PSYCHOPHYSICAL TUNING CURVES

IN

OTITIS MEDIA

(REGISTER NO. M 0113)

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

Bapama

Seek Your Blessings Always......

Certificate

This is to certify that the Independent project entitled *"Psychophysical Tuning Curves In Otitis Media"* is the bonaflde work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 0113).

Mysore

May 2002

Director

All India Institute of
Speech & Hearing
Mysore - 570006.

Certificate

This is to certify that the Independent project entitled *"Psychophysical Tuning Curves In Otitis Media"* 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.

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Declaration

I hereby declare that this Independent project entitled *"Psychophysical Tuning Curves In Otitis Media"* 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.

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INTRODUCTION

INTRODUCTION

The gift of language sets apart humans from their primitive counterparts and the role of HEARING in acquisition and use of language cannot be denied. Hearing is a vital essence of man's interaction with his environment, but this boon can be robbed of its abilities due to various causes, middle ear pathologies being one of them.

Middle ear pathologies like infections of the middle ear cleft or fixation of the ossicles, especially stapes etc. usually lead to conductive hearing loss. Until the sixth decade of 20^{th} century, it was believed that ears with middle ear pathology behave like a "plug in the ear". Thus, resulting hearing loss only attenuates 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 allcmiation of overall energy but it may have effects on function of Ihe higher central auditory nervous system (CANS), at least when the pathology is a long lasting one.

The possible routes between the inner ear and middle ear could be through the round or oval windows, through the facial canal, through the micro fissures or hematogenic routes (Morizono and Tono, 1991). Inflammatory products from the middle ear can stimulate the endolymphatic sac directly and cause cochlear dysfunctions. As the endolymphatic sac is assumed to play a central role in the immunological reactions (Saijo and Kirnura, 1984; Rask and Stahle, 1980) may then stimulate and spread the inflammatory process-releasing mediators (Gloddek and Harris, 1989). Mogi, Suzuki and Fujiyoshi, (1988) reported that various vasoactive mediators may cross round window membrane and thus may affect cochlear function.

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 the cochlea and higher central auditory system, and hence 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 physiologic tests include Acoustic reflex thresholds and otoacoustic emissions, which measure the sensitivity of the cochlea, but do not give the measure of frequency resolution of the cochlea. Psychophysical methods involve Narrow band masking, Psychophysical tuning curves, loudness summation etc. that give a better measure of the frequency resolution of the cochlea.

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 and to indicate weather PTC can act as an early predictor of inner ear damage with middle ear infection much before the bone conduction hearing threshold is affected.

Need for the Study

The importance of chronic inflammatory middle ear disease in the sensorineural mechanism remains a controversial issue and a review of literature reveals few studies on this relationship (English, Northern and Fria, 1973).

The present study seeks to investigate the frequency selectivity of the cochlea in conductive pathology using psychophysical tuning curves, which is an efficient tool for measuring frequency selectivity and requires only simple masked threshold judgment from the observer (Florentine, Buus, Scharf and Zwicker, 1980).

Aim of the Study

- To investigate whether middle ear inflammatory disease can affect cochlear function and alter PTC.

- To investigate whether there exists a relation between duration of the middle ear inflammatory disease and degree of cochlear dysfunction based on PTC.

Psychophysical tuning curve (PTC) is regarded as one of the best tools for obtaining the approximation of auditory filter in the cochlea and study cochlear conduction.

Thus, in this study, principle of PTC was used to study cochlear conduction in ears with conductive pathology namely, chronic suppurative otitis media and in ears with normal hearing and compare both, before it could affect the bone conduction thresholds. This test was used mainly for the following reasons:

1. It is a non-invasive technique to study cochlear function. Thus it is easy and non hazardous.
2. It allows investigating cochlear function in terms of Q10 value.
3. It helps evaluate the degree of cochlear disorder caused by changes in the mechanical properties of cochlear partition. (Densert, Kinberger, Arlinger, Densert, 1986).

The psychophysical tuning curve (PTC), which has recently become a popular measure of frequency selectivity, is meant to be an analogue of the frequency threshold curve (FTC). Therefore, 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 it in frequency. In the auditory system, such resolution bandwidths are a measure of the fundamental frequency filtering property of the auditory system.

