated with presbyacusis is a gradually progressive bilateral sensorineural hearing loss with excessive reduction in speech discrimination ability in terms of the degree of sensitivity loss. The puretone audiogram is characterized by a gradual reduction in sensitivity in the high frequency portion of the range increasing in severity as a function of age. The average audiograms of persons over the age of 30 show some degree of high frequency hearing loss. By the time age 80 is reached, a large number of persons will show an average puretone loss for the three mid frequencies (500 Hz, 1K and 2 KHz) of 30 dB or more.

Till date the histologic correlates of aging in the central nervous system are not full understood and agreed on and moreover the findings are not specific for a single etiology.

Thus, it could be concluded that a flaccid or a stiff tympanic membrane would affect the tympanometric results. If the tympanic membrane is flaccid, the admittance Increase and if stiff, the admittance decreases.

Normative data on acoustic immittance:

Even though acoustic immittance measures have proven valuable in a variety of diagnostic applications, very few reports of the normal confidence limits and variances are available for such measures. A few of the results of the normative data by different authors would be summarized here.

Feldman in 1967, Bicknell and Morgan (1968) and Burke and Nilges in 1970 established norms for compliance values in adults.

	125	250	500	750	iOOO	1500
Peldman (1968)	0.5-0.9	0.45-0.9	0.5-1.0	0.65-1.3	0.65-2.95	
Bicknell and Morgan(1978)	0.3-1.0	0.3-1.0	0.4-1.3	0.6-1.5	0.8-2.5	0.8-3.4
Burke et al (1970)	0.45-1.2	0.45-1.0	0.5-1.2	0.5-1.3	0.5-1.45	0.5-1.35

The norms established by Feldman (1968) and Burke et al. (1970) seems to be in better agreement with each other. The norms provided by Bicknell and Morgan (1968) have wider limits and therefore seem to give rise to a higher number of false negatives than do the other two.

Studies were done that measured static immittance in accordance with the recommended guidelines (MAX-MIN method). The pump seeds used were in the vicinity of 30 dapa/sed. The values should be useful for all subjects above 6 years. The norms are as follows:

		B	G	Y	Z
	Lower limit	0.44	0.20	0.50	570
226 Hz	Median	0.83	0.37	0.91	1104
	Upper limit	1.60	0.87	1.75	2000
	Lover limit	0.98	0.75	1.50	260
678 Hz	Median	1.53	2.29	2.90	345
	Upper limit	2.22	3.94	3.80	670

From this table, it is evident that at 226 Hz, susceptance is larger than the conductance whereas at 678 Hz susceptance and conductance are approximately equal with conductance values often exceeding the susceptance values.

Beaty and Leamy (1975) cited in Thompson, Sills, Recks, Bui (1979) used two groups of subjects ages 17-29 (N=20) and 60-78 (N=20). For a 660 Hz probe tone, they reported a mean static admittance of 3.43 mmho for the younger group and 5.25 mmho for the older group.

Blood and Greenberg (1976) cited in Thompson, Sills, Recks, Bui (1979) collected acoustic admittance data at 220 Hz from twenty persons in each of the age categories 50-59 years, 60-69 years and 70 years and above. The results indicated that the mean of acoustic admittance for the age group of 50-59 years was0.85 mmho, 0.81mmho for the age group of 60-69 years and 0.60 mmho for the age group of 70 years and over.

Influence of probe tone frequencies on acoustic admittance:

Not much difference exists between measurements with the different probe tones (low and high frequency) in normal ears in terms of pressure information, the magnitude of static acoustic impedance or shape of the tympanogram, but there are differences which appear in abnormal ears which do influence static measurements and the tympanogram shape, but not the pressure determination. The commonly used probe tones are 200 Hz, 660 Hz and 800 Hz. Each of these frequencies have their own advantages and disadvantages.

Terkeildson and Scott-Nei1son in 1960 made use of 220 Hz probe tone in their experiments because -

1. The acoustic characteristics of the then available microphones did not have a linear response at high frequencies. At low frequencies the main constituent of impedance is the stiffness reactance and hence it was easier to control the phase component which arises from the zero-balance principle.

2. The reflex thresholds for low frequency sounds is at a higher intensity than for high frequency tones.

3. At low frequencies, the wavelength is long enough to avoid the arousal of resonance which facilitates the calibration of the bridge.

Liden and his associates (1970, 1974 a & b) raised doubts on the validity of 220 Hz probe tone in tympanometric measurementa. Recently many investigators have stressed on the use of high frequency probe tone (Berry et al. 1975 a; Creten et al. 1980; Feldman, 1976 b; Newman, 1976; Van Camp, Raman and Creten, 1976) because -

1. A 220 Hz tone depicts changes in stiffness component alone. On the other hand, a 800 Hz tone depicts changes in both reactance and resistance components of impedance (Moller, 1965; Cited by Liden, Harford and Hallen, 1974 a).

2. Changes in the middle ear resonance do not affect the tympanogram obtained with a 220 Hz probe tone, while they have a clear influence on the tympanograms obtained with a 660 Hz tone. Their influence is maximally evident at 800 Ha which is close to the resonant frequency of the middle ear (Liden, Harford and Hallen, 1974 a).

3. As the pressure in the ear canal is changed, interaction occurs between changes in the resonance characteristics of the middle ear and the frequency of the probe tone. These interactions are greater and would be more pronounced at 800 Hz than at 220 Hz. This results in notching or undulating tympanogram in the case of ossicular chain discontinuity (Liden, Harford, Hallen, 1974 b).

4. The abnormalities noted in the tympanogram at 625 Hz ana 800 Hz may also be associated with the wave length of these frequencies in relation to the dimensions of the tympanic cavity. At 220 H_z, the wave length is large and therefore, there are no fluctuations in the tympanograms. This is the reason why tympanic membrane abnormalities manifest more clearly at higher frequencies (Liden, Peterson and Bjorkman, 1970).

The use of high frequency probe tones seems to have some significance while testing cases with combinations of middle ear defects. Feldman (1974 b) thus stressed on the importance of high frequency probe tones in tympanometry.

Alberti and Jerger (1974) tested, 1,143 ears with two Madsen Electroacoustic bridges. One of the bridges was modified to produce a 800 Hz probe tone. They found that 85% of the ears gave visibly indistinguishable tympanograms. 15% of the ears showed some difference between the tympanogram ebtained at the two probe tone frequencies.

The 15% of the ears which showed differences included differences both due to W-shape at 800 Hz and those not due to the occurence of W-shape. Half of these ears had some kind of tympanic membrane abnormality. They found that the complexity of the W-pattern increased with the severity of tympanic membrane abnormality. Although a 800 Hz probe tone was very sensitive in identifying tympanic membrane abnormalities, the incidence of W-shape tympano— grams in normals was very high. It was concluded that a 800 Hz probe tone is not of a special diagnostic value. It was also suggested that a 800 Hz probe tone may be of use in those subjects who give a history of otitis media and show a tympanometric abnormality (Alberti and Jerger, 1974).

A 'W' pattern at 660 Hz does not necessarily reflect a pathology. It only indicates that a part of the system is more mobile. The same theory also proves that W-notching is perfectly normal at very high probe tone frequencies (Van Huyse, 1974).

The positive pressure in the ear canal resulted in higher impedance for frequencies around 800 Hz than for frequencies approaching 200 Hz. It was observed that the notch becomes progressively deeper when moving to higher probe frequencies and that it shifts slightly to the left when moving from a high frequency probe tone to a low frequency probe tone (Moller, 1961).

The incidence of w-patterns or W-notching increased while going from low probe tone frequencies to high probe tone frequencies (Liden, et al. 1970).

The magnitude of asymmetry in the acoustic susceptance tyrnpanogram was roughly three times greater at 660 Hz than at 220 Hz while the acoustic conductance was symmetrical (Margolis and Propelka, 1975).

