PSYCHOPHYSCIAL TUNING CURVES

IN

MIDDLE EAR PATHOLOGY WITH 'A' TYPE TYMPANOGRAM

(REGISTER NO. M 0108)

An Independent project submitted in part fulfillment of the First year M.Sc (Speech and Hearing), University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI, MYSORE - 570006

MAY 2002


Dedicated to
Papa, Mummy,
Hubby & Daugter
"With all my love."

Certificate

This is to certify that the Independent project entitled *"Psychophyscial Tuning Curves In Middle Ear Pathology with 'A' type Tympanogram"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 0108).

Mysore
May 2002

Director
All India Institute of
Speech & Hearing
Mysore - 570006.

Certificate

This is to certify that the Independent project entitled *"Psychophyscial Tuning Curves In Middle Ear Pathology with 'A' type Tympanogram* " has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

Guide

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May 2002

Declaration

I hereby declare that this Independent project entitled *"Psychophyscial Tuning Curves In Middle Ear Pathology with 'A' type Tympanogram* is the result of my own study under the guidance of Animesh Barman, Lecturer in audiology, Department of audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier or in any other University for the award of any Diploma or Degree.

Mysore

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INTRODUCTION

Hearing is one of our most important senses and yet the mysteries by which we perceive sound are yet to be revealed fully. Furthermore the differential effect of various ear pathologies on hearing is not fully understood. Hearing impairment results from a number of causes, middle ear pathologies being one of them. Middle ear pathologies like fixation of the ossicles specially stapes or infections of the middle ear cleft usually lead to conductive hearing loss .Until the sixth decades of 20^{th} century, it was believed that ears with middle ear pathology behaves like a "plug in the ear". Thus, resulting hearing loss only attenuate the energy reaching the cochlea and does not affect the physiology of higher auditory system and therefore signal processing remains intact.

Recently many scientists do not accept the above concept (Dobie and Berlin, 1979; Webster and Webster, 1979;Gunnarson and Finitzo, 1991). They have reported that effect of conductive hearing loss is not just limited to the attenuation of the overall energy but it may have effects on higher central auditory nervous system (CANS) at least when the pathology is a long lasting one. Thus the general consensus among hearing scientists is that long-standing conductive pathology and resulting hearing loss could have deteriorous effect on structure and function of inner ear.

The possible routes between the inner ear and middle ear could be through the round or oval window, through the facial canal, through the micro fissures or hematogenic route (Morizono and Tono, 1991).The cause of damage

to the inner ear in case of middle ear focal disease (otosclerosis) seen as bony invasion of the scala tympani of the cochlea or circulatory changes in the cochlea as a result of abnormal bony foci or it may be due to damage to the cochlea by toxic metabolites from abnormal bone or an upset of equilibrium between enzymes in the microfoci of otosclerosis (Beales, 1987).

Otosclerosis is not restricted to the middle ear alone , instead it can involve structures of the inner ear mainly starting with the basal turn of the cochlea.

Inflammatory products from the middle ear can stimulate the endolymphatic sac directly and can cause cochlear dysfunctions as the endolymphatic sac is assumed to play a central role in the immunological reactions (Saijo and Kimura, 1984; Rask and Stahle, 1980). It may stimulate and spread the inflammatory process releasing mediators (Gloddek and Harris, 1989).

Various vasoactive mediators may cross round window membrane and thus may affect cochlear functions (Mogi, Suzuki and Fujiyoshi, 1988). Therefore long standing conductive pathology can affect the inner ear structure and function. Thus investigation of such conditions becomes necessary.

There are many ways of studying cochlear function, which can be grouped into two:

1. Electrophysiological and physiological methods
2. Psychophysical methods

Electrophysiological tests include auditory evoked potentials and physiological tests include acoustic reflex thresholds and otoacoustic emissions. They usually measure the hearing sensitivity, but do not give the amount of frequency resolution of the cochlea. Psychophysical methods involve narrow band masking, psychophysical tuning curves, loudness summations etc. which can give a measure of the frequency resolution of the cochlea.

Psychophysical tuning curve (PTC) is regarded as one of the best tool for obtaining the approximation of auditory filters in the cochlea and study cochlear conduction.Thus in this study, the principle of PTC was used to study and compare cochlear conduction in ears having middle ear pathology with 'A' type of tympanogram and ears with normal hearing . PTC was chosen as:

1. It is a non-invasive technique to study cochlear function. Thus it is easy and non hazardous.
2. It allows to investigate frequency selectivity in terms of Q10values.
3. PTC also helps to evaluate the degree of cochlear disorder caused by changes in the mechanical properties of the cochlear partition (Densert, Kinberger, Arlinger, Densert, 1986)

PTC, which has recently become a popular measure of frequency selectivity, is meant to be an analogue of the frequency tuning curve. PTC measures the extent to which the subject is able to filter one stimulus out from others on the basis of frequency. The resolution of the filter tells us how good it

is at passing one station while rejecting others that are close to in its frequency. In the auditory system such resolution bandwidths are a measure of the fundamental frequency filtering property of the auditory system.

PTC is measured by presenting a listener with a signal tone of fixed level and frequency and measuring the power that a second tone must have in order to mask the signal as a function of frequency of the masking tone. (Chistovich, 1957; Small, 1959; Zwicker, 1974).

PTC was thus used in the following study to investigate cochlear function in conductive hearing loss with 'A' type tympanogram and to indicate whether PTC can act as an early predictor of inner ear damage much before the bone conduction hearing threshold is affected.

