MULTICOMPONENT TYMPANOMETRY IN THE DETECTION

OF MIDDLE EAR PATHOLOGY

REG. No. M9601

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

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

MAY 1997

Dedicated

to

"Had"
My Pillar of strength
whose constant love,
affection and support
has made me what I am to-day.

CERTIFICATE

This is to Certify that this Independent Project entitled ***"MULTICOMPONENT TYMPANOMETRY IN THE DETECTION OF MIDDLE EAR PATHOLOGY™*** *is the bonafide work in part fulfilment for the first year "Master of Science (Speech and Hearing)" of the student with Register Number M9601.*

Dr. (Miss) S.NIKAM

Mysore
May, 1997

Director
All India Institute of Speech 8s Hearing
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CERTIFICATE

This is to Certify that this Independent Project entitled ***"MULTICOMPONENT TYMPANOMETRY IN THE DETECTION OF MIDDLE EAR PATHOLOGY"*** *has been prepared under my supervision and guidance.*

Mysore
May, 1997

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DECLARATION

I hereby declare that this Independent project entitled ***"MULTICOMPONENT TYMPANOMETRY IN THE DETECTION OF MIDDLE EAR PATHOLOGY"*** *is the result of my own study under the guidance of (Mrs.)* ***C.S. VANAJA*** *, Lecturer, Department of Audiology. All India Institute of Speech & Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.*

Mysore *{REG. No. .M9601}*
May, 1997

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CHAPTER I

INTRODUCTION

Acoustic immittance is a measure used to assess the normal middle ear function. The acoustic immittance refers to acoustic impedance, to acoustic admittance, or both quantities. A major clinical application of acoustic immittance evaluation is the identification and differential diagnosis of middle ear disorders. Immittance measures are also used as routine clinical tests in audiological evaluation. Immittance evaluation consists *of* tympanometry and measurement of acoustic reflexes. Tympanometry is the measurement of aural acoustic immittance at the probe tip or at the ear drum as a function of air pressure variations. Tympanometry can be carried out by measuring changes in acoustic impedance or admittance.

Admittance measurements are more effective to test middle ear function as the change in admittance is always linear to the change in the pressure applied to the external canal, whereas change in impedance is always non-linear with pressure change. Also from instrumentation point of view admittance is always easier to measure. Generally single component tympanometry at a low frequency probe tone (eg. 226 Hz) is used in routine testing of middle ear function using tympanometry.

For a low frequency probe tone which is far away from the resonant frequency of the middle ear, bell shaped tympanograms are produced for admittance (V), susceptance (B) and conductance (G) respectively (Vancamp, Raman and Creten, 1976). When conventional single component low frequency tympanometry is used in detection of middle ear disorders high impedance pathologies can produce an obvious alternation in the tympanometric shape, but low impedance pathologies cannot be identified by a single low frequency, single component tympanogram (Mayolis and Shanks, 1991) .

Margolis and Shanks (1984) reported that at low frequencies most of the ears whether normal or abnormal are stiffness dominated. Hence a change in middle ear resonance does not necessarily produce a marked change in the tympanometric shape. Lilly (1984) opined that low frequency single component tympanogram is insensitive to many lesions that affect the ossicular chain. Middle ear pathologies such as clinical otosclerosis,complete ossicular disruption, ossicular disruption with fibrous union, congenital ossicular malformation, fracture of the stapes head, neck or crura, congenital fixation of one or more ossicles, forcing of the stapes into the vestibule, fractured crura with stapes fixation, osteogenesis imperfecta tarda and ossicular fibrous displacement do not often yield distinct patterns when typical low probe tone frequency is used. Shanks (1984) found that for a small amount of fluid in the middle ear, 226 Hz tympanograms are single peaked, but 678 Hz tympanograms however showed dramatic change even when small amount of fluid is present.

Notched tympanograms are obtained using single component tympanometry, as the resonant frequency of the middle ear is approached. Hence separate su'sceptance and conductance tympanograms should be obtained to get a better idea of the middle ear system (Shanks, 1984). Vancamp et.al. (1976), states that information about ossicular chain discontinuity and ear drum pathology which is sometimes obscured in the 660 Hz admittance tympanometry can be regained when susceptance and conductance tympanometry is done.

Vande Heyning et.al. (1982) reported that two component tympanometry with a high frequency probe tone enables a better distinction to be made between mobile but normal middle ear systems and middle ear systems suffering from luxations, necrosis or disruption.

A study by shanks (1984) on abnormal ears showed a differential effect with regard to probe tone frequency and immitance companent for different pathologies. Shanks (1948) concluded that admittance or susceptance tympanograms at 226 Hz is preferable for estimating volume of the air medial to the probe. Susceptance (B) and conductance (G) seem to give important information regarding the status of the aditus and the mastoid air cell system. It was also found that for majority of the middle ear pathologies, the disease process had more profound effect on the tympanometric shape at 678 Hz than at 226 Hz.

Studies concerning multicomponent (susceptance and conductance) tympanograms at different probe tone frequencies (multi-frequencies) are limited in number and are mostly concerned with single case studies. Therefore the present study was carried out to study multicomponent tympanometry at different probe tone frequencies in subjects with conductive and mixed hearing loss.

Aim of the study

The aim of the study is as underlined below

1. To study patients with conductive or mixed pathology, whose findings for the 226 Hz admittance tympanograms are a normal 'A' type and who have absent ipsilateral and contralateral reflexes.

2. To compare admittance (Y), susceptance (B) and conductance (G) tympanograms at different probe tone frequencies - 226 Hz, 678 Hz and 1000 Hz for these patients for a better understanding of middle ear pathology.

CHAPTER II

REVIEW OF LITERATURE

Liden (1969) was the first to report on multifrequency tympanograms. They were thought to be an indication of tympanic membrane abnormality or ossicular discontinuity. Liden related this effect with some reserve to ear drum pathologies or fluid ear drums. He said that for a given subject this 'w' patterns become less pronounced and may become less pronounced and may disappear in going to low frequency probe tones.

Several studies have shown that double peaked tympanograms are related to interactions between the acoustic resistance and acoustic reactance components of acoustic impedance. If the resistance value is greater than reactance value near the* ambient pressure a double peaked susceptance tympanogram occurs (Vanhuyse, Creten and Vancamp, 1975; Margolis and Popelka, 1977; Liden et.al., 1977).

It has been shown the double peaked tympanogram may exist at 660 Hz in both normal and pathologic ears in adults. Double-peaked conductance, susceptance and impedance tympanograms occurs when reactance assumes a positive sign, a finding at 660 Hz in adults which is probably related to a lesion within the conductive mechanism (Margolis and Popelka, 1977).

Two approaches to the interpretation of tympanograms are in wide spread use: (a) clarification of tympanometric shape and (b) calculation of compensated static immitance. Calculation of static immitance can be of clinical value particularly for low frequency probe tones which most tympanograms are single peaked, but an analysis of the morphology of the tympanograms may be more informative for high probe tone frequencies at which many of the tympanograms are notched in both normal and pathological middle ears (Shanks et.al., 1988).

Various methods of classification of tympanograms are described in the literature (Liden, 1969; Liden Peterson and Bjorkman, 1970; Jerger, 1970; Feldman, 1976a, 1976b, 1977; Paradise, Smith and Bluestone, 1976). With the exception of Peldman (1976a, 1976b, 1977) majority of the classification procedures have been applied to only single component (admittance magnitude) single frequency (226 Hz) tympanograms.

The interpretation of multicomponent, multifrequency tympanometry is not as straight forward as that of low frequency single component tympanometry. When a high frequency probe tone is used to measure both components of complex acoustic admittance, a simple analysis of tympanometric shape may be sufficient to identify middle ear abnormalities (Margolis and Shanks, 1991). Many investigators (Vanhuyse, Creten and Vancamp, 1975; Margolis and Popelka, 1977; Liden et.al., 1977; Shanks. 1984; Shanks et.al., 1988; Margolis and Shanks, 1991) prefer to use a descriptive rather than a qualitative analysis of the shape.

The first step in analysing complex tympanograms is to understand how normal tympanometric shapes vary as a function of the immittance component measured and the probe tone frequency used. The tympanometric shape changes in an orderly fashion as the probe frequency increases. At the lowest frequency (220 Hz), the amplitude of susceptance is slightly less than that of admittance but approximately twice the conductance amplitude. As the probe tone frequency increases the peak magnitude of conductance increases rapidly and becomes greater than susceptance value by 510 Hz. This result is expected as mass susceptance (B_m) increases and compliant susceptance (B_c) decreases as a function of frequency. The algebraic sum of two susceptance values (B_t) then gradually decreases, reaches 0 at resonance (between 710 Hz and 810 Hz for descending pressures and between 510 and 610 Hz for ascending pressures) and then becomes negative or mass controlled (810 Hz for +/- and 610 Hz for -/+) as probe frequency increases further. The ear becomes mass controlled if the minimum susceptance value in the area of the notch is below the tail value at -400 dapa (Shanks, 1984).