Later a study was done on seventeen adults and it was found that this asymmetry is more than that predicted above (Margolis and Smith, 1977).

The relative occurrence of bell shaped and various types of W-shaped susceptance, conductance and admittance phase tympanograms, at a probe-frequency of 660 Hz on normal ears were studied. The diagnostic value of the susceptance, conductance versus admittance-phase representation of tympanograms was studied on 10 pathological middle ear systems using probe tone frequencies from 510 Hz to 910 Hz. On comparison it was concluded that the admittance phase approach at a probe tone frequency between 500 Hz and 700 Hz is good (Van Camp, Creten, Vande Heyning, Decraemer and Van Peperstraete, 1983).

A comparative analysis of static values at 220 Hz for subjects with single peaked 660 H_z tympanograms and for subjects with notched 660 Hz tympanograma but single peaked 220 Hz tympanograms was done. It was found that the static measures for both acoustic admittance components (acoustic susceptance and acoustic conductance) and both measurement condition (peak pressure and ambient pressures) were slightly higher for subjects with notched 660 Hz tympanograms compared to static values of subjects with single peaked 660 Hz tympanograms. This is because of lower resonance frequency of the middle ear transmission system for the subject with notched 660 Hz tympanogram (Wiley, Oviatt and Block, 1984) and conductance is close to 0 acoustic mmhos at both frequencies.

Acoustic immittancg and pressure:

The measurement of middle ear pressure represents an important diagnostic tool for identifying middle ear disorders. The tympanic membrane best transmits sound energy when the air pressure on both sides of the membrane is equal. Under this condition, the tympanic membrane approximates a vertical position (with respect to ear canal). If there is negative pressure on one side of the membrane, for eg, in the middle ear, the tympanic membrane will be sucked in toward the side with negative pressure ie. the middle ear.

Whereas researchers are in accord regarding the range of tympanometric peak pressures consistent with normal middle ear pressure in adults, they disagree about the range of tympanoraetric peak pressures consistent with normal middle ear pressure in children. Brooks (1980), Holmquist and Miller (1972), Peterson and Liden (1972) and Porter (1974) reported tympanometric peak pressures between -50 and 4-50 dapa in adults with normal middle ear. Holmquist and Miller' s (1972) criterion for normal middle ears was based on otomicroscopically normal tympanic membranes.

The lower limit of the range of tympanometric peak pressures considered with normal middle ears in children varies considerably from study to study and has been reported to be as high as - 30 dapa and as low as -170 dapa (Brooks, 1968* 1969; Feldman, 1975: Jerger, 1970: Liden and Renvall, 1978# Renvall, Liden, Jungert and Nilsson, 1975). Very few of these studies based on criterion of middle ear normalcy on the presence of normal otoscopic findings.

Terkildsen and Thomsen (1959) and Terkildsen (1968) suggested that the impedance of the middle ear system approaches infinity and admittance approaches 0 acoustic mmhos when considerable tension is placed on the tympanic membrane ie when the ear canal pressure is 200 dapa. Immittance measured under this condition is attributed to the tympanic membrane alone. Two assumptions are based on this -

a) ear canal volume does not change appreciably when ear canal pressure is varied.

b) the impedance at the tympanic membrane approaches infinity (admittance approaches 0 mmhos) when the ear canal is presumed to 200 dapa.

The first assumption was rejected when the ear canal volume changed by a mean of 113 ml over the ± 400 dapa range when tested in eight normal subjects.

The second assumption was tested comparing estimates of ear canal volume from susceptance tympanograms with a direct measurement of ear canal volume adjusted for changes in volume due to changes in ear canal pressure. This failed to support the second assumption.

Newman and Farger (1973) pointed out that a high pressure difference across the drum (3-5 kpa attained in the tails of the tympanogram) blocks the middle ear system leading to zero admittance at the drum.

On the other hand Margolis and Smith (1977) put forth the hypothesis that extreme positive and negative ear canal pressures drive the middle ear systems to finite and unequal admittance.

Moreover Rabinowitz (1977) stressed the fact that even at extreme pressure differences across the drum the person under test still hears the probe tone, which means that the middle ear system is not completely blocked. A small residual admittance at the drum is thus expected at both positive and negative ear canal pressures. A residual susceptance at the drum exists both for high positive and high negative transtympanic pressure. The susceptance for negative pressure across the drum is mostly larger than the susceptance for a positive pressure across the drum.

a) Rate of ear canal pressure change:

The rate of ear canal pressure change has a significant effect on tympanometric amplitude and shape and therefore on static acoustic immittance.

Creten and Van Camp (1974) reported a 50% increase in amplitude when the pressure rate was increased from ldapa/sec to 30 dapa/sec.

Several other investigators have noted more frequent notching of high frequency tympanograms recorded at high rates of pressure change than at lower rates (Alberti and Jerger, 1974; Creten and Van Camp, 1974; Feldman, 1976; Van Camp et al. 1976).

Shanks and Wilson (1986) studied to effects of rate of ear canal pressure changes (12.5, 25.0 and 50.0 dapa/sec) on three tympanometric measures (peak static admittance, shape and tympanometric peak pressure) on twenty four adults with normal middle ear transmission systems at 226 Hz and 678 Hz probe tone. The results indicated that the rate of pressure change affected the peak static admittance. For slow rates of pressure change, the tympanometric shape was broader and there was less frequent notching but there were not enough notched data to make a strong statement on the rate effect. Moreover, the tympanometric peak pressure shift was increased significantly with the rate of pressure change.

b) Direction of ear canal pressure change:

The direction of ear canal pressure change affects both the amplitude and shape of the tympanogram (Porter and Winston, 1973: Creten and Van Camp, 1974; Margolis and Smith, 1977; Wilson, 1984).

Creten and Van Camp (1962) and Williams (1952) observed greater amplitude susceptance and conductance tympanograms with a negative to positive recording although the difference in amplitude was not significant.

Porter and Winston (1973) calculated the mean value of susceptance and conductance for 220 Hz and 660 Hz probe tones for thirty two normal hearing adults under three drum tight and three drum free conditions for two pressure sweep directions. The results indicated that in the decreasing pressure condition all tracings for susceptance at 660 Hz assumed a rather smooth curve while for increasing pressure condition, there was a notch in the tympanogram.

The substantial asymmetries in the tympanograms of many infants subjects were studied. The acoustic susceptance tympanogram with a 660 H_z probe frequency assumed a monotonically increasing shape as ear canal pressure changed from negative to positive values. The acoustic conductance tympanograms were relatively symmetrical. This is due to volume change that occured as pressure was varied. Acoustic conductance values were significantly larger for increasing pressure than for decreasing pressure. Acoustic susceptance at 660 Hz was slightly smaller for increasing than for decreasing pressure. There was no significant effect of direction on acoustical susceptance at 220 Hz. Moreover W-notching occurs more frequently with increasing pressure than with decreasing pressure (Margolis and Propelka, 1975)«

The mean acoustic admittance is greater for increasing (negative to positive) than for decreasing (positive to negative) pressure change in normal ears, although this effect is not consistant across individuals (Wilson et al. 1984).

The tympanometric changes at 226 Hz and 678 Hz across ten trials ana for two directions (ascending and descending) of ear canal pressure change on twenty four young adults has been studied. The results can be summarized as follows:

a. The shape of the tympanogram becomes more complex as the number of trials increase.
b. The changes across trials generally were manifested as an increase in admittance, the majority of the changes occured by 3rd to 5th trial.
c. There was an increase in admittance, susceptance and conductance across trials when a 226 Hz probe tone was used.
d. The mean 678 Hz susceptance function, particularly for ascending pressure changes, decreased with successive tynpanometric trials. There was increase in susceptance magnitude for single peaked group. In the notched group, there was a decrease in susceptance magnitude (Wilson and Shanks et al. 1984).