Need for the Study

The relationship between conductive pathology with 'A' type tympanogram and inner ear mechanism has not been sufficiently cited in the literature. Thus the present study seeks to investigate the frequency selectivity of cochlear in conductive pathology using psychophysical tuning curves, which is an efficient tool for measuring frequency selectivity and required only simple masked threshold judgment from the observer, (Florentine, Buss, Scharf and Zwicker, 1980).

Aim of the Study

1. To investigate whether middle ear pathology with 'A' type tympanogram can affect the inner ear and alter the frequency resolution of the cochlea.
2. To investigate whether PTCs from ears with middle ear pathologies are altered only when Bone conduction thresholds are elevated.

REVIEW

REVIEW OF LITERATURE

Middle ear pathology and its complication can lead to sensorineural hearing loss due to cochlear damage, especially long lasting middle ear (ME) disease. In a retrospective study on adult suffering from long lasting recurrent middle ear disorders such as chronic otitis media, attic perforation of tympanic membrane(TM) leading to cholesteotoma, Ballenger (1977), Morizono and Tono, (1991) found that the bone conduction thresholds were also affected. Otosclerosis is an osseous dyscrasia limited to the temporal bone. Siebenman, (1912) originally described the regions as spongy but with resorption and formation of new bone occurring simultaneously. He described clumsy, irregular bone corpuscles with clearly visible projections. Not only were the haversian canals replaced but also remaining cartilaginous area in the cochlear capsule as well as the cartilage of the footplate in cases with stapedial involvement. In the majority of cases, the lesion appeared quiescent and limited to the anterior oval window, without stapes involvement. However the process can spread across the stapedial annular ligament and fix the stapes, producing a conductive loss or it can surround the cochlea and parts of the labyrinth causing a sensorineural hearing loss.

The amount of spread of the lesion varies substantially,some relatively small lesions appear to have ceased all activity. They appear as sclerotic lesions with no involvement of the stapes, other lesions spread across the stapedial annular ligament to fix the stapes or in the opposite direction to effect the cochlea or both(Linthicum, 1993).

Otosclerosis is usually stapedial but as seen it can also involve the cochlea leading to cochlear otosclerosis. The characteristics common to both is the total disorganization of the lesion that replaces normal bone. Thus it is clear that otosclerosis can be conductive, SN or a combination of both i.e., mixed hearing loss, that involves middle ear and cochlea.

Various authors have proposed the possible route of spread from Middle ear to inner ear and also histopathology of the onset of cochlear otosclerosis. Cochlear otosclerosis is characterized by the presence of a mixed or even primarily SN loss in which the air bone gap is minimal. Losses that exceed a moderate to moderately severe degree invariably have atleast a partial sensori neural component (Hannley, 1993).

Keleman and Linthicum,(1969) found however that the severity and configuration of the puretone audiogram does not map one to one on the area of the cochlea involved by extension of the otosclerotic process, although sensorineural hearing loss is more common with basal turn involvement and almost invariably present with endosteal layer involvement, varying directly with the number of involved sites.

Possible routes between middle ear and inner ear

Morizono and Tono, (1991) reported that substances in the middle ear fluid do not cause any inner ear damage until they enter into the inner ear. The possible routes between the inner and middle ear are through the round or oval window, through the facial canal through the microfissures or hematogenically.

Beales, (1987) stated the possible route of damage to the inner ear or in case of middle ear focal diseases (otosclerosis). According to his research the possible causes of cochlear degeneration seen in otosclerosis is bony invasion of the scala tympani of the cochlea or circulatory changes in the cochlea as a result of abnormal bony foci or it may be due to damage to the cochlea by toxic metabolites from abnormal bone or an upset of equilibrium between enzymes in the microfoci of otosclerosis.

Target structures in the inner ear

Saijo and Kimura, (1984) suggest that inflammatory products from the middle ear can stimulate the endolymphatic sac directly. As the endolymphatic sac is assumed to play a central role in the immunologic reactions(Rask and Stahle, 1980; Saijo and Kimura, 1984) it may stimulate and spread the inflammatory process releasing mediators such as interleukins (Gloddek and Harris 1989).

Keleman and Linthicum, (1969) observed that in otosclerosis involving inner ear the basal turn of the cochlea is involved and is almost invariably present with endosteal layer involvement. Later studies have revealed that degree of BC loss varies directly with the amount of hyalinization of annular ligament in the cochlea. The otosclerotic process may be limited to a small portion of the basal turn of the cochlea immediately adjacent to the anterior margin of the oval window and spread in to the basal turn or involve other areas of the cochlea. Occasionally the fundus of the internal auditory canal, the semicircular canal and the vestibule are affected(Valvassori,1993).

From the above discussion it is obvious about the relationship between middle ear pathology and cochlear dysfunction . However, Anderson and Barr, (1969) reported interesting phenomena what they called as conductive recruitment. In their Conductive hearing loss subjects they observed abnormal ART at lower SLs and abnormal ABLB which is usually seen in cases with cochlear pathology.

From the review it is clear that the general consensus among hearing scientists is that long standing conductive pathology and resulting conductive hearing loss could have adverse deteriorous effect on structures and function of the inner ear. Many studies have been carried out on animals to investigate the adverse effect of conductive pathology on the function of the cochlea and central auditory nervous system.

Thus it is clear that few studies have been carried out to investigate the effect of conductive hearing loss on cochlear functioning. Therefore there is a need for studying cochlear conduction in individuals with conductive pathology.

The present study investigates the cochlear resolution in middle ear pathology with a 'A' type of tympanogram using PTC. To understand PTC better its classic shape and factors affecting it needs to be discussed .

Shape of PTC

The shape of the PTC is a classic ' V shaped pattern (Snik and Horst, 1991) with a low frequency tail and a high frequency slope (Zwicker, 1974).