REVIEW

REVIEW

Otitis media is defined as inflammation of the middle ear and includes not only the middle ear cavity but also the Eustachian tube and mastoid. Sensorineural hearing loss has been documented in patients who have otitis media by many researchers. Cochlear losses were found to be associated with various types of otitis media such as chronic otitis media (Tos, 1988) Purulent otitis media (Walby, Barrera and Schuknecht, 1984) and otitis media with effusion (Arnold, Ganzer and Kleinmann, 1977)

The effect of long term Otitis Media (OM) on the inner ear has been investigated since long in literature, however studies searching for a possible relation between OM and cochlear function remain insufficient. Although OM incidence and prevalence estimates vary, it is especially prevalent in children under 2 years of age, 35% - 73% of infants under the age of 6 months have their first attack of OM (Casselbrant, 1989) while 74% of infants have an episode of OM between 6 and 18 months of age (Finitzo, Roland, Friel Patti, 1985). Thus it is evident that OM is a common disease of childhood and needs timely intervention to prevent its progression toward irreversible chronic otitis media, which can in turn affect the inner ear. Therefore OM population especially those suffering from chronic suppurative otitis media (CSOM) need to be monitored to investigate whether the inner ear physiology in such patients gets altered.

Possible Routes Between Middle Ear and Inner Ear

Morizono and Tono, (1991) observed that substances in the middle ear fluid do not cause any inner ear damage until they enter in to the inner ear. The possible routes between the inner and the middle ear are through the round or oval window, through the facial canal, through the micro fissures or hematogenically. Experimental labyrinthine lesions through stylo mastoid foramen were observed by Kumagami, (1976). Ohashi, Tomoda and Yoshie, (1989) produced endolymphatic hydrops after type II collagen immunization through the stylomastoid foramen of the guinea pig and confirmed presence of negative SP enlargement, which was indicative of hydropic ear.

Target Structures in the Inner Ear

Saijo and Kitnura, (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).

Mogi, Suzuki and Fujiyoshi, (1988) proposed that various vasoactive mediators may cross, round window membrane and concentration of these mediators in the perilymph may rise in the presence of Middle ear effusion. These mediators (eg. Histamine, prostaglandin, leukotrienes etc.) First reach the scala tympani of the cochlear basal end where the spiral modiolus vein runs interiorly and drains into the vein of the cochlear aqueduct and inflammatory cells migrate into the inner ear through systemic circulation (Harris, Futuda & Keithley, 1990).

However, Anderson and Barr, (1969) observed an interesting phenomenon what they called as conductive recruitment. In their conductive hearing loss subjects they observed abnormal acoustic reflex thresholds (at lower SLs) and abnormal ABLB, which is usually seen in cases with cochlear pathology.

Thus it is clear that conductive hearing loss can affect cochlear functioning. Therefore there is a need for studying cochlear conduction in individuals with conductive pathology.

The present study investigates the cochlear resolution in longstanding conductive pathology namely chronic suppurative otitis media (CSOM), using PTC.

To understand PTC better, its classic shape and factors affecting it are discussed below.

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 or 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 LF 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 while the lower skirt of the PTC becomes shallower as signal level increases at high intensities indicating a non-linearity. This maximum non-linearity is seen when masker frequency is about 0.8 times the signal frequency (Abeele, Heyning, Cretin, Graff and Marquet, 1992).

(3) <Beats

When a sinusoidal signal and a sinusoidal masker are presented simultaneously, the envelope of the combined stimulus fluctuates regularly resulting in 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 Tones

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 pattern, to detect it. As the signal rises above threshold, 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) T*ype of masking*

Two types of masking can be used in PTC (Bacon and Moore, 1986). They are

(a) Simultaneous masking: Here the signal occurs at the beginning, in the temporal center, or 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 simultaneously masking, the broadest PTC is for the signal at the beginning of the masker. Q_{10} 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.

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, PTC has 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 10dB from the tip. A similar approach was adopted by Florentine, Buus, Scharf and Zwicker, (1980) and Ritsma, Wit and VanderLans, (1980) to quantify PTC obtained from hearing impaired listeners. Bonding (1979f) gave a measure called d_I 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 d_I oct overestimated the tuning curve in many hearing impaired listeners.

b. Other approach is given by Tyler, Small and Abbas, (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 slope of a PTC obtained with several masker frequencies.