Notching first occurs at a higher probe frequency (610 Hz vs. 510 Hz) and is less marked for the descending than for the ascending direction of pressure changes. For the descending direction, the conductance and admittance tympanogram show little notching for probe frequencies upto 910 Hz (Margolis et al) .

The ear canal contribution based on different tympanometric pressure estimates were evaluated where the pressure was reduced from-250 dapa to -600 dapa. The results indicated that the acoustic conductance and acoustic susceptance values reduced for both probe frequencies. There was no appreciable difference between acoustic conductance and acoustic susceptance based on ear canal estimates at -250 and -400 dapa, (Wiley, Oviatt and Block in 1984) .

The acoustic conductance, acoustic susceptance and acoustic admittance static values variability across subjects is lower for static estimates at ambient ear canal pressure when compared with static estimates at the tympanometric peak pressure. This is consistent with the results of Porter and Winston (1973 a, b) for young adults and with that of Margolis and Propelka (1975) for normal subjects.

The effects of direction (ascending and descending) ear canal pressure change on peak static admittance, shape and tympanometric peak pressure on twenty four adults with normal middle ear system at 226 Hz and 678 Hz probe tone was studied. The results indicated that the peak static admittance was significantly affected by the direction of pressure change. The tympanometric shape was broader and there was less frequent, notching for the descending pressure change. The shape, specified in terms of tympanometric width of unnotched susceptance, conductance and admittance tympanograms showed a significant change with the direction of ear canal pressure change. At 226 Hz, the negative segment of the susceptance and admittance tympanogram increased by 8-9 dapa and the positive segment decreased by 3-4 dapa for descending vs ascending pressure changes. At 678 Hz, the negative segment of all tympanograms again was wider for descending pressure changes by a mean of 32 dapa than for ascending pressure changes but the positive width remained unchanged with direction of pressure change. The tympanometric peak pressure for all admittance components and both probe frequencies changed significantly with the direction of ear canal pressure changes. Peak pressure was more positive for ascending than for descending pressure changes by 15-38 dapa at 226 Hz and by 7-38 dapa at 678 Hz. Tympanograms recorded with descending pressure changes tend to be stiffer (ie. consistent with a higher middle ear resonant frequency), broader and less complex than those recorded in the ascending direction (Shanks and Wilson, 1986).

Another effect of varying direction of pressure change is to shift the pressure peak apparently as a consequence of hysteresis. Beattie and Leamy in 1951 studied 660 Hz acoustic susceptance and acoustic conductance tympanograms and found no significant direction effect in a group of normal hearing young subjects. The mean directional difference ranged from 2.2 mm of H,o for acoustic conductance to 7 mm of H_2o for acoustic susceptance. They did find a significant hysteresis effect in an older (above 60 years) adult group with peak differences ranging from 16-21mm of H_2o.

In a study which compared some of these variables in normals and flaccid ears, Williams (1952) found a similar difference between her two populations where flaccidity was a factor rather than age. However, the magnitude of the shift was inconsequential in either group. The maximum average shift was about 4 mm of H_2o for the normal subjects and 9 mm of H_2o for the flaccid ears at any speed.

For most clinical applications it appears that direction has an inconsequential influence on the peak pressure point.

c) Number of consecutive pressure sweeps

Van Peperstrate et al in 1979 first noted that the test retest reliability was enhanced if two tympanometric sweeps were completed prior to data collection.

Osguthorpe and Lan (1981) and Wilson et al (1984) reported a continuous increase in admittance across successive recordings that was largest over the first 3-5 tyrnpanometric sweeps. The latter investigators reported an increase in mean static admittance to 10-18% across 10 consecutive trials and hypothesized that the effect is attributive to the viscoelastic changes of the middle ear caused by repeated extremes of air pressure introduced into the ear canal.

Acoustic immittance and physical volume

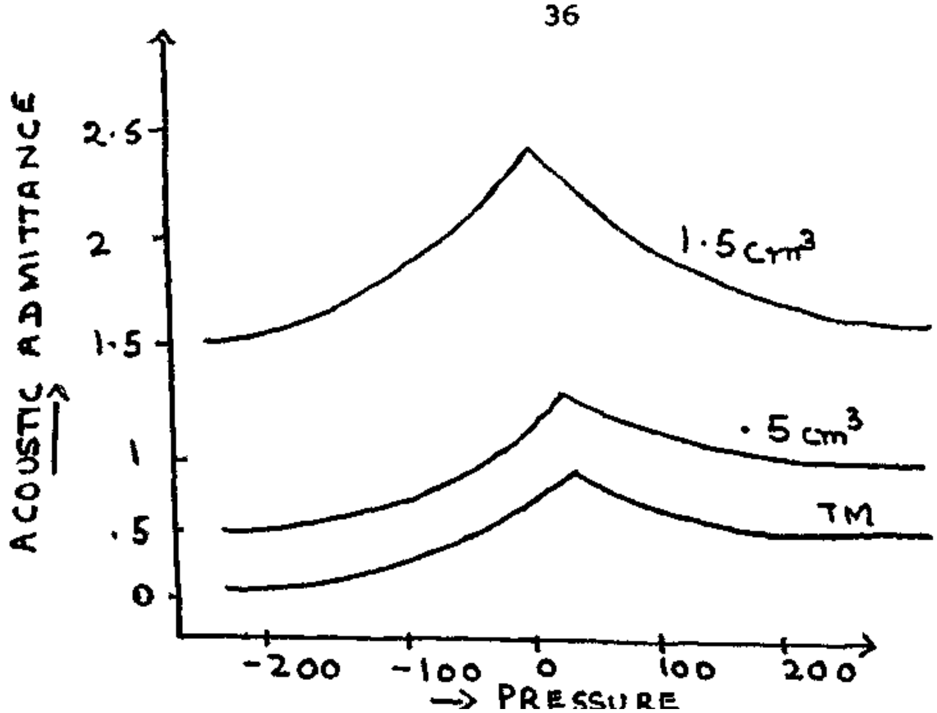
Physical volume is a measurement of the volume of the external auditory canal as a sealed cavity under a positive pressure of 200 dapa. For children the normal volume peripheral to an intact drum is approximately 0.6 cc to 0.8 cc, for adults approximately 1.00 cc to 1.5 cc (Northern and Grimes, 1978). This use of measurement has been called the physical volume test (Northern 1976).

Some investigators regard the ear canal volume as pure susceptance (Moller, 1960; Van Peperstraete, et al. 1979) whereas other investigators suggest the ear canal volume contributes some finite conductance.

Moller (1960, 1972) reported that the ear canal has no effect on the real component of admittance. Creten did not assume that the ear canal could be modeled as pure susceptance. They reasoned that the hairs and cerumen lnthe earcanal produce some sound absorption and thus a finite value of ear canal conductance. Both susceptance and conductance at a given ear canal pressure are attributed to ear canal volume.

The asymmetries in the tympanograms were reported by Margolis and Propelka (1975) and Margolis and Smith (1977), suggesting that the asymmetry in susceptance tympanogram was due to volume change that occured in the ear canal as pressure was varied.

The amplitude and bandwidth (gradient)are related inversely to the volume of the ear canal, that is, the tympanometric amplitude and gradient are greater for smaller ear canal volume. More over the tympanometric amplitude decreases nonlinearly with increase in physical volume. The change in sound pressure level will be greater and therefore tympanometric amplitude will be greater in smaller ear canals.



This demonstrates the main advantage of plotting tympanograms in acoustic admittance units. An increase in physical volume produces a linear increase in the baseline of the tympanoarams, but the tympanometric shape remains same whether it is corrected for physical volume or not (Wiley, Oviatt and Block, 1984).

