CLINICAL APPLICATIONS OF BEKESY AUDIOMETRY : A REVIEW

Register No. 8802

An Independent Project Work submitted as part fulfilment for fist year M.Sc.(Speech and Hearing)to the University of Mysore, Mysore.

All India Institute of Speech and Hearing

Mysore - 570 006

MAY 1989

To

My Parents

who yave me

my fundamental values and dispositions

And.

To Those

who ever provide me with the opportunity

to prove the validity

of

those values and dispositions

CERTIFICATE

This is to certify that the Independent project entitled "Clinical Applications of Bekesy Audiometry: A Review " is the bonafide work done in part fulfilment for first year M.Sc. (Speech and Hearing) of the Student with Register No - 8802

Place:Mysore
Date : 5.5.1989

Director
All India Institute of Speech and Hearing Mysore - 570 006

CERTIFICATE

This is to certify that the independent project entitled "Clinical Applications of Bekosy Audiometry : A Review " *has of been prepared under my supervision and guidance.*

Place : MYSORE

Date : 5.5.89

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Lecturer in Audiology

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DECLARATION

This Independent project entitled " **Clinical Applications of Bekesy Audiometry : A Review"** *is the result of my own work undertaken under the guidance of Dr M.N. Vyasamurthy, lecturer in Audiology, All India Institute of Speech and Hearing, Mysore* - 6, *and has not heen submitted earlier at any University or Institution* ***for any*** *other Diploma or Degree.*

Mysore

Dated **-5.5.89** **Register No. 8802**

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CONTENTS

1. INTRODUCTION

Bekesy audiometry is one of the procedures which provided early impetus for differential diagnostic testing in Audiology. George Von Bekesy developed the first automatic audiometer in 1947. Refinements of Bekesy audiometer were proposed by Gardner (1947), Reger (1952), Rudmose (1963) and others. Many other Behavioral and electrophysiological tests have been developed for clinical use since the advent of this procedure, which are used in conjunction with Bekesy in the diagnostic test batteries.

The diagnostic contribution of individual test measures depend on the degree of hearing loss. (Hayes and Jerger 1980). When the loss is only mild, the acoustic reflex test (ART) and auditory brain-stem response (ABR) are most sensitive to 8th nerve disorder. When sensitivity loss is severe, results of ART and ABR audiometry become ambiguous. In such conditions, the more "traditional" audiometric test battery of Bekesy audiometry, Suprathreshold adaptation test (STAT) and speech audiometry provides the most useful diagnostic information (Jerger & Jerger, 1980). Since the degree of sensitivity loss, at the time of initial evaluation is an uncontrollable variable, diagnostic strategy must include the tests appropriate to a wide range of hearing loss.

In addition, Bekesy audiometry gives a lower and more reliable hearing threshold, ErLandsson (1979). The hearing threshold itself is not a very well defined dividing-line between hearing and not hearing. The uncertainty is illustrated by the swing in the curve of the Bekesy audiogram, where it is also possible to determine the ability of the subject to state the threshold in a pure tone audiometry and particularly where the steps are 5 dB and where the threshold is defined as the reading where the subject marks 2 out of 3 bursts, the uncertainty is greater. Erlandsson (1979) compared the hearing thresholds of 115 workers in a shipyard obtained, both by Bekesy Sweep audiometry and by conventional pure tone audiometry at fixed frequencies. It has been possible to find a useful linear relation between pure tone and Bekesy hearing thresholds with the help of retest experiments, it has been established that standard Deviation of hearing thresholds, obtained under similar condition in a pure tone investigation are about twice as large as those obtained in a Bekesy investigation. The regression equation for Bekesy threshold (HLB) on pure tone threshold (HLT) for audiometric frequencies 1-6 KHz is HLB = -3.4 + 0.93 HLT and for pure tone on Bekesy is HLT = 8.0 + 0.96 HLB.

Many authors, through their experimental studies have re-emphasized the importance of Bekesy audiometer in an audiological clinic and this single piece of instrument has proved its futility in studying the wide range of hearing and hearing disorders. The conventional Bekesy procedure has been modified into a number of different tests and also many other tests have been modified, so that they can be performed on the Bekesy audiometer. These modifications are aimed at obtaining additional diagnostic information in a wide variety of pathological conditions eg. conductive, cochlear, retro-cochlear and also the central audiotory disorders. It has been used to study the phenomena like audiotory adaptation, recruitment, temporal integration, coohlear microphonica, phonophobia, raised intracramial pressure, aural harmonic distortion and frequency discrimination. In addition, the value of the procedure in providing additional evidence of functional hearing disorders should be emphasized. (Jerger and Jerger 1972) He further adds, that although we have a wide variety of tests for functional hearing loss, the ease with which Bekesy audiometer can be used and its applic-ability to virtually any audiometric configuration enhances its utility in routine clinical evaluation.

Rintleman and Hardford (1967) suggested that one value of Bekesy audiometry is that no special techniques are involved, making it possible even for an inexperienced clinician to identify patients with functional hearing loss.

It would be worth mentioning that efforts of Dancer and Ventry (1984) in evaluating the potentials for amplification and rehabilitation using the suprathresholds tests has added new dimension in the application of Bekesy audiometer for the evaluation of hearing aid, its use and acceptance in a hearing impaired ear.

Many test procedures which were developed earlier, slowly lost their significance with the increasing knowledge in the field of audiology, but Bekesy audiometry due to its accuracy, sensitivity and because of the continuous research and modification of the conventional procedure, has survived the test of time and is being used till today. This is not to say that Bekesy audiometer aline can satisfy all the needs of an audiologist, but it can prove to be an important asset in an audiology clinic, though it has its obvious limitations in case of Children. The present study aims at evaluating the clinical applicability of the Bekesy audiometery in the light of current informations available and the expanding body of knowledge in the field of audiology.

2. INSTRUMENTATION AND TEST PARAMETERS

A typical Bekesy audiometer is comprised of a continuously variable beat frequency oscillator which covers a range of frequency from 100 to 10,000 Hz (some are 250 to 8000 Hz). The intensity range is about 120 dB. The masking is generally white or narrow band noise. Attenuation of the signal is done by a motor drive which is under the control of the client . The threshold is traced over a period of time. It takes around 7 minutes to trace from 100 to 10,000 Hz. The threshold is recorded simultaneously by a pen linked to the attenuator and in contact with an audiogram moving on a metal plate.

The stimulus is pure tone and is presented in two modes, continuous (c) and interrupted (I) with typically 2.5 interruption per sec or 5 interruption in 2 sec. The automatic intensity increase can be set at a rate of 2.5 or 5 dB per sec. The task of the client is to trace the thresholds for selected frequencies. Two tracing modes are possible - sweep frequency tracing and fixed frequency tracing, Sweep frequency tracings are those in which frequency continually changes from 100 to 10,000 Hz or reverse.

The fixed frequency condition allows any one of a number of frequencies to be assessed individually (e.g 500, 1000 & 2000Hz).

3. GENERAL CLINICAL PROCEDURE

A view on the Bekesy method used by different authors (Jerger 1960, Owen 1964, Blegrad 1967, Orchik et.al., 1977) indicates similarity in the procedures. The conventional Bekesy audiometry consists of either sweep or fixed frequency thresholds, first traced for I and then followed by C. tone tracing. The attenuation rate is 2.5 dB per Sec. The frequency changes from low to high at the rate of one octave per minute.

In the fixed frequency mode there is no standard for the frequency to be assessed and the amount of time for the I and C tone tracings, (Brunt, 1985). Clinically it is preferable to trace the thresholds at three or more frequencies. A stable I tone tracing to obtained usually in 30 sec to 1 minute. For the C tone, a 2 to 3 minute tracing should reveal any significant adaptation.

Instructions to the client are very important. The instruction for the sweep frequency I tone mode is - "you are going to hear an interrupted or beeping tone. The pitch will keep getting higher and higher. Don't pay any attention to the pitch of the tone but just to its loudness. As long as you hear the tone, I want you to hold this switch down (demonstrate). The tone will keep getting softer and softer. When you no longer hear the tone, release the switch (demonstrate). When you hear the tone again press and hold the switch down. Remember as long as you hear, you should have the switch depressed and release it way the tone goes away."

Instruction for the C-tone tracings are similar . The exception is noting that the tone will be continuously on, with no interruption. Instructions for fixed frequency tracings are like those for sweep without indicating the gradual increase in the pitch.

The initial tone presentation level should be at a level easily heard to maximize the chances that the client will respond appropriately. The client may be allowed to listen the stimulus before formal testing, so that he knows what to listen for or a 20-30 sec of tracing may be used to see that client has understood the task. If he has not understood the task; he should be reinstructed.