Evans, (1975) reports that fibres in the 10KHz region show the steepest slopes. Here the high frequency slopes measured at 5 dBSL 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, Wood and Fernandes, (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, Q_{10} 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 psychoacoustics and physiological experiments (Evans, 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.
2. PTC in conductive hearing loss.

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, Buus, Scharf, Zwicker, 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 correlation 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 resolution in most individuals with sensorineural hearing loss.

PTC in Conductive Hearing Loss

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

The classic study done on PTC is by *Schorn, Wurzen, Zollner,* and *Zwicker,* (1977) and *Zwicker and Schorn,* (1978). Tuning curve was measured in normal hearing at 500Hz and 4000Hz, in ears with conductive loss, otosclerosis, degenerative hearing loss, noise induced hearing loss, ototoxicity and Meniere's disease. 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 with Bone conduction being lOdB HL showed decreased frequency selectivity, though otosclerosis is commonly regarded as conductive hearing loss.

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

The conductive and otosclerotic groups were tested prior to otological surgery. The conductive group consisted of observers with acute or chronic otitis media, ruptured tympanic membrane or ceruminal occlusion.

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

Frequency selectivity was evaluated on the basis of Q value and Q value 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 statistical analysis revealed that the Q value did not differ significantly among the groups i.e. conductive (non otosclerotic) vs normals at 500Hz and 4000Hz.

In the otosclerotic group, at 4KHz significant difference among the group were indicated by the Q value with larger Q values in the group with normal bone conduction threshold than in the group with elevated BC thresholds. The authors based on the results of the study concluded that:

1. Q values are significantly smaller in all the groups of observers with elevated BC thresholds.
2. Sensitivity of Q values is demonstrated by the fact that tip of PTC is altered even for small hearing losses (Evans, 1975a,b).
3. Q values provide a measure of degree of cochlear impairment.

Snik, Teimisson and Cremers, (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 ages of 18 to 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 lOdB SL. dl 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_I oct values of the normal hearing and normal ear of the patients with atresia were 44.3 ± 2.0dB 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 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 viz. congenital atresia of ear canal.

Margolis and Nelson, (1993) reported of a patient with acute otitis media with transient sensorineural hearing loss. Early symptoms included otalgia, progressive sensorineural hearing loss and tinnitus with inflammation of the tympanic membrane. During the second week, a conductive component emerged resulting in a 60dB mixed loss in the 2-4 KHz regions. The conductive component lasted 15 days while the sensory neural hearing loss recovered more slowly with complete recovery at 6 months.

The psychophysical tuning curves were measured with a 4 interval Alternate Forced Choice psychophysical procedures using a laboratory system designed for psychoacoustic experiment. Tuning curves were measured for a 4KHz, 250msec probe tone temporally centered in 500msec, simultaneous maskers that were 400Hz bands of multiplied noise.

PTC indicated impaired frequency selectivity during the mixed hearing loss stage wherein there was a mixed component. When the threshold at 4KHz was 75dB SPL, the tuning curve obtained with an 85dB SPL tone in the impaired ear had a high frequency slope that was more gradual (92dB/octave) than would be expected from a normal hearing ear with large conductive loss.

The PTC obtained in the normal ear of the same patient showed a steep high frequency (HF) slope (200dB/octave) over the same range of masker frequencies. This more gradual HF slope in the impaired ear is consistent with cochlear abnormality at 4KHz region of the cochlea.

Later on day 29, the threshold at 4KHz recovered to 55dB SPL, the tuning curve obtained with an 85dB SPL probe tone from the Right ear had a steep HF slope (220dB/octave) as did the tuning curve with 45dB SPL tone (180dB/octave) from the same ear. These steep high frequency slopes are consistent with normal or near normal hearing at 4KHz.

Thus it is evident that as the sensorineural component of the pathology improved, the tuning curve showed steeper slopes similar to that obtained in normal ears.

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

/. *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 monitor whether middle ear inflammatory disease can affect cochlear function and alter PTC and also if the severity of cochlear damage can change with the duration of middle ear infection.