It has been observed that at 220 Hz the tympanogram is symmetrical with a single peak near the ambient pressure. As the probe frequency increases the tympanograms become more assymmetrical with B_A values on the positive pressure side of the tympanogram. At 880 Hz, B_A becomes a monotonically increasing function of the ear canal pressure. The mean G_A typanograms for normal subjects increases in magnitude as probe frequency increases, but remain nearly symmetrical around the maximum that occurs near the ambient ear canal pressure. The increase in assymetry that occurs in B_A tympanogram as probe frequency increased can be explained by arithmetic interaction of R_A and X_A- It is assumed that X_A decreases monotonically as probe frequency increases from 440 to 880 Hz, while R_A remains constant. Again similar increase in peak conductance was obtained across trials (Wilson, Shanks and Kaplan, 1984).

The tympanograms begin to notch as the probe tone frequency is increased. Shanks (1984) reported that as probe tone frequencies increases notching of the susceptance tympanogram occurs first, and then the conductance and admittance tympanograms are notched. Similar results were also obtained by Sabitha (1994) and Monica (1994) in a study of children and adults on the Indian population.

It has also been noted that with the increase in trials there has been changes in the static susceptance and conductance values and also in the tympanometric patterns. Osguthrope and Lam (1981) reported a 12% mean increase in the 678 Hz peak susceptance across 10 tympanometric sweeps in 5 human subjects. Similarly they also reported that the peak susceptance and the peak conductance values increased as the number of tympanometric runs increased. The mean 678 Hz susceptance peak in cats increased 13% between first and second trials, with a 17% increase in the tenth trial. Similar increases was also found for conductance.

Wilson et.al. (1984) on a study on 24 normal subjects concluded the following:

(1) The shape of tympanograms for many subjects became more complex as the number of trials increased. Eg: a 1B1G tympanometric set.on initial set evolved to 3BlG set.on latter trials.

(2) Changes among trials generally are manifested as increase in admittance, susceptance and conductance for 226 Hz probe tone. Inter subject variability for the 678 Hz probe tone was attributed to notched tympanograms. The mean 678 Hz susceptance function, particularly for ascending pressure changes, decreased with successive tympanometric

trials. The susceptance magnitude increased across trials for the single peaked group. In contrast for the notched group, the depth of susceptance notch increased with trials, thereby producing decrease in the susceptance magnitude.

The complexity of the admittance, susceptance and conductance tympanograms is also found to vary as a function of direction of ear canal pressure change and the rate of ear canal pressure change. Several investigators (Porter and Winston, 1973; Margolis and Smith, 1977; Margolis, Osguthrope and Popelka, 1978) have also noted that 678 Hz susceptance tympanograms often are single peaked for descending pressure changes but notched for ascending pressure changes.

The complexity of the tympanograms obtained with ascending (-/+) ear canal pressure direction is greater than that with descending (+/-) pressure directions (Wilson, Shanks, Kaplan, 1984).

Several others (Creten and Vancamp, 1974; Wilson et.al., 1984; Margolis et.al., 1985) have noted that tympanometric shape at 678 Hz is less complex, with less frequent notching for descending than for ascending ear canal pressure changes.

Wilson et.al. (1984) quantified the unnotched susceptance, conductance and admittance tympanograms at

226 Hz and 678 Hz in terms of tympanometric width. They found that the tympanametric width varied significantly with pressure change. The mean negative tympanometric widths for both susceptance and admittance were significantly wider for descending than for ascending pressure changes at 226 Hz.

At 678 Hz, the mean total tympanometric width for unnotched tympanograms was affected by the direction of pressure change. The tympanometric width was significantly greater for descending than ascending pressure changes for susceptance, conductance and for admittance (Shanks and Wilson, 1986).

On the other hand data from several studies (Beattie and Leamy, 1975; Porter and Winston, 1973; Williams, 1976) have shown that direction of pressure change does not affect peak susceptance and conductance in normal middle ears.

The effect of the rate of ear canal pressure change on peak static immitance, peak static admittance is lower for slower rates of pressure change than for faster rates (Feldman, Fria, Palfrey and Dellecker, 1984; Ivarsson, Tjernstrom, Bylander and Benrup, 1983; Williams, 1976).

Several other authors have reported a higher incidence of tympanometric notching and/or deepening of the notch for ascending than for descending pressure changes and for fast rates (greater than 30 dapa/s) for pressure change with high frequency probe tones (678 or 800 Hz) (Alberti and Jerger, 1974; Creten and Vancamp, 1974; Margolis, Margolis and Smith, 1977; Osguthrope and Popelka, 1978; Porter and Winston, 1973; Wilson et.al., 1984).

On the other hand Shanks and Wilson (1986) concluded that notching was slightly less frequent for the slowest rate of pressure change, but the rate effect could not be stated strongly due to the absence of data. When shape was specified in terms of trympanometric width unnotched susceptance, conductance and admittance tympanograms did not change significantly with width.

Vanhuyse et.al. (1975) made an attempt to classify multicomponent tympanograms into different categories based on the shape of the susceptance and conductance tympanograms. A review of Mathematical papers by Vanhuyse et.al. (1975) and Vancomp et.al. (1978) suggests the following types of regular and 'W' shaped susceptance and conductance tympanograms using a 220 Hz and 660 Hz probe tone. The tympanograms were classified according to the number of positive and negative peaks (extrema) exhibited in the susceptance and conductance tympanograms:

id) Type 1B1G - In type 1B1G, both the susceptance (B) and conductance (G) tympanograms are single peaked.

(2) Type 3 BIG - The recorded susceptance (B) displays a maximum situated on either side of the ear canal pressure value of central minimum. The conductance (G) has only one maximum near the pressure value of the central minimum in the susceptance.

(3) Type 3B3G - As the middle ear system becomes more mobile (but normal), both susceptance and conductance show two maxima on either side of a central minimum. Both curves have 3 extremas. The specific sequence of occurance of extreme determine the pattern is regular. As a consequence therefore the pressure interval between the conductance maxima is smaller than the pressure interval between susceptance maxima; both central minima are found to be nearly at the same pressure value.

4. Type 5B3G - This complex regular pattern occurs seldom, but if systematics are obeyed and pattern is not too broad, this tympanogram set must be considered normal. In either the positive or negative pressure direction, the following sequence of pressure extrema are encountered.

(a) A susceptance maximum, (b) a conductance maximum, (c) a susceptance minimum, (d) close together, the central maximum in the susceptance and central minimum in the conductance, (e) a susceptance minimum, (f) a conductance maximum, (g) last a susceptance maximum.

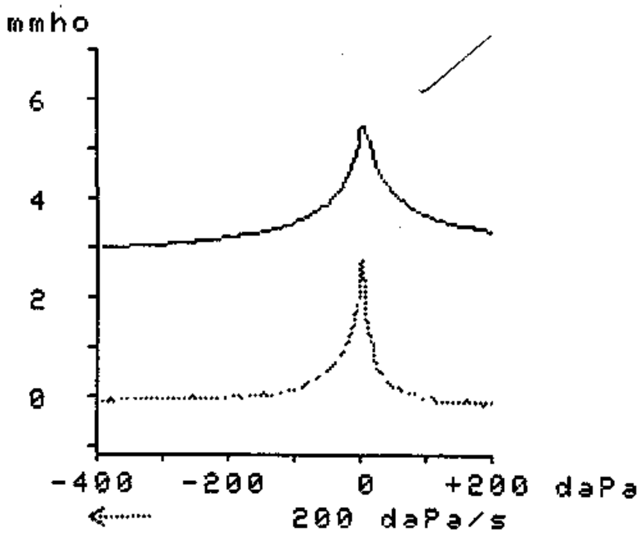

Figure 1: (a) Tympanograms with one extrema in the susceptance (B) and conductance (G) (1B1G tympanogram).

