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CLINCIAL IMPLICATIONS OF CONTIUOUS TONE MASKING (CTM) TEST USING DIAGNOSTIC AUDIOMETER

Register No.2

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A dissertation submitted in part fulfilmentfor second year M.Sc. (Speech and Hearing) to the University of Mysore.

MAY 1984

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CERTIFICATE

This is to certify that the dissertation entitled "Clinical Itnplicationsof Continuous Tone Masking (CTM) Test using Diagnostic Audiometers" is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with Register No.2

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CERTIFICATE

This is to certify that the dissertation entitled "Clinical Implications of Continuous Tone Masking (CTM) Test using Diagnostic Audiometer" has been prepared under my supervision and guidance.

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DECLARATION

This dissertation is the result of my own study undertaken under the guidance of Dr. M.N.Vyasamurthy, Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore

April 1984. REGISTER NO.2

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CHAPTER-I

INTRODUCTION

INTRODUCTION:

Not many years ago the Otologist had to be content with an audiologic assessment telling only whether the loss was conductive,sensory-neural or mixed. As audiology evolved it became possible to determine where in the sensory-neural pathway the site of lesion was, and for that matter, where in the conductive pathway as well. Cochlear, retro-cochlear and central lesions can be identified in an ever increasing percentage of cases. When dealing with sensori-neural hearing loss the Otologist looks to the audiologist for the site of the pathology. The audiologist and otologist, working as a team, can discover early cerebellopontine angle tumours such as acoustic neurinomas and by their cooperative efforts actually perform a life-saving function. Careful, meticulous audiology reaps its largest rewards in these cases (Gensberg and White, 1978).

The audiometric approach to site of lesion testing is accomplished by two different methods that include behavioral and physiological measures. Behavioural techniques require an overt response from the subject, with responses ranging from an involuntary eye blink to a description of the pitch and loudness characteristics of the signal that is being perceived. Measures of physiological changes that occur within the organism in response to acoustic stimuli include changes in the electrical activity of the brain, peripheral blood flow, respiration and heart rate, activity of the middle ear muscles, etc. The interpretive basis of diagnostic audiometry lies in recognizing patterns of response that occur for lesions located at different sites in the auditory system. These patterns result from different symptoms that are attributed to damage to the middle ear, cochlea, nerve VIII or central auditory pathways. (Keith, R.W, 1980).

In a sense, all audiometry is diagnostic since it contributes, in some sense, to the ultimate localization of the auditory disorder. The relationship between air-conduction and bone-conduction thresholds, for example, is one of the principle bases for differentiating conductive from sensori-neural hearing loss. However, some specialized techniques have been advanced in relatively recent years for the express purpose of sharpening the ability to differentiate among the various sites of auditory disorder (Jerger, J, 1973).

The results of Bekesy audiometry, tone decay and word discrimination tests, which are now generally considered the most efficient indicators of retrocochlear lesion, all three fall on a continuum - normal - cochlear - retrocochlear. Instead of a true qualitative difference, a retrocochlear sign is one which is "more cochlear than cochlear". It is the same type of response, only more so. We have seen mild retrocochlear problems giving cochlear characteristics and mild cochlear disorders giving results consistent with normal hearing. On the other hand, severe or acute cochlear disturbances have given the appearance of a retrocochlear condition.

The Continuous Tone Masking (CTM) test is unlike the aforementioned procedures in that the normal pattern falls between the cochlear and retrocochlear. While the test has received only a small series of clinical trials it appears to have considerable promise as a tool for differential diagnosis (Katz, J, 1969).

Aim of the present study:

To establish clinical implication of continuous Tone Masking test using diagnostic audiometer.

Null Hypothesis:

1) There is no significant difference between the threshold shifts obtained in normal hearing and conductive loss subjects, using continuous tone masking test.

2) There is no significant difference between the threshold shifts obtained in normal hearing and sensorineural (cochlear) hearing loss subjects using continuous tone masking test.

3) There is no significant difference between the threshold shifts. Obtained in normal hearing and sensorineural hearing loss with tone decay. Using continuous tone masking test.

4) There is no significant difference between the threshold shifts obtained in conductive loss subjects and sensori-neural (cochlear) hearing loss subjects. Using continuous tone masking test.

5) There is no significant difference between the threshold shifts obtained in conductive loss subjects and sensori-neural hearing loss subject with tone decay. Using continuous tone masking test.

6) There is no significant difference between the threshold shifts obtained in sensorineural (cochlear) hearing loss subjects and sensorineural hearing loss with tone decay subjects.

CHAPTER-II

REVIEW OF LITERATURE

REVIEW OF LITERATURE:

The use of a single test for the assessment of human hearing is a thing of the past. Even the most basic audiologic examination includes a battery of hearing tests. As more complex questions concerning the auditory system are asked, additional test items are added to the battery. Tests specifically designed to investigate the locus of pathology of the auditory system beyond those used in the standard examination include tests for cochlear pathology, retrocochlear pathology and brain pathology. More than one test in each area should be employed.

Test battery interpretation includes not only the evaluation of each test individually but an analysis of the "gestalt". Additional tests, both audiologic and extra-audiologic, do not confuse the diagnostic process at all but, rather, clarify and enhance the quality of audiologic investigation of the patient.

As we are dealing with a test for the differential diagnosis of cochlear and retrocochlear pathology, we shall also look into other tests used for the same purpose:

Tests of Cochlear and Nerve VIII Function:

(i) Loudness_Discomfort level:

The typical auditory symptom of patients with hair cell damage of the organ of corti is auditory recruitment. One simple measure of auditory recruitment is to obtain the loudness Discomfort Level (LDL) for speech or pure tones.

In the normal ear, the discomfort threshold is between 90 and 105 dB HL (Hood and Poole, 1966), so that the dynamic range between threshold of audibility to discomfort is also 90 to 105 dB.

Patients with conductive and nerve fiber deafness show discomfort threshold beyond the limits of the audiometer, i.e. greater than 110 dB HL. (Dix, 1968).

Patients with Meniere's disease, noise induced hearing loss, or other causes of hair cell damage have discomfort thresholds within the limits of the audiometer at levels closer to the threshold of audibility than normal. This narrow dynamic range indicates abnormal loudness growth and auditory recruitment (Keith, 1980).

The subjective nature of the test limits its exactness but nevertheless it does provide a useful screening procedure.

especially if impedance audiometry is not available,

(ii) The Most Comfortable Listening Level (MCL):

MCL is also obtained at reduced levels above hearing threshold when auditory recruitment is present. For example, Clemis and Carver (1967) found that the MCL for speech occurred at approximately 22 dB above speech reception thresholds for patients with Meniere's disease with moderate hearing loss. This compares to an MCL at approximately 55 dB above speech reception threshold for patients with normal hearing (Keith, 1979). To obtain an MCL, the examiner presents speech at varying intensities and ask the patient to report when speech is at a level that is most comfortably loud.

Some authors claim that the test is of little value for patients who are habitually exposed to loud sounds in their work environment, while other patients are sensitive to loud sounds for reasons that are not associated with hearing loss.

(iii) Displacusis:

Pitch disorders, known as diplacusis, indicate hair cell damage that accompanies Meniere's disease or noise trauma (Davis, 1962). In some patients diplacusis is reported to be so severe that pure tones have no tonal quality and sound like a buzz.

This test can be done by switching an air conducted pure tone between ears at levels of equal - loudness and asking the patient. Whether the tone has the same or a different pitch. While a modest pitch difference between ears can be normal, a substantial difference indicates inner ear pathology on the involved side (Carhart, 1973).

Information regarding the presence of severe diplacusis is also helpful in interpreting responses to ABLB, SISI, tone decay or other pure-tone tests.

(iv) Speech Discrimination:

In the routine assessment of hearing measurement of speech discrimination can yield important diagnostic clues to the presence of cochlear or retrocochlear hearing loss. In general, patients with cochlear hearing impairment have speech discrimination scores that are compatible with the degree of hearing loss (Keith, 1980).

By contrast,the presence of a nerve VIII lesion will often yield speech discrimination scores that are poorer than would be expected from the pure-tone thresholds. Since almost all of the monosyllabic test materials used in speech discrimination testing are quiet easy for most hearing impaired patients

(Carhart, 1965; Keith and Tails, 1972), deterioration of speech discrimination ability beyond what is "reasonable" should be viewed as being diagnostically important.

(v) Short Increment Sensitivity Index (SISI):

The SISI is a test of a patient's ability to perceive a series of 1 dB increments superimposed on a continuous pure tone presented at 20 dB above the threshold of the test frequency. It was described by Jerger, Shedd, and Harford in 1959.

Low SISI scores (0.30%) are said to be typical of a neural hearing loss. There are, however, several difficulties encountered on applying the test. Some patients give a high SISI score at one frequency and a low SISI score at another frequency. Johnson (1977) gave several examples; one patient had a SISI score of 0 per cent at 1 KHz and a SISI score of 100 per cent at 2 KHz. In other patients the hearing loss is so severe that the test can only be applied at certain frequencies if at all. Sometimes abnormal auditory adaptation account for a high score initially and then the patient reports that he no longer hears the carrier tone.

The SISI procedure remains an easy to perform but one which must be interpreted with great care in difficult diagnostic circumstances.