Factors Affecting PTC

1. Frequency of test tone

The sharpest/narrowest PTCs are those associated when the frequency of test tone is in the mid-frequencies, 0.8 to 3.2 KHz (Small 1959). The low frequency tail of the V shaped PTC increases drastically for high characteristic frequencies of the test tone (Zwicker, 1974).

2. Sensation level of test tone

The tip of the PTC is slightly sharper at higher sensation level of test-tone. The upper skirt of the PTC becomes sharper as signal level increases while the lower skirt of the PTC becomes shallower as signal level increases at high intensities indicating a nonlinearity. This nonlinearity, is maximum when masker frequency is about 0.8 times the signal frequency (Abeele, Heyning, cretin, Graff and Marquest,1992).

3. Beats

When a sinusoidal signal and a sinusoidal masker are presented simultaneously, the envelope of the combined stimulus fluctuates regularly resulting in a phenomenon called beats. Beats will be most effective as a cue in the region of the tip of the PTC, and will raise the masker level needed to obscure the signal. The value of the cue changes i.e., decreases as the frequency separation between the signal and masker increases(patterson and Moore, 1986).

4. Combination Tone

In simultaneous masking, the interaction between the signal and masker can produce combination products that are more audible than the signal (Greenwood, 1972). The level of the combination tone is determined by the frequency separation of the primary and consequently it has the largest effect on the tuning curve in the region of the tip where the primaries are close together. The presence of combination tone can necessitate an elevation in the masker level required for threshold (Patterson and Moore, 1986).

5. Off-frequency listening

It refers to describe the listener's use of signal excitation away from the peak of the signals excitation pattern, to detect it. As the signal rises above threshold, off-frequency listening increases since excitation pattern spreads over a greater region.Therefore off frequency listening increases since excitation pattern spreads over a greater region.Thus, off frequency listening leads to sharper PTCs. (Patterson and Moore, 1986)

6. Type **of masking**

Two types of masking can be used in PTC. They are

a. Simultaneous masking: Here the signal occurs at the beginning, in the temporal center, or at the end of the masker.

b. Forward masking: Here the signal occurs immediately after the masker offset.

The forward masking PTC is generally sharper than the simultaneous masking PTC with the signal at the end of the masker. In simultaneous masking, the broadest PTC is for the signal at the beginning of the masker, Q10 increases by a factor of 1.9 as the signal moves to the center of the masker but then decreases as the signal is moved to the end of the masker. (Bacon and Moore, 1986)

Quantification Of Tuning Curves

PTCs are a measure of frequency resolution of the cochlea and the degree of frequency resolution has been mainly expressed in 2 ways:

a. Measuring the bandwidth of the tuning curve at some fixed intensity above the best threshold.

b. Slope of tuning curve above and below the characteristic frequency.

a. Traditionally, PTCs have been quantified in a manner similar to analogue filters. A measure of frequency resolution near the tip of the tuning curve is determined by dividing the signal frequency by the bandwidth measured at lOdB up from the tip. A similar approach was adopted by Florentine et.al., (1980) and Ritsma,Wit,Vander Lan, (1980) to quantify PTC obtained from hearing impaired listeners.

Bonding (1979f) gave a measure called (d1 oct) defined as the distance between the tip of the PTC and level at which it is 1 octave wide. But Tyler, Wood and Fernandes, (1983) found that d1 oct overestimated the tuning curve in many hearing impaired listeners.

b. Other approach is given by Tyler, Small, Abbus, (1979) who quantified the high and low frequency slopes of the PTC. The slope was calculated between only two masker frequencies which is not a good match to measure the slope of a PTC obtained with several masker frequencies.

Evans, (1975a) reports that fibres in the 10KHz region show steepest slopes. Here the high frequency slopes measured at 5dBSL and 25 dBSL with respect to best threshold range from 100 to 600 dB/ octave and low frequency slope from 80-250 dB/ octave.

Tyler et.al., (1983) used a tip-tail difference score i.e., difference between the masker level in the tail of the PTC and masker level at the tip of the PTC.

Though it is not clear which measure or which combination of measures, provides the most useful description of PTCs in the hearing impaired, Qi_0 values have been used as a measure of frequency resolution widely in literature and also in the present study.

PTC in abnormal population

Frequency selectivity is impaired in the hearing impaired. This analytic ability has been measured in normally hearing and hearing impaired subjects in psychoacoustic and physiological experiments (Evan, 1978 and Scharf, 1978). Despite the many measurements, there does not exist a consensus on the relation between auditory pathologies and frequency selectivity.

Although the studies differ in detail, their results are in general agreement that PTCs are broader than normals in the impaired subjects. The literature on PTC in the abnormal population is discussed as below:

1. PTC in sensorineural hearing loss

There have been many studies comparing PTCs in normal subjects and subjects with cochlear hearing loss (Leshowitz, Lindstrom and Zurek, 1975; Hoekstra and Ritsma, 1977; Zwicker and Schorn, 1978; Bonding, 1979b; Florentine et.al., 1980; Tyler, Wood and Fernandes, 1982; Carney and Nelson, 1980; Festen and Plomp, 1983; Stelmachowicz, Jesteadt, Gorga and Mott, 1985; Nelson, 1991).Most studies have found that sharpness of tuning of PTC decreases with increasing absolute threshold, although the co-relation between threshold and sharpness of tuning varies markedly across studies. In some cases PTCs have been found to be 'W shaped rather than 'V'shaped (Hoekstra and Ritsma, 1977) but in general PTCs have indicated impaired frequency selectivity in most individuals with sensori neural hearing loss.