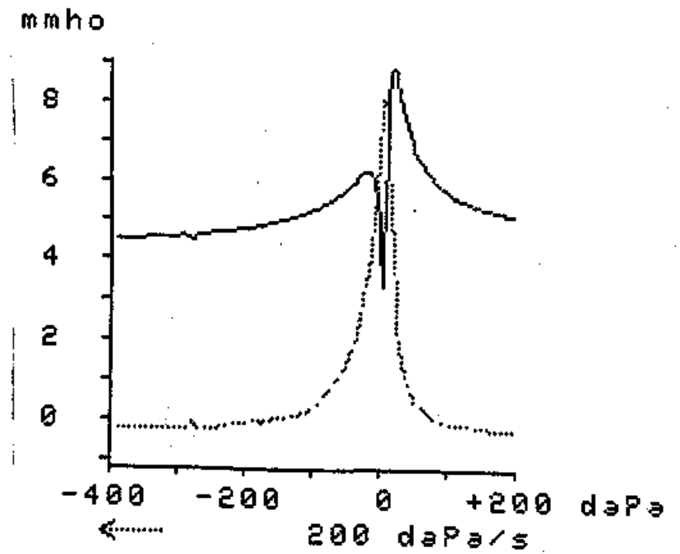

Figure 1: (b) Tympanograms with three extremas in the susceptance (B) and one extrema in the conductance (G) (3B1G tympanogram)

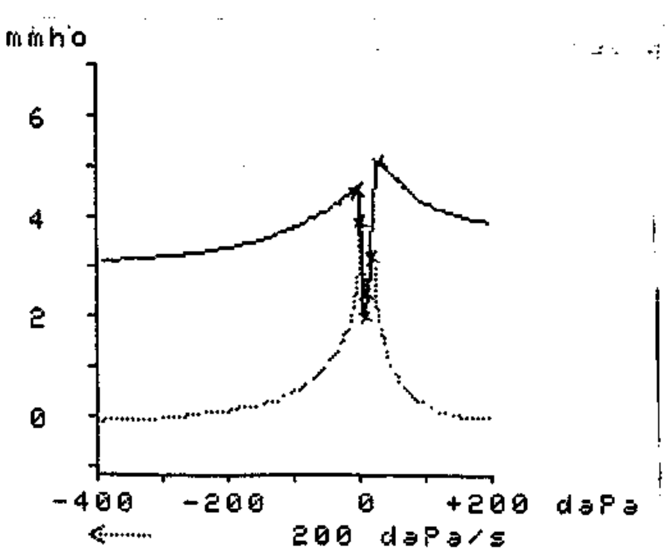

Figure 1: (c) Tympanograms with three extremas in the susceptance CBT and three extremas in the conductance (G) (3B3G tympanograms)

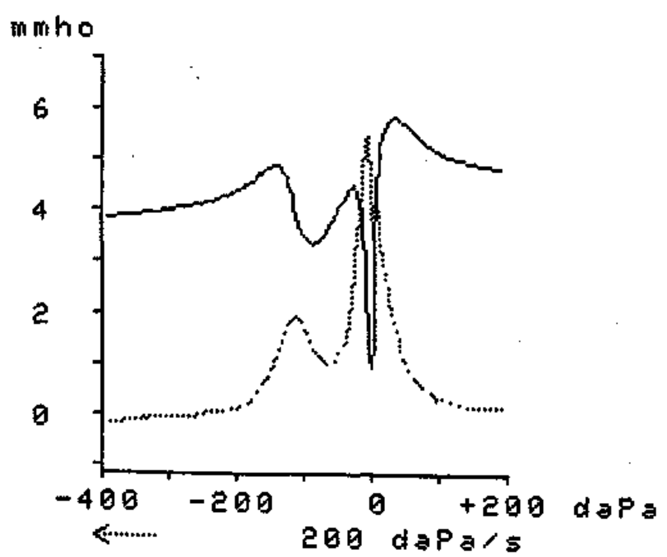

Figure 1: (d) Tympanograms with five extremas in the susceptance (B) and three extremas in the conductance (G) (5B3G tympanograms)

All curves with more than five extrema for susceptance and/or three extrema for conductance are irregular. Other combinations such as 5BIG or curves with scrambled sequence of extrema are also irregular.

Although normal 226 Hz susceptance and conductance tympanograms are always 1BIG, normal tympanograms at 678 Hz, fall into all four categories (Margolis and Shanks, 1984).

Vande Heyning et.al. (1982) reported that the pressure difference between the first and last susceptance maximum in all normal cases was less than 75 dapa for 3BIG or 3B3G and less than 100 dapa for type 5B3G. They further reported that the very broad type of 3BIG tympanogram can occur occasionally for perfectly normal subjects. However the term broad was not defined.

A study by Vancamp et.al. (1983) and further study by Wiley et.al. (1987) on young adults for a 660 Hz (or 678 Hz) probe tones, a pump speed of 30 dapa/s and the negative to positive direction, obtained the percentage of occurance of each of the Vanhuyse categories in the adults. These values are shown in table.

Study	Category			
	1B1G	3B1G	3B3G	5B3G
Vancamp et.al. (1983)	57	28	6	9
Wiley et.al. (1987)	76	17	6	1

The study by Sabitha (1994) and Priya (1994) found that at higher probe tone frequencies (678 Hz and 1000 Hz) notched tympanograms were obtained in susceptance (B) while at all frequencies majority of the ears showed single peaked conductance tympanograms.

Several studies have confirmed that the Vanhuyse model accounts for a wide variety of tympanometric patterns observed in normal and abnormal ears (Liden, Bjorkman, Nyman and Kunov, 1977; Margolis and Popelka, 1977; Creten, Vanpeperstraete and Vancamp, 1978; Margolis, Osguthrope and Popelka, 1978).

In the presence of a middle ear disease, the relation between stiffness, mass and friction elements will change, resulting in a shift in resonance frequency of the middle ear transmission system. If the middle ear is stiffened because of a pathology such as otosclerosis, then the ear will remain stiffness controlled over a wider frequency range than normal, and thus the resonant frequency of the middle ear will be shifted towards a higher than normal frequency. In contrast if the ear becomes mass controlled because of any pathology such as ossicular discontinuity, then the resonant frequency of the middle ear will decrease (ASHA Working Group on Dural Acoustic-Immittance Measurements Committee on Audiologic Evaluation, 1988).

Vancamp et.al. (1986) applied the Vanhuyse et.al. model (1975), to simulated high impedance pathologies and identified the underlying system and tympanometric patterns associated with otosclerosis, secretory otitis media and lateral ossicular fixation. Data from previous experiments on shape and absolute value of resistance and reactance tympanograms at 226 Hz and 678 Hz were taken. The results were unique to each of the three high impedance pathologies simulated.

Margolis and Shanks (1991) reported that the criteria used by Vanhuyse et.al. (1975) was effective for detecting the two major categories of low impedance pathologies - ear drum abnormalities and ossicular lesions, and some high impedance pathologies such as otitis media in intermediate stages of development and remission.

High impedance pathologies

High impedance pathologies of the middle ear are associated with various forms of otitis media, ossicular fixation and space occupying lesions such as primary and invading tumours. The effects of these pathologies are complex and the degree of the tympanometric abnormality is not closely associated to the severity of the disease. Potentially life threatening middle ear diseases may produce subtle tympanometric abnormalities and clinically unimportant conditions of the middle ear may produce gross abnormalities in the tympanogram. The most obvious form of high impedance pathology is a flat tympanogram, when fluid or neoplasm occupies the normally air filled cleft the impedance of the middle ear is increased and the tympanogram is flat. However there are more moderate high impedance conditions that represents clinically significant pathology that do not produce flat tympanograms. In some of these conditions, the tympanograms go through a stage in which because of mass loading of the middle ear the impedance is actually lower than normal and a variety of multipeaked patterns occur. As the condition progresses, the tympanograms begin to flatten and the impedance becomes abnormally high (Margolis and Shanks, 1991).

Berry et.al. (1975) performed a tympanometric evaluation on children with a history of recurrent otitis media or otoscopic evidence of persistant middle effusion or both, followed by myringotomy.

Tympanometric patterns of susceptance (B) and conductance (G) at 220 Hz and 660 Hz were compared and criteria was developed to determine the presence or absence of effusion. The results revealed (1) High negative middle ear pressure is not necessarily a reliable indicator of middle ear effusion. (2) Tympanometry can be used reliably as an indicator of middle ear effusion. (3) In general otoadmittance at 660 Hz appears to be a better indicator of effusion than 220 Hz.