Acoustic immittance and age:

There have been various studies conducted to find out the relationship between static acoustic immittance and the age, but the results are contradictory.

Sweitzer (1964) measured acoustic resistance and acoustic reactance in twenty one young persona (19-33 years) and 15 older person (59-85 years) with a Grason-Stadler (Zwlslocki) acoustic bridge. He found a significant decrease of both quantities in the older group at several carrier frequencies.

Brooks (1971) observed indications in his data of an increase in compliance as a function of age.

The acoustic impedance increase beyond the age of approximately 60 years, that is, there is a decrease in the mean value of the measured compliance past the fourth or fifth age decade. (Maudlin, 1972; Alberti and Kristen sen 1972).

Jerger (1972) reported that the overall compliance decrease as the age increases.

Beaty and Leamy in 1975 reported that the mean static admittance is lesser for the younger age group, that is, ages 17 to 21years than when compared to the older age group, that is,60 to 78 years.

Blood and Greenberg (1976) cited in Tompson, Sills, Ruke, Bui (1979) reported that the mean of acoustic admittance decreases as the age progresses.

Nerbonne et al (1973) presented a study on variations of static compliance with age in which he found a slight but not significant tendency for static compliance values to decrease with age.

Osterhammel and Osterharamel (1979) studied age variations and reported that there was no dependency of tympanometric compliance values on age.

The static conductance, static susceptance and static admittance were studied in sixty subjects, twenty through seventy nine years of age with normal hearing. It was reported that the static immittance changes are minimal upto approximately 60 years and also stated that those in their sixty's and seventy's have higher acoustic admittance than the averaged remainder of the sample. When this study was compared with previous studies or reports, it suggests that the effects of age on measures of static acoustic admittance and presumably acoustic impedance is complex, that is, static conductance at 220 Hz varies little across age. The static susceptance at 220 Hz and 660 Hz and Static conductance at 660 H_z shows an initial high (relative) value in the sixties and seventies (Thompson, Sills, Recke and Bui, 1979).

Wilson in 1981 computed the aural acoustic immittance (admittance and impedance) during the quiescent and reflexive states on 18 subjects with normal hearing in each of the two age groups (less than 30 years and greater than 50 years). The results indicated that there was no significant differences between the two groups. The relationship between the magnitude changes in the susceptance and conductance from the quiescent to the reflexive state was the same for the two groups.

Acoustic immittance and interaural difference:

Most of the studies concerning the relationship between static acoustic inunittance and interaural difference indicate that there is no significant differences in the immittance values obtained for both ears. A summary of such studies are given below:

Jonge and Valente (1979) asserted that the static compliance measurements must be done in both ears individually rather than estimating the overall static compliance. They used the Madsen ZO70 electroacoustic impedance bridge and found that the mean static compliance for right and left ears was 0.67 and 0.71 respectively. The average difference between two ears, that is, 0.04 was not statistically significant and therefore the average difference between ears for all practical purposes can be regarded as '0' cc and the average static compliance $\left(\frac{\text{Right ear + left ear}}{2}\right)$ as 0.69 cc.

Osterhammel and Osterhammel (1979) studied the right-left differences for the tympanometric compliance values on 286 persons in the ages of 10-80 years. The results indicated a very small right-left differences in the absolute compliance values.

The interaural difference in the acoustic immittance characteristics of the middle ear transmission system in 48 subjects using a 220 Hz probe tone were studied. The results indicated that there was no significant difference between the right and left ear measurements (Wilson, Shanks, and Velda, 1981).

Static Immfttance and Sext

Jerger (1972) reported that men show higher acoustic compliance than female at all ages. But in the case of children there is no significant difference in compliance values interms of sex.

Osterhammel and Osterhammel (1979) studied sex variations for the tympanometric compliance values on 286 persons in the ages of 10-80 years and reported that there was no dependency of compliance values on sex.

Acoustic immittance and test retest reliability;

Nixon and Glorig (1964) and Tillman (1964) reported test-retest-correlations for compliance and found it to be extremely high (0.8 - 0.9) at frequencies upto 800 Hz.

Feldman (1967) studied the test-retest correlation (1 week Interval) for compliance on 13 subjects and found that there was high positive correlation of 0.71. He also studied the mean ear canal volume for group of 84 ears and found it to be 0.56 CC and for the left and right ears taken separately was also 0.56 CC. He also found a high correlation between ear canal volume of a person's ears (0.37).

The static compliance measures and the compensated static acoustic impedance measures were computed and compared for a Zwicloski Acoustic Bridge and a Madsen (Z070) electroacoustic bridge respectively. Eleven normal hearing subjects experienced three trials for each instrument. High test-retest correlations between trials and between instruments were reported for the two sets of measures (Feldman, Djupesland and Grimes, 1971).

The reliability data for compensated static acoustic admittance measures on sixteen normal hearing subjects across five test session were reported for 220 Hz and 660 Hz Acoustic susceptance was measured with pressure decreasing from +200 dapa and acoustic conductance was measured with pressure increasing from -200 dapa. Values obtained at

-200 dapa and ambient pressure or tympanometric peak pressure vere used to calculate compensated static values* Test-retest correlations were high for static measures referenced to tympanometric peak pressure. However, low test correlation coefficients were reported for static measures referenced to ambient pressure, particularly for low measures of acoustic conductance. They suggested that these reflected small shifts in the tympanometric peak pressure over time. The tympanometric peak pressure varied from test to test, although never more than 4-20 dapa. (Porter and Winston, 1973).

The test retest reliability for tympanometric measures across five sessions in twenty subjects with normal hearing and normal middle ear function were evaluated for probe tones of 226 Hz, 678 Hz and 1000 Hz. Using both ascending and descending directions of pressure change. Across all conditions, the tympanometric measure that consistently demonstrated for highest test-retest reliability was compensated static acoustic admittance, Test-retest correlations for peak compensated static acoustic admittance measures were higher than those for ambient measures across all probe frequencies and both directions of pressure change, the differences in correlations for peak and ambient measures, however reached significance only for 226 Hz conditions. A cross-section correlations for tympanogram width did not differ significantly for measures referenced to the lowest tympanogram tail and those referenced to +200 dapa.

METHODOLOGY

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

1. Subjects
2. Instrumentation
3. Calibration
4. Test environment
5. Test procedure

1. Subjects: A total of fifty geriatric subjects (twenty five males and twenty five females) inthe age group of 50 years and above were selected.

Criteria for selection:

The subjects were selected in such a way that they had either normal hearing or mild sensori-neural hearing loss. The subjects with mild sensori-neural hearing loss were also included because geriatrics with normal hearing are rarely found as hearing deteriorates with aging.

Moreover, the subject should have an 'A' type tympanogram , with reflexes present on an immittance instrument which would indicate the absence of any middle ear pathology.

2. *Instrumentation: The* Grason-Stadler middle ear analyzer 33 version 2 was used for the present study. It is a microprocessor based admittance instrument which has facilities for complete automatic or manual diagnostic testing for analysis of middle ear function. Admittance (Y) and its components, susceptance (B) and conductance (G) can be measured with probe tone frequencies of 226 Hz, 678 Hz and 1000 Hz.

An audiometer namely Madsen 0B822 calibrated according to ISO standards was also used to check the behavioural thresholds (air conduction and bone conduction) at octave frequencies using the modified Hughson-Westlake procedure.

3. Calibration: The Grason-Stadler Middle Ear Analyzer 33 version 2 was calibrated according to the standards specified in the manual.