2. PTC in Conductive Hearing Loss

Limited literature exists regarding measurement of PTC in conductive hearing loss, but the general trend as found in the existing study indicates that by comparing the tuning curves of normally hearing subjects with those produced by listeners with conductive hearing loss, that in the latter case the whole tuning curve is shifted upwards corresponding to the hearing level.

The classic study done in PTC is by Schorn, Wurzen, Zollner and Zwicker, (1977) and Zwicker and Schorn, (1978). Tuning curve was measured in normal hearing, conductive loss, otosclerosis degenerative hearing loss, noise induced hearing loss, ototoxicity and Meniere's disease at 500Hz and 4000Hz. The resulting tuning curve data indicated reduced but not completely absent frequency selectivity, especially in the range of greater hearing loss. The measured data indicated that in conductive hearing loss, PTCs were normal but more than 50% of the patients with otosclerosis showed decreased frequency selectivity, although otosclerosis with Bone conduction being10dB HL showed decreased frequency selectivity, though otosclerosis is commonly regarded as conductive hearing loss.

Florentine et.al., (1980) conducted a study in which observers with normal hearing and observers with conductive (non otosclerotic), otosclerotic, noise induced or degenerative hearing losses were taken. Around 7-10 observers were tested at each center frequency.

The conductive (non otosclerotic group) and otosclerotic group were taken prior to otological surgery. The conductive group consisted of observers with acute/chronic otitis media, ruptured tympanic membrane or ceruminal occlusion.

For the 500Hz test tone, the pure tone maskers were at 215, 390, 460, 540, 615 and 740Hz. For the 4000Hz test tone the pure tone maskers were at 1720, 3120, 3680, 4320, 4920 and 5920Hz.

Frequency selectivity was evaluated on the basis of Q values. The Q values was defined as the center frequency divided by the bandwidth of the tuning curves at 12dB above the level of the test tone for 500Hz and 14dB above the level of the test tone for 4000Hz. The study indicated that at 500Hz the Q values did not differ significantly among the groups(conductive otosclerotic vs normals).

At 4KHz significant difference among the group were indicated by the Q values in the group with normal bone conduction than in the group with elevated Bone Conduction thresholds. The authors based on the results of the study concluded that:

1. Q values are significantly smaller in all groups of observers with elevated Bone Conduction thresholds.
2. The sensitivity of Q values may be related to the demonstration that the tip of the physiological tuning curve is altered even for small hearing losses (Evans, 1975a,b).
3. Q values provide a measure of degree of cochlear impairment.

Snik et.al., (1991) studied frequency resolution in patients with unilateral congenital ear defects (atresia) having conductive hearing loss who were successfully operated as compared to their normal ears and subjects with normal hearing. 10 patients were selected between the age group of 11 to 45 years and subjects with normal hearing were taken between the age of 18-38 years.

PTC was obtained for all the above 3 groups using the method described by Zwicker and Schorn, (1978) at 2KHz. Pure tone was masked by a pure tone. The masker consisted of frequencies of 812, 1562, 1812, 2187, 2437 and 2687Hz, while the test tone was presented at l0dB SL. d_1 oct value was used to make a comparison with the values in literature.

The PTC shape was same for all the 3 groups.

1. Averaged d_1 oct values of the normal hearing and normal ear of the patients with atresia were 44.3 ± 2.0 and 45.5 ± 4.6dB respectively. Both values agree closely with values published in literature (Stelmachowicz and Jesteadt, 1984).

2. The PTC of the operated ear was shifted by about the air bone (AB) gap, but after appropriate corrections were made for the AB gap, the PTCs of all the operated ears lay reasonably well within the 2 standard deviation range of the average PTC obtained in subjects with normal hearing. Thus it indicated a good frequency resolution in congenital hearing loss namely congenital atresia of ear canal.

The above literature indicates that through the various studies differ in details of carrying out PTC, the results are in general agreement with each other and that is

1. PTC is sensitive to even small degrees of hearing loss, which is indicated by the elevation in the tip of the PTC.
2. PTC is broadened depending on the degree of cochlear involvement.

METHOD

METHOD

The aim of the study was to investigate whether middle ear pathology with 'A' type Tympanogram can affect the inner ear and alter the psychophysical tuning curve (PTC) with normal BC threshold or elevated BC threshold.

Subjects

The subjects taken for the study were selected under two groups. Group A was the control group and consisted of 25 ears with normal hearing. Group B was the experimental group and consisted of 23 ears with middle ear pathology having 'A' type tympanogram with reflexes absent.

Criteria for selection of subjects for the control group

- Age range was between 18-35 years irrespective of gender
- No otological or neurological history reported
- Audiological Findings:
    a) Puretone hearing thresholds were within 15 dBHL at the conventional audiometric frequencies ranging from 250 Hz to 8KHz
    b) Immitance results showed 'A' type tympanogram with normal reflexes.

Criteria for selection of subjects for the experimental group

- Group consisted of patients having middle ear pathology with 'A' type tympanogram with static compliance from 0.5 to 1.75 ml and

tympanometric peak pressure ranging from +60 to -100 dapa with absent reflexes.

- Age range was between 18-45 yrs irrespective of gender.

They were further divided in to two groups based on bone conduction threshold.

a) The first group consisted of 14 ears with normal bone conduction threshold ranging from -lOdBHL to 15dBHL at frequencies from 250Hz to 4KHz.

b) The second group consisted of 9 ears with elevated bone conduction thresholds with air bone gap atleast greater than 15dB at all the frequencies. The BC threshold ranged from 20 to 30 dBHL at least at 1KHz, 2KHz and 4KHz.

c) The AC threshold for both the groups ranged from 20dB to 65dB between 250Hz to 8KHz at the conventional audiometric frequencies. Rise or fall for AC threshold did not exceed 10 dB/octave.