In a study of fresh human temporal bones by Shanks (1984), tympanograms were recorded with 0.4 cm^3 of water in the middle ear space, the magnitude of admittance (Y) remained normal but susceptance (B) was notched,particularly at 678 Hz. This finding was consistent with increase in mass of the tympanic membrane. When tympanograms were recorded with 1 cm^3 of fluid in the middle ear, the 226 Hz tympanograms were single peaked but the admittance (Y) and susceptance (B) tympanograms reduced in amplitude and broadened. The 678 Hz probe tone, showed a much more dramatic change with a small amount of fluid in the middle ear space than 226 Hz tone. The 678 Hz probe tones had broad notching demonstrating the superiority of a high frequency probe tone in showing effects of increased mass.

Margolis and Shanks (1985) studied tympanograms in subjects with secretory otitis media, the 226 Hz, 'Y', 'B' and 'G' tympanograms were characterised by shallow peaks and the 678 Hz susceptance tympanogram were abnormal as the notch width in the tympanogram exceeds 75 dapa.

When data from resistance and reactance tympanograms were used for simulations of tympanometric patterns associated with secretory otitis media three extrema conductive tympanograms were seen, the conductance maxima shifted towards more extreme ear canal pressures as reactance was shifted increasingly more positive. The shapes of susceptance tympanograms were extremely difficult to classify as the notches were extremely broad and became progressively flatter as reactance increases towards more positive values. The susceptance tympanogram also showed 3B patterns as predicted by Vanhuyse et.al. (1975) model (Vancamp et.al., 1986).

Vancamp et.al. (1986) recorded tympanograms at the plane of the probetip from a subject with resolving secretory otitis media. They found that susceptance was mass controlled with all the three tympanograms recorded at the probe tip displaying a broad notch near 0 dapa.

Tympanograms obtained in cases of otitis media in a resolving stage, show a slightly low static admittance and a normal tympanic width at 226 Hz; at 678 Hz the pattern is a very wide 3B3G, indicating a mass controlled ear, probably due to mass loading of the middle ear. The pattern is abnormal because of the broad interval between susceptance peaks (Margolis and Shanks, 1991).

It has been reported that tympanograms recorded on cases with external otitis media and debris against the tympanic membrane are normal at 226 Hz but are abnormally, broadly notched (greater than 100 dapa) and mass controlled at 678 Hz (Shanks, 1984). Margolis and Shanks (1991) additionally found that tympanograms with external otitis are characterised by normal height and width at 226 Hz. At 678 Hz, the pattern was a very wide 5B3B due to mass loading of the ear drum. The pattern was abnormal because of wide interval between the peaks.

Shanks (1984) recorded tympanograms from patients associated with three middle ear conditions:

1. Patent PE tube and a history of chronic ear achs
2. Nasopharyngeal mass occluding the Eustachian tube
3. Tympanic membrane perforation

It was observed that for patient with PE tube at 678 Hz, the susceptance and conductance tympanograms were reverse, i.e., conductance elevated and susceptance below the level of the equipment. For nasopharyngeal mass occluding the Eustachian tube, the conductance and susceptance tympanograms were reversed and all functions were off sale. For tympanic membrane perforation, the reversal of susceptance and conductance tympanograms occurred even at 220 Hz. Thus it was concluded that in the absence of PE tube, a reversal of conductance and susceptance provides strong evidence for normal middle ear and mastoid system.

Colletti (1977) reported that probe tone frequencies at which notched tympanograms occurred in otosclerosis are higher (M = 1300 Hz) in comparison with normal ears. In addition to the increase in stiffness due to otosclerosis, a steeper or more sharply peaked tympanograms have been reported in some subjects with confirmed ossicular fixation in comparison with normal subjects (Ivey, 1975; Dieroff, 1978).

Shanks (1984) observed that tympanograms for cases with otosclerosis are characterized by greater amplitudes of susceptance tympanograms than conductance tympanogram (phase angle greater than 45°) at 678 Hz, that is the resonant frequency of the middle ear was increased due to stiffness caused by the disease process. The increase in resonant frequency was more obvious at 678 Hz than at 226 Hz. The 678 Hz tympanograms usually showed a narrow peak in patients with otosclerosis.

Vancamp et.al. (1986) reported that when tympanograms characteristic of otosclerosis were simulated from normal, stiffness controlled reactance tympanograms, as predicted by Vanhuyse et.al. (1975) Model all the tympanograms were bell shaped and belonged to lBlG type at 660 Hz. They further reported that for admittance tympanograms (Y_1, B_1 and G_1) recorded in the plane of the probe tip for a subject with surgically confirmed otosclerosis, the resemblance of tympanograms to simulated tympanograms was good. In both cases, the magnitude of susceptance was approximately twice as large as conductance, and the peaks are sharper than normal.

Margolis and Shanks (1991) reported that the tympanograms from patients with stapedeal fixation in otosclerosis are frequently normal at 226 Hz and 678 Hz, hence they concluded that it may be necessary to use more than two probe frequencies to detect otosclerosis. They also opined that multifrequency tympanometry, by providing a method of estimating the resonant frequency of the middle ear, may prove to be an effective method for detecting stapedial fixation.

In lateral ossicular fixation, stiffness instead of mass is added to the entrance of the middle ear system. Because the fixation is located lateral to the incudo-stapedial joint, the entire ossicular chain is severely impaired in its vibratory movement for all pressures across the tympanic membranes (Vancamp et.al., 1986). In the three simulated tympanograms generated for lateral ossicular fixations by Vancamp et.al. (1986), one condition produced 3B1G pattern and the other two conditions produced 1B1G types. Admittance (Y_1) and susceptance (G_1) tympanograms recorded at the probe tip showed no central extremum, instead the two tympanograms increased monotonically as a function of ear canal pressure. Vancamp et.al. (1986) further observed that the admittance (Y_1 and the susceptance (B_1) tympanograms recorded from a subject with fibrous adhesions fixing the entire ossicular chain were flat and the conductance (G_1) tympanograms showed a broad peak. These tympanograms recorded using probe tone of 678 Hz was similar to the shape of the simulated typanograms.

The resultant effect of stapes fixation in cats of an acoustic susceptance and conductance tympanograms was studied by Margolis et.al. (1978). The results showed marked increase in the height of the tympanometric peak in cats with stapes fixation except for 220 Hz G_a tympanograms which in normal animals did not have a clearly defined peak. On visual examination, the tympanograms for stapes fixation condition were not clearly different from the normal, whereas when data was converted to estimate static acoustic impedance of the middle ear, the two groups - normal and stapes fixation separate into two distinctly different distributions.

Shanks (1984) obtained admittance (Y), susceptance (B) and conductance (G) typanograms on patients with different middle ear conditions - tympanic membrane retraction, fibrous adhesions and middle ear effusions secondary to nasopharyngeal mass occluding the Gustaetian tube, flat tympanograms were obtained which were indistinguishable for all the three cases. These findings highlight the fact that same tympanograms may be obtained for different middle ear conditions and hence reinforces the idea that tympanometry does not indicate the exact disease process causing a conductive hearing loss.

Low impedance pathologies

Although not as common as high impedance pathologies low impedance pathologies can be identified more easily because they produce an obvious alteration of the typanometric shape. These shape alterations are more evident near the resonant frequency of the middle ear than at frequencies remote from the middle ear resonance. Consequently high frequency probe tones such as 678 Hz are more effective than low frequencies in identifying these pathologies (Margolis and Shanks, 1991).

Margolis et.al. (1978) studied effects of experiment-ally induced ossicular lesions on susceptance and conductance tympanograms. The results showed single peaked B_a and G_a tympanograms at 220 Hz, although when compared with normal control condition the amplitude of the peaks were increased. At 600 Hz, the susceptance and conductance tympanograms had double peaks. For data obtained after removal of incus, the B_a and G_a tympanograms tended to be more dramatically notched and more displaced towards positive values.

Susceptance (B) and conductance (G) tympanograms were recorded from a fresh temporal bone following fracture of anterior stapes crus with intact stapedial tendon and fracture of both crura. An unusual notched pattern was seen when one crus was removed, but 678 Hz tympanogram did not become grossly abnormal until both crura were fractured. Tympanometric shape was altered more at 678 Hz than at 226 Hz by increase in mass (Shanks, 1984).

Van de Heyning et.al. (1982) studied patients with ossicular abnormalities and human temporal bones and reported three types of susceptance conductance tympanograms for tympanossicular systems having an incudo-stapedial pathology.

(1) The most common from patients and temporal bones consisted of regular 'W shaped but broad tympanograms with one or more supplementary (pathological) peaks superimposed on susceptance and/or conductance curves. In cases of W-shaped patterns of type 3B3G or 5B3G, the supplementary

peaks were nearly always situated between the outer regular susceptance maxima of the underlying 'W' shaped pattern. The pressure interval between the outer regular maxima, when present was greater than 75 dapa.