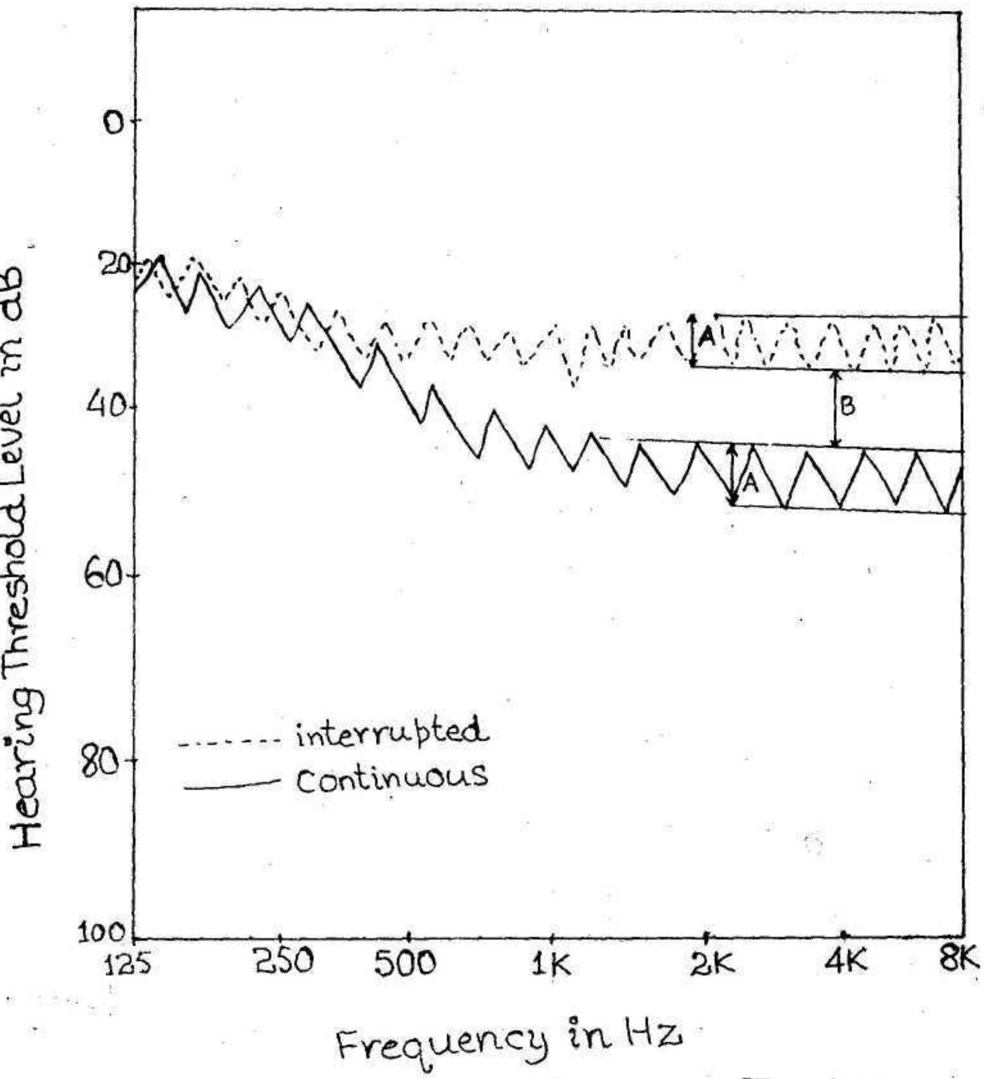


FIG.1. Bekesy Sweep Frequency Tracing.

A - Excursion Width

B - Separation between I and C tones.

If tinnitus is present, if may interfere with tracing behavior at high frequencies and more commonly with the c-tone mode. Sometimes two patterns are seen in case of tinnitus:-

1) very wide tracings, which may be because the client is confusing the test tone with the tinnitus.

2) Flat tracings, because the client keeps the signal switch depressed at the lower limits of the audiometer in response to the tinnitus rather than to the tone. To overcome this problem the client should be reinstructed and the test should be started with another frequency or the test should be started at a level known to be audible to the client.

4. TRACINGS: THRESHOLD WIDTH AND SEPARATION

The characteristic features considered to be of diagnostic significance in the conventional Bekesy Audiometry are as follows:-

1) The relationship between Bekesy threshold tracings and routine pure tone thresholds.
2) Width of the tracings which refers to the peak to trough range in dB.
3) Separation seen between the interrupted and the continuous tone tracings. (Fig 1)

Many researches (Roger, 1952; Corso, 1956, 1957; Burns and Minch cliff, 1957; Stream and McConnell 1961) have compared Bekesy- traced threshold to those of conventional pure tone audiometry,close correspondence between voluntary pure tone and Bekesy thresholds have been observed for normal ears. Variations in the research methods like direction, attenuation rate etc have resulted in the suggestion that mid - point of the tracing seems good to be considered as threshold for clinical purposes. More recent works by Erlandsson et. al., (1979) adds further support for strong correlation between the I-tone tracing and manual pure tone audiometry. Additional confirmation suggested by a series of research reports on Bekesy, conventional puretone and computerised Behesy type audiometers (Harris and Smith, 1979; Harris, J.D 1978; Harris, D.P. 1979a)

Tracing width for normal ears ranges between 5 and 15 dB for both I- and C-tones (Lundberg, 1952; Palva, 1950; Epstein, 1960; Jerger, 1960) The same applies to the pathologic ears for the I-tone. More attention has been paid to the width of continuous tone tracings in the pathologic ears. Early reports suggested that a narrow trace might be related to recruitment or a measure of difference limen for intensity. Thus a narrow tracing was thought to be indicative of a cochlear lesion . On the other hand Jerger (1960) noted that many cases with diagnosed cochlear problems didn't show reduced width, In an unpublished research study by Brunt, the author and several normal hearing colleagues were given the SISI test and Bekesy Audiometry before and after ingestion of Ritalin. Post-Ritalin results were high SISI scores i.e 80 -100% and narrow Bekesy tracings (3dB or less). Thus presence of narrow C-tone tracing should not be taken, alone, as suggestive of a cochlear lesion. However it is noted that clients with cochlear problems are more apt to give narrow tracings for the C- tone.

Early study on pathologic ears reported a separation between I and C-tone tracings with the C falling below the I, i.e C is less sensitive than I. such results were typically obtained in patients with cochlear and retrocochlear lesions. The largest difference were seen in retrocochlear lesions. In cochlear cases, upon sustained stimulation the C-tone tracing stabilizes while for retrocochlear disorders often threshold shift reaches the audiometer limits.

Thus clinical interpretation involves the comparison of the C to the I tone tracing whether done in the sweep or fixed frequency mode the I- threshold tracing can be thought of as the base line performance and should approximate pure tone threshold. The C-tone threshold is compared to the I with regard to amount of separation between them.

5. **FACTORS AFFECTING BEKESY TRACTINGS**

Excursion size for normal hearing subjects is accepted to be between 5 and 15 dB. However, 15 percent of the normals produce tracings which exceed these limits. (Muma and Siegenthaler, 1965). Variability in excursion size has been found to be related to frequency of the test tone with higher frequencies having smaller excursion size (palva, 1956), reaction time of the apparatus and patient (Mclay, 1959) and attenuation rate (corso 1955; welson 1966; Epstein, 1960; Hirsh, 1962; Muma and Siegenthaler, 1966)

Siegenthaler (1975) collected Bekesy tracings from 63 normal hearing adults. Pen excursion size using 2.5 and 5 dB/s attenuation rates, were obtained on test and retest at 250 Hz, 1 KHz and 2 KHz. Standard errors of estimates were 1.7 - 2.0 dB for slow attenuation rate and 2.4 - 3.7 for fast attenuation rate. In general slow attenuation and higher frequencies produce greater reliability.

The other factors affecting the Bekesy Automatic Audiometric findings may be such as contralateral masking, starting frequency, starting level, exposure to the stipulating sound and different stages of some disease entity. (Young, Harbert and Lowry, 1983). These findings are seen Mostly on steady tone tracings as revealed by peak - to - peak amplitude reductions and threshold drifts. According to the study done by Young et.al., (1983), the contralateral masking in the normal ear can produce striking effects on tracings to steady state tone in the affected ear. Various starting frequencies produced masked effects on separation between pulsed - and steady - tone tracings if hearing was tested starting at a suprathreshold levels. A patient diagnosed as having an early endolymphatic hydrops retested within one hour following an episodic attack displayed varieties of findings demonstrating the interrelation of level and adaptation.

Young et al., (1985) obtained Bekesy fixed frequency thresholds for pulsed and continuous tone at 1 KHz using descending - only technique and compared with suprathreshold starting levels of 38, 58, 78 and 98 dB SPL and attenuation rates of 1,-2,4 and 8 dB/sec with associated attenuation steps of 0.25, 0.5, 1 and 2 dB respectively with 3 normal hearing adults. For pulsed tone of 250 in sec (duty cycle 50%) thresholds were not significantly affected by attenuation rate / step size or by starting level. However for continuous tones increasing attenuation rates / step size yielded better thresholds for a given starting levels. Thus deteriorated thresholds were yielded by the slower attenuation rates/ step sizes and by higher starting levels. These data must be explained as a manifestation of normal adaptation. The similar relative effects found here at attenuation rate / step size and of starting level as compared to data of an early study of Harbert and young (1968) which used the traditional up and down Bekesy method of threshold tracing, lend support to the possible future of clinical use of a descending technique only.

6. CONVENTIONAL BEKESY PROCEDURE.

The conventional Bekesy procedure and the interpretation of the results are largely based on Jerger's (1960) classification. The attenuation rate used by Jerger was 2.5 dB per sec with a frequency change of one octave per min. In 1960 Jerger described four types of Bekesy audiograms and related them to disorder; of hearing. This classification was based on the results of 434 clients.

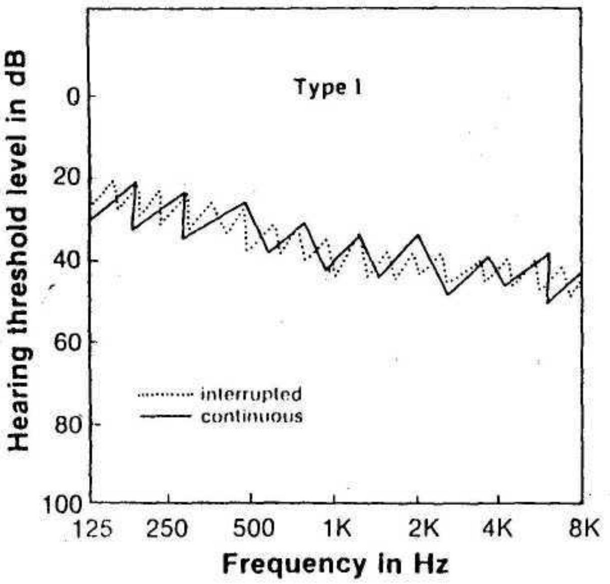


FIG.2. Bekesy Type I Sweep Frequency Tracing.

Each was tested first in sweep mode, I followed by c. Fixed frequency tracings of 3 min each for I & C tones followed. Although not specifically stated, figures show fixed frequency of 250, 1000 and 4000 Hz. In 1961 Jerger and Herer added a fifth type of tracing to the original four. These five types of threshold tracings and their reported application are as follows:-

Bekesy Type 1

Sweep frequency tracings were characterized by an overlapping of I and C tracings with the tracing width of about 10 dB. Jerger noted, however, that tracing width as small as 3 dB and similar pattern was seen for the fixed frequency mode. (Fig 2)

The type 1 pattern was found in 96% of normal and conductive loss ears. In addition 47% of the ears designated under the categories of meniere's, noise - induced loss, presbycusis or Sensory neural loss of unknown etiology gave type 1 patterns of the category clearly thought to be cochlear, Meniere's and noise - induced loss, only 20 % were type 1.