Equipment

Maico MA-53 calibrated dual channel diagnostic audiometer was used with TDH-39 ear phones to obtain the puretone thresholds and the PTC,

- Caliberated Grason and Stadler (GS1 33) version-2 immittance audiometer was used to assess middle ear condition

- PTCs were obtained for those subjects who passed the criteria in both experimental and control group.

Test Procedure

- Testing was done in an air-conditioned sound treated double room situation with the ambient noise levels within permissible limits (ANSI-1991).
- Initially the puretone thresholds were obtained using the Carhart and Jerger modified Hughson -Westlake procedure (1959).
- Later immittance measurement was done and based on the findings of these two tests, the subjects were divided into control group and experimental group.
- Finally the PTCs were obtained for the selected ears.

Instructions

The testing was carried out under headphones and pulsed tone was presented in presence of ipsilateral noise and the patients were instructed to respond to the pulsed tone whenever they heard it, by raising the index finger. .

Measurement of PTC

The PTCs were obtained at fixed test tone frequency of 500Hz, 1KHz and 2KHz to see whether conductive pathology can affect speech frequencies. To obtain the PTC, first the threshold of the test tone was determined. Next, the test tone was set at 10 dB SL (sensational level) and the masker levels were determined at all masker frequencies. The masker was a Narrow Band Noise

(NBN) comprising of center frequency in steps of 100Hz. The 10 dBSL test tone was masked by the NBN starting at 0dBSPL. If the subject indicated to the test tone in presence of the masker, the level of the masker was increased in l0dB steps and if he did not respond, it was then decreased by 10 dB and later increased by 5 dB. This procedure was repeated till the test tone could just be heard in the presence of noise (Silman and Silvermann 1991). The level of the masker noise was noted at that point. Similarly, masker noise level was found at 4 points above and 4 points below the center frequency. A curve of the masker level versus the frequency was plotted to represent the PTC. Similar procedure was followed to obtain PTCs at all the test frequencies.

Quantification of PTC

Q_{10} value was used as a measure of frequency resolution near the tip of the tuning curve. It is the most widely used approach to quantify PTCs and is defined as the center frequency divided by the bandwidth at 10 dB above the level of the test tone.

$$Q \text{ value} = \frac{\text{center frequency}}{\text{Bandwidth}}$$

The Q_{10} values were calculated at different frequencies for all the subjects independently.

Statistical analysis

The Q_{10} values which were obtained for each individuals at different frequencies were tabulated and subjected to statistical analysis. Independent t-test was used to find out whether

a) There is any significant difference between ears with normal hearing and ears with conductive hearing loss with normal BC threshold.
b) There is any significant difference between ears with normal hearing and ears with elevated BC threshold.
c) There is any significant difference between normal BC and elevated BC threshold in ears with middle ear pathology.

RESULTS

RESULTS

In the present study the aim was to investigate whether middle ear pathology with 'A' type tympanogram can effect the inner ear and alter the physiology of the cochlea much before it can elevate the BC threshold and weather there is a change in cochlear physiology with the elevated BC threshold. To study the above phenomena PTC was obtained in normal and ear with middle ear pathology having normal and elevated BC threshold. The data obtained from the study was subjected to statistical analysis and the results are as follows

1) **Comparison of frequency selectivity in ears with middle ear pathology having normal BC threshold versus ears with normal hearing.**

PTCs obtained from 25 normal hearing ears were compared with 14 ears having middle ear pathology with normal BC at 500 Hz, 1 KHz and 2KHz. Q_{10} values were computed as a measure of frequency selectivity for each of the ear at all the frequency in both the groups. The mean and SD for the Q values is tabulated. T- test was administered on this data to find out whether there is a significant difference between the PTCs obtained from the ears with normal hearing and ears with middle ear pathology with normal BC. The T- value obtained was highly significant at 0.01 ($p < 0.01$) level at frequency of 2KHz as shown in table -I

Test **Frequency**		**Control Group N=25**	**Experimental Group N=14**	**T-Value**	S/NS
500Hz	Mean	2.5852	2.3586	1.443	NS
	Standard Deviation	0.5699	0.4041		
lOOOHz	Mean	4.1756	4.2757	0.534	NS
	Standard Deviation	0.7581	0.4135		
2000Hz	Mean	8.4512	6.9964	3.220**	S
	Standard Deviation	1.8496	0.9701		

** P < 0.01 NS : Non Significant S : Significant

***Table** -1: Shows the mean and SD for the Q values obtained from the control group and experimental group along with the t-value.*

It was observed that when compared to ears with normal hearing, the PTCs in ears with middle ear pathology having normal BC are elevated with the increase in air bone gap, in all the frequencies.

The mean Q_{10} values in the middle ear pathology with normal BC were lesser except at 1 KHZ than the ears with normal hearing at all the frequencies but it was statistically significant only at 2KHz.The rate of decrease of frequency resolution was higher at higher frequencies when compared to lower frequencies.

In general the Q_{10} values showed a rising trend from 500Hz to 2KHz in both the groups.

2) Comparison of frequency selectivity in normal hearing ears versus middle ear with pathology having elevated BC threshold.

PTCs obtained from 25 normal hearing ears were compared with 9 ears having middle ear pathology with elevated BC at 500Hz, 1KHz and 2KHz. Q_{10} values were computed as a measure of frequency selectivity for each of the ears at all frequencies for both the groups. The mean and SD values was calculated and subjected to t- test to find out whether there is a significant difference between the PTCs obtained from ears with normal hearing and ears with middle ear pathology with elevated BC threshold. The 't' value obtained was highly significant at 0.01 ($P < 0.01$) level at all frequencies as shown in Table-II.