Subjects

The subjects taken for the study were divided in to two groups -

a) *Control group*

b) *Experimental group*

Each of the groups consisted of 19 ears with normal hearing and 19 ears with conductive hearing loss.

Criteria for selection of subjects for the control group

- Age range was between 17-35 years, irrespective of gender
- No otological or neurological history reported

Audiological findings:

a) Air conduction and bone conduction pure tone hearing thresholds were within 15 dBHL at the conventional audiometric frequencies from 250 Hz to 8KHz

b) Immittance results showed 'A' type tympanogram with normal reflexes.

Criteria for selection of subjects for the experimental group

- Group consisted of ears with conductive hearing loss due to chronic suppurative otitis media.

- Age range was between 12-30 yrs irrespective of gender.
- All the patients had middle ear infection and were diagnosed to have chronic suppurative otitis media (CSOM) by an Otologist.

Audiological findings:

- The Air bone gap ranged from 15dB-45dB and BC threshold was within normal limit (<15dBHL) at all frequencies ranging from 250 Hz to 4KHz.
- The AC threshold ranged from 20dB to 65dB between 250 Hz to 8KHz at all the conventional audiometric frequencies.
- Rise and fall did not exceed l0dB/octave for pure tone AC threshold.
- Immittance showed 'B' type tympanogram with absent reflexes.

The experimental group was further subdivided into 3 groups based on the duration of Otitis media, which are as follows-

(1) Group D_I Consisted of 8 ears with bouts of Otitis media since 5 years

(2) Group D_2: Consisted of 5 ears with bouts of Otitis media since 5-10 years

(3) Group D_3: Consisted of 6 ears with bouts of Otitis media since more than 10 years

Equipment

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

- Calibrated Grason and Stadler (GSI 33) version-2 immittance audiometer was used to assess middle ear condition
- PTCs were obtained for those subjects who passed the criteria in both the 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 pure tone thresholds were obtained using the Carhart & 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 the patient had to raise his index finger even for the softest tone heard.

Measurement of PTC

The PTCs were obtained at fixed test tone frequency of 500Hz, 1KHz and 2KHz (as those are 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 (sensation 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 lOOHz.The 10 dBSL test tone was masked by the NBN starting at OdBSPL. If the subject indicated to the test tone in presence of the masker, the level of the masker was increased in lOdB 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 Silvennann, 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

Qio 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.

$$Q_{value} = \frac{\text{Center frequency}}{\text{Bandwidth}}$$

The Q_{I0} values were calculated at different frequencies for all the subjects independently.

Statistical analysis

The Q_{I0} values, which were obtained for each individual 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 in Q_{10} values between ears with normal hearing and ears with conductive hearing loss due to otitis media.

b) There is any significant difference in Q_{10} values between ears with normal hearing and each of the sub groups of otitis media depending on the duration.

c) There is any significant difference in Q_{10} values within the conductive hearing loss group as the duration of otitis media increases.

RESULTS

RESULTS

In the present study the aim was to investigate whether middle ear inflammatory disease could affect cochlear function or duration of the disease affected the degree of cochlear dysfunction.

The data obtained from the study was statistically analyzed and the results are as follows

I) Comparison of frequency selectivity, using PIC, in ears with conductive hearing loss due to otitis media versus ears with normal hearing.

PTCs obtained from 19 normal hearing ears were compared with 19 ears having conductive hearing loss due to otitis media at 500 Hz, 1 KHz and 2KHz.

Q_{10} values were computed as a measure of frequency selectivity for each of the ears at all the frequencies 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 conductive hearing loss due to otitis media. The T- value obtained was not statistically significant at all the frequencies as seen in table -I

Test Frequency		Control Group N=19	Experimental Group N=19	T-Value	S/NS
500Hz	Mean	2.4126	2.1289	1.660	NS
	Standard Deviation	0.4960	0.5560		
lOOOHz	Mean	4.2363	3.8205	1.600	NS
	Standard Deviation	0.7437	0.8542		
2000Hz	Mean	8.2526	7.2342	1.676	NS
	Standard Deviation	1.8401	1.907		

Table - I: *Shows (he mean and SD for (he Q values from (he con(rol 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 conductive hearing loss were elevated with respect to the puretone AC threshold, at all the frequencies.