(vi) Alternate Binaural Loudness Balance Test (ABLB test):

Clinical interest in abnormal loudness growth, which was labelled recruitment by Fowler (1937), began with his report and description of the alternate binaural loudness balance (ABLB) test (Fowler, 1936).

It was Dix, Hallpike and Hood (1948) who demonstrated that recruitment may point to a cochlear lesion. They noted that recruitment very seldom occurred in persons with cranial nerve VIII tumours, while recruitment was typically seen in patients with Meniere's disease.

There is, at present, some disagreement on the diagnostic significance of recruitment (Coles, 1972? Priede and Coles, 1974). However, the measurement of loudness growth remains a valuable part of diagnostic audiology.

(vii) Bekesy Audiometry:

BeKesy audiometer is a testing method in which patients trace their auditory threshold on a self-recording audiometers

(Bekesy, 1947? Reger, 1951). Pure tones are traced under various conditions, including sweep frequency (continuously variable from low to high or high to low frequency) or discrete frequency (at selected fixed frequencies) for either pulsed or continuous tones.

Attention was drawn to threshold adaptation that occured as patients traced their threshold over time. This attention was brought into focus by Jerger (1960) who classified Bekesy test results into four categories or types, to which he ascribed various otological pathologies.

Type I : Interweaving of continuous and interrupted tones and a tracing width which is constant over frequency and average about 10 dB.

Type II : The continuous tracing drops below the interrupted at high frequencies. The gap seldom exceeds 20 dB or appears at frequencies below lOOOHz. Second the width of the continuous tracing is smaller than the pulse tone tracings at high frequencies.

Type III : The continuous tracing drops below the interrupted to a remarkable degree and may diverge at relatively low frequencies (100 to 500 Hz). The width of the continuous tracing remains quiet normal.

Type IV : Resembles the type II except that the continuous tracing falls consistently below the interrupted at all frequencies, although it does not show the precipitour drop of the type III. The tracing width may or may not become abnormally small.

In general terms, the relationship between anatomic site of lesion end Bekesy type is as follows:-

Type I : Normal hearing or lesion of the middle ear (Otosclerosis, Otitis media, other conductive loss).

Type II : Cochlear lesion (Meniere's disease, noise-induced).

Type III & IV - VIIIth nerve lesion.

Unfortunately many clinicians have been confused when results do not fit into neat categories, or they have been too literal when interpreting Bekesy test results.

Conventional Bekesy testing can often yield a Type I or II tracing when a retrocochlear lesion is present. While this may not be a fault of the Bekesy test per se, since often a cochlear and retrocochlear lesion exists simultaneously, a more sensitive test of nerve VIII lesion is desirable.

(viii) Bekesy Comfortable Loudness Test:

Another recent modification of the conventional sweep-frequency Bekesy audiogram changed the Bekesy procedure into a supra-threshold, rather than a threshold task. This modification is based on the concept that abnormal adapatation first appears only at the highest audiometric intensities. As the VIII nerve disorder progresses, the abnormal signs begin to appear at lower and lower suprathreshold levels until eventually, they finally reach threshold.

. In this new procedure called the "Bekesy Comfortable Loudness" test, patients are instructed to press and release a response switch in the conventional manner. However, instead of pressing when the signal is just - inaudible, the patients task is to press the button when the signal is just more than "Comfortably loud" and to release the button when the signal is just less than "Comfortably loud". This distinction among BCL pattern is based on the relation between interrupted and continuous tracings. The patterns are not, however, classified into one of the five conventional threshold Bekesy types. Instead, BCL results are reported as either positve or negative. Positive findings are consistent with a retrocochlear site, negative findings are consistent with normal, conductive or cochlear findings (Jerger and Jerger, 1974).

(ix) Forward-Backward Discrepancy:

Substantial evidence has accumulated during the past decade, showing that the diagnostic value of the conventional sweep-frequency threshold Bekesy audiogram can be enchanced by reversing the direction of frequency. The patient's threshold tracing for this "backward" direction of frequency change (i.e. from high to low) is compared with his threshold tracing in the conventional "forward" mode of frequency change (i.e. from low to high).

Jerger et al (1972) formulated a general criterion for this discrepancy based on the magnitude of the divergence, irrespective of its pattern:-

1) a separation greater than 10 dB over at least two octaves, or

2) a separation of more than 30 dB over at least one octave, or

3) a separation of more than 50 dB over at least one - half octave.

Using this set of criteria, Jerger et al (1972) analyzed results in 150 patients with either cochlear, retrocochlear or functional disorder. Abnormality (i.e., a significant forward - backward discrepancy) was rare in cochlear disorders but common in both retrocochlear and functional disorders. Of particular interest for the differentiation of cochlear and VIII nerve disorders, moreover, was the observation that in some patients with acoustic neuroma, the forward - backward discrepancy was present even though the conventional threshold tracings failed to demonstrate either a type III or a type IV pattern. On the basis of these encouraging findings it was concluded that the continuous - backward tracing should become an integral part of conventional Bekesy audiometry.

(x) <u>Critical Off-Time (COT)</u>:

When the interrupted stimulus is given the two parameters are very important. They are:

1) signal duration - on time

2) Off time

Usually the on time is equal to off time (50% duty cycle). A on time = off time = 200 m sec.

When the tone is given to a normal ear, the ear gets fatigued and it weakness the stimulus. But when rest or recovery time is given (without stimulus) then the nerve fibres are ready to take another stimulus. This recovery period in normals is 40 m. sec.(Carterette, 1955).

"Critical off time" is the time in m.sec, at which the threshold and amplitude of interrupted signal falls down (becomes worse). This results in lessening the gap between the continuous and interrupted tracing. So COT is the time in m.sec, which is not sufficient to preserve neural independence among successive tones. So the interrupted tone behaves as a continuous tone and both the tracings come together.

In six cases of cochlear lesions the critical off-time varied between 25 and 75 m.sec. for both threshold and amplitude change. An abnormally adapting ear showed a critical off-time of 120 m.sec. for threshold and .25 m. sec. for amplitude (Young, I.M and Harbert, F, 1968).

(xi) Brief_Tone_Audiometry:

BTA is an emerging procedure that may be considered the complement of the more traditional Bekesy audiometry. BTA examines the relative threshold differences among pulsed tones which vary in their duration. BTA both augments and supplements the findings of Bekesy audiometry and can be incorporated with it to achieve a diagnostic potency which neither alone provides.

When the duration of a tone is progressively decreased below 1 sec, the intensity required to maintain its audibility must be continuously increased. Zwislocki (1960-69) indicates that this phenomenon is due to the psychophysiologic process of temporal - summation.

The threshold for 500-, 200-, 100-, 50-, 20- and 10- m.sec tones at a single frequency is tracked at an attenuation rate of 2.5 dB/sec over successive 1 min. intervals. All tones are presented at a repetition rate of 1/sec with a rise-fall time of 10 m.sec as defined between 10% and 90% of maximum amplitude. The durations are specifically defined in terms of the effective sound pressure at the half-power points.

The instructions to the listener are essentially the same as those used for routine Bekesy audiometry.

The individual tracking results 14 BTA are analyzed by visually estimating the threshold for each duration tone from the mid points of the tracings. The thresholds thus obtained are then referred to those obtained for either 500 or 20 m.sec tones to derive relatively complete descriptions of how threshold varies with duration.

Three categorical findings, or guidelines, can be used to interpret our results:

(1) When the threshold difference is on the order of 10 dB,

this is consistent with normal hearing, conductive hearing loss, or nerve VIII dysfunction.

(2) When the threshold difference is 5 dB or less, the audiologic differential is cochlear involvement either with or without a conductive component.

(3) When the threshold difference is 15 dB or more, this is audiologic support for temporal lobe dysfunction or pseudohypacusis.

(xii) Rollover (PI-PB Function)

The original observation by Schuknecht and Woellner(1955) that the speech discrimination score may be severely reduced inspite of only slight reduction in pure-tone sensitivity, in patients with VIII nerve disorder, has been repeatedly confirmed by other investigations. The diagnostic value of this phenomenon is limited, however, by the substantial overlap of PB max scores in cochlear and VIII nerve patients with similar sensitivity loss (Johnson, 1966). Recent evidence (Jerger and Jerger, 1971), demonstrates, however, that valuable diagnostic information resides in the shape of the performance versus intensity (PI) function for PB words (PI-PB). These investigators demonstrated a uniqe "rollver" configuration of the PI-PB function in patients with VIII nerve disorder. As the intensity of the speech signal was increased, performance rose to a maximum level. As intensity was increased above the level yielding maximum performance, however, there was a paradoxical reduction in performance often to an astonishing degree. At very high speech levels performance often declined to 0%. In other words, the PI-PB function, in the ear with VIII nerve disorder, showed pronounced "rollover" above the point of maximum performance.

Although slight rollover occurred in some cochlear patients substantial effects characterized the retrocochlear sites. A "rollover index" for the PI-PB function may be computed by subtracting the PB min (lowest score above PB max) from the PB max, then dividing by the PB max.

$$\text{Rollover index} = \frac{\text{PB max - PB min}}{\text{PB max.}}$$

The rollover phenomenon highlights the importance of testIng for speech intelligibility at several supra-threshold levels.