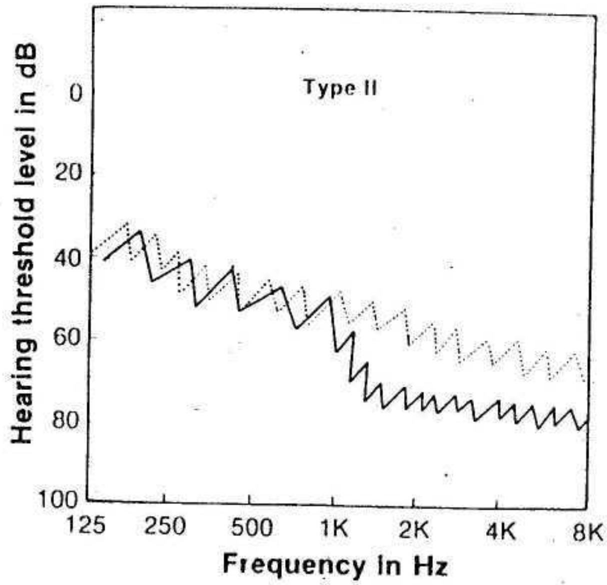


FIG.3(a). Bekesy Type II Sweep Frequency Tracing.

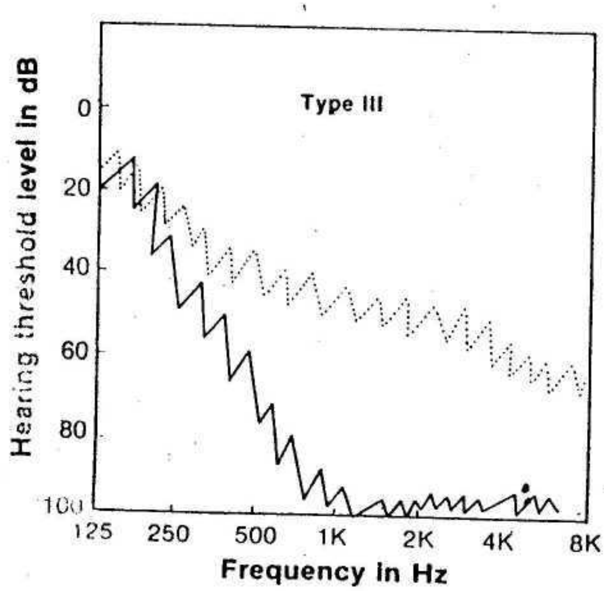


FIG.4(a) Bekesy Type III Sweep Frequency Tracing.

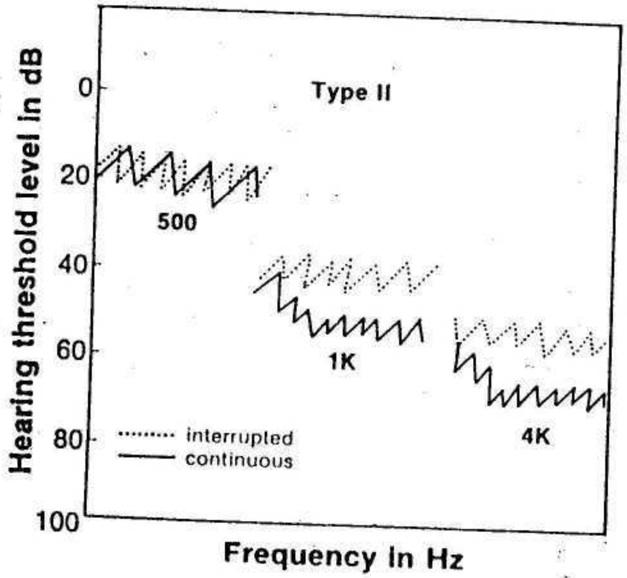


FIG. 3 (b). Bekesy Type II Fixed Frequency Tracing.

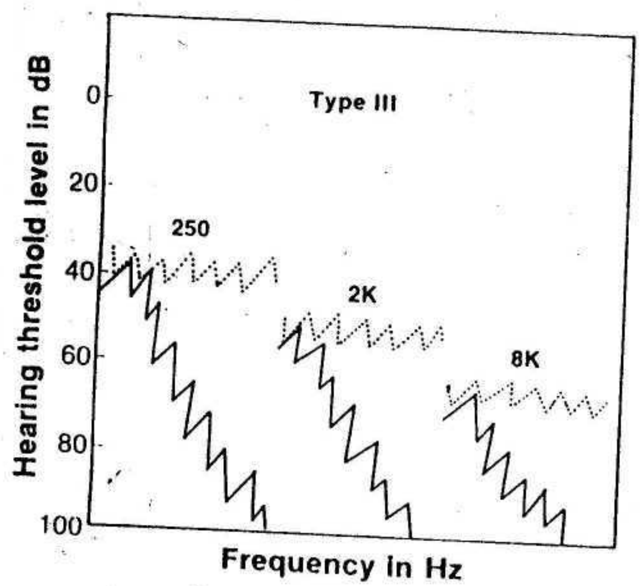


FIG. 4(b) Bekesy Type III. Fixed Frequency Tracing.

Bekesy Type 11

In this pattern, the C tracing falls below the I in sweep mode, generally at or above 1000 Hz. The c tracing seldom falls more than 20 dB below the I. A similar pattern was seen in the fixed - frequency mode with a drop of the C of 5 - 20 dB in the 1st min. of tracing. Ears in this category were primarily diagnosed as cochlear problems or presbycusis as well as those with sensory neural loss of unknown etiology of these three groups 60 % showed a type II pattern. In the strictly cochlear categories, 76% were classified as type II patterns. (Fig 3)

Bekeys type III

In the sweep mode, the type III pattern is characterized by a dramatic drop of the C - below the I . This often occurs at 100 to 500 Hz with a separation of 40 to 50 dB or to the -limits of the audiometer. The C- width was approximately the same as I . Similar results were seen for fixed frequency tracings. Evaluation of 6 of 10 ears with acoustic neuroma showed a type III. The only other category demonstrating a type III was loss of sudden onset (10 to 16 ears). (Fig 4)

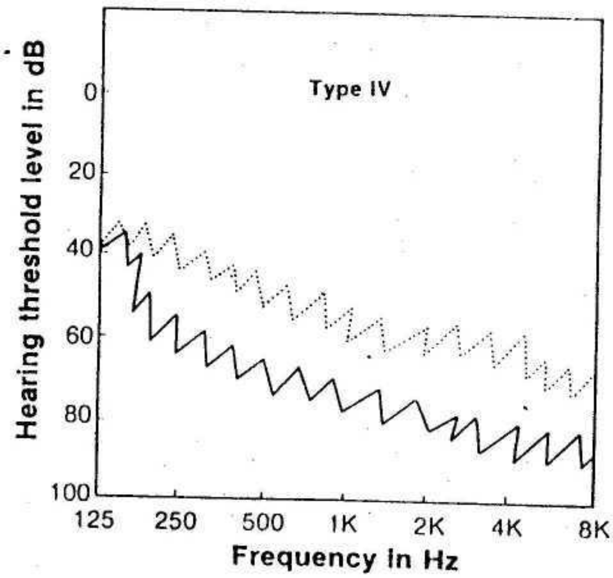


FIG.5(a).

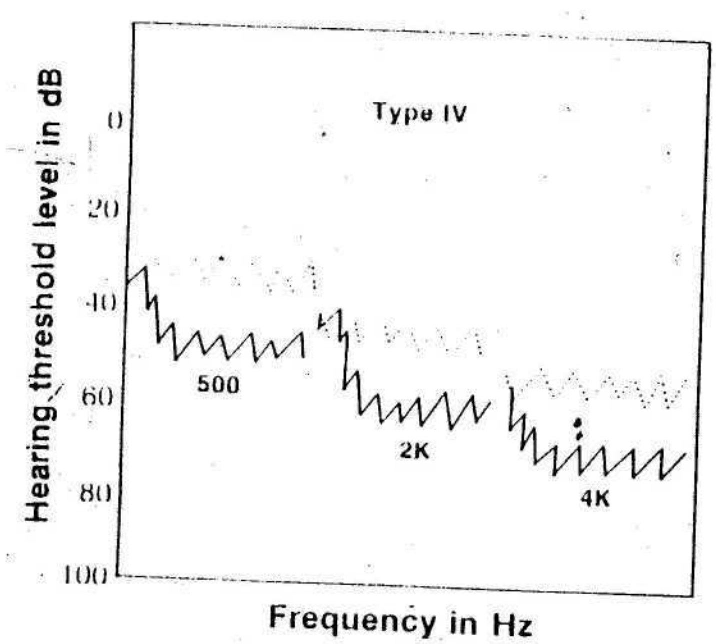


FIG 5(b).

Bekesy Type IV Sweep- & Fixed- frequency tracings.

Bakesy Type IV

Type IV is characterized by the C - dropping below I at frequency lower than 1000 Hz as opposed to type II in which the separation was at 1000 Hz or beyond. This was seen for both sweep and fixed frequency modes tracing width varied. Some clients showed "abnormally small" tracing width. The type IV was seen in 4 of 10 neurinoma ears, in a small percentage of those with unknown etiology and 4 of 16 ears with sudden losses. (Fig 5)

In summary, jerger's classification relative to site of lesion suggested that type I patterns would be expected primarily with normal and conductive ears (as well as some cochlear cases) Type II will be typical of cochlear losses. Clients with eighth nerve lesions would be likely to present with type III or IV patterns (as might those with sudden losses)

Revisions:-

Since 1960 the type I pattern has gained clinically acceptance. However various author including Jerger, have suggested the revision of type II, III and IV. Revisions have centered on (1) The amount of separation of C and I

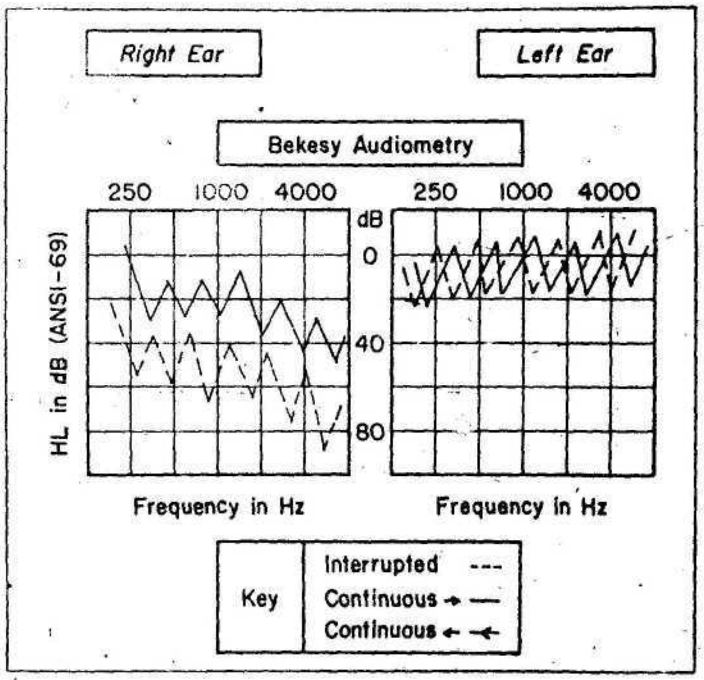


FIG.6. Bekesy Type V Sweep Frequency Tracing in the Right ear.

tracings and (2) where the separation occurs relative to frequency. Mo formal protocol by one author is followed by all. However, current clinical practice suggests ignoring the frequency where C and I tones separate. Relative to amount of separation many would designate separation upto 20 to 25 dB as a type II, implying a cochlear problem. The type IV would show a separation of greater than 26 dB but not to the limit of audiometer, pointing to a retrocochlear lesions.