The mean Q_{1o} values in the conductive hearing loss ears were lesser than the ears with normal hearing but not statistically significant.

In general the mean Q_{10} values showed a rising trend from 500Hz to 2KHz in both the groups indicating better frequency resolution at higher frequencies which is also reported by Densert et.al., (1986).

2) Comparison of frequency selectivity in normal hearing ears versus each of the subgroup in **otitis** media that is D_1 D_2 and D_3.

PTCs obtained from 19 normal hearing ears were compared with PVCs obtained from each of the subgroups D_1, D_2 and D, each having 8,5 and 6 subjects respectively. Q_{10} values were computed as a measure of frequency selectivity for each of the ears at 500 Hz, 1KHz and 2KHz for all the groups. The mean and SD of Q_{10} was calculated and subjected to t- test to find out whether there is a significant difference between the ears with normal hearing and ears with conductive hearing loss with otitis media group as the duration of otitis media varies.

There was no significant difference in mean Q_{10} values, as can be seen in table -II, between the ears with normal hearing and the ears with otitis media, based on duration at all the frequencies except at 1KHz.

Test Frequency		**Control Group**	Dl N=6	**Control Group**	**D2 N=5**	**Control Group**	D3 N=8
500Hz	Mean	2.4126	2.0933	2.4126	2.2175	2.4126	2.1233
	Standard Deviation	0.4960	0.5366	0.4960	0.4257	0.4960	0.7314
	T-Value	1.506 (NS)		0.808 (NS)		0.905 (NS)	
lOOOHz	Mean	4.2363	3.8589	4.2363	3.2250	4.2363	4.1600
	Standard Deviation	0.7437	0.7099	0.7437	0.5377	0.7437	1.1056
	T-Value	1.294 (NS)		3.176*		0.158 (NS)	
2000Hz	Mean	8.2526	6.8889	8.2526	9.0375	8.2526	9.5500
	Standard Deviation	1.8401	1.6465	1.8401	1.3671	1.8401	2.0500
	T-Value	1.890 (NS)		0.977 (NS)		1.813 (NS)	

* $P < 0.05$

Table -II: *Shows the mean and SD for the Q values obtained from the Control group and sub groups of otitis media along with the t-value.*

Where in there was a significant difference seen for normal versus D_2 (duration of otitis media between 5-10years) group at 0.05 level which could be due to the presence of least number of ears in the D_2 group. It was also seen that the mean Q_{10} value for D_2 group at 2000Hz is comparatively higher than D_1 and D_2which might be due to extremely high Q_{10} values obtained in 3 out of 5 subjects in D_2group.

3) Comparison of frequency selectivity within the subgroup of otitis media that is D_1, Vs D_2, D_2 Vs D_3, D_1, Vs D_3.

The mean and SD for the Q_{10} values for each of the group, D_1 D_2 and D_3 is tabulated at 500 Hz, 1KHz and 2KHz as in table -III

Test Frequency		Dl N=6	D2 N=5	D2 N=5	D3 N=8	Dl N=6	D3 N=8
500Hz	Mean	2.0933	2.2175	2.2175	2.1233	2.0933	2.1233
	Standard Deviation	0.5366	0.4257	0.4257	0.7314	0.5366	0.7314
	T-Value	0.447 (NS)		0.257 (NS)		0.086 (NS)	
lOOOHz	Mean	3.8589	3.2250	3.2250	4.1600	3.8589	4.1600
	Standard Deviation	0.7099	0.5377	0.5377	1.1056	0.7099	1.1056
	T-Value	1.770 (NS)		1.7801 (NS)		0.591 (NS)	
2000Hz	Mean	6.8889	9.0375	9.0375	9.5500	6.8889	9.5500
	Standard Deviation	1.6465	1.3671	1.3671	2.0500	1.6465	2.0500
	T-Value	2.451 *		2.299 *		2.238 *	

* $P < 0.05$

Table — III: *Shows the mean and SD for the Q values obtained from the subgroups of otitis media with different durations along with the t- value.*

To find out whether there is a significant difference based on increasing durations of otitis media, independent sample t-test was used. At 2 KHz the difference was significant at 0.05 level ($P < 0.05$) between the subgroups of otitis media due to high mean Q_{10} value obtained for D_2 subgroup. It is seen that there is no specific trend seen between the mean Q_{10} values and the increasing duration of otitis media at all the test frequencies i.e., with the increase in frequency, there is similar increase in Q_{10} value in all the sub groups as seen in ears with normal hearing.