(xiii) Acoustic Reflex Measures:

Cochlear - In the ear with a cochlear disorder, the reflex sensation level (SL) for pure tones in the 500 to 4000 Hz region declines in exact proportion to the degree of hearing loss (Jerger et al, 1974b, 1978). It is a decibel-for-decibel trade. The practical implication is that if a patient has a sensorineural loss that does not exceed 85 to 100 dB, and the loss is cochlear, he ought to show a reflex when a sufficiently intense sound is introduced into that ear.

Eight Nerve Lesion:

Anderson and colleagues (1969) were the first investigators to describe essentially three abnormal acoustic reflex findings in patients with eight nerve disorders. These are

(1) elevated acoustic reflexes?

(2) absent acoustic reflexes; and

(3) acoustic reflex decay.

Reflex Elevation and Absence:

The phenomenon of "elevated" reflex thresholds in eight nerve disorder refers to the elevation of the reflex HTL in relation to expectation based on "normal" and "cochlear" ears. In terms of reflex SL, however, the threshold is quiet "normal".

Since the reflex SL tends to remain "normal" (i.e. 85 dB) in eight nerve disorders, increasing hearing loss will eventually drive the reflex HTL beyond the upper limit of the audiometer producing the reflex - eliciting signal is 100 dB, we would expect the reflex to disappear altogether when hearing loss exceeds 25 dB. It is not surprising, then, that reflexes are the exception rather than the rule in eight nerve disorders.

(Jerger et al 1974b). Unless the audiometric loss is very slight, the acoustic reflex is usually not elicited at all in eight nerve disorders.

Reflex Decay:

A useful test for reflex decay is to sustain 500 or 1000 Hz test signal for 10 sec at a reflex SL of 10 dB. If the reflex amplitude declines to less than one half of its initial value within 10 second test period, abnormal decay is present. Its appearance at either of those frequencies is strongly indicative of eight nerve site.

(xiv) Tone Decay:

Abnormal tone decay is a symptom that is associated with retrocochlear lesions. Extreme tone decays can occur even when thresholds for pure tones of short duration are only midly or moderately elevated. Both Bekesy and conventional audiometers are employed to assess tone decay. Reger and Kos (1952), using Bekesy instrumentation, made the observation that an abnormally rapid temporary threshold shift occurred in an individual with a cranial nerve VIII tumour. This discovery led to increased interest in the assessment of tone decay and to refinements in techniques of measurement with both standard and Bekesy audiometer.

There are several different tests of abnormal adaptation which can be measured both at near hearing threshold levels as well as at higher suprathreshold levels.

(a) The Carhart threshold Tone Decay:-

Carhart (1957) described a tone decay test involving presentation of an air-conducted pure tone at threshold. If the patient reports that the tone has faded into inaudibility, the intensity is increased 5 dB without interruption. The process is continued until 0 level is found at which the tone is heard continuously for 60 sec. The different between the initial threshold and the final intensity level is the amount of auditory adaptation that is reported in decibels of threshold shift. Carhart noted that normal hearing persons had only 0 to 5 dB of auditory adaptation, and patients with sensorineural hearing loss (i.e. cochlear) do not reveal appreciable tone decay. However, research has shown, that auditory adaptation in excess of 30 dB is an indication of VIII nerve pathology (Tillman, 1969? Rosenberg, 1969).

(b) The Modified Carhart Procedure:-

Rosenberg (1958) suggested a modification of the Carhart test in which the patients auditory adaptation to a continuous pure tone is measured for a total of 60 sec at each frequency tested. The test is started at threshold and 5 dB increments are added each time the tone fades to inaudibility. The amount of threshold change that occurs during the 60 sec is recorded as the amount of tone decay.

(c) Olsen and Noffsinger. Tone Decay Test:-

The Carhart, Rosenberg, 20 dB SL modification of the Carhart, and fixed frequency Bekesy tone decay tests were administered by Olsen and Noffsinger (1974). It was hypothesized that a tone decay procedure that was initiated at 20 dB SL would be an effective way to screen out persons with cochlear lesions, who commonly manifest as much as 20 dB of decay. At the same time, the authors felt that the test would still be effective in identifying persons with VIII nerve lesions.

Green (1972) pointed out that, while there appears to be general agreement that 30 dB of adaptation indicates a retrocochlear pathology, each dB of shift above 15 should raise the index of suspicion that a retrocochlear lesion may exist. He states further that the greater the decay and the number of frequencies involved, the greater the possibility of retrocochlear pathology.

(d) Jerger's Suprathreshold Test For Abnormal Auditory Adaptation:

Jerger and Jerger (1975) suggested a method of using the pure tone audiometer to measure suprathreshold adaptation. A pure-tone (500, 1000 or 2000Hz) is presented continuously at 110 dB SPL. If the patient ceases to hear the sound within 60 seconds, the test is regarded as positive. The test should not be done at frequencies above 2000 Hz or when thresholds exceed 90 dB SPL. The authors comment that the procedure called the Suprathreshold Adaptation Test (STAT) has three advantages:

(i) It takes an absolute minimum of time.

(ii) It seems to have a lower false- positive rate than threshold tone decay tests.

(iii) It seeks abnormal adaptation at suprathreshold regions where it is most likely to be found.

(xv) The Auditory Evoked Brainstem Electric Response Audiometry (ABR_or_BRA)

The use of BRA for assessment of hearing as well as for discriminating between cochlear and retrochlear hearing loss rests on the clinical experience that the ABR is strikingly resistant to cochlear lesions, but is easily distorted by retro-cochlear lesions. However, this does not imply that cochlear lesions do not alter the ABR, and the alterations caused by peripheral lesions are qualitatively of the same kind as those caused by the retrocochlear lesions. Nevertheless, the changes are generally smaller (provided the cochlear loss is not very severe), and they may be systematically correlated with the actual hearing loss, which is not the case with retrocochlear lesions (Rosenhamer, 1981).

The ABR parameters studied are primarily the latencies of waves I, III and V, absolute latencies as well as inter-peak latencies (IPL) and interaural latency difference (ILD). Sometimes amplitude are observed besides latencies, absolute amplitudes as well as relative amplitudes and interaural amplitude differences.

(xvi) The continuous Tone Masking Test (CTM)

The CTM test is based on a procedure reported by Lilly and Thalmann (1964). In an ingenious study they tested the hypothesis that masking occurs in the cochlea. They used a number of patients with retrocochlear problems and complete pure-tone adaptation for the experiment. The patient traced his threshold for a pulse tone. Then a slightly different continuous tone was introduced, which shifted the pulse-tone threshold. Despite the inaudibility of the masker, threshold was adversely affected. Lilly and Thalmann noted that even 10 dB of the masking made a significant it shift in the pulsed threshold.

In order to test the hypothesis that a conductive hearing loss produced a retrocochlear effect,(Katz, 1965; Katz and Willis, 1967) tested normal listeners, both with or without earplug on the CTM. They also tested patients with conductive hearing loss and found that conductive ears behaved in a manner similar to that described by Lilly and Thalman. The conductive subjects shifted +8 dB at 10 dB SLy +15 dB at 20 dB SL and + 22 dB for 30 dB SL for 0.5, 2 and 6 KC/s. The normals were similar in both plugged and unplugged conditions. The normal values for that study were +1, +9 and +17 dB at those three levels. For CTM, threshold appears more critical than frequency.

The test has received only a small series of clinical trials. It can be valuable particularly in mild cases which show normal Bekesy audiograms. It can also be used when tone decay is great enough to cause uncertainty, but is not severe, for example 20 to 25 dB on the Rosenberg test or a Bekesy type II D or II E (Katz, 1969).

CHAPTER-III

METHODOLOGY

METHODOLOGY:

Subjects:

Four groups of subjects were selected for the testing purpose,

Group-I: Normal hearing group:

Subjects having hearing within normal limits (20 dB HL ANSI 1969) as indicated by audiometric results were selected. 15 subjects (9M, 6F) in age range of 18-26 years with mean age of 20.93 years were selected.

Group-II: Conductive hearing loss group:

Subjects having bilateral conductive hearing loss of 70 dB HL, were selected for this group. 10 subjects (3M, 7F) in age range of 9-46 years with mean age of 28.1 years were selected.

Group-III: S.N.(Cochlear) Hearing loss group:

Subjects having bilateral cochlear hearing loss of 70 dB HL at the test frequencies were selected for this group. 10 subjects (6M, 4F) in the age range of 29-70 years with mean age of 46.4 years were selected.

Group-IV: S.N.Hearing loss with +ve Tone decay group:

Subjects having symmetrical loss of 70 dB HL at the test frequency with +ve tone decay at 500, 1000, 2000 or 4000 Hz using Olsen and Noffsinger Tone Decay Test, were selected for this group. 10 subjects (8M, 2F) in the age range of 25-61 years with the mean age of 41.4 years were selected. In this group, 5 ears had +Ve Tone Decay at 500Hz, 8 ears had +Ve Tone Decay at 1000 Hz, 9 ears had +Ve Tone Decay at 2000Hz and 6 ears had + Tones Decay at 4000 Hz.

Instrumentation:-

Beltone, Model 200-C audiometer was used as a test instrument. It furnishes two channels for audiometric testing. Channel one provides a calibrated speech circuit as well as eleven fixed test frequencies; and Channel Two provides six frequencies, plus several modes of available masking (i.e. White-spectrum, speech spectrum, and narrow-band noise).