Test Frequency		**Control Group N=25**	**Experimental Group N=9**	**T-Value**	S/NS
500Hz	Mean	2.5852	1.5644	6.372**	S
	Standard Deviation	0.5699	0.3377		
lOOOHz	Mean	4.1756	2.5689	6.961**	**S**
	Standard Deviation	0.7581	0.5222		
2000Hz	Mean	8.4512	5.0233	6.981**	**S**
	Standard Deviation	1.8496	0.9688		

**P<0.01 S: Significant

Table *— II: Shows the mean and SD for the Q values obtained from control group and experimental group along with the t-value.*

3) Comparison of frequency selectivity in middle ear pathology with normal BC versus elevated BC threshold.

Q_{10} value as a measure of frequency selectiviy were computed for 14 ears with normal BC threshold and 9 ears having middle ear pathology with elevated BC at 500Hz, 1KHz and 2KHz. The mean and SD values was

calculated and subjected to t- test to find out whether there is a significant difference between the PTCs obtained from ears with middle ear pathology having normal BC and elevated BC threshold. The 't' value obtained was highly significant at 0.01 ($P < 0.01$) level at all frequencies as shown in Table-Ill.

Test Frequency		**Ears with normal BC N=14**	**Ears with elevated BC** N=9	**T-Value**	S/NS
500Hz	Mean	2.3586	1.5644	5.091**	S
	Standard Deviation	0.4041	0.3377		
1000Hz	Mean	4.2757	2.5689	8.278**	S
	Standard Deviation	0.4135	0.5222		
2000Hz	Mean	6.9964	5.0233	4.764**	**S**
	Standard Deviation	0.9701	0.9688		

**P<0.01 S: Significant

Table - III *: Shows the mean* ***and*** *SD for the Q values obtained* ***from*** *the experimental group with normal and elevated BC threshold.*

In general the Q_{10} values showed a rising trend from 500Hz to 2KHz in normal hearing ears and ears with middle ear pathology. Normal hearing ears had good frequency resolution as compared to ears with middle ear pathology. The Q_{10} values decreased as the BC threshold increases in ears with middle ear pathology. This variation of Q_{10} values was greater at high frequencies as compared to low frequencies.

DISCUSSION

DISCUSSION

The PTC is an alternative means of measuring properties of frequency selectivity of the auditory system which has become popular partially because of the analogy with neural tuning curve. PTC is an efficient method and requires only a simple masked threshold from the observer.

Results in this study suggested that middle ear pathology with 'A' type tympanogram can effect frequency selectivity of cochlea depending on pure tone BC threshold. PTCs obtained in normal hearing ears showed a sharply tuned characteristically V shaped PTC (Snik and Horst, 1991) with a low frequency tail and a high frequency slope (Zwicker, 1974) at all the test frequencies.

In the present study, the Q_{10} values which is a measure of frequency selectivity increased with increase in the test frequency as also reported by Densertet. al., (1986).

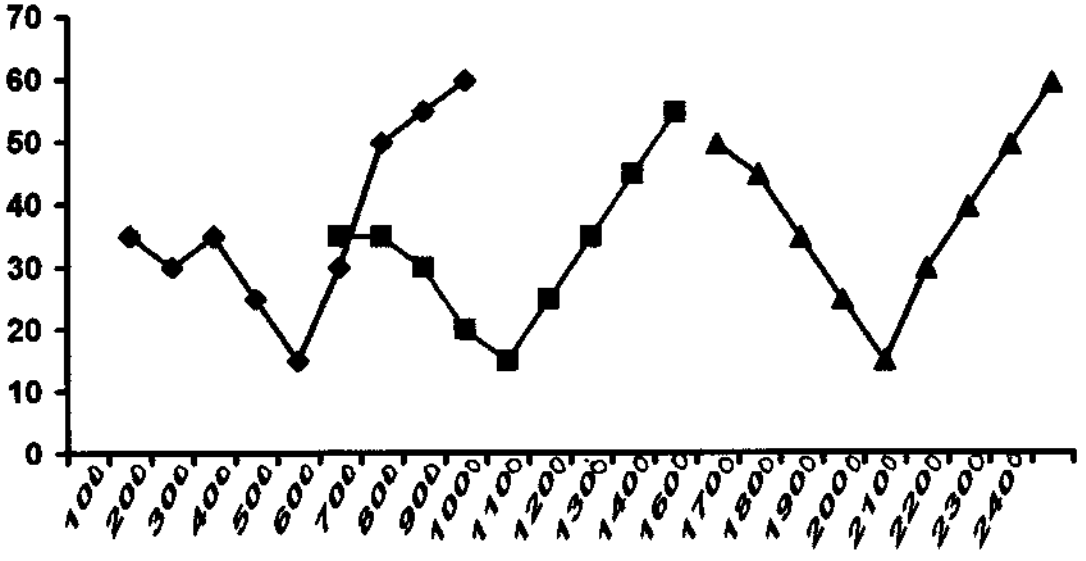

Figure 1: PTC at 500Hz, 1KHz, 2KHz in normal hearing individual

As shown in the figure 1 all the normal hearing subjects showed very similar tuning curves with general flat low frequency portion and shallow V shape in the regions of the probe tone (Carney and Nelson, 1982).