DISCUSSION

DISCUSSION

Psychophysical tuning curves are alternative means of measuring properties of frequency selectivity, of the auditory system, (Moore and Patterson, 1986). It is an efficient method and requires only simple masked threshold judgments from the observer.

In the present study PTCs were plotted for the ears with normal hearing and the ears with otitis media. All the normal hearing ears showed very similar tuning curve morphology with general flat low frequency portion and shallow V-shape in the region of the pure tone as also observed by Carney and Nelson, (1982). Pathological ears showed tuning curves, morphologically similar to normal ears, but the whole tuning curves was shifted corresponding to the pure tone AC thresholds at all the test frequencies. Zwicker and Schorn, (1978) also observed a similar pattern in their study and attributed it to the attenuation taking place in the middle ear corresponding to the air bone gap as can be seen in Fig I a and I b.

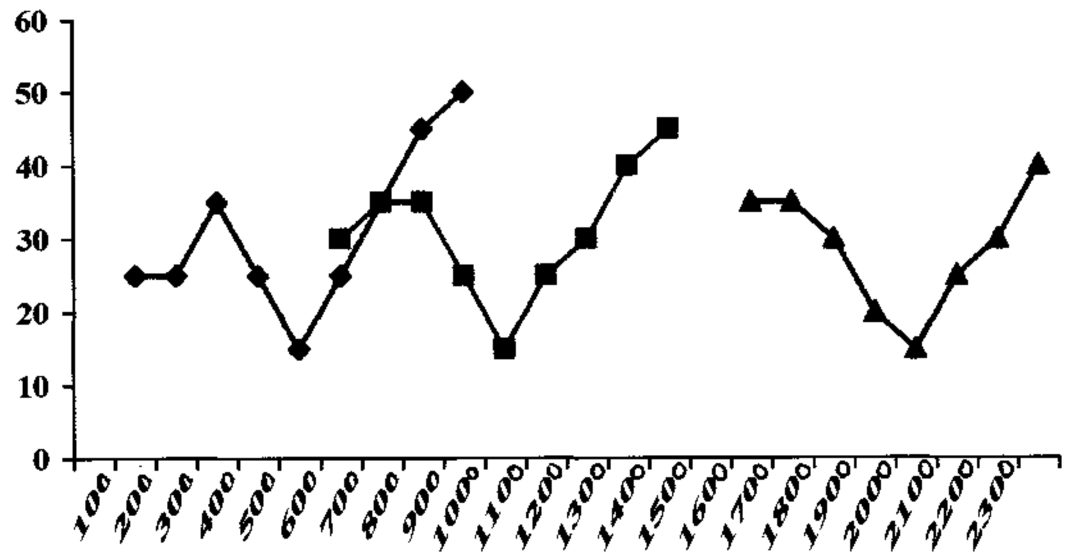

Figure 1 a

PTC at 500Hz, 1KHz and 2KHz in a normal hearing individual

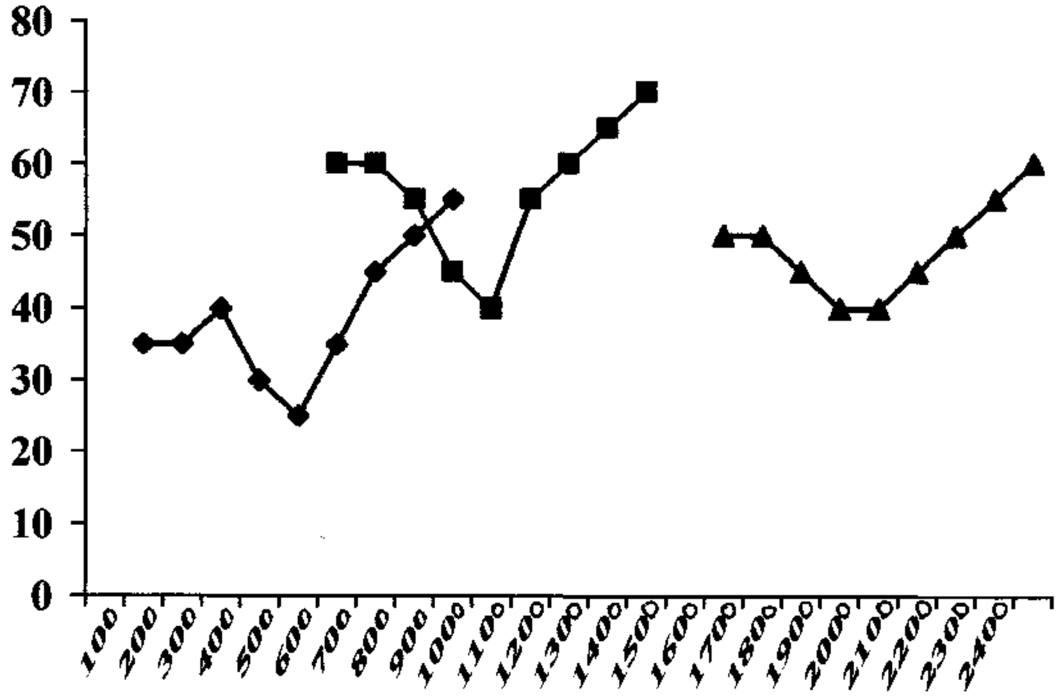

Figure I b

PTC at 500Hz, 1KHz and 2KHz in individual with Otitis media

The frequency selectivity WHS expressed in terms of Q_{10} values. The averaged Q_{10} values increased with increase in test frequency in both the groups, which can be explained by the improving cochlear resolution with increasing frequency (Densert, Kinberger, Arlinger and Densert, 1986).

TheQ_{10} values of otitis media group did not significantly differ from the normal hearing ears, yet there was a reduction in the Q_{10} value in otitis media group which can be inferred to a decrease in frequencies selectivity as reported by Florentine et. al., 1980. This alteration in Q_{10} values exists even for small hearing losses as observed in this study which is also supported by Evans, 1975 a,b.

Thus it was observed that in ears with conductive hearing loss due to otitis media, though the BC threshold was within normal range, the frequency resolution of the cochlea was impaired to a certain extent when compared to ears with normal hearing, which was not reflected in the BC threshold.