The continuously variable intensity attenuators allow the selected stimuli to be varied over a 110 dB range and, by means of individual output selectors, to be directed to single phones or mixed phone combinations.

Testing Environment:

A two room situation was utilized for testing. The testing room was isolated and sound treated. The noise levels in the testing were well within the maximum allowable noise levels in dB SPL.

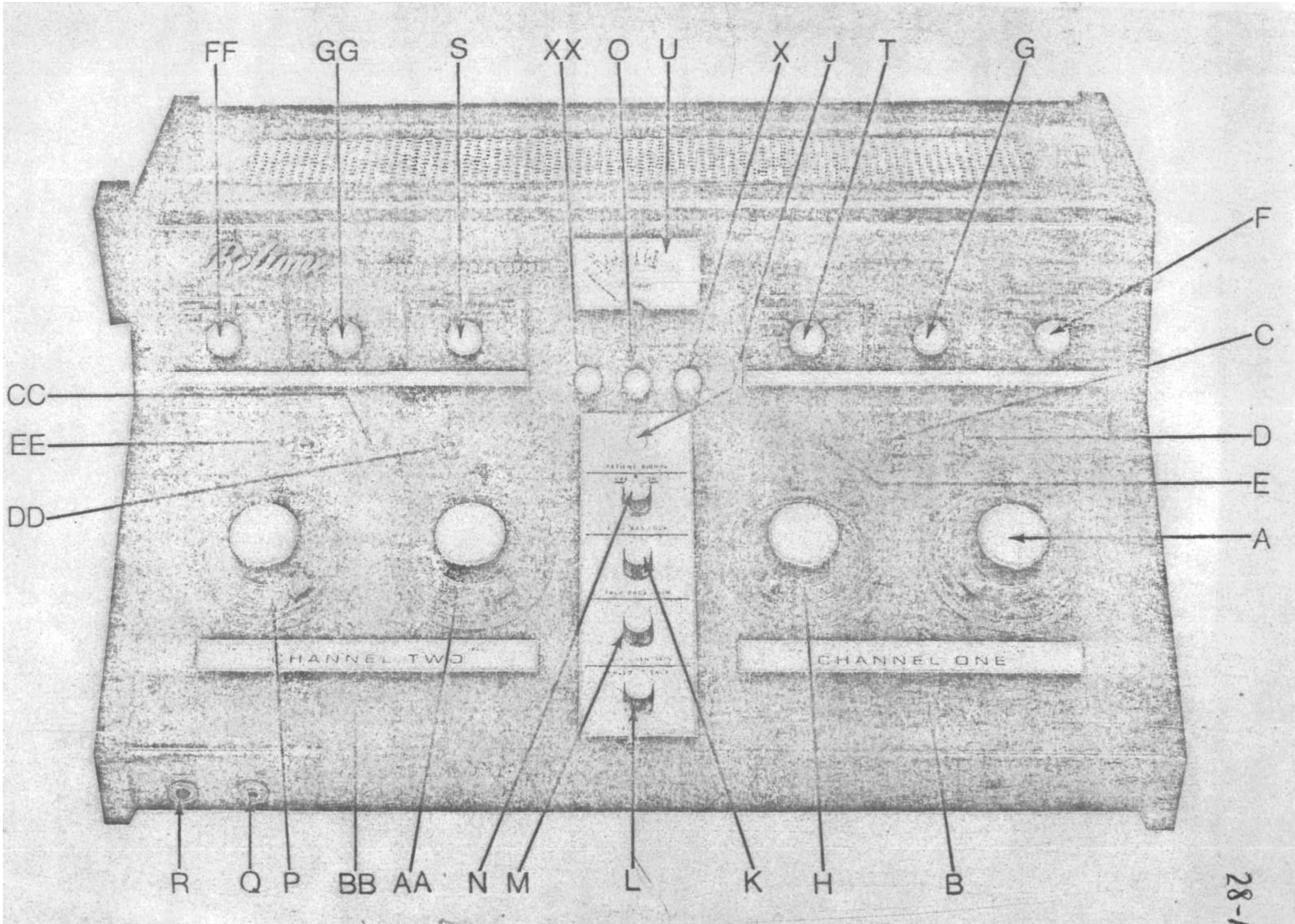


FIGURE # 1 ILLUSTRATION OPERATING CONTROLS

CALIBRATION OF THE AUDIOMETER:

The audiometer was calibrated to ANSI 1969 specifications, using Bruel and Kjaer equipment. The headphones (Telephonics TDH-49) of Beltone 200-C was coupled to the condensor microphone (B & K type 4145) of the SPL meter (B & K type 2203) with its associated octave band filter set (B & K type 1613) by means of a standard 6 cc coupler. The SPL output of each earphone of both the channels 1 and 3 were ehecked at octave band intervals from 250 Hz to 8000 Hz (Appendix B) .

Audiometer was checked for its linearity. Frequency calibration was done by coupling first, the TDH-49 earphones of the audiometer to the condenser microphone (B & K type 4145) of the SPL meter (B & K type 2203) with its associated octave band filter set (B & K type 1613) by means of 6 cc coupler. The output of the SPL meter was then fed to the frequency counter (Radart type 926 B) to check its frequency calibzation at different frequency settings.

Harmonic distortion of the signals was checked at one octave higher than the test frequency signals and was found to be less than 3% distortion.

Calibration of the audiometer was done once in fifteen days.

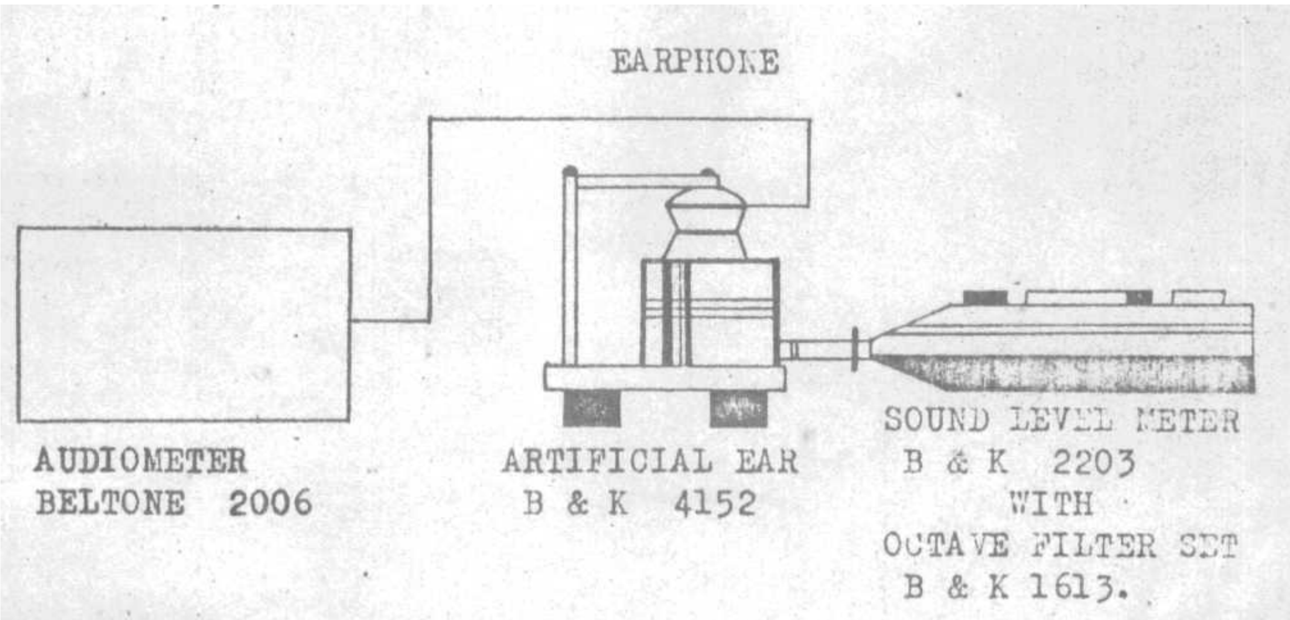


Fig.2 : Block Diagram of Pure Tone Calibration

Test Procedure:

Instructions for Step-l: "I am going to present some tones to your right (left) ear. Each time you hear it raise your hand quickly so that I know you heard it. These tones will be faint so you will have to listen carefully".

A pure-tone threshold is obtained in the test ear using the attenuator and interrupter for the continuous tone channel.

Instructions for Step-2: "You are now going to hear a faint continuous tone. Pay no attention to the tone and just listen for the pulsed tone. Raise your hand when you just hear the pulsed tone and drop your hand when the pulsed tone just disappears. Later, I will make that continuous tone even louder but you just ignore it and keep responding to the pulsed tone".

Step (2) a: The continuous tone is set 10 dB sensation level(SL) (Ref: Threshold obtained in Step 1) and the threshold for the pulsed-tone is obtained in the presence of the 10 dB SL continuous tone masking.

Step (2) b: The continuous tone is raised by 10 dB i.e. to 20 dB SL, and the threshold for the pulsed - tone is obtained in the presence of the continuous tone.

Step (2)c: The CTM is raised another 10 dB i.e. to 30 dB SL. Although this step may not be entirely necessary it is reassuring to see that the diagnostic pattern continues.