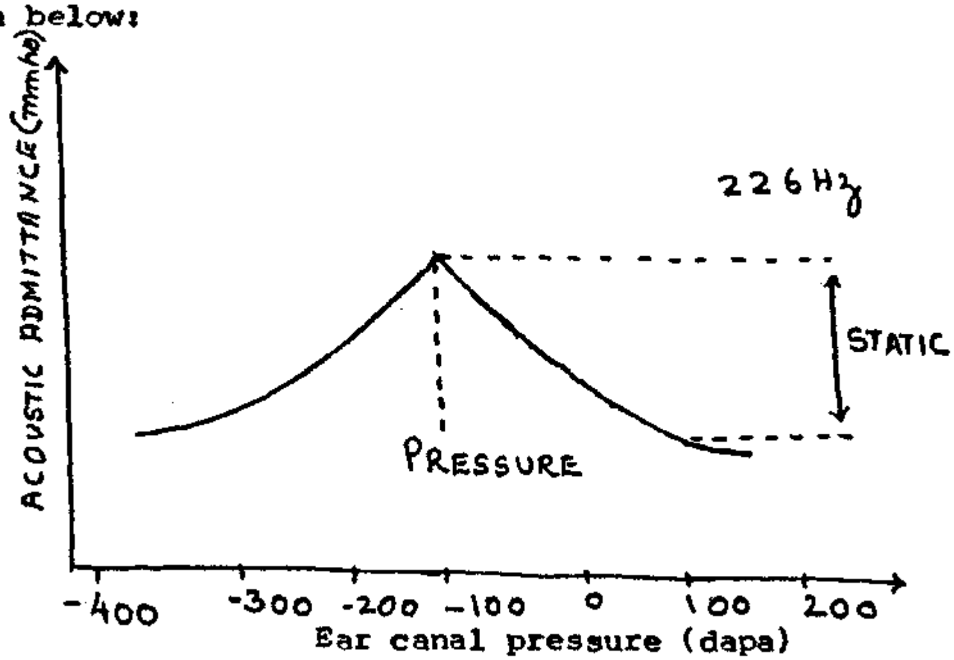
The audiometer was calibrated using a Sound Level Meter (B&K 2230) and a microphone (B&K 4144). The calibration of earphone (TDH 39p) output has been accomplished with the help of an artificial ear (B&K 4152) along with the sound level meter and microphone (B&K 4144).

4. Test Environment: The test was conducted in a air conditioned sound treated room. The environmental conditions

namely temperature (85°F) and the humidity conditions were within normal limits. The noise levels were measured using a sound level meter (B&K 2209), an octave filter set (B&K 1613) and a condensor microphone (B&K 4165) and the noise levels were within the permissible limits as given in ANSI Standards.

5. Test Procedure: The patient was seated comfortably. The probe box was attached to the veloro strip on the shoulder mount or clothes clip and position on the patient. Then the presence of cerumen in the ear canal was checked. The correct size of ear tip was selected and positioned on the probe. Then it was securely inserted into the ear canal to obtain an airtight seal. The probe tone of interest (226 Hz) was selected and the pump speed was selected as 200 dapals. Then the ' start' button was pressed. Since the instrument is an automatic one, the tympanometric values including the values of physical volume, static compliance, peak pressure and gradient were displayed on the screen after getting the tympanogram. Similarly the above mentioned values were obtained for 678 Hz and 1000 Hz by moving the cursor accordingly. The gradient value was estimated only at 226 Hz.

The tympanogram obtained at 226 Hz is represented as shown below:



Changes in acoustic admittance were measured as the air pressure in the sealed ear canal was varied over a maximum range of +200 to -400 dapa (l dapa = 1,02 mm H_2o). At high positive and high negative pressure, the eardrum became extremely stiff. At these pressures, little acoustic energy flowed into the middle ear and the admittance decreased to a minimum. As the air pressure in the ear canal approached atmorspheric pressure (0 dapa), there was an increase in the flow of energy into the middle ear, and admittance increased to a maximum or peak value. The maximum flow of energy into middle ear occured when the pressure on both sides of the eardrum were equal. From the above tympanogram, the middle ear pressure, the physical volume and the peak compensated static admittance was calculated.

Middle ear pressure:

The peak of the tympanogram occured When the pressure in the ear canal was approximately equal to middle ear pressure. The ear canal pressure corresponding to the tympanometric peak, therefore provided an estimate of the middle ear pressure.

Physical volume;

The volume of the ear canal was also estimated. A high positive pressure of +200 dapa was built in the ear canal. The immittance value measured at this pressure provided an estimate of the ear canal volume or the physical volume.

Peak compensated immittance at the tympanic membrane

The acoustic immittance was calculated in the following manner:

1. The acoustic immittance was calculated with the pressure at +200 dapa. This was the minimum acoustic immittance

2. Nextly, the acoustic immittance was calculated at the tympanometric peak pressure. In other words, it was calculated at the ear canal pressure corresponding to zero pressure difference across the tympanic membrane. This was the maximmum acoustic immittance (Y_{max})•

3. Thus, the acoustic admittance at the tympanic membrane was calculated using the following formula -

$$Y_{Tm} = Y_{max} - Y_{min}$$

Y_{TM} " admittance at the tympanic membrane.

The suseceptance and conductance was calculated at the tympanic membrane.

Similarly, $B_{TM} - B_{max} - Y_{min}$

$$G_{TM} = G_{max} - G_{min}$$

For notched admittance tympanograms, the static value was calculated at the minimum in the notch. When susceptance and/or conductance tympanograms were notched, static susceptance was calculated at the minimum in the notch and static conductance was calculated at the ear canal pressure corres--ponding to the minimum in the susceptance notch.

Tympanometric gradient: The gradient calculation was based on determining the width of the tympenogram in dapa at one half or 50% of the amplitude (height) of the tympanogram. The gradient was calculated for the admittance tympanogram only at 226 Hz as the instrument did not have the facility at other probe tone frequencies.

Thus all the values were displayed automatically on the screen. A similar procedure was repeated at all the three frequencies for admittance, conductance and susceptance for both males and females.

RESULTS AND DISCUSSION

The main aim of the present study was to establish the normative data of physical volume, peak pressure for admittance, conductance and susceptance and the admittance, conductance and susceptance at the tympanic membrane across the three probe tone frequencies namely 226 Hz, 678 Hz, and 1000 Hz for male and female geriatrics (above the age of fifty years).

At lower probe tone frequencies (226 Hz), a single peaked tympanogram was obtained, but at higher frequencies especially at 1000 Hz• notched tympanograms were obtained* In the present study, at 226 Hz, there were no notched tympanograms for admittance, conductance and susceptance, but at higher frequencies, the incidence of notching increased to 85-90%.

MALES

Admittance	Conductance	Susceptance
226 Hz - 0	226 Hz - 0	226 Hz - 0
678 Hz - 16%	678 Hz - 0	678 Hz - 62%
1000 Hz - 76%	1000 Hz - 24%	1000 Hz - 92%

FEMALES

Admittance	Conductance	Susceptance
226 Hz - 0	226 Hz - 0	226 Hz -0
678 Hz - 4%	678 Hz	678 Hz - 20%
1000 Hz - 44%	1000 Hz -0	1000 Hz - 72%
	-12%	

Thus, at higher frequencies, the notching was less common for the conductance tympanogram when compared to the admittance and susceptance tympanogram. The notching was most frequent for the sueceptance tympanogram. This supports the results of Margolis et al (1984). Margolis et al. (1984) reported that as the probe tone frequency -increases notching first occurs for susceptance tympanogram and then for admittance and conductance tympanogram.

The data obtained was statistically analyzed. The mean, standard deviation and the range was calculated. Further, the 'paired and unpaired' 't' test was used to find out the significant difference at .01 level between the following parameters.

1. Physical volume for admittance, conductance and susceptance at the three probe tone frequencies for males and females.
2. Peak pressure for admittance, conductance and susceptance at the three probe tone frequencies for males and females.
3. Admittance, conductance and susceptance at the tympanic membrane at the three probe tone frequencies for males and females.

Further, the significant difference for all the above parameters between males and females and between right and left ears were found.