When each of the subgroups with different durations of otitis media were compared independently with the normal hearing ears, based on Q_{10} values, it was observed that the average Q_{10} values did not show a decreasing trend with increasing duration of otitis media as should have been the pattern based on available literature on PTCs, which could be attributed to the pre-treatment versus post treatment measurement of PTC, a variable which might have arrested the course of otitis media at any of its stages and was not controlled during the study.

There was a significant difference between the mean Q_{10} values between the normal hearing ears and ears with otitis media with a duration of 5-10 years (D_2) only at lOOOHz. While other test frequencies showed no significant difference, which could be due to the presence of least number of ears in the experimental group.

A significant difference was obtained in the Q_{10} values within the conductive hearing loss group between the various durations of otitis media, though there was no specific trend seen in the shift of Qio values.

At 500Hz and 2KHz the Q_{10} values for D_3 group (wherein the history of CSOM extended for greater than 10 years) were least when compared to D_2 and D_1 , which indicates that the frequency selectivity of the cochlea was most affected when the middle ear infection persisted for a long duration.

There is evidence available from animal studies (Fukaya and Nomura, 1983, Harris and Ryan, 1985, Woolf and Harris, 1986, Spandow, Anniko and Hellstrom, 1989) that the pathology in persistent conductive hearing loss cases is not confined to the middle ear only. The spread of infection from the middle ear to the inner ear can be through the round window or oval window and cochlear damage can be caused as a result of leakage of toxins from the middle ear through the Round window membrane, through the facial canal or through the microfissures hematogenically. These findings are reported by Downs, (1985); English, Northern and Fria, (1973); Paparella, Brady and Hoel, (1970); Tos, (1988); Walby, Barrera and Schuknecht, (1984); Munker, (1981); Arnold Ganzer, Kleinmann, (1977); Aviel and Ostfeld, (1982); Munker, (1977). This structural damage can alter the physiological properties of the auditory system viz. by altering the mechanical properties of the cochlea (Densert, Kinberger, Arlinger and Densert, 1986).