CHAPTER -IV

RESULTS

RESULTS:

The analysis of the results obtained in normal hearing, bilateral conductive hearing loss, S.N(cochlear) loss and S.N hearing loss with tone decay group, using continuous tone masking test was done. The mean and S.D. values of threshold shift at the test frequencies aid different sensation levels for the above mentioned subjects are shows in tables, 1,2,3 and

Significance of difference between means among the four groups was calculated at all the test frequencies and different sensation levels.

Between the conductive hearing loss and normal hearing groups, there was no significant difference with regard to the threshold shift except at 1000 Hz for 10 dB SL (0.05 level) (Table-5).

Between the S.N.(cochlear) hearing loss and normal hearing subjects there was no significant difference with regard to the threshold shift at all test frequencies and different sensation levels (SL) (Table-6).

Between the SN hearing loss with tone decay and normal hearing subjects there was significant difference in terms of threshold shift at 500 Hz for 10 dB SL, lOOOHz for 10 dB SL, 20 dB SL, and 30 dB SL? 2000 Hz for 10 dB SL, 20 dB SL and 30 dB SL,(at 0.01 level of significance). However, there was no significant difference at 4000 Hz at all the three sensation levels (Table-7).

Between the SN (cochlear) hearing loss and the SN hearing loss with tone decay subjects there was significant difference in terms of threshold shift at 500 Hz for 20 dB SL (0.05 level), 30 dB SL (0.01 level); 1000 Hz for 10 dB SL, 20 dB SL (0.01 level), 30 dB SL (0.05 level); 2000 Hz for 10 dB SL, 20 dB SL (0.05 level), 30 dB SL (0.01 level); 4000 Hz for 30 dB SL (0.01 level) (Table-8).

Between the conductive hearing loss and SN (cochlear) hearing loss subjects there was no significant difference in terms of threshold shift, except at 1000 Hz for 10 dB SL (0.05 level) (Table-9).

Between the SN hearing loss with tone decay and conductive hearing loss subjects, there was significant difference in terms of threshold shift at 500 Hz for 30 dB SL (0.05 level); 2000 Hz for 20 dB SL (0.05 level); 30 dB SL (0.01 level) and 4000 Hz for 30 dB SL (0.01 level) (Table-10).

The mean values of threshold shift at three sensation levels for all the test frequencies, in the four groups of subjects, were plotted (Fig. 3, 4, 5, 6). The SN (cochlear) hearing loss and SN hearing loss with tone decay subjects fall at two extremes and are clearly differentiable. Normals, conductive hearing loss and SN (cochlear) hearing loss subjects showed overlap.

Table:1 - Shows the Mean and S.D. values of threshold shift at the test frequencies and sensation levels (SL) in Normal Hearing Subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
10 dB SL				
Mean	6.66	1	0.66	0
S.D.	7.23	4.70	4.57	5.97
20 dB SL				
Mean	12.66	9.33	7.33	9.66
S.D.	6.70	4.16	4.16	6.39
30 dB SL				
Mean	18.66	17.33	14.33	15.66
S.D.	5.49	4.95	4.90	6.22

Table:2 - Shows the Mean and S.D. values of threshold shift at the test frequencies and sensation levels (SL) in conductive hearing loss subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
s.				
10 dB SL				
Mean	9.0	8.0	5.0	9.0
S.D.	5.67	4.83	4.0	6.99
20 dB SL				
Mean	11.0	12.0	9.5	8.5
S.D.	7.37	4.83	4.37	5.29
30 dB SL				
Mean	17.5	19.5	17.0	14.5
S.D.	5.40	3.68	2.58	4.37

Table:3- Shows the Mean and S.D. values of threshold shift at the test frequencies and sensation levels (SL) in SN (cochlear) hearing loss subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
10 dB SL				
Mean	1	0	0.5	-1.4
S.D.	10.20	6.23	4.97	2.43
20 dB SL				
Mean	7	7.50	8	7.8
S.D.	7.14	5.40	5.86	2.67
30 dB SL				
Mean	14.5	15	15	13.57
S.D.	5.50	7.45	5.27	3.77

Table:4 - Shows the Mean and S.D. values of threshold shift at the test frequencies and sensation levels (SL) in SN hearing loss with +ve tone decay subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
10 dB SL				
Mean	13.0	11.25	12.22	4.16
S.D.	7.58	5.17	12.01	3.76
20 dB SL				
Mean	18.0	15.0	18.88	10.83
S.D.	5.70	4.62	10.83	4.91
30 dB SL				
Mean	24.0	23.12	25.55	20.83
S.D.	5.47	3.72	7.26	2.04

Table:5 - Showing the obtained 't' values for difference between conductive hearing loss and Normal hearing subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
10 dB SL	0.74 (N.S)	2.60*	1.76 (N.S)	-0.12 (N.S)
20 dB SL	-0.58 (N.S)	1.48 (N.S)	1.25 (N.S)	-0.07 (N,S)
30 dB SL	-0.52 (N.S)	-1.18 (N.S)	1.57 (N.S)	-0.51 (N.S)

Key:

N.S : Not significant

* : Significant at 0.05 level

** : Significant at 0.01 level

Table:6 - Showing the obtained 't' values for different between SN (cochlear) hearing loss and Normal hearing subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
10 dB SL	-1.63(N.S)	-0.45(N.S)	-0.08(N.S)	0.57(N.S)
20 dB SL	-2.00(N.S)	-3.90(N.S)	0.33(N.S)	0.43(N.S)
30 dB SL	-1.85(N.S)	-0.9(N.S)	0.32(N.S)	-0.82(N.S)

Key:

N.S. : Not significant

* : Significant at 0.05 level

** : Significant at 0.01 level

Table:7 - Showing the obtained 't' values for different between SN hearing loss with tone decay and Normal hearing subjects. ?

	500 Hz	1000Hz	2000Hz	4000Hz
10 dB SL	1.49**	4.49**	3.39**	1.57(N.S)
20 dB SL	1.57(N.S)	3.00**	3.73**	0.40(N.S)
30 dB SL	1.88(N.S)	2.89**	4.52**	1.97(N.S)

Key:

N.S. - Not significant

* - Significant at 0.05 level

** - Significant at 0.01 level

Table:8 - Showing the obtained 't' values for difference between SN (cochlear) hearing loss and SN hearing loss with tone decay subjects.

	500 Hz	1000 Hz	2000 Hz	4000 Hz
10 dB SL	2.09(N.S)	3.82 **	2.83 *	1.28(N.S)
20 dB SL	2.98 *	3.12 **	2.76 *	0.70(N.S)
30 dB SL	3.16 **	2.80 *	3.66 **	4.19 **

Key:

N.S. - Not significant

* - Significant at 0.05 level

** - Significant at 0.01 level

Table:9 - Showing the obtained 't' values for different between conductive hearing loss and SN (cochlear) hearing loss subjects.

	500Hz	lOOOHz	2000Hz	4000Hz
10 dB SL	1.92(N.S)	2.35 *	1.54(N.S)	1.49(N.S)
20 dB SL	I.23(N.S)	1.96(N.S)	0.64(N.S)	-1.14(N.S)
30 dB SL	I.23(N.S)	1.71(N.S)	1.08(N.S)	0.55(N.S)

Key:

N.S - Not significant

* - Significant at 0.05 level

** - Significant at 0.01 level

Table-10: Showing the obtained 't' values for difference between SN hearing loss with tone decay and conductive hearing loss subjects.

	500 Hz	1000Hz	2000 Hz	4000 Hz
10 dB SL	6.78 (N.S)	0.86 (N.S)	1.57 (N.S)	-0.73 (N.S)
20 dB SL	1.85 (N.S)	1.33 (N.S)	2.53*	0.87 (N.S)
30 dB SL	2.19*	2.06 (N.S)	3.50**	3.31**

Key:

N.S. : Not significant

* : Significant at 0.05 level

** : Significant at 0.01 level

Fig.3 :- Showing Mean Threshold Shift in dB at three Sensation Levels.