Bekesy Type V

Type V is characterized by the I - tone dropping below C-tone tracing. It is found in non-organic hearing losses. (Fig 6)

7. CONVENTIONAL BEKESY AND SITE OF LESION

Owens (1965) reported that type II and V as well as type I tracing occur in normal hearing ears. A Psychological basis is offered as a possible explanation of the type V tracings Type II tracings may reflect neural adaptation rather than sensory cell pathology. It must be stressed that clinical interpretations of the Bekesy audiograms should be re-evaluated and strict adaptation to Jerger's original classification could possibly be misleading.

Hopkinson (1965) examined and questioned the concept of the type V audiogram as the predictor of non-organic hearing loss on the basis of its incidence in a clinical population having conductive impairment. Stein (1963) suggested that Bekesy audiometry should be used as a supplemental test. Bekesy audiometry is of universal value as a clinical test but administration of test depends on whether we need quantitative data for assessing degree of communication problem or qualitative data for determining site of lesion. Robertson (1966) re-emphasized that Bekesy audiometry should be confined to site, rather than the etiologic differentiation. The Bekesy audiometry is useful in predicting the 8th nerve lesion, but absence of Bekesy usual pattern doesnot exclude the absence of neural lesions.

Conventional Bekesy Audiometry has been used in test batteries primarily to differentiate cochlear from retrocochlear pathology / lesions. Most reported retrocochlear lesion cases have been of the auditory nerve, usually acoustic neuromas. Other reported dysfunctions have either primarily or secondarily affected the eight nerve.

In 23 patients with labyrinthine hydrops reported by Tillman (1969), all had type I or Type II pattern while 70 % of a like number of acoustic tumor patients evidenced a type III and IV patterns. Sanders et.al., (1974) cited Sweep Bekesy results on 27 cases with acoustic tumors in which 51 % gave type III or IV patterns while rest were Type I or Type II. Fixed frequency Bekesy was performed on several patient group by Olsen and Noffsinger (1974). Among 78 individual with menieres disease, acoustic tranma or presbycusis all showed Type I and II patterns. Of 19 patients with auditory nerve tumor 74% evidenced type III or IV patterns. While the rest gave type I or II. Clemis and Curtis (1977) noted that among those patients with acoustic tumors who were given Bekesy 47% presented with type III or IV audiograms.

One difficulty in discussing the value of the Bekesy technique in detecting retrocochlear disorders is the relatively small member of cases reported in many studies. However, Johnson (1965, 1966, 1968, 1970, 1977) and his colleagus (Johnson and House, 1964; Johnson and Sheehy, 1966) have reported on Bekesy results on an increasing number of patients with surgically confirmed acoustic neuromas. Johnson (1977) compared test results of 500 8th Nerve cases to previously reported smaller series of those given Bekesy (363 patients) 57 % demonstrated the expected Type III or IV patterns.

This was some what smaller series in 1968 but much smaller than the 71 % reported on 53 cases in 1964. He attributed this reduction in classical findings on Bekesy and other tests (SISI, ABLB, TDT, word Discrimination Score) to earlier tumor detection and consequently fewer " large tumor". Data relative to tumor size indicated that for large tumors 72% of the cases produced Type III and IV patterns, those for medium and small tumor 47% and 39% respectively. This suggests that Bekesy is most useful in detecting large tumors or other lesions affecting the auditory nerve in a similar fashion.

Johnson (1977) further noted that he was abandoning use of Bekesy audiometry and SISI test in his test battery. They were to be replaced by acoustic reflex testing and auditory brainstem response i.e Among 75 patients 85% showed positive findings on acoustic reflex testing. While conventional Bekesy is neither as quick nor as accurate in identifying retrocochlear disorders one should not at this stage assume that behavioral test such as Bekesy and its modification should be abandoned eg. many circumstances may make it impossible or questionable is to carry out acoustic reflex testing. In suck cases, the audiologist should have a variety of, techniques from which to choose.

Using the convention Bekesy audiometry we can know about the site of lesion. In order to improve the accuracy of diagnostic results the conventional Bekesy has been modified into a number of tests and also other tests have been modified so that they can be administered using Bekesy audiometer. The different tests and their results will be dealt here separately in relation to different sites of lesion or different types of hearing loss i.e how we can arrive at differential diagnosis of hearing loss using the Bekesy Audiometer.

8. CONDUCTIVE HEARING LOSS

Acoording to Jerger's (1960) classification the conductive loss cases show type I Bekesy pattern. Hopkinson (1965) reported high incidence of Bekesy Type V pattern in a clinical population having conductive Impairment.

8.1 BING TEST

Fieldman, Zeldner and Grimes (1967) suggested a modification of the BING TEST utilizing Bekesy audiometry. The BING TEST (Bing, 1891) is based on the occlusion effect to differentiate conductive from sensori-neural hearing losses. The occlusion effect is the perception of an increase in loudness of a bone conducted tone when external auditory canal is occluded. In Bing test the external auditory canal is alternately occluded and unoccluded during the presentation of a signal via tuning fork placed on the mastoid. The perception is of a pulsing tone for nerve losses or normal ears and a steady tone for conductive losses.

The modified version of Bing test used at communication disorder unit of the Upstate Medical Centre. The procedure involves delivering a pulse tone via a Radioear bone conduction oscillator placed on the forehead and connected to the earphone receptacle of a Grason Stadler Bekesy E-800 audiometer. An occluded bone conduction measurement of the test ear is obtained for either discrete or continuous frequencies through 1000 Hz. The non-test ear (NTE) is masked with narrow band noise. The test ear is then occluded with a TDH -39 earphone set in an MX-41 AR cushion and the tracing repeated. Because the E-800 is not calibrated for bone conduction threshold measurement . Anticipated bone conduction losses (re: 150) in excess of 35 dB at 250 Hz, 50 dB at 500 Hz, 60dB at 750 Hz and 65 dB at 1000 Hz are not suitable for this test. The measurement obtained provide a graphic recording of the presence of a shift between the occluded and unoccluded states.

There are some limitations involving the use of Bekesy audiometer for observation of the occlusion effect. Masking problem (i.e insufficient masking of NTE) enter into the - modified Bing test as they do in other bone conduction tests. The modified Bing test only indicates the presence of conductive component but it has proved useful when the proper precautions are observed in the differential diagnosis of middle ear pathology, particularly when small air-bone gaps exist and also in other instances when there is a doubt. In addition to providing a more concrete, accurate and reliable record of shift produced by occlusion, hearing levels can be traced overtime. When the norms are established for occlusion effect 1 or 2 dB changes may be significant in determining the type and extent of pathology. These slight changes can be measured more accurately with automatic audiometers.

8.2 6ELLR IRSI

Arnold and Schindler (1964) d^cribed the technique of Qelle Test with Bekesy audiometry and formed out the range of normal valu.es. They did Bekesy audiometry in cases of Eustachian Salpingitis. It could be confirmed that negative intratympanic pressure is counteracted by negative meatal pressure. At the moment, the hearing loss resulting from tubal obstruction is temporarily corrected. It appears that negative pressure application during Gelle Test closes the AB gap of Salpingitis momentarily. For this reason the normal threshold shift, observed with negative meatal pressure, is inverted to an improved hearing level.

9. COCHLEAR HEARING LOSS

As mentioned earlier, the conventional sweep frequency tracing in case of cochlear pathology results in Bekesy type II pattern. A similar pattern is seen in fixed frequency also. Although the evidence of type II has been reported in normals, conductive loss and sensori-neural loss, (Owen, 1965; Sanders, 1974; Tillman, 1969; Olsen and Noffsinger, 1974;) but there frequency is less.

Bilger (1965) obtained the Bekesy audiograms for I and C tones of 4000Hz on a sample of 120 patients whose sensitivity ranged from 0 to 95 dB HL and whose cochlear function ranged from normal to severely impaired. He concluded that width of the Bekesy tracing around the threshold for continuous tone indicates the non-normal population and provides the only basis for classification of fixed- frequency Bekesy audiograms into the categories of pathological or normal cochlear function.

Elmer Owens (1965) administered pune tone audiometer test of tone decay to 86 subjects at octave-interval frequencies 250 - 4000Hz and fixed frequency I and C tone Bekesy tracing were obtained from the same subjects. Twelve subjects showed type III Bekesy tracings and 74 subjects showed type II and type I tracings, shifts occurred in the Bekesy tracings according to whether tone decay was present by the standard audiometric test. Type II Bekesy tracings were predicted when there was slowing of tone decay as intensity increased, and type III was predicted when tone decay maintained essentially the same rapidity regardless of intensity increase. He hypothesized that type II Bekesy tracing may reflect at once loudness recruitment and tone decay.

9.1 Brief Tone Bakesy Audiomatry

Another modification of the conventional Bekesy Audiometry was given by Wright (1968) known as Brief tone Bekesy audiometry. This is based on the fact that auditory system integrates energy overtime. Greater intensity is required ,to detect a 20 msec tone than for a 200 msec tone. This means that for brief tone greater intensity is required for threshold response. This is due to psychophysiological process of temporal summation.