(2) The second type was obtained from 2 of 5 temporal bones. These temporal bones produced regular broad 3B3G or 5B3G tympanograms with a pressure interval between the outer susceptance maxima of about 150 dapa.

(3) The third type of susceptance -conductance tympanograms involved a double 'W' shaped patterns.

Shanks (1984) reported that for increased mass attributable to tympanosclerosis of the tympanic membrane, the tympanogram was abnormally notched at both probe tone frequencies (220 Hz and 660 Hz). Similar results were obtained in a later study by Shanks et.al. (1988). They reported that typanograms in tympanosclerosis are abnormal; broad notching occurs at 226 Hz and the shapes are too complex and broadly notched at 678 Hz. Pathologies of the tympanic membrane such as tympanosclerosis, and monomers often produce abnormal mass controlled tympanograms with little if any affect on hearing sensitivity. Margolis and Shanks (1991) also found that tympanograms obtained with tympanosclerotic plaques on the tympanic membrane have three extrema, an abnormal result at 226 Hz. At 678 Hz with an increasing air pressure, the pattern meets the requirements for normal multipeaked tympanograms although the shapes are somewhat irregular.

Whether multifrequency, multicomponent tympanometry is useful in the detection of an ossicular abnormality when ear drum abnormality coexists is controversial. Zwislocki (1982) demonstrated that acoustic impedance at the ear drum is more sensitive to abnormalities of the ear drum, malleus and incur than those of the stapes.

In a study of the tympanometric effects of specific ear drum scars and ossicular abnormalities in cats, Osguthrope and Charleston (1986) found that a normal middle ear could be differentiated from stapes fixation or incudostapedial discontinuity using static immitance parameters and tympanogram morphology. Twenty per cent of the myringotomy scars produced abnormal 660 Hz typanograms but this effect could be distinguished from changes caused by a concomittant ossicular abnormality. The very low impedance of a 50% myringectomy scar resulted in tympanograms which could not be differentiated from an ossicular discontinuity alone. With this neomembrane, stapes fixation could even not be differentiated from an ossicular discontinuity. These facts supported the view that tympanometry should be interpreted as a part of battery of tests which includes otoscopy, audiometry and acoustic reflex measurements.

The above mentioned studies in the review of literature provides the evolution of multifrequency multi-component tympanometry, its findings in normal ears and the effects produced on it for various pathologies causing middle ear lesions. As evidenced from the literature it can be stated with confidence that a combination of multi-frequency and multicomponent tympanometry is a better indicator of a middle ear condition than a low frequency single component tympanometry.

A majority of the studies proving the superiority of multifrequency multicomponent tympanometry over single frequency single component tympanometry have been carried out on pathologies such as otosclerosis, ossicular discontinuity, tympanic perforation, external otitis, tympanosclerosis. These pathologies may or may not show a changes in the 226 Hz single component tympanometry.

One of the ways of studying the advantage of the multifrequency, multicomponent tympanometry over single component low frequency tympanometry is to study the then tympanograms in subjects with conductive pathologies which show normal tympanograms with normal static compliance at 226 Hz.

Therefore the present study was carried out to study multicomponent (admittance, susceptance and conductance) tympanometry at 226 Hz, 678 Hz and 1000 Hz in subjects (adults and children) with conductive or mixed hearing loss, with a normal 'A' type tympanograms and absent ipsilateral and contralateral acoustic reflexes.

CHAPTER III

METHODOLOGY

1. **Subjects:** A total of 20 ears of adults and children (adults = 17, children = 3) with conductive or mixed hearing loss were included in the study. Age of the subjects ranged from 5 years to 76 years with a mean age of 36.56 years.

All the ears had a pure tone average (PTA) of greater than or equal to 20 dB HL with a significant air-bone gap (greater than 10 dB) in the octave frequencies from 250 Hz to 8 kHz (ANSI, 1969). Also immitance evaluation using 226 Hz probe tone revealed 'A' type tympanogram with normal static compliance value in all the ears. Both ipsilateral and contralateral reflexes were absent in the ear with conductive or mixed pathology.

Instrumentation

An audiometer namely Madsen OB822 caliberated according to ISO standards (1969) was used to check the behavioural thresholds (air conduction using earphone TDH 39 housed in Mx/41 ear cushion and bone conduction using bone vibrator radio ear B-71) at octave frequencies (air conduction from 250 Hz to 8000 Hz and bone conduction from 250 Hz to 4000 Hz).

A calibrated Granson Stadler Middle Ear Analyser 33 version 2 was used for the present study. It is a micro-processor based admittance meter which has facilities for complete automatic or manual diagnostic testing 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.

Test procedure

1. A pure tone audiogram was initially obtained for the octave frequencies 250 Hz to 8000 Hz for air conduction and for the frequencies 250 Hz to 4000 Hz for bone conduction, using the Modified Hughson-Westlake procedure.

2. Then immitance evaluation was done. The patient was seated comfortably. The probe box was attached to the velcrostrip on the shoulder mount or clothes clip and positioned on the patient. The ear canal was then inspected for presence of any wax, foreign body or discharge. The probe with an appropriate sized eartip was selected and was securely inserted into the ear canal to obtain an airtight seal.

Initially admittance tympanogram was recorded using 226 Hz probe tone and following parameters were recorded.

a. Static compliance

b. Peak pressure

Ipsilateral and contralateral acoustic reflexes were checked at the frequencies 250 Hz, 500 Hz, 1000 Hz and 4000 Hz.

In the second step, multicomponent tympanometry (B and G) were recorded using the parameters mentioned below for 226 Hz, 678 Hz and 1000 Hz.

Starting pressure

The starting pressure for the study was from +2000 dapa.

Pressure range

The pressure was varied from +200 dapa to -400 dapa.

Pump speed

Pump speech selected for the study was 200 dapa/sec.

Compensated/uncompensated tympanometry

Uncompensated tympanometry was obtained for the study.

For admittance tympanogram, peak pressure and static compliance values were recorded.

The susceptance (B) and conductance (G) tympanograms were classified as 1B1G, 3B1G, 3B3G or 5B3G using the criteria given by Vanhuyse et. al. (1975). Further the difference in pressure between the outermost maxima in the susceptance tympanogram was also recorded.

CHAPTER IV

RESULTS AND DISCUSSION

The aim of the present study was to study the admittance (Y), susceptance (B) and conductance (G) tympanograms at three different probe tone frequencies (226 Hz, 678 Hz and 1000 Hz), in subjects who had conductive hearing loss and in whom the middle ear pathology could not be inferred using single frequency, single component tympanometry (i.e. an 'A' typitympanogram at 226 Hz admittance (Y)).

The data was collected from a total of 22 ears. Based on the symptoms presented by the subjects, they were classified into two main groups.

Group 1 - Consisted of subjects with the complaint of ear pain.

Group 2 - Consisted of subjects with previous history of ear discharge.

In addition to subjects in these two groups there was one subject with the complaint of ear pain as well as a previous history of ear discharge.

Another subject complained of tinnitus and blocking sensation in the ear.

The Van Huyse et.al. (1975) model was applied to the collected data. The tympanograms obtained from each ear was classified as 1B1G, 3B1G, 3B3G and 5B3G. A tympanogram from these set of categories was considered abnormal if

1. the difference between the outermost pressure maxima for each susceptance tympanograms classified as 3B1G or 3B3G were greater than 75 dapa and/or the difference between the outermost pressure maxima for each susceptance tympanograms classified as 5B3G exceeded 100 dapa.

2. the tympanometric patterns was observed at a frequency lower than what is expected in normals.

3. tympanometric patterns could not be fitted into any of the categories which were described in the model (Eg. 5B1G, 3B5G, 5B5G, etc.).

Based on these measures taken into consideration the data collected was divided into two subgroups.

1. Normal findings (NF) subgroup for the admittance (Y) susceptance (B) and conductance (G) tympanograms at all probe tone frequencies.

2. Abnormal findings (ABF) subgroup for the admittance (Y), susceptance (B) and conductance (G) tympanograms for all or any of the three tone frequencies.

No statistical method could be applied for analysis of data as it was a heterogenous group and the number of subjects in each group was limited.