PHYSICAL VOLUME:

Table-la: Shows the mean, standard deviation and range for physical volume for admittance, conductance and susceptance at 226 Hz, 678 Hz, and 1000 Hz for males and females.

Parameter	Probe tone frequency	Mean		Standard		Range	
		Male	Female	Male	Female	; Mile	Female
	226 Hz	1.43	1.25	0.26	0.,35	0.9 to 2	0,8 to 2.8
Admittance	678 Hz	4.09	3.63	0.79	0,,73	2,6 to 6.2	2.3 to 5.7
	1000 Hz	5.14	5.93	1.09	1,,27	2.9 to 7.6	3.3 to 8.7
	226 Hz	0.33	0 .30	0.23	0,,26	0.15 to 1. 38	0.15 to 1.3
Conductance	678 Hz	0.68	0.70	0.,49	0,,86	0.21tO 3.5	.06 to 3.8
	1000 Hz	0.76	0.90	0,,83	1..45	-0 .26 to 5 .5	-0.64 to 6
	226 Hz	1.13	1 .22	0,.26	0 .3	0.9 to 2	0.7 to 2.1
Susceptance	678 Hz	4.02	3 .6	0,.78	0•78	2.6 to 6.1	2.3 to 5.1
	1000 Hz	6.7	6 .6	1 .41	1 .2	4.3 to 1.07	3.3 to 8.7

Table-lb: Shows the results of 't' test for physical volume.

Parameter	Probe tone frequency	Males	Females
PHYSICAL VOLUME	226 Hz & 678 Hz.	Significant difference	Significant difference
	226 Hz & 1000 Hz	Significant difference	Significant difference
	678 Hz & 1000 Hz	Significant difference	Significant difference

From Table-la it could be inferred that as probe tone frequency increases, the physical volume also increases for admittance, conductance and susceptance and this difference was statistically significant at .01 level as evident from Table-IB.

Moreover, the physical volume was compared between males and females at all the three probe tone frequencies and it was found that there was a significant difference between the physical volume values for males and females.

But there was no interaural difference in physical volume.

PEAK PRESSURE:

Table-2a: Shows the mean, standard deviation and range for peak pressure for admittance, conductance and susceptance tympanoqrams at the three probe tone frequencies for males and females.

Parameter	Probe tone frequency	Mean		Standard deviation		Range	
		Male	Female	Male	Female	Male	Female
Admittance	226 Hz	-6.02	-2.5	29.41	14.32	-80 to 35	-40 to 25
	678 Hz	-0.95	-1.18	28.3	13.2	-75 to 78	-45 to 30
	1000 Hz	1	-2.5	17.8	15.1	-27 to 40	-50 to 15
Conductance	226 Hz	-8.29	-1.57	23.2	21.9	-85 to 30	-60 to 80
	678 Hz	-4.3	+1.84	21.8	20.7	-75 to 35	-50 to 95
	1000 Hz	3.3	20	7.52	27.8	-5 to 15	-5 tp 50
Susceptance	226 Hz	-4.6	2.1	22.8	21.4	-80 to 35	-55 to 85
	678 Hz	6.7	13.5	11.3	42.1	-10 to 35	-45 to 85
	1000 Hz	-3.3	0.2	21.8	26.1	-60 to 40	.60 to 55

Table-2b: Shows the results of 't' test for peak pressure.

Probe tone frequency	Parameter	Males	Females
226 Hz & 678 Hz	Admittance	No significant difference.	No significant difference
	Conductance	No significant difference	No significant difference
	Susceptance	No significant difference	No significant difference
226 Hz & 1000 Hz	Admittance	No significant difference	No significant difference
	Conductance	Significant difference	No significant difference
	Susceptance	Significant difference	Significant difference
678 Hz & 1000 Hz	Admittance	No significant difference	No significant difference.
	Conductsnce	No significant difference	No significant difference
	Susceptance	No significant difference	No significant difference

Table-2a shows that the range for the peak pressure falls between -80 to 35 dapa for males and -45 to 25 for females at 226 Hz probe tone frequency for admittance tympanogram. Brooks (1980), Holmquist and Miller (1972), Peterson and Liden (1972) and Porter (1974) reported the range for tympanometric peak pressures between -50 and +50 dapa in adults. Alberts and Kristenson (1970) suggested the use of + 50 mm H_2o as normal middle ear pressure in adults, while others agree that -100 mm H_2o be used as a point between normal and abnormal negative pressure (Renvall, Liden, Jungert, and Nilsson, 1973/ Jerger, 1970f Harker and Van Wagoner, 1974; McCandless and Thomas, 1974), The results of the present study support the statement that peak pressure upto -100 mm H,o should be considered as normal.

Prom Table-2b it is evident that there is no significant difference between the peak pressure of admittance tympanograms at the three probe tone frequencies.

There was no significant difference between peak pressure values for conductance tympanograms at 226 Hz and 678 Hz, at 678 Hz and 1000 Hz for both males and females and 226 Hz and 1000 Hz for females. But there was a significant difference between the values at 226 Hz 1000 Hz for males.

There was no significant difference between peak pressure values for susceptance at 226 Hz and 678 Hz and 678 Hz and 1000 Hz for both males and females. But there was a significant difference between these values at 226 Hz and 1000 Hz for males and females.

Moreover, the peak pressure values were compared between males and females and the results indicated that there was no significant difference between males and females at all the three probe tone frequencies.

The peak pressure values were compared between the right and left ears and it was found that there was no significant difference in terms of peak pressure between the right and left ears.

IMMITTANCE AT THE TYMPANIC MEMBRANE:

Table-3a: Shows the mean, standard deviation and range for admittance, conductance and susceptance at the tympanic membrane across 226 Hz, 678 Hz and 1000 Hz for males and females-

Parameter	Probe tone frequency	Mean		Standard deviation		Range	
		Male	Female	Male	Female	Male	Female
Admittance	226 Hz	1.09	0.64	1.17	0.34	0.3 - 1.7	0.2 - 1.5
	678 Hz	2.4	1.53	1.13	0.8	0.43-2.8	0.3 - 4.1
	1000 Hz	-0.11	0.44	2.06	1.43	-2.2 - 1.17	-1.4 -1.3
Conductance	226 Hz	0.91	0.66	0.29	0.24	0.2-1.45	0.41-1.27
	678 Hz	4.1	-1.5	1.97	2.19	1.3-4.8	-0.6-3.7
	1000 Hz	5.4	4.1	2.08	1.3	1.9-3.4	1.01-4.8
Susceptance	226 Hz	2.31	1.9	0.54	0.45	1.3-3.6	1.2-3.2
	678 Hz	3.2	3.0	1.4	0.75	1.2-4.4	1.8-3.9
	1000 Hz	4.07	4.3	1.9	1.7	-0.13-4.4	1.3-4.4

Table-3b: Shows the results of 't' test for admittance, conductance and susceptance at the tympanic membrane.

		Male	Female
226 Hz & 678 Hz	Admittance	Significant difference	Significant difference
	Conductance	Significant difference	Significant difference
226 Hz & 1000 Hz	Admittance	No significant difference	No significant difference.
	Conductance	Significant difference	Significant difference
	Susceptance	Significant difference.	Significant difference
678 Hz & 1000 Hz	Admittance	No significant difference	No significant difference
	Conductance	Significant difference	No significant difference
	Susceptance	No significant difference	No significant difference.

From Table-3a, it can be seen that the admittance at the tympanic membrane lies between 0.3 to 1.7 for males and 0.2 to 1,5 for females at 226 Hz. However only one subject had a static admittance of 0.16 which lies below the normal range and another male subject had a static admittance of 4.15 which lies well above the normal range. Further exploration is warranted for these two subjects. The normative data according to the present study is almost similar to the normal range reported by Margolis and Shanks (1985) for subjects above 6 years of age.