Brief tone are used to find the thresholds using a Bekesy audiometer, so it becomes Brief tone Bekesy audiometry. But use of brief tone produces some acoustic artifacts. The sounds may be heard as clicks or side bands, if switch is turned off and on quickly. If rise decay time is less than 5 msecs then acoustic artifact will be there. If we want to avoid clicks rise- decay time should be more than 5 m secs. In brief tone audiometry rise-decay time is 10 m secs.

The subject is asked to trace his thresholds for 1 min. period for 20 m secs and 500 msecs tone. The other signal parameter used are:-

1) Rate of presentation = 1 per sec.
2) Rate of attenuation = 2.5 dB/sec.
3) Rise - decay time = 10 m secs.

The frequency is kept constant i.e. fixed frequency tracing is done

Instructions:- You will hear a beep-beep sound when the sound is audible, press the switch, keep the switch pressed as long as it is audible and release it when it becomes inaudible. Threshold for 20 msecs and 500 msecs tone is determined.

In normal subjects the difference is about 10 dB. In case of conductive loss the difference is again 10 dB, but in case of cochlear pathology the difference is reduced to 5 dB. (Dean, 1974)

The processing of long duration tones take place at cochlear level, so integrity of outer hair cells is important. If there is cochlear dysfunction, +hen processing of long duration tones is impaired and hence the difference is reduced when the normal subjects were subjected to brief tone audiometry, the difference was seen to be reduced at high frequencies, so we may suspect cochlear dysfunction inspite of his normal thresholds that pure tone audiometry might not have revealed. According to katz, Brief tone Bekesy audiometry is a very sensitive test to detect cochlear lesions. Eisenberg (1956) and Sanders and Honig (1967) suggested that Brief tone audiometry may be unusually sensitive to cochlear pathology Comvell and Counter (1969) speculated that the reduced temporal integration might possibly reflect minimal sensorineural impairment. Barry and Larson (1974) showed that in deaf children with cochlear pathology the temporal integration (Mean) were only about one-third of those yielded by their normal counterpart except at 500 Hz possibly because the vibrotactile stimulation might have contaminated the measurements of auditory temporal integration. Pederson (1874) studied the ability to integrate acoustic energy over a period of time by brief tone audiometry on 14 young persons treated with salicylate and after the salicylate has been excreted. The investigations were done in a sound proof room for each of the frequencies 500, 1000, 4000, and 8000 Hz. The patients were investigated for 10 tones with a duration varying from 1000 to 1 msec. The investigation showed that the temporal integration can be reverslbly reduced by salicylate treatment and a relation was demonstrated between changes in temporal integration and salicylate concentration in the blood. As the test person had had general anesthesia, a control test was performed on seven persons. It was shown that hearing loss produced by salicylate is due to an inhibition of enzymatic system in cochlea. Anaesthesia does not influence temporal integration. Reduced cochlear function causes reduced temporal integration.

Olsen and Buckles (1979) studied the influence of age and sex on temporal integration on 50 subjects aged between 6 to 24 years. A threshold tracking paradigm was employed. Age did not systematically influence temporal integration. Variability of integration values among subjects of 6-7 years indicates that such children are capable of tracking threshold successfully in a brief tone paradigm. Significant sex differences in integration slope were obtained across frequency and age group.

Chung and Smith (1980) reported that the cases with noise induced hearing loss show less temporal integration, however both normals and hearing impaired show frequency effect. The Bekesy tracing procedure used in their study was same as used by Wright (1968) and the non-test ear was masked by a continuous white noise at 90 dB SPL. The discrepancy in the findings of frequency effect was supposed to be probably due to subclinical cochlear lesion present in some of the normal listeners. This study supported the findings of Barry and Larson (1974) and Martin and Woffords (1970). It is hoped that addition of a masker in Brief tone audiometry may yield more diagnostic value.

Olsen (1987) reviewed the studies on Brief tone audiometry and the validity and usefulness of the test procedure was questioned on the basis of considerable overlap seen in the distribution of data for normal and hearing impaired group and also in the cochlear and retrocochlear pathology cases. He suggested that new test procedures or new methods of interpretation of results of Brief tone audiometry must be developed if it is to be a viable and useful test procedure.

9.2 Relationship between continuous and interrupted tones at threshold and suprathreshold levels.

When normal hearing subjects are asked to track equivalent loudness levels for C and I tones at suprathreshold levels including M C L, Listeners unexpectedly track the C tone at a lower (better) hearing level than the I tone. Ventry et. al., (1971) had normal hearing listeners track C and I tones at MCL via fixed - frequency Bekesy audiometry at 500Hz, 1KHz and 2 KHz. On the average the C tone was tracked approximately 5 dB lower than I tone at the attenuation rate 2.5 dB/sec.

In the hearing impaired ears interest has centered on the C-1 relationship at MCL as a site of lesion indicator. Jerger and Jerger (1974) found Sweep-Frequency Bekesy comfortable Loudness (BCL) tracing of C and I tones helpful in-differentiating cochlear and retrocochlear pathology.

Dancer and Ventry (1984) studied the C.I difference at threshold and at MCL on normals and cochlear pathology cases and found that C-I difference was small. They suggested that the small C-I difference should increase the value and use of fixed frequency Bekesy tracings, Large C-I difference at MCL or between threshold and MCI should be considered as indicative of possible pathological conditions beyond cochlea. The excursion width is reduced for the continuous tone tracing in cases with cochlear pathology at suprathreshold levels (Domico, 1985) It is suggested that most comfortable level (MCL) should be traced as one feature of site-of-lesion testing in sensorineural cases. An excursion width of 5 dB or less for continuous tone at MCL and this criterion in a sweep frequency Bekesy is suggested to be of clinical value.

It has been suggested that more similar the impaired ear is to the normal ear in the processing of suprathreshold loudness better in the potential for amplification and rehabilitation. Ears with cochlear pathology continue to share many of the characteristics of normal ears equalization of loudness at equal intensity levels, discriminability of small intensity increments at high intensity levels, presence of ipsi and contralateral acoustic reflex and loudness discomfort level for speech around 100 dB Spl. Mc candles and Perkins (1974) supported that people with cochlear pathology are only second to those with conductive pathology in acceptance and use of hearing aid.

9.3 Bekesy tracked Aural Harmonic Distortion threshold and Uncomfortable Loudness Level.

Sweep Frequency Bekesy audiometry has been used to determine the uncomfortable loudness and threshold levels for the perception of an aurally generated Harmonic distortion phenomenon in normal and sensorineural hearing impaired listeners. The concept of aurally generated harmonic distortion phenomenon as a result of cochlear overload to a pure-tone stimulus of Moderate intensity is one of importance to the fields of audiotory perception and clinical audiology. The sensory overload capabilities of the human ear have long been studied, (Stevens and Newman, 1936). Researchers have discussed a type of non linear harmonic producing distortion occurring when a system driven by a force fails to responds proportionally with further increase in amplitude of driving forces (Lawrance and Yantis, 1956a 1957; Wever and Lawrance, 1954; Yantis, Millin, Shapiro, 1966) The overload was believed to be a response of outer hair cells within the organ of corti (weven and Lawarance, 1954) and more recently associated with cochlear microphonic (Dallos and Wang, 1974; Dallos and cheathan, 1976). This electrical output of cochlea has been shown to display a frequency dependent saturation or nonlinear onset at low-to-moderate intensity levels.

The intensity level at which this distortion first becomes audiometrlcally evident was termed as threshold of aural overload (Lawrance and Yantis, 1956). The aural overload test is a difficult and lengthy process (Carhart, 1973; Clark and Bess, 1969) even with recent modification, (Fausti, 1971; Humes, 1978) and the method of best- beats according to Bekesy (1960) does hot give a measure of overload within the organ of corti. Domico (1986) used Bekesy audiometer to measure both aural harmonic distortion (AHD) and uncomfortable condenses (UCL)

1. UCL measurements - The patient is asked to manipulate an intensity control to first an interrupted (I) and then continuous (C) Sweep frequency stimulus which began at 100 Hz and OdB HL and increased at 1 oct/min and 2.5 dB/sec to 8000 Hz. The instructions used to define UCL was the point at which the stimulus becomes uncomfortably loud. Determination of intensity level per test frequency was made using a transparent overlay graduated in one dB Step.

2. Aural Harmonic distortion (AHD) - during UCL tracking many subjects reported a perceived distortion of C tone at high intensity and frequency level. Subjects were asked to track the onset of perceived distortion as the C tone was swept from 100 to 8000 Hz. The intensity level for each test frequency was determined in the same manner as was the peak value for UCL tracings.

The conclusion of the above study was that an aurally generated harmonic distortion phenomenon can be observed as a perceived change in tonal quality and that the thresholds of distortion can be tracked at its onset with Bekesy audiometry. This perceived distortion is believed to result from an overload of cochlear system, when presented with a

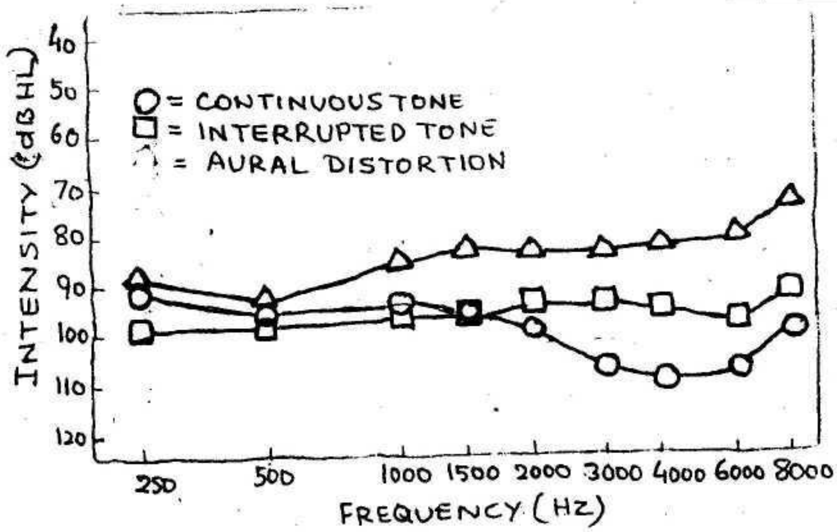


Fig. 7a.
Mean UCL and AHD threshold levels for 15 normal-hearing subjects reporting the perception of distortion.