Group 1: Ear pain

NF	ABF
N = 5	N = 8

Group 2: Previous history of ear discharge

NF	ABF
N = 1	N = 4

NF = Normal findings; ABF = Abnormal findings;
N = Number of ears

Group 1: Ear pain

There were 13 ears with the complaint of ear pain, among them 5 ears showed normal findings (NF subgroup) for both conventional and multicomponent tympanometry whereas 8 ears showed abnormal findings (ABF subgroup). No abnormality was detected during otological evaluation for all the five ears with normal findings obtained during multicomponent tympanometry. Out of the 8 ears in the ABF subgroup, 4 ears did not reveal any abnormality during evaluation, the other 4 ears had retracted tympanic membrane, out of these 4 ears, 1 ear had a 3B1G pattern at 1 kHz probe tone and other 3 ears had 3B3G pattern at 1 kHz. The difference in pressure between the outer most extrema of the susceptance (B) tympanogram ranged from 80 dapa to 225 dapa. Three ears with otologically normal findings showed 3B3G tympanograms at 1 kHz with pressure difference of 120 dapa, 95 dapa and 220 dapa respectively and one ear with otoscopically normal findings showed a 3B1G tympanogram with a pressure difference of 130 dapa at 1 kHz.

All the ears in the ABF group with otologically normal findings had minimal conductive hearing loss and abnormal tympanometric patterns using the multifrequeny, multicomponent tympanometry. These findings suggest that subtle changes in the middle ear can be detected using multicomponent tympanometry. A follow up of these patients are essential to prove this assumption.

The findings obtained from the above data are consistent with the findings of Alberti and Jerger (1974) that multifrequency especially high probe tone frequency, multicomponent tympanograms are sensitive even to the slightest abnormality of the tympanic membrane and that multiple tympanograms can occur without visible ear drum pathology.

2. Group 2: Previous history of ear discharge

A total of 5 ears were included in this group. All the ears showed pure tone audiograms which revealed minimal or mild conduction hearing loss. Out of the 5 ears, only one ear showed normal findings both for conventional tympanometry and multicomponent,tympanometry. No abnormality was detected during otological evaluation for the ear with normal findings (NF subgroup).

Out of the 4 ears in the ABF group, otological evaluation revealed scarred tympanic membrane in 2 ears and tympanosclerotic path in one ear. One subject reported that surgical intervention was carried out in his left ear, but the details of the surgery was not available.

The ear with tympanosclerotic patch had a 5B3G tympanometric pattern at 678 Hz with a pressure difference of 175 dapa between the outermost pressure maxima and a 5B5G tympanometric pattern at 1 kHz with a pressure maxima of 285 dapa. These tympanograms were classified as abnormal as the tympanometric patterns (5B3G) were obtained at a lower probe tone frequency than what is to be obtained in normals (i.e. 5B3G at 1 kHz probe tone) and 5B5G tympanometric pattern which could not placed in any of the categories described by the model. These abnormal tympanometric patterns are shown in the figure (Figures 2a,b,c,d).

Another ear diagnosed as 'early ear discharge with scarred tympanic membrane' by the otologist showed an abnormal tympanometric configuration at 1 kHz. The abnormal configuration consisted of the presence of small peaks (2 in number) over the susceptance tympanograms and one small additional peak in the conductance tympanogram. The abnormal tympanometric configuration is shown in figure (Figure 3a).

For another ear diagnosed as 'scarred tympanic membrane' abnormal tympanogram was obtained at 1 kHz probe tone frequency and the tympanometric configuration was of the type 3B3G. The pressure difference between the outermost maxima was 85 dapa for this ear.

The ear in which no abnormality was detected during the otologic examination but had a history of surgical

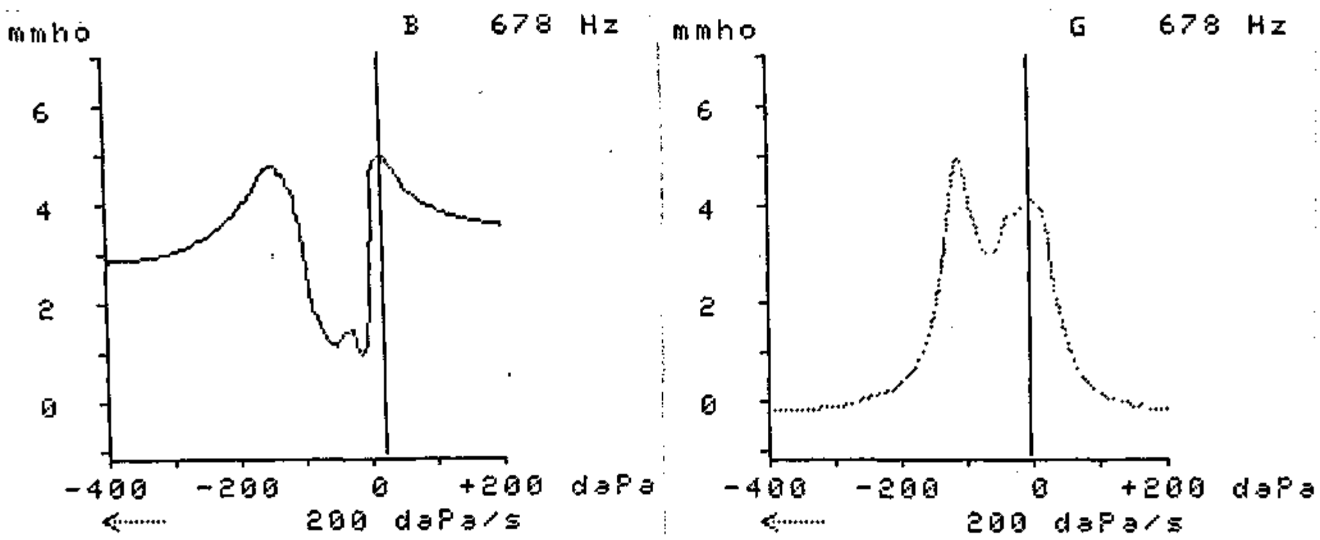

Figure 2: (a) 5B3G tympanogram obtained from an ear with a 'tympanosclerotic patch' at a probe tone frequency of 678 Hz.

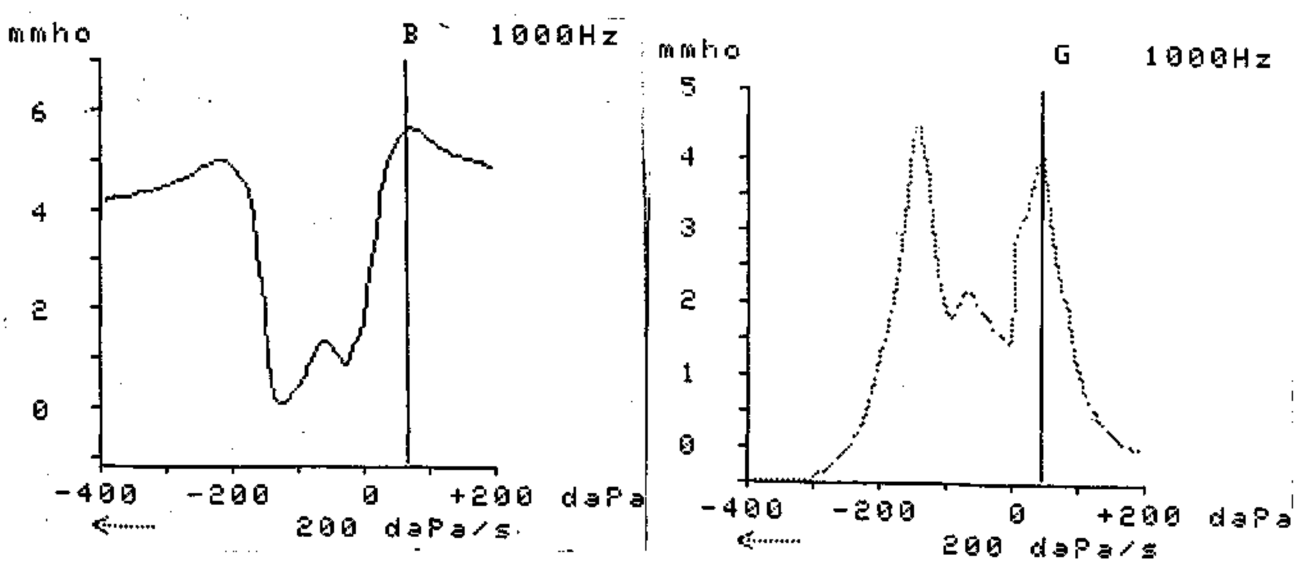

Figure 2: (b) 5B5G tympanogram obtained from the ear with 'tympanosclerotic patch' at a probe tone frequency of 1000Hz.