Pathological ears showed tuning curves that differed from those produced by the normal hearing group (Zwicker and Schorn, 1978). The comparison between the ears with normal hearing and ears having middle ear pathology with normal BC was based on the Qio values. It can be clearly seen by comparing the tuning curves of the above group i.e., in the latter case morphology of the tuning curve was similar but the whole tuning curve was elevated corresponding to the pure tone AC threshold at all test frequencies (Fig 2) as also reported by Zwicker and Schorn (1978).

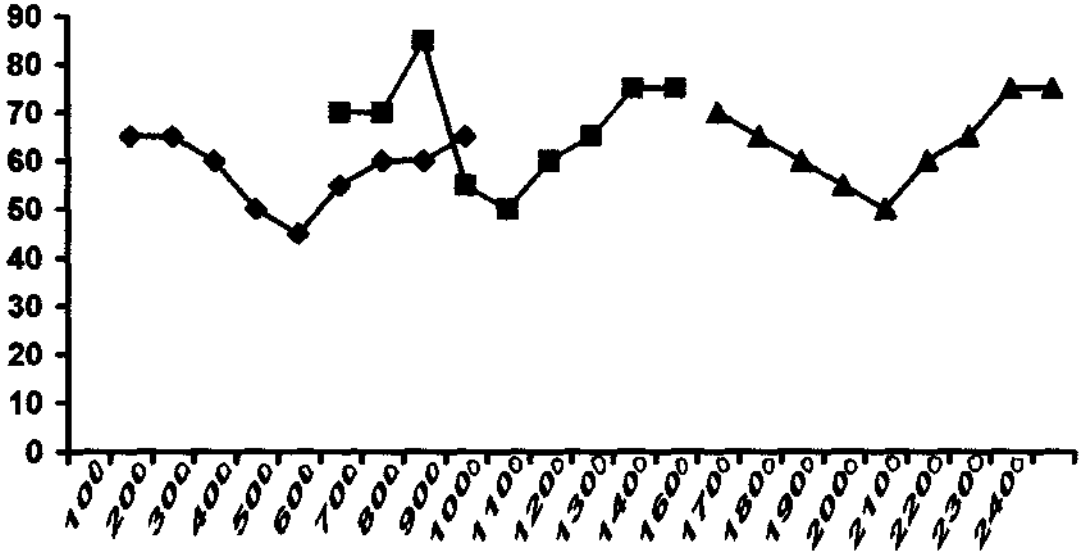

***Figure 2** : PTC at 500Hz, 1KHz, 2KHz in middle ear pathology with normal BC thresholds*

Q_{10} values are significantly lower at 2KHz in ears having conductive pathology with normal BC as compared to normal hearing ears at the same frequency. This can be explained on the basis that middle ear pathology is reported to cause damage to the round window membrane with localized inflammatory changes starting in the adjacent and then proceeding to the apical end. Specifically with respect to otosclerosis, the lesion can spread towards the inner ear causing damage to the endosteum of the cochlea in the basal turn leading to new bone formation. Since the basal region of the cochlea is responsible for high frequency therefore the Q_{10} values which is a measure of frequency selectivity were significantly lower at 2KHz.

Comparison of frequency selectivity in normal hearing ears versus ears with middle ear pathology having elevated BC thresholds at the frequencies tested indicated an abnormal broadly tuned PTC as seen in Fig 3

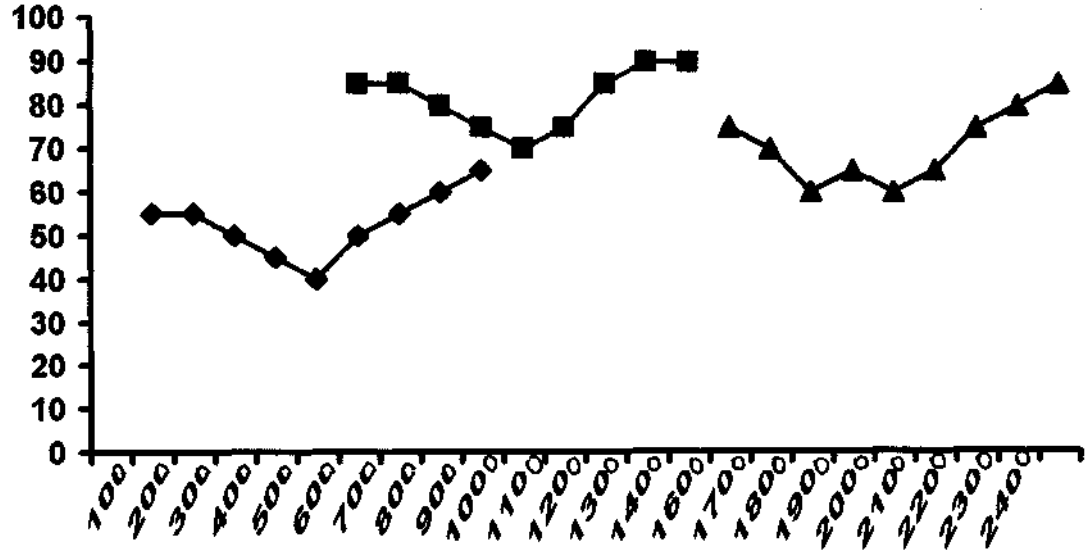

Figure 3 : PTC at 500Hz, 1KHz, 2KHz in middle ear pathology with elevated BC thresholds

The Q_{10} values were significantly smaller in the ears with elevated bone conduction threshold at all frequencies. The sensitivity of the Q values may be related to the fact that the tip of the PTC is altered even for small degrees of hearing losses (Evans, 1975 a,b). Therefore it is not surprising that these measures reveal reduced frequency selectivity even in the group with middle ear pathology having elevated BC at all frequencies although the cochlear impairment in these observers were presumably small as supported by Schorn et. al., (1977), Zwicker and Schorn, (1978) and Florentine et. al., (1980).