Fig. 7b.
Mean UCL and AHD threshold levels for 4 hearing-Impaired subjects reporting the perception of distortion.

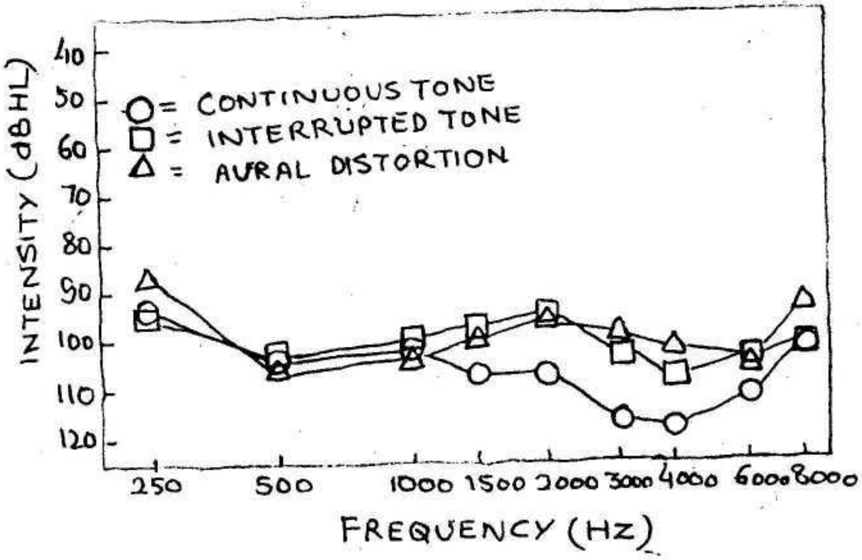
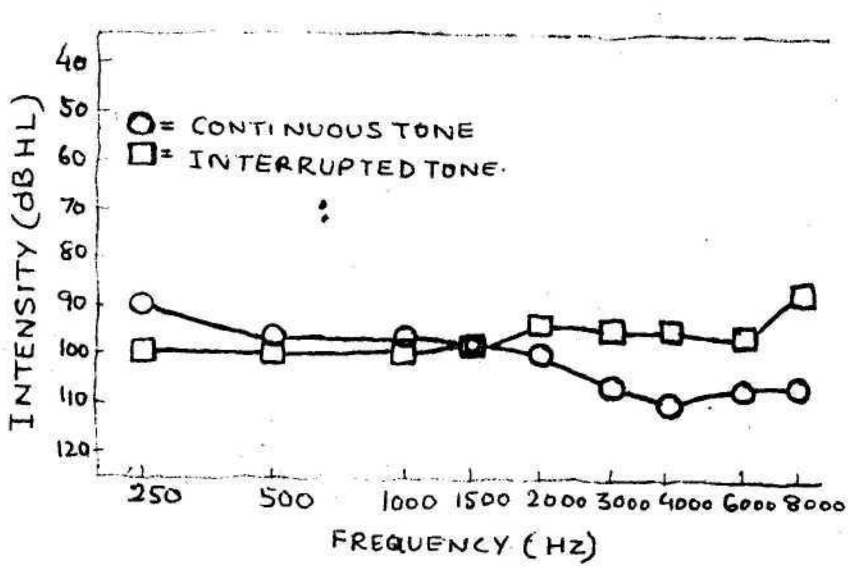


Fig. 8.
Mean UCL levels for C and I tones for 13 normal Hearing subjects tracking the cross-over Pattern.



puretone of sufficient intensity, frequency and duration. This study supported 3 reported efforts of sensory impairment, a reduced dynamic range, an elevation in intensity required for overload of cochlear system, a reduced intensity range from audiometric threshold to the onset of saturation. (Fig .7 a,b)

Also the distortion is perceived not only as a change in tonal quality but also a change in loudness. The high degree between frequency range of onset for the perception of distortion and C-I separation forming a cross-over. (Fig.8) Uncomfortable loudness tracking pattern suggests that as the continuous stimulus was allowed to cross over the subjects threshold of distortion a perceived decrease in loudness occurred. A subsequent compensation was made by the subject allowing the tone to increase in intensity as a means of restoring the stimulus to pre-defined loudness level which resulted in cross over UCL pattern.

Implications :- With respect to intensity levels of aural distortion phenomenon, it is possible that various procedures such as Bekesy comfortable loudness, suprathreshold adaptation tests may be affected by perception of distortion. Consideration of this variation in the interpretation of results of these tests may used to increased clinical accuracy. The examiner may also wish to obtain a measure of AHD when dealing with cochlear impaired listener. Here elevation of AHD thresholds are correlated with cochlear loss. The limitation in this procedure is that severe losses may elevate both the UCL and AHD levels above the maximum output of the audiometer.

9.4. Cochlear Minrophonics

Roger, Voots and Watson (1964) reported a technique by which cochlear microphonics (CM) in animals can be measured using the Bekesy audiometer. The only modification to the audiometer is that a relay is substituted for the response key. When cochlear microphonic reaches a certain value the relay closes and when CM decreases to some minimal value the relay opens. With this system CMS to sound stimuli of 30 to 40 dB SPL can be recorded. This technique has not been used with human being so far and hence its clinical utility is not yet known.

10. RETROCOCHLEAR HEARING LOSS

Bekesy Type III and Type IV patterns in convention Sweep frequency tracing usually indicates retrocochlear pathology. Uphold (1972) suggested that the Bekesy type found in sweep frequency tracing depends on the proportion of frequencies at which adaptation occurs and their distribution. In case there are no or relatively few adapting frequencies a type I or Type II pattern would follow. If there is a high proportion of adapting frequencies, then a type III or Type IV pattern would follow, depending on the proportion involved. Fixed frequency tracing can be more sensitive than sweep frequency tracing in adaptation detection. When Sweep frequency tracing provides ambiguous results or doesnot display significant adaptation,when there are consistent sign of retrocochlear lesion, more attention should be paid to Bekesy fixed frequency tracings. When the tone decay is leas, we may get type II Bekesy pattern. Owens (1965) suggested that type II tracing may reflect neural adaptation rather than sensory cell pathology.

The Bekesy audiometry is useful in predicting the 8th nerve lesion, but the absence of Bekesy neural pattern does not exclude the absence of neural lesions; (Robertson, 1965) Jerger and Jerger (1980) evaluated a single case 8th nerve disorder twice, first when the loss was mild and again when it became severe. They suggested that when loss is severe Bekesy audiometry and suprathreshold adaptation test (STAT) provides most useful diagnostic information.

In case of Brief tone Bakesy audiometry as described in 9.1 if the difference between 20 m sec and 500 msec tone threshold doesnot decrease than 10 dB and there are consistent signs of sensorineural pathology, it is indicative of a retrocochlear lesion.

10.1. Bekesy comfortable loudness

The Bekesy comfortable loudness (BCL) procedure was first described by Jerger and Jerger (1974 a,c). BCL is carried out in Sweep frequency mode. Instruction regarding the I and C tones and the use of signal switch are same as in conventional Bekesy audiometry. However, rather than tracing threshold the client is "instructed to press the button when signal is just uncomfortably loud and to release the button when the signal is just less than comfortably loud". (Jerger and Jerger, 1974 a) In addition the client is told that he will hear a continuous noise (masking) in the non test ear during the procedure (Jerger and Jerger 1974 c).

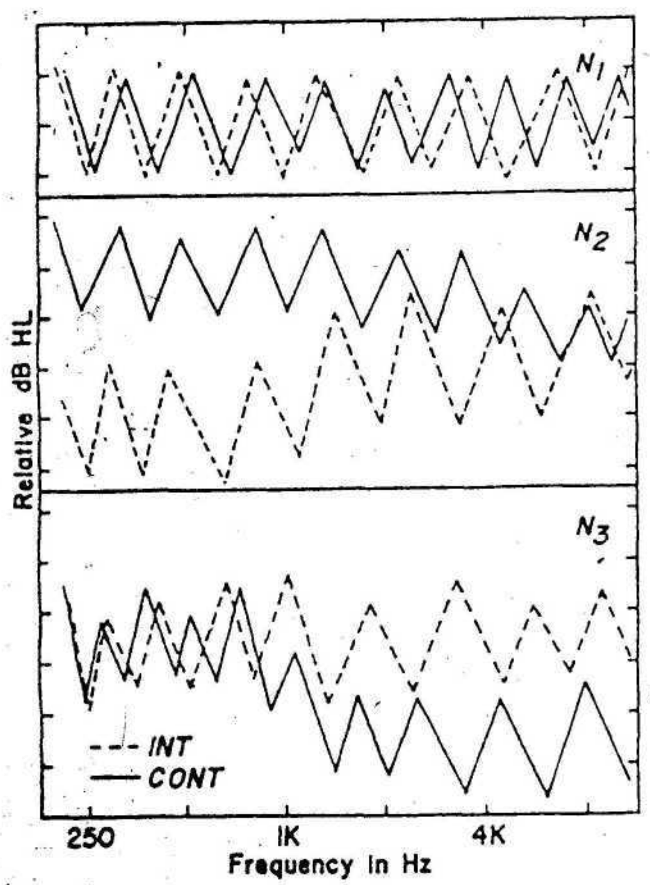
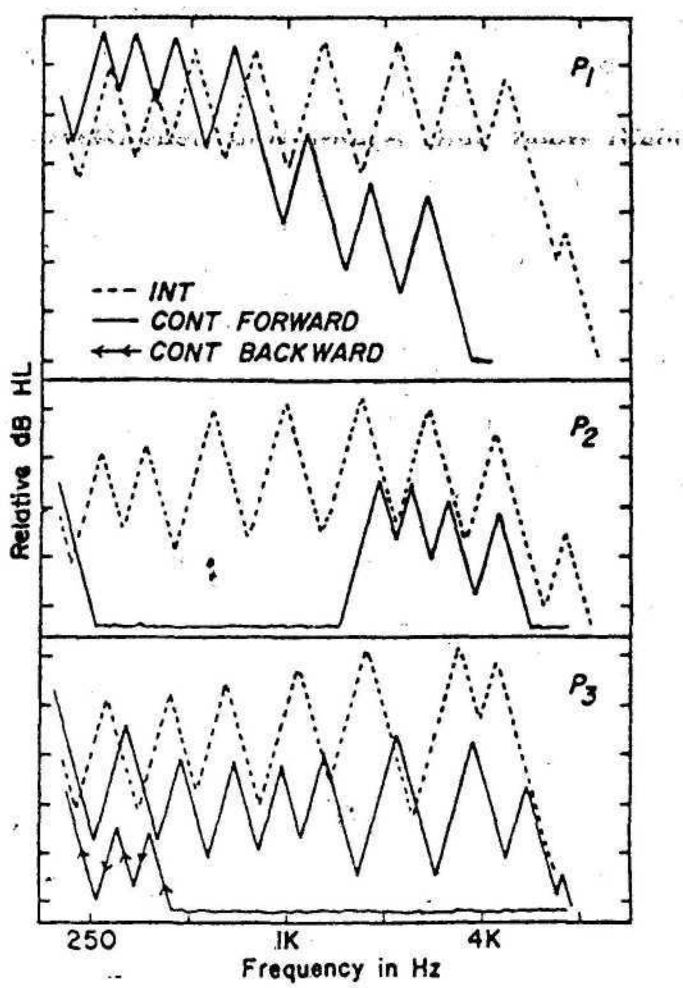


FIG. A. Negative BCL results.