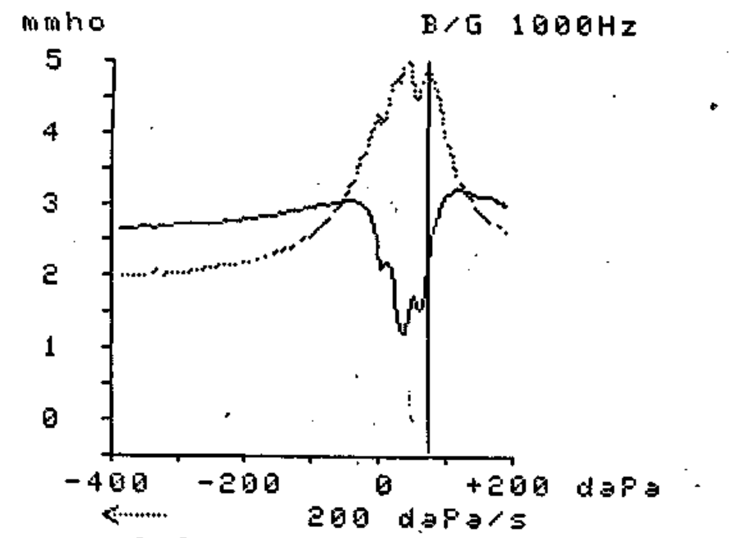

Figure 3: Tympanometric configuration obtained for an ear diagnosed as 'early ear discharge with scarred tympanic membrane' at a probe tone frequency of 1000 Hz.

Group 1: (ABF subgroup)

	3B1G		3B3G		5B3G	
	678 Hz	1000 Hz	678 Hz	1000 Hz	678 Hz	1000 Hz
Normal otoscopic findings N = 4	-	1	-	3	-	-
Abnormal otoscopic findings N = 4	-	1	-	3	-	

Group 2: (ABF subgroup)

	3B1G		3B3G		5B3G		5B5G	
	678 Hz	1000 Hz	678 Hz	1000 Hz	678 Hz	1000 Hz	678 Hz	1000 Hz
Abnormal otoscopic findings N = 3	-	-	-	2	1	-	-	1

N = Number of ears; ABF = Abnormal findings intervention also showed an abnormal tympanogram only at 1 kHz. The tympanometric pattern was 3B3G with a pressure difference of 90 dapa.

3. Group 3: Ear **pain with previous history of ear discharge**

One subject with the complaint of ear pain and previous history of ear discharge in the right ear showed a scarred tympanic membrane during otological evaluation. The pure tone audiogram showed minimal conductive hearing loss. Multicomponent tympanometry showed a 3B3G pattern at 1 kHz with the pressure difference of the outer maxima of the susceptance tympanogram of 120 dapa.

The data obtained in groups 2 and 3 for ear pain and previous history of ear discharge are in confirmation once again with the studies reported by Alberti and Jeyer (1974) that high frequency tympanograms (especially 800 Hz) are exquisitely sensitive to the slightest abnormality at the tympanic membrane. The data above suggests that any abnormality at the tympanic membrane which does not produce an obvious hearing loss in pure tone audiometry or which cannot be visible under otoscopic examination may be detected if multicomponent multifrequency tympanometry is used and that probe tone frequencies around 1000 Hz are more reliable indicators of an ear drum pathology.

Margolis and Shanks (1991) have also reported multipeaked tympanograms with excessive number of extrema in a subject with a manomere resulting from a healed perforation.

Further it can be concluded that symptoms of ear pain and previous history of ear discharge may not produce or show changes in low frequency single component tympanometry, but produce distinct patterns when multifrequency, multicomponent tympanometry is done.

Early stages of otitis media

One subject with the complaint of hearing loss, blocking sensation and tinnitus in the right ear was evaluated. Pure tone audiometry revealed minimal conductive hearing loss in that ear. The 226 Hz admittance (Y) tympanogram revealed a positive peak pressure with normal static compliance and gradient values ('A' positive). Multi-component tympanometry showed 3BlG pattern with a pressure difference of 115 dapa between outermost extrema of susceptance tympanogram at 1 kHz. The subject was diagnosed as having 'early stage of otitis media' after otological evaluation. Thus multicomponent tympanometry proved to give a valuable information compared to low frequency single component tympanometry in demonstrating the effects of 'early stages of otitis media' in the middle ear system.

Similar results were reported by Mayolis and Shanks (1991), who stated that in early stages of fluid in the middle ear, the tympanograms go through a stage in which, because of the mass loading of the middle ear the impedance is actually lowered than the normal and a variety of multi-peaked patterns occur.

CHAPTER V

SUMMARY AND CONCLUSION

The multiple component tympanometry at different probe tone frequencies is more sensitive to abnormalities of the middle ear at the tympanic membrane and enables a better distinction between mobile but normal middle ear and middle ear systems suffering from luxations, necrosis or disruption.

The first attempt in classification of multifrequency multicomponent tympanograms were attempted buy Van Huyse et.al. (1975) who classified multicomponent tympanograms as 1B1G, 3B1G, 3B3G and 5B3G depending on the number of pressure extremas.

A majority of the studies proving the superiority of multifrequency multicomponent tympanometry over single frequency single component tympanometry have been carried out on pathologies such as otosclerosis, ossicular discontinuity, tympanic perforation, external otitis, tympanosclerosis. These pathologies may or may not show a changes in the 226 Hz single component tympanometry.

One of the ways of studying the advantage of the multifrequency, multicomponent tympanometry over single component low frequency tympanometry is to study the then tympanograms in subjects with conductive pathologies which show normal tympanograms with normal static compliance at 2 26 Hz.

Therefore the present study was carried out to study multicomponent (admittance, susceptance and conductance) tympanometry at 226 Hz, 678 Hz and 1000 Hz in subjects (adults and children) with conductive or mixed hearing loss, with a normal 'A' type tympanograms and absent ipsilateral and contralateral acoustic reflexes.

The present study was carried out on 20 ears of 17 adults and 3 children with conductive or mixed hearing hearing loss. The age of the subjects ranged from 5 years to 76 years.

Based on the symptoms presented by the subjects the data were divided into three different groups:

Group 1 - Ears with the complaint of ear pain

Group 2 - Ears with the complaint of previous history of ear discharge

Group 3 - Ear pain with previous history of ear discharge.

and a ear of a subject with a complaint of tinuitus and blocking sensation in the ear.

Pure tone thresholds were obtained for all the ears using the audiometer Madsen OB822 for both air and bone conduction at octave frequencies from 250 Hz to 8000 Hz using the Modified Hughson-Westlake procedure.

Immitance measurements were obtained using Grason-Stadler 33 version 2 middle ear analyser. Initially an admittance tympanogram was recorded using 226 Hz probe tone and the static compliance and peak pressures for the tympanograms were obtained. In the second step multi-component tympanograms (susceptance (B) and conductance (G)) were obtained at probe tone frequencies of 226 Hz, 678 Hz and 1000 Hz. The susceptance (B) and conductance (G) tympanograms were classified as 1B1G, 3B1G, 3B3G or 5B3G and the difference between the outermost pressure maxima were recorded for the tympanograms classified as 3B1G, 3B3G and 5B3G.

Each group was further divided into subgroups with normal finding (NF subgroup) and abnormal findings (ABF subgroups). All the ears in the ABF subgroup were characterised by a pressure difference between the outer most pressure maxima which exceeded 75 dapa in case of ' 3B1G or 3B3G tympanograms and/or a pressure difference greater than 100 dapa in the case of 5B3G tympanograms and/or and abnormal shape or morphology of the tympanogram.

The following conclusions were drawn from the data collected.

1. In the group with the complaint of ear pain, some of the ears had abnormal tympanometric patterns in the multicomponent tympanometry despite normal otological findings, indicating that even subtle changes in the middle ear system could be detected by multicomponent tympanometry.

2. For all the subjects in the group with previous history of ear discharge and ear pain with previous history of ear discharge abnormal findings were obtained in the multicomponent tympanometry and most of these findings were obtained at a higher probe tone frequency of 1 kHz. This suggests that multicomponent tympanometry at 1 kHz is more sensitive to pathology at the tympanic membrane than when using single component single frequency tympanometry.

3. Multi frequency multicomponent tympanometry demonstrated significantly greater effects than single frequency single component tympanometry in early stages of otitis media probably due to mass loading of the ear.

4. In general, it can be said that multicomponent tympanometry is more advantageous over single component tympanometry in detecting low impedance pathologies especially pathologies at the tympanic membrane, but all

cases of conductive or mixed pathology may not show abnormal patterns on multi frequency, multi component tympanometry. Hence multi frequency, multi component tympanometry should be used along with a battery of tests for a better understanding of the middle ear conditions.