According to the present study, the mean admittance at the tympanic membrane for 226 Hz probe tone was 1,09 for males and 0.64 for females. According to Blood and Greenberg (1976), the mean admittance at 220 Hz for the age range of 50-59 years was 0.85 mmho, 0.81 mmho for the age range of 60-69 years and 0.60 mmho for the age of 70 years and above for males and females as a whole. In the present study if male and female are considered as a group the results correlate with the findings of Blood and Greenberg (1976).

At 678 Hz, the mean admittance for males was found to be 2.4 and for females it was 1.53. The range at the same probe tone frequency was found to be 0.76 to 2.8 for males and 0.3 to 2.89 for females. However one male subject had an admittance value of 0.76 and one female subject who had an admittance value of 4.1. According to Margolis and Shanks (1985), the normal range for admittance at 678 Hz was 1.5 to 3.8 for subjects above 6 years. The present study shows that the admittance at the tympanic membrane may be lower in the geriatric group. However these results do not correlate with that of the findings of Beattie and Leamy (1975) This may be because of the difference in the instruments used.

At 1000 Hz, the mean admittance for males was found to be -0.11 while for females it was 0.44. The range for the same was found to be -2.2 to 1.17 for males and - 1.4 to 1,3 for females except for 1 male and 1 female who had an admittance value of 5.1 and 5.3 respectively.

At 226 Hz, the mean conductance at the tympanic membrane was found to be 0.91 for 0.66 for females. The range was found to be 0.26 to 1.45 for males and 0.41 to 1.27 for females. The range reported by Margolis and Shanks (1985) was 0.20 to 0.87 at 226 Hz. The lower limit is almost similar but the upper limit is slightly higher in the present study.

At 678 Hz, the mean conductance at the tympanic membrane was 4.1 for males and -1.5 for females. The range at the same probe tone frequency was 1.3 to 4.8 for males and -0.6 to 3.7 for females. The range according to Margolis and Shanks (1985) was 0.75 to 3.94 for subjects above 6 years of age. The values of the present study are almost similar to the values reported by Margolis and Shanks (1985).

At 1000 Hz, the mean conductance value at the tympanic membrane was found to be 5.4 for males and 4.1 for females. The range was found to be 1.9 to 3.4 for males and 1.01 to 4.8 for females except for 1 female who had a static conductance value of 5.3.

At 226 Hz, the mean susceptance value at the tympanic membrane was found to be 2.31 for males and 1.9 for females. The range at the same probe tone frequency was 1.3 to 3.6 for males and 1.2 to 3.2 for females. This value is slightly higher than the values reported by Margolis and Shanks (1985) which was 0.44 to 1.6 for subjects above 6 years.

At 678 Hz, the mean susceptance at the tympanic membrane was 3.2 for males and 3.0 for females. The range at the same probe tone frequency was 1.2 to 4.4 for males and 1.8 to 3.9 for females. These values are slightly higher than the values reported by Margolls and Shanks (1985). They reported the range to be 0.98 to 2.22 for subjects above 6 years.

At 1000 Hz, the mean susceptance at the tympanic membrane was 4.07 for males and 4.3 for females. The range at the same probe tone frequency for males was -0.13 to 4.4 and 1.3 to 4.4 for females. However one female subject had a susceptance value of 5.1. Further investigation is needed for the subject.

Prom table 3b, it is evident that there was a significant difference between the static admittance values of 226 Hz and 679 Hz in both males and females but there was no significant difference between 226 Hz and 1000 Hz and between 678 Hz and 1000 Hz.

There was a significant difference between static conductance values at all the three probe tone frequencies (ie. between 226 Hz and 678 Hz between 226 Hz and 1000 Hz and between 678 Hz and 1000 Hz) for both males and females.

There was a significant difference between static susceptance values at 226 Hz and 678 Hz and 226 Hz and 1000 Hz for males and females. But there is no significant difference at 673 Hz and 1000 H_z for both males and females.

Moreover* the static immittance values were compared between males and females and the results indicated that there was a significant difference between males and females in terms of static immittance values at all the three probe tone frequencies.

This is in agreement with the finding by Jerger (1972) who stated that there was a significant difference in compliance values between males and females.

But the above finding is at variance with the finding by Osterhammel and Osterhammel (1979) who stated that there was no sex-related dependent compliance values.

Next, the static compliance values were compared between the right and left ears and there was no significant inter aural difference.

The supports the findings of Wilson, Shanks and Velda (1981) who stated that there was no significant difference between the right and left ear measurements in acoustic immittance characteristics.

But the above finding is at variance with the finding by Osterhammel and Osterhammel (1979) who stated that there was a small right - left difference in absolute compliance values.

GRADIENT:

Table-4i Shows the normative data for gradient at 226 Hz admittance tympanogram for males and females.

Probe tone frequency	Mean		Standard deviation		Range	
	Male	Female	Male	female	Male	Female
226 Hz	73.0	82.6	33.7	26.7	20 to 185	20 to 160

Table-4 shows the mean and range of gradient values for males and females. American Speech-Language-Hearing Association (1989) cited in Silman and Sllverman, reported a range of 50 dapa to 110 dapa for adults. The present study suggests that the range may be wider for geriatrics.

There was no significant difference between the gradient values for males and females.

There was also no interaural difference in the gradient values at 226 Hz admittance tympanogram.

Thus, the present study investigated the acoustic immittance characteristics in the geriatrics. The results indicate that there is no interaural difference in the immittance characteristics considered in the present study. The physical volume and the admittance, conductance and susceptance at the tympanic membrane was gender related at all the three probe tone frequencies. The tympanograms start notching as the frequency of the probe tone is increased and the notching is more common for susceptance tympanograms than conductance and admittance tympanogram.

SUMMARY AND CONCLUSION

The aim of the study was to establish normative data for admittance and its components, namely conductance and susceptance for the three different probe tone frequencies (ie, 226 Hz, 678 Hz and 1000 Hz) for physical volume and peak pressure and for the gradient at 226 Hz.

A total of 50 geriatric subjects (25 males and 25 females) in the age group of 50 years and above were selected. None of them had middle ear pathology,

Grason-Stadler Middle Ear Analyzer 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 deviations and range were obtained. Significant differences between the mean values of physical volume, peak pressure for admittance, susceptance and conductance at the three probe tone frequencies were found out. These were then compared between males and females and the right and left ears. The following results were obtained.

I. PHYSICAL VOLUMES

a) The physical volume increases with increase in probe tone frequency for admittance, conductance and susceptance and this difference was statistically significant.

b) There is a significant difference between the physical volume values for males and females.

c) There is no interaural difference in the physical volume.

II. PEAK PRESSURE:

a) There is no significant difference between peak pressure values for admittance at the three probe tone frequencies for both males and females.

There is no significant difference between peak pressure values for conductance at 226 H_z and 678 Hz, at 678 Hz and 1000 Ha for males and females and at 226 Hz and 1000 Hz for females. But there is a significant difference between the values at 226 Hz and 1000 Hz for males.

There is no significant difference between peak pressure values for susceptance at 226 Hz and 678 Hz and 678 Hz and 1000 Hz for males and females. But there is a significant difference between these values at 226 Hz and 1000 Hz for males and females.

b) There is no significant difference between males and females in terms of peak pressure at all the probe tone frequencies.

c) There is no significant interaural difference in peak pressure.

III. <u>ADMITTANCE. CONDUCTANCE AND SUSCEPTANCE AT THE TYMPANIC MEMBRANE</u>

a) There is a significant different between the static admittance values at 226 Hz and 678 Hz for males and females but there is no significant difference at 226 Hz and 1000 Hz and 678 Hz and 1000 Hz.

There is a significant difference between conductance values at the tympanic membrane at all the three probe tone frequencies for both males and females.