FIG. B. Positive BCL results.



Various cases with normal hearing and conductive, cochlear and retrocochlear hearing losses were studied comparing conventional and BCL procedures.Fig.A and B, illustrate the most common patterns seen. The negative (Fig A,N1,N2,N3) patterns were typical of normal ears or non-retrocochlear lesions. Positive (Fig B, P1,P2,P3) tracings typified the retrocochlear cases P3 pattern including reverse BCL C-tone tracing of importance in BCL is the relationship between the I- and C-tone tracings rather than absolute dB differences. Among non-retrocochlear ears, only three with cochlear disorders showed a positive (P1) result. Sixteen patients had retro cochlear problems (eighth nerve or brain-stem lesion) of these, 11 evidenced positive BCL results the remaining five gave negative results or had unclassified tracings. BCL results were positive in the 10 confirmed cases (surgical/ radiological) while only three evidenced type III or IV pattern on conventional Bekesy. Orchik et.al.,(1977) reported on one confirmed and one suspected retro-cochlear case comparing BCL to conventional Bekesy Type I tracings were found in forward and reverse C threshold tracings, while reverse C BCL tracings fell to audiometer limits. He supports the use of BCL as a means of improving the sensitivity of

Bekesy audiometry in identification of retrocochlear lesion. In case of acoustic neuroma it demonstrates significant auditory adaptation.

10.2 Reverse Bekesy tracings

Reverse Bekesy tracings have been suggested to separate cochlear from retrocochlear disorders. Initially conventional sweep tracings are collected. The client then traces the C tone again but in reverse direction relative to frequency. The individual is told that he or she will again, hear a C tone but it will gradually decrease from high to low pitch. The person is to trace the C tone ignoring the pitch change while responding to loudness as in conventional tracing. Here one must instruct the patient to reverse the switch response (i.e. to press the switch when the tone goes away and release when it is heard) A change in instructions initially may confuse the client.

Reports on comparison of backward and reverse tracings of the C tone note that little difference is seen in most cases except for those ear showing abnormal adaptation and associated retrocochlear disorder (Karja and Palva, 1970; Young and Harbert, 1971, Jerger et.al., 1972). Generally the major separation for this method is in the middle and high frequencies. The most separation is seen in retrocochlear cases with the reverse C threshold being P orer than the forward trace.

Palva and his Coworkers (Karja and Palva, 1970; Palva and Janhiainen, 1976; Palva et al, 1978) supported the strength of the forward and backward tracing comparison for distinguishing cochlear for retrocochlear disorder. In 1970, Karja and Palva reported on a number of patients with a variety of cochlear and retrocochlear disorders. Among 284 ears evaluated, 17 evidenced separation of the two tracings, usually a difference of 30 to 50 dB. Significant adaptation on tone decay test was also noted for these cases. These findings were seen with a variety of retrocochlear disorders and 2 cases of "pure cochlear" cases. The significant finding on the reverse Bekesy was in contrast with the conventional Bekesy Type I and Type II patterns. Jerger and Jerger (1974 C) suggested that a routine C averse tracing should be included with routine Bekesy to increase the likelyhood of predicting a retrocochlear problem.

The value of reverse C tracing was further substantiated by the Palva et al (1978) report on 36 cases each of Meneire's discrete and acoustic neuroma. Findings on Bekesy forward reverse tracings accurately reflected cochlear or acoustic nerve sites 71% of the time. This compared favorably with 71% for acoustic reflex testing conventional

Bekesy type III and IV were obtained only in 54% of patients. The later figure is markedly similar to Johnson's (1977) 57% Type II and IV patterns in 363 acoustic neuroma cases.

10.3 Tone Dacay Test

The tone decay test for Bekesy audiometer was modified by Simon . Here patient presses the response button so long as he hears a constant frequency tone at 6 dB sensation level, when or if he releases the button indicating inaudibility, experimenter raises intensity by 6 dB and so on for a total session of one min. duration.

Northern (1964) studied the relationship between TTS as shown by Rosenbergs modified tone decay test as further modified by simon for Bekesy audiometer and the type II Bekesy audiogram tracing (difference in dB at any frequency between a continuous(C) and an I tone tracing in conventional Sweep frequency Bekasy audiometer). At 2000 and 6000 Hz it was possible to predict quite well the latter measure from the first within 15 dB error. A highly significant pearson correlation (r) between two measure at 6000 Hz, a positive correlation at 2000 Hz and no significant correlation at 4000 Hz was found in 25 ears from 18 patients who exhibited type II BeKesy audiogram tracing plus reduced peak - to- peak amplitude pen excursion above 1000 Hz in conventional C tone Sweep - frequency BeKesy Audiometry the patients had all been operationally defined in clinics as having cochlear loss for such a population these results suggest that the two audiometric test may measure the same process of auditory adaptation.

Suzuki, Yoshie, Sakabe and Igarashi (1966) administered the threshold tone decay (TTD) and BeKesy fixed frequency threshold tracing shift (TTS) to 10 listeners with normal Rearing, 16 patients with conductive hearing loss and 42 patients with SN loss. The test stimuli for both tests were 1000 Hz and 4000 Hz tones. On the basis of the results obtained from normal ears, the following criteria were used in the evaluation of test results from the pathological ears for both TTD and TTS results, threshold increases of less than 10 dB over a 3 min period were regarded as negative and threshold increase of more than 11 dB over the same period were regarded as positive. Results indicated that for C tones of 1000 and 4000 Hz, normal listeners and those with conductive hearing loss showed negative results and some of the listeners with sensori neural hearing loss showed positive results. Positive results occurred more often for TTD and TTS 4000Hz showed a higher positive rate for both

TTD and TTS than did 1000Hz. All listeners who had positive TTS alao showed positive TTD results. The authors concluded that although abnormal adaptation is a common factor in both the TTD and TTS Phenomenon, TTD is not an equivalent for TTS or vice-versa. The two tests cannot be substituted for each other, so both should be done to detect abnormal adaptation.

Lehnhardt and Battoner (1980) suggested that only dynamic recording of the tone threshold can give information on pathological adaptation, auditory fatigue and aggravation. Therefore the authors have automated the tone decay test. This was achieved by modifying the Grason-Stadler audiometer E-800 and concurrently by developing a special device with integrated circuits for this purpose. Print out is made on a commercial X-Y recorder which is also used for recording impedance test results. During automated TDT the patient himself increases the intensity of the tone until he can hear the tone again, the intensity of the tone otherwise remaining constant. Thus we obtain either a flat (adaptation) or a sharply decline (auditory fatigue) curve which correlates with the Bekesy continuous tone curve but may show a distinctive separation. The tone decay test is, in contrast

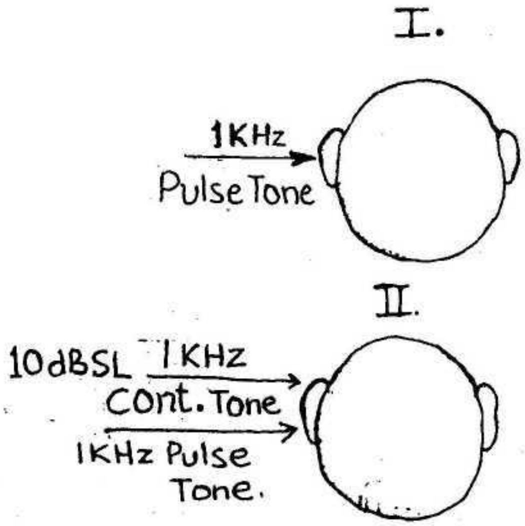


FIG.9 Continuous Tone Masking.

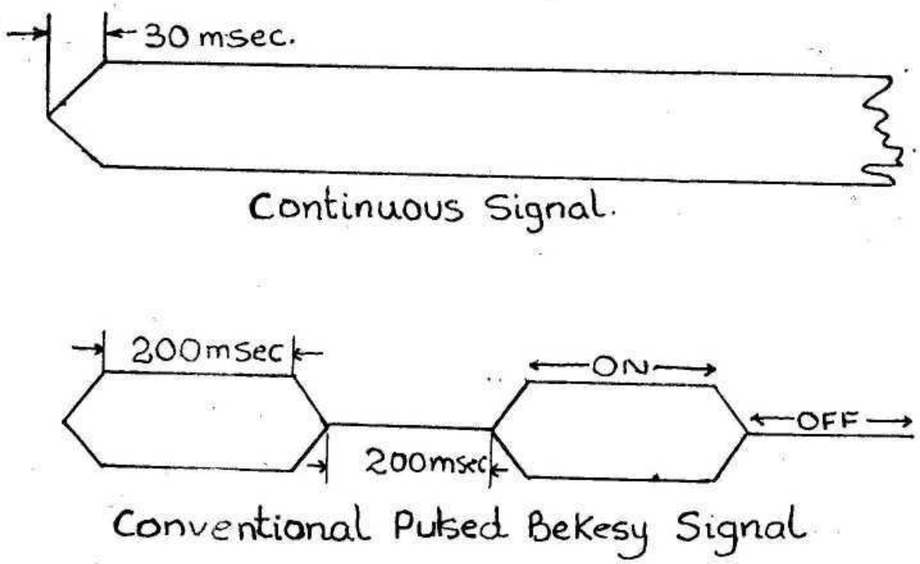


FIG.10. Signal Parameters

to all other suprathreshold tests, independent of the amount of hearing loss. If can therefore give information on the kind of hearing impairment for normal short duration threshold as well.