Freq. 500 Hz

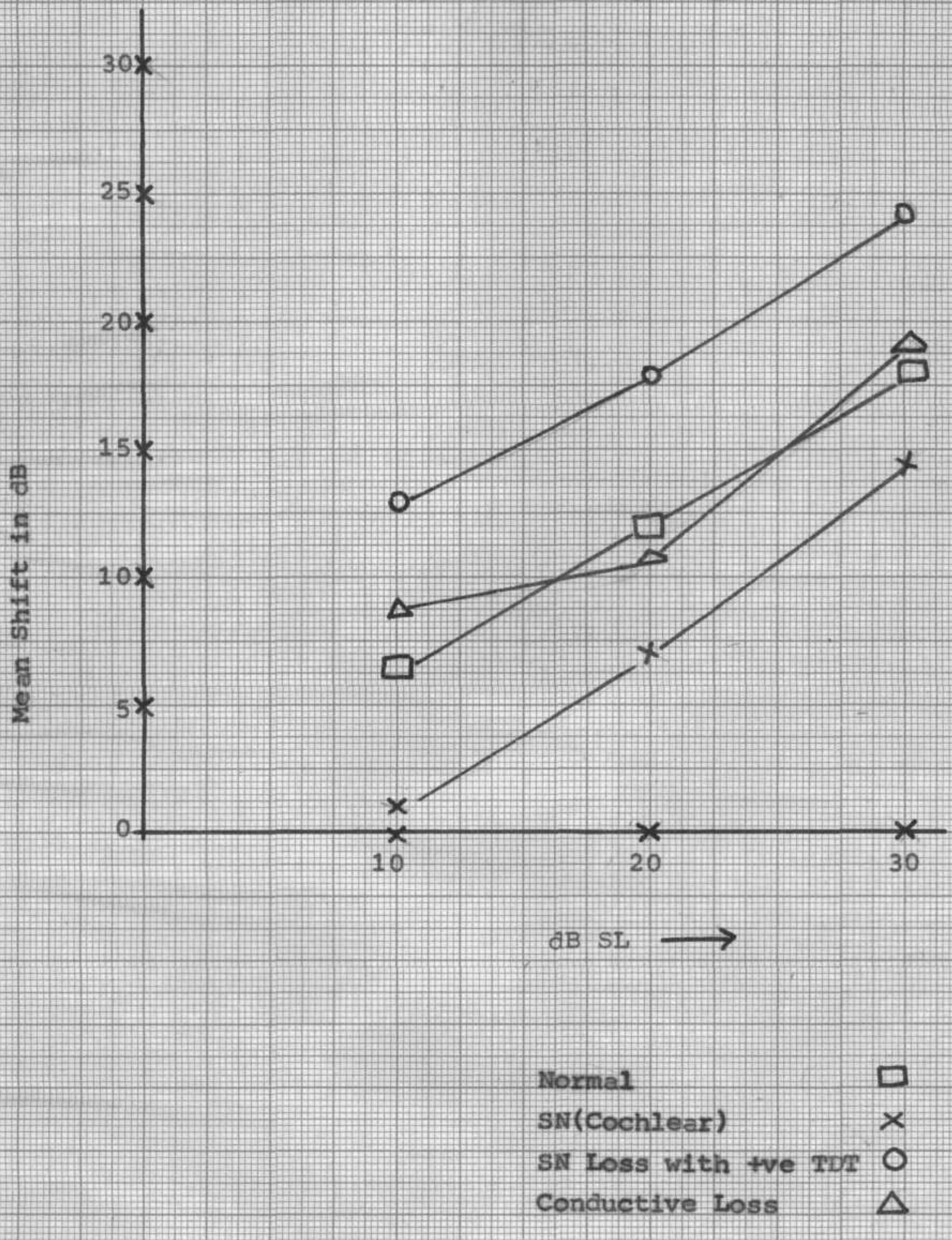
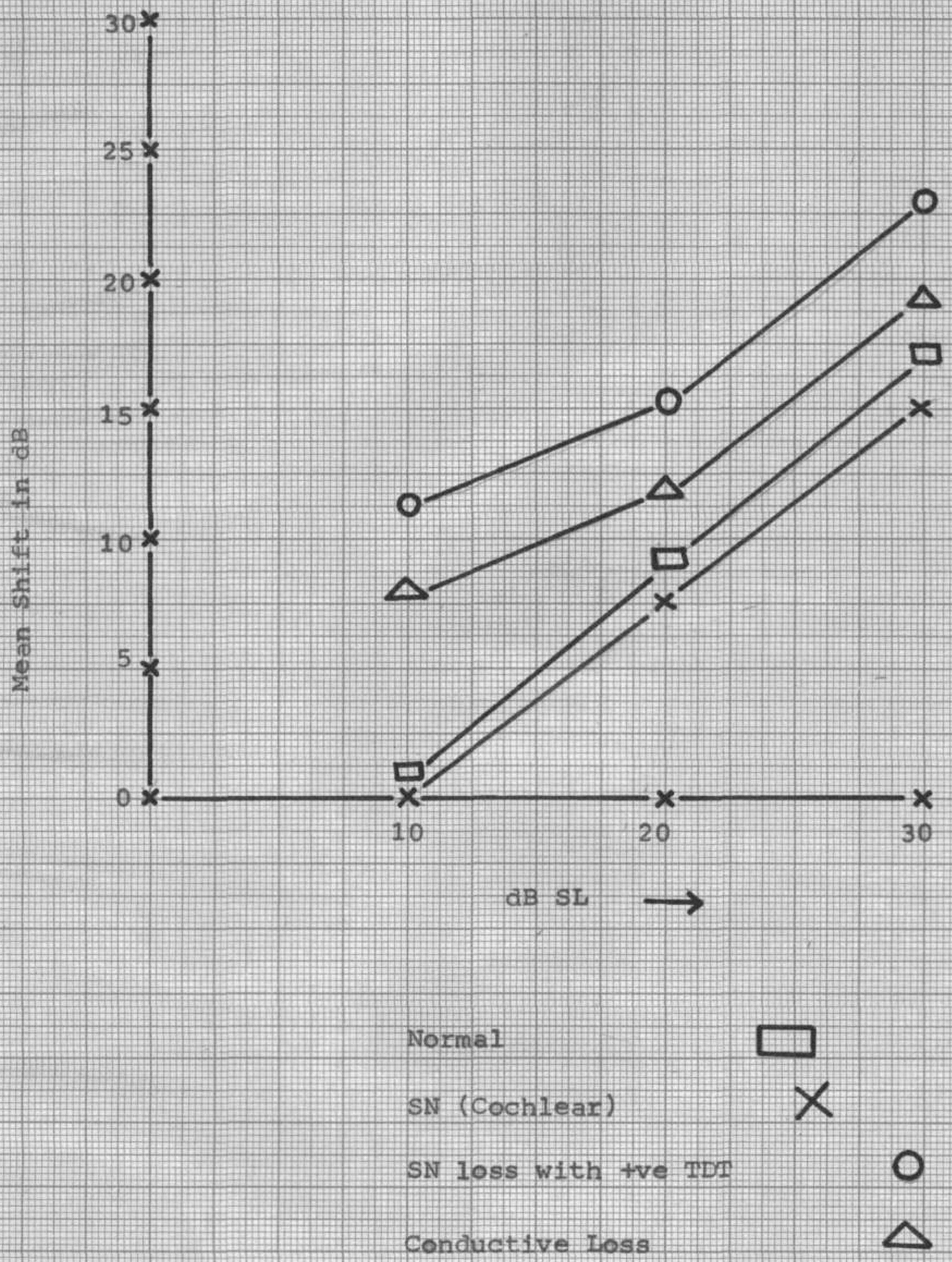


Fig.4 : Showing Mean Threshold Shift at Three Sensation Levels.