Limitations of the present study

The limitations of the study are as given below:

1. The data obtained for the study were too small and were heterogenous in nature, so the fact the multicomponent tympanometry is more useful for detection of low impedance pathologies at the tympanic membrane cannot be generalised.

2. Most of the ears studied had a pathology at the level of the tympanic membrane.

Directions for future research

1. The tympanometric patterns can be obtained using multicomponent tympanometry for groups of subjects with different middle ear disorders such as ossicular discontinuity, tympanic membrane perforation, early otitis media, otosclerosis, etc.

2. The effect of high impedance pathologies on multifrequency, multicomponent tympanometry can be studied

as a majority of the studies of multicomponent tympanometry are limited to low impedance pathologies.

3. Multifrequency tympanometry consisting of probe tone frequencies ranging from a low probe tone (eg. 200 Hz) to high probe tones (eg. 2000 Hz) can be done for different disorders affecting the middle ear, to see if any valuable information could be obtained.

4. The criteria used for classifying susceptance (B) and conductance (G) tympanograms as normal (i.e. 75 dapa pressure difference between the outermost pressure maxima for 3B1G and 3B3G tympanograms and 100 dapa difference between the outermost pressure maxima for 5B3G tympanograms) can be varied, i.e. can be increased or decreased and its effect can be studied in various pathologies affecting the middle ear.

CHAPTER VI

REFERENCES

Alberti, P.W. and Jerger, J.F. (1974): "Probe tone frequency and the diagnostic value of tympanometry". Archives of Otolaryngology. 99, 206-210.

ASHA working group on aural acoustic-immitance measure-ments committee on audiologic evaluation. (1988): "Tympanometry". Journal of Speech and Hearing Disorders. 53, 354-377.

Beattie and Leamy. (1970), Cited in "Effects of direction and rate of ear canal pressure changes on tympanometric measures" by Shanks, J.E. and Wilson, R.H., Journal of Speech and Hearing Research. 29, 11-19.

Berry, Q.C., Andrus, W.S., Bluestone, C D . and Cantekin, E.J. (1975): "Tympanometric pattern in relation to middle ear effusions". Annals of Otology, Rhinology and Laryngology". 84, 56-64.

Colletti, V. (1977): "Multi frequency tympanometry". Audiology. 16, 278-287.

Creten, W.L.and Van Camp, K.J. (1974): "Transient and quasi-static tympanometry". Scandinavian Audiology. 3, 39-42.

Creten, W.L., Van pepperstraete, P.M. and Vancamp, K.J. (1978): "Impedance and admittance tympanometry". Audiology. 17, 97-107.

Dieroff, H.G. (1978): "Differential diagnostic value of tympanometry in adhesive process and otosclerosis". Audiology. 17, 77-86.

Feldman, A.S. (1976a): "Tympanometry: Application and interpretation". Annals of Otology, Rhinology and Laryngology. 85, 202-215.

Feldman, A.S. (1976b): "Tympanometry - procedures, interpretations and variables". In A.S. Feldman and L.S. Wilber (Ed.). Acoustic impedance and admittance Ed. pp. 103-155. Baltimore: Williams and Wilkins.

Feldman, A.S. (1977): "Diagnostic application and interpretation of tympanometry and acoustic reflex". Audiology. 16, 294-306.

Feldman, R.M., Fria, T.J., Palfrey, C.C. and Dellecker, CM. (1984): "Effects of rate of air pressure change on tympanometry: Ear and Hearing". 5, 91-95.

Ivarsson, A., Tjernstrom, O., Bylander, A. and Benrup, S. (1983): "High speed tympanometry and ipsilateral reflex measurements using computerized impedance meter". Scandinavian Audiology. 12, 157-163.

Ivey,R.G.(1975):"Tympanometric curves and otosclerosis". Journal of Speech and Hearing Research, 18, 554-558.

Jerger, J. (1970): "Clinical experience with impedance audiometry". Archives of Otolaryngology. 92, 311-324.

Liden (1969). Cited in "Tympanometry: Basic principles and clinical applications" by Margolis, R.H. and Shanks, J.E.

In W.F. Rintlemann (Ed.) Hearing Assessment Ed. pp. 179-245. London: Allyn and Bacon.

Liden, G., Peterson, J.L. and Bjorkman, G. (1970): "Tympanometry". Archives of Otolaryngology. 92, 248-257.

Liden, G., Bjorkman, G., Nyman, H. and Kunov, H. (1977): "Tympanometry and acoustic impedance". Acta Otolaryngology. 83, 140-145.

Lilly, D.J. (1984): "Multiple frequency, multiple component tympanometry: New approaches to an old diagnostic problem". Ear and Hearing. 5, 300-308.

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

Margolis, R.H. and Smith, P. (1977): "Tympanometric assymetry". Journal of Speech and Hearing Research. 20, 437-446.

Margolis, R.H., Osguthrope, J.D. and Popelka, G.R. (1978) : "The effects of experimentally-produced middle ear lesions on tympanometry in cats". Acta Otolaryngology. 86, 428-436.

Margolis, R.H. and Shanks, J.E. (1991): "Tympanometry". In J. Katz (Ed.). Handbook of clinical audiology. Ed. pp. 438-475. Baltimore: Williams and Wilkins.

Margolis, R.H., Vancamp, K.J., Wilson, R.H. and Creten, W.L. (1985). Cited in "tympanometry" by ASHA working group on aural acoustic immitance measurements committee on audiologic evaluation. Journal of Speech and Hearing Disorders. 53, 354-377.

Margolis, R.H. and Shanks, J.E. (1991): "Tympanometry: Basic principles and clinical applications". In W.F. Rintlemann (Ed.). Hearing Assessment Ed. pp. 179-245. London: Allyn and Bacon.

Monika, P. (1994):"Effect of age on susceptance".Unpublished Master's Independent Project, AIISH, University of Mysore.

Osguthrope,0. and Lam,C. (1981). Cited in "Tympanometric changes at 226 Hz and 678 Hz across 10 trials and for two directions of ear canal pressure change" by Wilson, R.H., Shanks, J.E. and Kaplan, S.K. Journal of Speech and Hearing Research. 27, 257-266.

Osguthrope, J.D. and Charleston. (1986): "Effects of tympanic membrane scars on tympanometry". A study in cats. Laryngoscope. 96, 1366-1377.

Paradise, J., Smith, C. and Bluestone, C. (1976): Cited in "Tympanometry" by ASHA working group on aural acoustic immitance measurements committee on audiologic evaluation. Journal of Speech and Hearing Disorders. 53. 354-377.

Porter, T.A. and Winston, M.E. (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, 268-280.

Shanks, J.E. and Wilson, R.H. (1986): "Effects of direction and rate of ear-canal pressure changes on tympanometric measures". Journal of Speech and Hearing Research. 29, 11-19.

Sabitha, C.N. (1994): "Effect of age on conductance". Unpublished Master's Independent Project, AIISH, University of Mysore.

Vancamp, K.J., Raman, E.R. and Creten, W.L. (1976): "Two component versus admittance tympanometry". Audiology. 15, 120-127.

Vancamp, K.J., Creten, W.L., Vande Heyning, P.H., Decraemer, W.F. and Van Peperstraete, P.M. (1983): "A search for the most suitable immitance components and probe tone frequency in tympanometry". Scandinavian Audiology. 12, 27-34.

Vancamp, K.J., Shanks, J.E. and Margolis, R.H. (1986): "Simulation of pathological high impedance tympanograms" Journal of Speech and Hearing Research. 29, 505-514.

Van de Heyning, P.H., Vancamp , K.J., Creten, W.L. and Vanpeperstraete, P.M. (1982): "Incudo-stapedial joint pathology: A tympanometric approach". Journal of Speech and Hearing Research. 25, 611-618.

Vanhuyse, V.J., Creten, W.L. and Vancamp, K.J. (1975): "On the W-notching of tympanograms". Scandinavian Audiology. 4, 45-50.

Vanpaperstraete, D.M., Creten, W.L. and Vancamp, K.J.(1979): "On the assymmetry of susceptance tympanograms". Scandinavian Audiology. 8, 173-179.

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

Williams (1976). Cited in "Effects of direction and rate of ear canal pressure changes on tympanometric measures" by Shanks, J.E. and Wilson, R.H. Journal of Speech and Hearing Research. 29, 11-19.

Wilson, R.H., Shanks, J.E. and Kaplan, S.K. (1984): "Tympanometric changes at 226 Hz and 678 Hz across 10 trials and for two directions of ear canal pressure change". Journal of Speech and Hearing Research. 27, 257-266.

Zwislocki, J.J. (1982): "Normal function of the middle ear and its measurement". Audiology. 21, 4-14.