Finally the comparison of frequency selectivity in middle ear pathology with normal BC and elevated BC indicated that the broadening of PTCs was associated with decrease in Q_{10} values as the BC threshold increased as supported by Schorn et. al., (1977), Zwicker and Schorn, (1978) and Florentine et. al., (1980)

The present study has been carried out in middle ear pathology with 'A' type tympanogram which is usually indicative of otosclerosis. Since BC is elevated in some of the ears with middle ear pathology it suggest cochlear otosclerosis. Cochlear otosclerosis is characterized by the presence of a mixed component.

Keleman and Linthicum, (1969) found that the severity and configuration of pure tone audiogram do not map one to one on the area of cochlea involved by the extension of otosclerotic process, although sensory neural component is more common in basal turn involvement due to endosteal layer involvement. Although its not sure that these data accurately reflect the

amount of change in the frequency selectivity mechanism, there appears to be no doubt that frequency selectivity is radically altered in ears with elevated BC indicating a cochlear impairment.

Literature suggests that in general PTC becomes less sharply tuned as absolute thresholds become higher, upto about 50 dBHL, when very little frequency resolution remains.(Hoekstra and Ritsma, 1977 and Hoekstra, 1979). But in the present study there is no specific trend seen in Q_{l0} values as the pure tone AC thresholds increased.

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

Psychophysical tuning curve appears to be a reliable clinical tool for the indication of frequency selectivity and thus a measure of the cochlear function or dysfunction in normals and pathological groups.

Various studies imply that middle ear pathology can affect the inner ear leading to a permanent damage. Therefore the present study aims to investigate whether middle ear pathology with 'A' type tympanogram can affect the inner ear and alter the physiology of the cochlea much before it can elevate the BC threshold and whether there is a change in cochlear physiology with the elevated BC threshold. For this psychophysical tuning curve (PTC) was used which is a non-invasive technique and requires simple masked response from the observer. PTC has been found to be one of the most sensitive psychophysical procedure for investigating frequency resolution of the cochlea.

In the present study 25 normal hearing ears in the control group and 23 ears with middle ear pathology having 'A' type tympanogram with absent reflexes were taken in the experimental group.

The experimental group was further divided into 2 subgroups based on the BC threshold.

a. The first subgroup consisted of 14 ears with normal bone conduction threshold.
b. The second subgroup consisted of 9 ears with elevated bone conduction threshold with an air bone gap of greater than 15 dB at all frequencies.

PTC was measured for this entire group at speech frequencies (500Hz, 1KHz and 2KHz) on 4 points either side of the center frequency.To measure the frequency resolution, the PTC was quantified in terms of Q_{10}values, which was calculated independently for all the subjects and later subjected to statistical analysis. The analysis was done in three phases

1. *Comparison of PTC and Q_{10} values in ears with middle ear pathology having normal BC threshold versus ears with normal hearing.*
2. *Comparison of PTC and* Q_{10} *values in ears with normal hearing versus ears with middle ear pathology having elevated BC threshold*
3. *Comparison of PTC and* Q_{10} *values in ears having middle ear pathology with normal BC versus elevated BC threshold.*

The result indicate that

1. When compared to ears with normal hearing, the PTCs in ears with middle ear pathology having normal BC are elevated with respect to the pure tone AC threshold, in all the frequencies. The mean Q_{10} values in the middle ear pathology with normal BC were slightly lesser than the ears with normal hearing at all frequencies but it was statistically significant only at 2KHz, which signifies that basal turn of the cochlea might be affected.
2. In ears with elevated BC the PTC were abnormally broad and Q_{10} values were significantly smaller at all frequencies as compared to ears with normal hearing.

3. In middle ear pathology with normal BC and elevated BC indicated that the broadening of PTCs was associated with decrease in Q_{10} values as the BC threshold increased.

Thus the above results supports that PTC is a sensitive measure of frequency selectivity of the cochlea. It helps us to understand the physiology of the cochlea in middle ear pathology much before it can elevate the BC threshold and also the change in frequency selectivity as the BC thresholds get affected.

Thus PTCs can act as a detector and predictor of inner ear involvement in cases with middle ear pathology.

Clinical Implication

The most sensitive measure of decreased frequency selectivity are the PTCs (Florentine et. al., 1980). The sensitivity of the Q_{10} values is related to the alteration of the tip of PTC even for small hearing losses (Evans, 1975 a, b).

Therefore PTC helps us to understand mechanism of cochlear function and dysfunction in ears with middle ear pathology with normal and elevated BC. The broadening of PTC inspite of the conductive pathology with normal BC can act as a detector and predictor of inner ear involvement in conductive pathologies. Indication of prognosis of treatment in middle ear disorder can also be done using measurement of PTC.

Drawbacks of the Study

1. In the present study ears having middle ear pathology with 'A' type tympanogram were tested in general and specific pathologies like otosclerosis, ossicular chain discontinuity, early stages of cholesteostoma not impinging on tympanic membrane where 'A' type tympanogram is found were not categorized.
2. Simultaneous masking was used to obtain PTCs, but literature suggests that when compared to simultaneous masking forward masking gives sharper PTCs.
3. In the present study duration of middle ear pathology was not considered

Suggestions For future Studies

1. Frequency resolution can be studied by categorization of middle ear pathology into otosclerosis, ossicular chain discontinuity, early stage of cholesteostoma not impinging on the tympanic membrane where 'A' type tympanogram can be obtained
2. PTCs can be done beyond conventional audiometric frequency range using extended high frequency audiometry, in patients with conductive hearing loss to examine cochlear function.

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