Freq - 1000 Hz



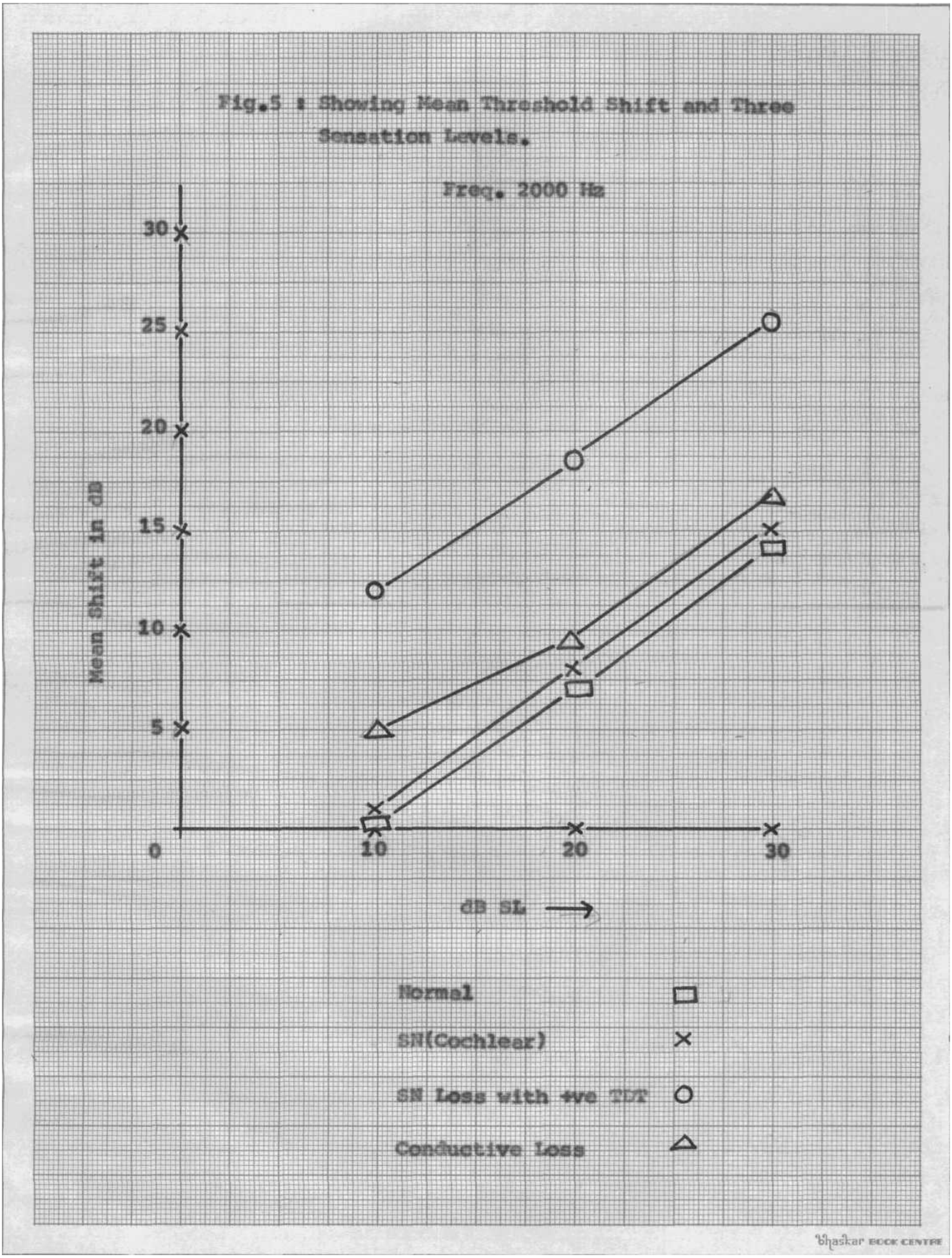
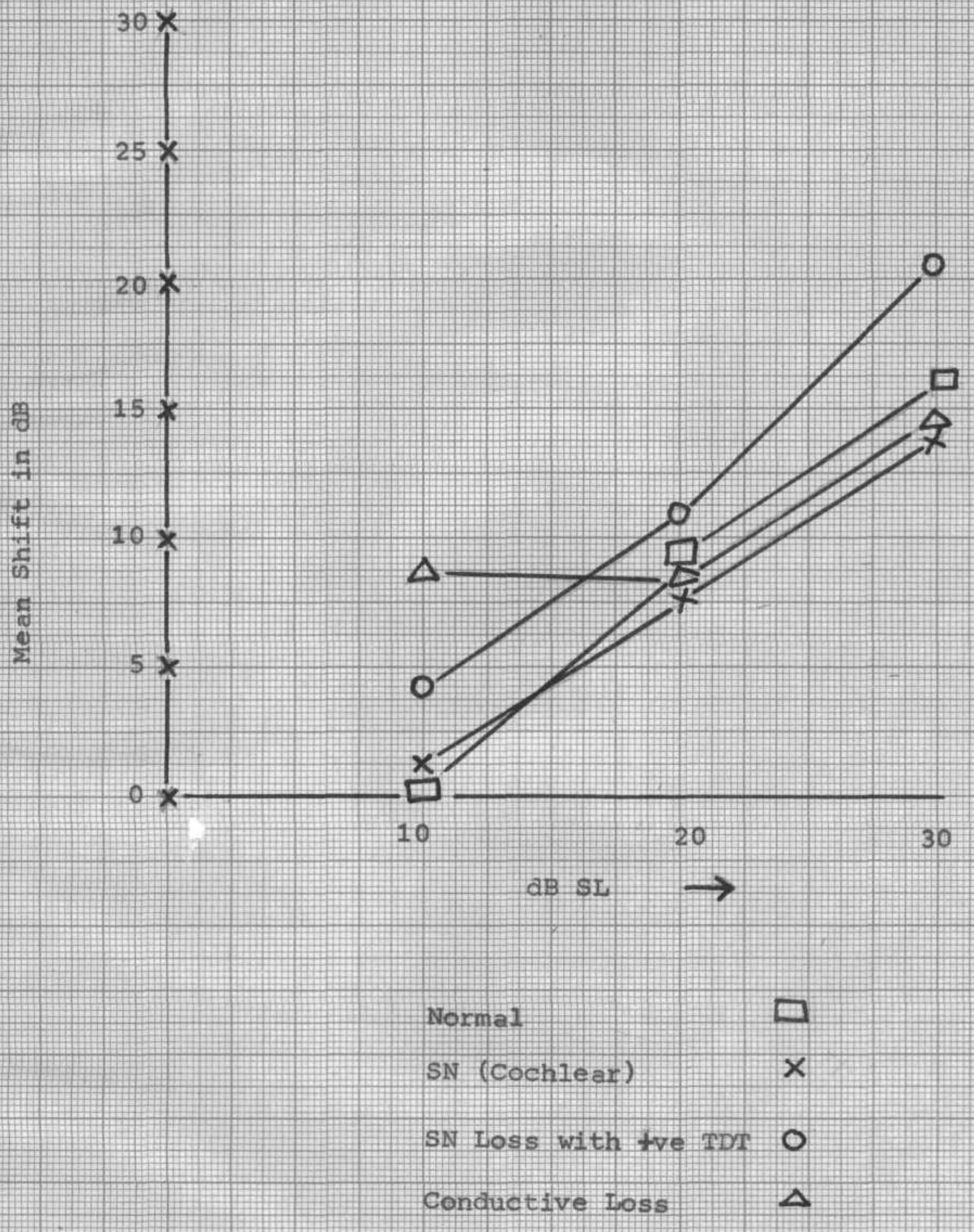


Fig.5 : Showing Mean Threshold Shift and Three Sensation Levels.
Freq. 2000 Hz
Mean Shift in dB
30
25
20
15
10
5
0
10
20
30
dB SL
Normal
SN(Cochlear)
SN Loss with +ve TDT
Conductive Loss
bhaskar BOOK CENTRE

Fig.6 : Showing Mean Threshold Shift at Three Sensation Levels.
Freq. 4000 Hz



CHAPTER - V

DISCUSSIONS

DISCUSSION:

The CTM test is based on a procedure reported by Lilly and Thalmann (1964). In an ingenious study they tested the hypothesis that masking occurs in the cochlea. They used a number of patients with retrocochlear problems and complete tone decay for the experiment. The patients were required to trace their thresholds for a pulsed tone in the absence and in the presence to a continuous tone. Despite the inaudibility of the masker (continuous tone) threshold was adversely affected. Lilly and Thalmann noted that even 10 dB of the masking made a significant shift in the pulsed threshold.

In the present study also patients with retrocochlear problems and tone decay were taken. It was found that particularly at 1000 Hz and 2000 Hz, the CTM test, could differentiate between SN (cochlear) and SN hearing loss with tone decay. There was a tendency of normal hearing, conductive loss and SN (cochlear) subjects overlap.

In order to test the hypothesis that a conductive hearing loss produced a retrocochlear effect, Katz, 1965, Katz and Willis, 1967, tested normal listeners both with and without earplugs on the CTM. They also tested patients with conductive hearing loss and found that conductive loss behaved in a manner similar to that described by Lilly and Thalmann. However, in the present study there was no significant difference in terms of threshold shift between the conductive hearing loss and normal hearing subjects. The findings of the present study do not support Katz's (1978) auditory deprivation hypothesis, which states that "the effects of deprivation (Conductive Hearing Loss) may be far reaching and involve the retrocochlear system and the brain". The greater the hearing loss and longer the period of deprivation, the more extreme the retrocochlear signs.

While the test has received only a small series of clinical trials it appears to have considerable promise as a tool for differential diagnosis between cochlear and retrocochlear pathology. The threshold seems to improve in the presence of continuous tone in cochlear pathology, whereas the threshold is elevated in retrocochlear pathology because of adaptation.

Earlier studies reported on continuous tone masking test, have used Bekesy audiometer, however, the present study was carried out using a diagnostic audiometer.

CHAPTER - VI

SUMMARY AND CONCLUSIONS

SUMMARY AND CONCLUSIONS:

The present study was conducted to evaluate the clinical usefulness of continuous tone masking test. Four groups of subjects were selected, namely :

1. Normal hearing subjects.
2. Conductive hearing loss subjects.
3. SN (Cochlear) hearing loss
4. SN Rearing loss with +ve tone decay.

The test was conducted using a diagnostic audiometer which provided individual output selectors, by means of which two signals (continuous and pulse) were directed to single phone.

The test procedure involved finding of the threshold for the pulsed tone in the test ear and then finding the threshold for the pulsed tone in the presence of 10 dB SL, 20 dB SL and 30 dB SL continuous tone. Thresholds for the pulsed tone of the frequencies 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz were determined. The threshold shift in the presence of continuous tone was calculated for all the four groups at the test frequencies and at different sensation levels.

Threshold shift = Threshold obtained in the presence of continuous tone. - Absolute threshold

Comparison of the results obtained in all the four groups, led to the following conclusions: -

1. There was no significant difference between the normal hearing and conductive loss subjects,with regard to the threshold shifts.

2. There was no significant difference between the normal hearing and SN (cochlear) hearing loss subjects,with regard to the threshold shifts.

3. There was significant difference between the normal hearing and SN hearing loss with +ve tone decay, except at 4000 Hz, with regard to threshold shifts.

4. There was significant difference between the SN (cochlear) and SN hearing loss with +ve tone decay, with regard to threshold shifts.

5. There was no significant difference between the conductive hearing loss and SN (cochlear) hearing loss, with regard to threshold shifts.

6. There was significant difference between the conductive hearing loss and SN hearing loss with +ve tone decay, with regard to threshold shifts.

Above all, the present study has revealed that the CTM test is useful even when it is administered using a two channel audiometer. Hence, one need not depend up on Bekesy audiometer (automatic audiometer) to administer CTM test.

LIMITATION:

Surgically confirmed retrocochlear pathology cases exhibitory abnormal tone decay were not included in the present study.

RECOMMENDATIONS:

1. Since CTM test has been found to be very useful in differentiating Cochlear and retrocochlear (or SN loss cases exhibiting abnormal tone decay) cases, it is recommended that the 6TM test should be included in the battery of special tests used for differentiating cochlear Vs retrocochlear pathology.