There is a significant difference between static susceptance values at 226 Hz and 678 Hz and 226 Hz and 1000 Hz for males and females. But there is no significant difference at 673 Hz and 1000 Hz for males and females,

b) There is a significant difference between males and females in terms of static admittance, static conductance and static susceptance.

c) There is no significant interaural difference in terms of static admittance, static conductance and static susceptanc

IV.GRADIENT

a) There is no significant difference in the gradient value at 226 Hz (admittance) between the males and females.

b) There is no interaural difference in the gradient values at 226 Hz (admittance).

CLINICAL IMPLICATIONS

Thus, the present study provides the normative data for peak pressure, physical volume for admittance, conductance and susceptance and the admittance, conductance and susceptance at the tympanic membrane at the three probe tone frequencies for males and females. Any values above and below this data may be considered pathological. However, further study on clinical population is required to ascertain these values at different frequencies.

BIBLIOGRAPHY

Alberti, P.W., and Jerger, J. (1974). Probe tone frequency and the diagnostic value of tympanometry. Arch. Otolaryngol. 99, 23-27.

Beattie, R.C., and Leamy, D.P. (1975). Otoadmittance: normative values, procedural variables and reliability. J.Am. Audiol.Soc.l, 21-27.

Berry, Q.C, et al. (1975). Tympanometric pattern classification in relation to middle ear effusions. Ann.Otol.Rhino.Laryngol. 84, 50-64.

Brooks, D.N. (1971). A new approach to identification audiometry. Audiol. 334-339.

Creten, W.L., and Van Camp, K.J. (1974). Transient and quasi-static tympanometry. Scand.Audiol. 3, 39-42.

Creten, W., Vande Heyning, P., and Van Camp, K. (1985). Immittance audiometry. Scand, Audiol. 14, 115-121.

de Jonge, R.R., and Valente, M. (1979). Interpreting ear difference in static compliance measurements. J.of Sp. and Hear.Dis. 44, 201-231.

Feldman, A.S. (1967). Acoustic impedance studies of the normal ear. J.of Sp. and Hear. Res. 10, 165-176.

Feldman, A.S., Djupesland, G., and Grimas, C.T. (1971). A comparison of impedance measurement with mechanical and electroacoustic impedance measuring devices. Arch. Otolaryngol. 93, 416-418.

Feldman, A.S. (1973). A report of acoustic admittance parameters in normal ears. J.Acoust.Soc.Am. 54, 57.

Feldman, A.S. (1974 b). Ear drum abnormality and the measurement of middle ear function. Arch. Otolaryngol. 25, 202-209.

Feldman, R.M., Fria, T.J. et al. (1984). Effects of rate of air pressure change in tympanometry. 5, 91-95.

Feldman, A.S. Tympanometry-procedures, interpretation and variables. In A.S. Feldman, and L.A. Wiber (Eds.). Acoustic impedance and admittance - The measurement of middle ear function. Baltimore: The Williams and Wilkins Company, Chap.6.

Jerger, J. (1972). Suggested nomenclature for impedance audiometry. Arch. Otolaryngol. 96, 1—3.

Liden, G., Peterson, J.L., and Bjorkman, G. (1970). Tympanometry. A method for analysis of middle ear function. Acta Otolaryngol Suppl. (Stockholm) 263, 218-224.

Liden, G., Harford, E., and Hallen, 0. (1974). Automatic tympanometry in clinical practice. Audiol. 24, 126-139.

Liden, G., Harford, E., and Hallen, 0. (1974 a). Tympanometry for the diagnosis of ossicular disruption. Arch. Laryngol. 99, 23-29.

Liden, G., Harford, E,, and Hallen, 0. (1974 b). Automatic tympanometry in clinical practice. Audiol. 13, 126-139.

Margolis, R.H., and Popelka, G.R. (1975 a). Static and dynamic acoustic impedance measurement in infant ears. J. of Sp. and Hear. Res. 18, 435-443.

Margolis, R.H., and Smith, P. (1977). Tympanometric asymmetry. J. of Sp. and Hear. Res. 20, 437,446.

Margolis, R.H., and Popelka, G.R. (1977). Interactions among tympanometric variables. J. of Sp. and Hear. Res. 20, 447-462.

Nerbonne, M.A., Bliss, A.T., and Schow, R.L. (1973). Acoustic impedance values in the elderly. J.Amer.Aud.Soc. 4, 57-59.

Nadol, J.B., The aging peripheral hearing mechanism. In D.S. Beasley, G.A. Davis, (Eds.) Aging Communication process and disorders. Grune and Stratton, Inc, Chap.4.

Osterhammel, D., and Osterhammel, P. (1979). Age and sex variations for the normal stapedius reflex thresholds and tympanometric compliance values. Scand. Audiol. 8, 153-158.

Porter, T.A., and Winstor, M.E. (197 3). Methodological aspects of admittance measurements of the middle ear. J.of Aud. Res. 13, 172-177.

Shanks, J., and Lilly, D. (1981). An evaluation of tympanometric estimates of ear canal volume. J. of Sp. and Hear.Res. 24, 557-566.

Shanks, J.E. (1984). Tympanometry. Ear and Hear. 5, 268-279.

Shanks, J., and Shelton, C. (1991). Basic principles and clinical applications of tympanometry. In Osguthorpe, J.D., and Melnick, W. The Otolaryngologic clinics of North America - Clinical Audiology, 24, 299-328.

Silman, S., and Silverman, C.A. Acoustic immittance assessment. In Academic Diagnosis. Academic press. Limited,Chap, 3.

Silman, S., and Silverman, C.A, Basic audiologic testing. In Auditory diagnosis. Academic Press Limited, Chap.6,

Terkildsen, K., and Nielsen, S.S. (1960). An electroacoustic impedance measuring bridge for clinical use. Arch. Otolaryngol. 72, 339-346.

Thompson, D.J., Sills, J.A., Recke, K.S., and Bui, D.M. (1979). Acoustic admittance and the aging ear. J.of Sp. and Hear, Res. 22, 29-36.

Vanhuyse, V.J., Creten, W.L., and Van Camp, K.J. (1975). On the W-Notching of tympanograms. Scand. Audiol. 4, 45.

Van Camp, K.J., Raman, E.R., and Creten,W.L. (1976). Two component Vs, admittance tympanometry. Audiol. 15, 120-127.

Van Camp, K.J., Vanhuyse, V.J., Creten,W.L.. and Van Peperstraete, P.M. (1978). Impedance and admittance tympanometry II Mathematical approach. Audiol. 17, 108-117.

Van Peperstraete, P., and Creten, W. (1979). On the asymmetry of susceptance tympanograms. Scand. Audiol, Van Camp, K., Creten, W,, Vande Heyninz, P., Decraemer, W. and Van Peperstraete, P. (1983). A search for the most suitable immittance components and probe tone frequency in tympanometry, Scand. Audiol. 12, 27-34.

Wilson, R.H. (1981). The effects of aging on the magnitude of the acoustic reflex. J.of Sp. and Hear. Res. 24, 406-414.

Wilson,H., shanks, E., and Velda, M. (1981). Aural acoustic immittance measurements: Inter-aural differences. J. of Sp. and Hear. Res. 46, 413-321.

Wilson and Shanks, et al. (1984). Tympanometric changes at 226 Hz and 678 Hz across ten trials and for two directions of ear canal pressure change, J.of Speech and Hear. Res. 27, 257-266.

Wiley, T.L., Oviatt, D.L., and Block, M.G. (1987). Acoustic immittance measures in normal ears. J. of Sp. and Hear. "es. 30, 161-170.

Wiley, T.L., and Block, M.G., Overview and basic principles of acoustic Immittance measurements. In J. Katz (Eds.) Handbook of clinical audiology. Williams and Wilkins, Baltimore, Chap.22.