The least Q_{10} values for D_3 group can thus be assumed to indicate the reduced frequency selectivity of the cochlea with increasing duration of middle ear infection.

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 was no specific trend seen in Q_{10} values as the pure tone AC thresholds increased.

In general, the results are in agreement with existing studies that PTCs are broader than normals in hearing impaired subjects and elevated as the air bone gap increases.

SUMMARY
AND
CONCLUSION

SUMMARY AND CONCLUSION

PTC appears to be a suitable clinical tool for the indication of frequency selectivity and thus a measure of the cochlear function / dysfunction in normals and pathological groups.

Various studies imply that long-term middle ear infection can affect the inner ear leading to a permanent damage.

Therefore the present study aims to investigate whether long-term middle ear infection can alter the frequency selectivity of the cochlea. Psychophysical tuning curve (PTC) was used which is a non-invasive technique and requires simple masked responses from the observer. PTC has been found to be the most sensitive psychophysical procedure for investigating frequency resolution of the cochlea.

In the present study 19 normal hearing ears and 19 ears with conductive hearing loss due to otitis media were taken and PTC was measured at the speech frequencies (500Hz, I KHz and 2KHz) on 4 points either side of the center frequency. The conductive group was further sub divided in to three sub groups

D_1 - Consisting of 8 ears with history of otitis media since 5 years

D_2 - Consisting of 5 ears with history of otitis media since 5-10 years.

D_3 - Consisting of 6 ears with history of otitis media for more than 10 years

To measure the frequency resolution, the PTC was quantified in terms of Q_{10} value, which was calculated independently for all the subjects and later subjected to statistical analysis. The results obtained are as follows -

1. There was no significant difference between the mean Q_{10} values for ears with normal hearing and conductive hearing loss due to otitis media at all the frequencies, as supported by existing literature.

2. There were no significant differences between the mean Q_{10} values for ears with normal hearing and the subgroups of increasing duration of otitis media except at lOOOHz for duration D_2 that could be due to the presence of least number of subjects in D_2.

3. There was a significant difference in the mean Q_{10} values within the subgroups of increasing duration of otitis media, at all the frequencies.

In general though the mean Q_{10} values of the experimental and control group were not statistically significant, the Q_{10} values in the otitis media ears was lesser than ears with normal hearing i.e. PTCs were broader, in spite of the BC threshold being normal.

Conclusion

Hence, the study indicates that even for slight hearing loss, PTCs can be elevated and tend to be broader. Thus it can be hypothesized that though there may not be a significant shift in the tip of the PTC, middle ear pathology can alter the frequency resolution of the cochlea.

Clinical Implication

The most sensitive measure of decreased frequency selectivity are the PTCs (Florentine, Buus, Scharf and Zwicker, 1980). The sensitivity of the Q 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 conductive pathology due to recurrent middle ear infection like CSOM. The broadening of PTC inspite of normal BC threshold, though not statistically significant, can act as a detector and predictor of inner ear involvement in conductive pathologies. The prognosis of a treatment in middle ear infections can be inferred by measuring a pre-treatment versus post treatment PTC.

Drawbacks of the Study

1. In the present study simultaneous masking was used to obtain PTCs but literature suggests that when compared to simultaneous masking, forward masking gives sharper PTCs

2. The inter-subject variability in the Q_{10} values in the ears with CSOM can be attributed to the pre-treatment versus post treatment variable, which was not controlled during the measurement of PTC.

3. The duration of otitis media was recorded as reported by the patient. Since most of the patients belonged to a rural background, the awareness

about their hearing problem might have been limited and thus the duration of ear discharge as reported by them may not be authentic.

4. Number of subjects under each control group was limited.

Suggestions for Future Studies

1. Cochlear function may be studied in ears with persistent middle ear effusion having abnormal BC thresholds.
2. PTCs can be done beyond conventional audiometric frequency range using extended high frequency audiometry, in conductive hearing loss, to examine cochlear function.

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