2. It is recommended that the CTM test, (as described in the present study) be administered to many confirmed retrocochlear pathology cases.

BIBLIOGRAPHY

BIBLIOGRAPHY:

Anderson, H., Barr, B, and Wedenberg, E :"Intra-aural reflexes in retrocochlear lesions. In Hamberger, C and Wersall, J (Eds): Nobel Symposium 10. Disorders of the skull-Base Region. Stockholm Almquist and Wiskell, 49-55, 1969.

Bekesy, G.V.,: A new Audiometer, Acta Otolaryngol., 35, 411-422, 1947.

Carhart, R., : Clinical determination of abnormal auditory adaptation. Arch.Otolaryngol., 65, 32-39, 1957.

Carhart, R., : Problems in the measurement of speech discrimination. Arch. Otolaryngol., 82, 253-260, 1965.

Carhart, R : Updating special hearing tests in Otological diagnosis. Arch, Otolaryngol., 97, 88-91, 1973.

Carterette, E.c. : Perstimulatory auditory fatigue for continuous and interrupted noise, J.Acoust.Soc.Amer., 27, 103-111, 1955.

Clemis, J.D., and Carver, W.F. : Discrimination scores for speech in Meniere's disease, Arch.Otolaryngol., 86, 614-618, 1967.

Coles, R.R.A., : Can present day audiology really help in diagnosis? An Otologist's opinion, J.Laryngol. Otol., 86, 191-224, 1972.

Davis, H.A., : A functional classification of auditory defects, Ann.Otol.Rhinol.Laryngol., 71: 693-704, 1962.

Dix, M., Hallpike, C, and Hood, J., : Observations upon the loudness recruitment phenomenon with especial reference to the differential diagnosis of disorders of the internal ear and eighth nerve. J.Laryngol.Otol., 62, 671-686, 1948.

Dix. M., : Loudness recruitment and its measurement with especial reference to the loudness discomfort level test and its value in diagnosis. Ann.Otol. Rhinol.Laryngol., 77: 1131-1151, 1968.

Fowler, E.P., : The diagnosis of diseases of the neural mechanism of hearing by the aid of sounds well above threshold. Trans.Am.Otol.Soc, 27, 207-219, 1937.

Fowler, E : A method for the early detection of Otosclerosis, Arch.Otolaryngol., 24, 731-741, 1936.

Gilsberg, I.A., and White, T.P.: Otological Consideration in Audiology in Katz, J (Ed) Hand book of Clinical Audiology (Second Ed), The Williams and Wilkins Company, Baltimore, 1978.

Green, D.S., (Threshold tone decay. In Handbook of Clinical Audiology, edited by J.Katz, Ed.2., Chapter-17, Williams and Wilkins, Baltimore, 1972.

Hood, J., and Poole, J., : Tolerable limits of loudness: Its clinical and physiological significance, J.Acoust. Soc. Am., 40: 47-53, 1966.

Jerger, J., Shedd, J., Harford, E., : On the detection of extremely small changes in sound intensity. Arch. Otolaryngol. 69, 200-211, 1959.

Jerger, J., Hayes, D, Anatony, L., and Mauldin, L., : Factors influencing prediction of hearing level from the acoustic reflex. Monographs in contemporary Audiology, Vol.1, Sept., 1978.

Jerger, J., Burney, P., Mauldin, L., and Crump, B., Predicting hearing loss from acoustic reflex, J.Speech and Hearing Dis., 39: 11,1974.

Jerger, J. and Jerger, S : Simplified tone decay test, Archs. Otolar, 101? 403-407, 1975.

Jerger, J., and Jerger, S., diagnostic significance of PB word functions, Arch.Otolaryngol., 93, 573-580, 1971.

Jerger, J., and Jerger, S., Mauldin, L., "The forward - backward discrepancy in Bekesy audiometry". Arch Otolaryngol. 96, 400-406, 1972.

Jerger, J., and Jerger, S., Diagnostic value of Bekesy comfortable loudness tracings, Arch, Otolaryngol., 99: 351-360, 1974.

Jerger, J., : Bekesy audiometry in analysis of auditory disorders, J.S.H.R., 3, 275-287, 1960

Jerger, J., : Diagnostic audiometry, In Modern Developments in Audiology, Ed.2, Chapter-3, Academic Press, New York, 1973.

Johnson, E.; Auditory test results in 500 cases of acoustic neuroma. Arch. Otolaryngol., 103, 152-158, 1977.

Johnson, E., : Confirmed retrocochlear Lesions, Arch.Otolaryngol. 84, 247-254, 1966.

Katz, J., : The continuous tone masking (CTM) test for identifying site of lesion, J.of Auditory Research, 9, 76-80, 1969.

Katz, J., and Willis, V., :Continuous tone masking test. Paper presented at the American Speech and Hearing Convention, 1967.

Katz, J., :The effects of conductive hearing loss on auditory function, Asha, 20, 879-886, 1978.

Katz, J., : Temporary threshold shift, auditory sensory deprivation, and conductive hearing loss, J.Acoust.Soc. Amer, 37; 923-924, 1965.

Keith, R.W., and Talis, H.P., :The effects of white noise on PB scores of normal and hearing - impaired listeners, Audiology, 11: 177-186, 1972.

Keith, R.W., : Loudness and the acoustic reflex: Normal hearing listeners, J.Am.Audiol.Soc, 4(4): 152-156, 1979.

Keith, R.W.,:Diagnostic audiometry in audiology for the physician, (Ed) by Keith, R.W., 33-60, 1980.

Lilly, D.J., and Thalmann, R.,:The masking of interrupted pure tones by inaudible continuous pure tones in pathological ears, ASHA, 6: 397(A), 1964.

Ollen, w., and Noffsinger, D., :Comparison of one new and three old tests of auditory adaptation, Arch.Otolaryngol., 99: 94-99, 1974.

Priede, V.M., and Coles, R.R.A., : Interpretation of loudness recruitment tests - some new concepts and criteria, J.Laryngol. Otol., 88, 641-662, 1974.

Reger, S., and Kos., C :Clinical measurements and implications of recruitment, Ann.Otol.Rhinol.Laryngol., 61: 810-823, 1952.

Reger, S., : A clinical and research version of the Bekesy audiometer. Laryngoscope, 62, 1333-1351, 1952.

Rosenberg, P, : Rapid clinical measurements of tone decay. Presented at the Annual Convention of the American Speech and Hearing Association, New York, November, 1958.

Rosenberg, P. :Tone decay, Maico audiological Library series, Vol.7, Report-6, 1969.

Rosenhamer, H., ;The auditory Evoked Brainstem Electric Response (ABR) in cochlear Hearing Loss, Scandinavian Audiology, Supplement-13, 83-93, 1981

Schuknecht, H., Woellner, R :An experimental and clinical study of deafness from lesions of the cochlear nerve, J.Laryngol. Otol. 69, 75-97, 1955.

Tillman, J.,:Special hearing tests in Otoneurological diseases. Arch. Otolaryngol., 89: 25-30, 1969.

Young, I.M and Harbert, F., : Effect of off-time on Bekesy tracings, J.A.R., 8, 339-343, 1968.

Zwislocki, J.J., : Temporal summation of loudness, an analysis, J.Acoust. Soc. Am., 46, 431-441, 1969.

ZwisRocki, J.J., :Theory of temporal auditory summation, J. Acoust. Soc. Am., 32, 1046-1060, 1960.

APPENDIX

APPENDIX - 'A'

NOISE LEVELS IN AUDIOMETRIC ROOM, dB ref. .0002 $dynes/Cm^2$

A Net work - 23 dB

B Net work - 28 dB

C Net work - 36 dB

OCTAVE BAND ANALYSIS

CENTRE FREQUENCY	LEVEL
125 Hz	25 dB
250 Hz	20 dB
500 Hz	19 dB
1000 Hz	19 dB
2000 Hz	10 dB
4000 Hz	12 dB

APPENDIX - 'B'

TDH-49 Earphone (with MX 41/AR Cushion) output of Channel I and Channel 2 of the Audiometer Beltone 200-C at different frequencies.

Frequency in Hz	ANSI-1969 reference equivalent threshold sound pressure levels at 80 dB HL	Channel 1 output in dB SPL	Channel 2 output in dB SPL
250	106.0	112	113
500	91.0	99	100
1000	87.0	96	95
2000	89.0	98	99
4000	93.5	99	100
6000	88.5	103	102
8000	91.0	97	96

FRONT PANEL INDICATORS, CONTROL KNOBS OF BELTONE 200-C

A, (AA) .. Output (Hearing level control)

B, (BB) .. Tone Interruptor

C, (CC) .. Tone 'on' lamp

D, (DD) .. Automatic/Manual switch

E, (EE) .. Tone reversing switch

F, (FF) .. Out put selector

G, (GG) .. Monitor control

H .. Frequency

J .. Patient signal lamp

K .. Talk back gain

L .. Talk over switch

M .. Talk over gain

N .. Tone Bar Lock

O .. VU Meter selector switch

P .* Frequency input

Q .. Monitor ear phone

R .. Power

S .. Speech unit

T .. SISI

U .. VU Meter

X .. Channel one VU meter gain control

XX .. Channel two VU meter gain control