10.4 Continuous Tone Masking

The test is used to differentiate a case of retrocochlear pathology from that of cochlear pathology. Here a C tone at 1KHz and 10 dB SL is presented and the subject is asked to trace his threshold for pulse tone. (Fig.9)

First we obtain the threshold for pulse tone in absence of a continuous tone. We can repeat the test at 2 KHz also and even at 20 dB SL.

In retrocochlear pathology, there is a shift in threshold in presence of a continuous tone which can be explained on the basis of tone decay. eg. In the absence of a continuous tone, the threshold is 40 dB for the pure tone of same frequency and in the presence of a continuous tone the threshold is 70 dB, so there is a 30 dB shift in presence of a continuous tone.

10.5. Critical-Off- Time (COT)

The difference in threshold is seen for a continuous and an Interrupted tone. The on-off time for a I tone is 200 msec. When the off-time is reduced, at some value the I tone also starts behaving like a C tone. This critical off-time is different in different types of hearing losses. This phenomenon is made use of in this test to differentiate a retrocochlear loss from a cochlear loss. (Fig. 10)

If the I tone behaves like a C tone when the COT is 125 msec it is retrocochlear pathology. Cor for cochlear loss is 75 msec and for normals it is 45 msec.

This is also explained on the basis of tone decay. Because of the less off-time, the I tone behaves like a continuous tone.

11. CENTRAL AUDITORY DISORDERS

Ohta (1981) selected 66 patients showing large tracing amplitudes above 15 dB from about 1000 patients with sensorineural hearing loss. 38 of the 66 cases showed a difference in tracking amplitude between left and right ears. It was considered from this data that some of the large amplitude values indicate certain pathological conditions of the central auditory system. In order to elucidate the causative mechanism for the large amplitudes, 3 groups of patients were selected for investigations from those revealing large amplitude. These groups were:-

a) Those showing type III or type IV trace of Jerger's classification.

b) Those with poor speech discrimination.

c) patients demonstrating poor discrimination for distorted speech sound with normal hearing for normal speech sounds.

A detailed analysis of these data indicated abnormally large amplitudes of BeKesy tracings are caused by some types of wide spread central lesions. The results of Binaural separation test in those with pathologically wide tracing amplitude were analysed. He concluded that wide excursion may be caused not only by disorders of right hemisphere but also by some types of dysfunction of the whole cerebrum.

11.1 Brief Tone BeKesy Audiometry

In case of normals the difference between the long and short duration tone threshold is about 10 dB. If in a subject this difference is increased, say 15 or 20 dB , it is indicative of temporal lobe pathology in the lobe contralateral to the ear in which this increase is observed.

The difference increases because processing of short duration tone occurs in temporal lobe within auditory reception area and Heschel's gyrus in Superipr temporal lobe.

12. FUNCTIONAL HEARING LOSS

Jerger and Herer (1961) first reported that non-organic impairments result in type V BeKesy tracing in which there appeared to be greater loss for hearing for pulsed than for continuous tones. But the concept of type V BeKesy tracing as a predictor of non-organic hearing loss was questioned on the basis of its incidence in a clinical population having conductive loss by Hopkinson (1965).

Puxeddu (1964) suggested that malingering in audiological evaluations can be easily and rapidly detected by the tests performed with BeKesy audiometer. The repetition of the threshold tracing is frequently sufficient to give the evidence of the unreliability of the response. A further threshold tracing, obtained by increasing or diminishing (by 20 dB) the reference intensity level of a audiometer may give a further confirmation of malingering tendency in tested subjects. In this case, both tracing do not show an exactly parallel course as it must be the case under non-malingering conditions. Finally, a malingerer does not succeed in keeping constant, over a given period of time (1 to 2 min) the level of a threshold tracing for a signal of fixed frequency.

Rintleman and Hardford (1967) suggested that one value of BeKesy audiometry is that no special techniques are involved making it possible for even unexperienced clinicians to identify patients with functional hearing loss. Ventry (1971), based on a case study concluded that BeKesy results cannot be used to determine the extent of functional overlay or to estimate true threshold, but it offers some possible insight into the listening strategies - conscious or unconscious- employed by the patients presenting functional hearing loss.

Kacker (1971) studied the implications of BeKesy audiometry in the cases of simulated hearing loss and arrived at following conclusions:-

1) A test-retest discrepancy, consistently present in all the subjects with simulated hearing loss, was the most reliable criterion for detecting such loss
2) Type V Bekesy tracings indicated simulated hearing loss and were found in 70% of the cases.

3) Saucer shaped curves and increased Bekesy excursion are not reliable indicators of simulated hearing loss.

4) BeKesy audiometer is a reliable tool in detecting simulated hearing loss.

Jerger and Jerger (1972) reported that the discrepancy between Forward and Backward BeKesy tracing is observed in relatively large percentage of retrocochlear or functional hearing loss cases. They suggested that presence of a discrepancy should always alert the clinician to the strange possibility of a functional problem.

If case of Brief tone BeKesy audiometer the difference in threshold for short and long duration pulse tones and continuous tone is indicative of Pseudohypacusis. (Katz 1978)

12.1. Lengthened -Off-time

Hattler (1968) reported that the type V tendency entrances by lengthening the off-time by the BeKesy pulsed signal. Hattier (1970 found that by lengthening the BeKesy off-time from conventional 200 msec to 800msec, the loudness tracing of well trained normal hearing subjects

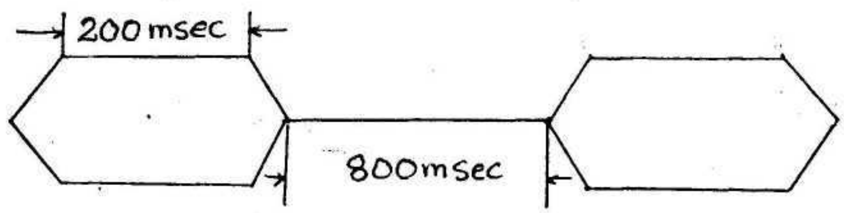


FIG. 11. Lengthened-Off-Time

significantly increased in sound pressure level. When on-time is held constant at 200 msec manipulation of the off-time should not effect the threshold measurement provided that the hearing loss has an organic basis and that there is no excessive tone decay for a (200/200) signal, Harbert and Young (1962). (Fig. 11)

It is highly possible for a person feigning a hearing loss to be successful if he is familiar with the principle of type V audiogram, especially if only standard off-time (200 msec) and continuous tracings are obtained, Monro(1975).

Hattler (1970) suggested that LOT tracings are found to be move efficient tool than SOT (Standard-Off-time) for the discovery of type V pattern because of its consistency. A sophisticated person could conceivably produce any one of the four other BeKesy types indicating Pseudohypacusis. So in case of suspected Pseudohypacusis all three signals (continuous, LOT and SOT) can be used in performance of BeKesy audiometry.

Hattler and Schuchman (1970) recommended that if LOT tracing is 5.5 dB or greater than the continuous, the test is considered to be positive and indicative of non-organic hearing loss.Behnke and Lankford (1976) suggested that the false positive results could be reduced by changing the criterion to 6 dB. The false positive results were found to drop to 2% for 1000, 2000 and 4000 Hz. At 500 Hz the false positive results were 12%. So they do not recommend 500 Hz discrete frequency tracing for children.

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12.2. STKNGER TEST

Watson and Voot (1964) reported on the use of the BeKesy audiometer in the performance of Sbenger test. The addition of a simple attenuator arrangement permits the stenger test to be performed on the BeKesy audiometry. Using this arrangement the examiner may vary the intensity of the test tone on the supposedly poorer ear. While the patient is tracing his BeKesy threshold on the good ear. Signal intensity increases or decreases on bot ears simiultaneously as the patient operates the BeKesy response key. This test method provides an approximation of the true organic threshold in the bad ear. Several cases demonstrating different types of BeKesy stenger tracing obtained with the procedure. The test appeared to have high clinical dependibility.

The stenger variable attenuator was set at -10 dB (10 dB greater attenuation on the test ear than on the reference ear) The BeKesy audiometer was soheat an intensity level below the patients threshold and audiometer set into operation at a test frequency of 250 Hz. No attempt was made to do stenger test for this frequency since it was felt that practice at this initial test frequency was desirable to acquaint the patient with the BeKesy test procedure and adequate information for the test purpose could be gained by testing at three speech frequencies only. Conrequently, the threshold for 250 Hz was estableshed in normal manner. The intensity of the BeKesy audiometer was run back below the zero reference level, the frequency selector held out at 500Hz and a new run begun.

After the patient threshold on* the reference ear has stablized, the stenger proper was initiated by changing the variable attenuato to a setting of zero. At this setting the attenuator was changed to - 10 dB (that 10 dB greater intensity in the test ear channel). This procedure as continued using 10 dB steps til either a threshold shift was noted or until attenuat was at -50. (i.e zero attenuation) If the minimum value of attenuator was reached without proceduring a significant threshold shift, the jack leading to the reference ear was disconnected or, alternatively an additional 20 dB of attenuation introduced into this ear phone by means of the standard attenuation pad on the BeKesy audiometer. If the patient was truely tracing his thresholds for the reference channel tone, then a threshold shift would immediately occur. If such shift didnot occur then the examiner could assume that the test tone lateralized to the test ear and therefore the patient could not perceive the change in intensity in the reference ear. This situation may arise with sophisticated patients who simulate a threshold tracing by rhythmically processing and releasing the signal key.

12.3 . The Fit Test

The "fusion at the inferred threshold" test based on the findings of Stenger and others, reveals that when the two ears are stimulated with the same sound at different intensities, the result is a fused single localization. The Bekesy modification of the Fit test was given by Bergman (1964). This test was found to be useful in cases of unilateral loss, interfering tinnitus and malingering or inconsistent standard audiometric results. One of the major advantage of the test is the elimination of masking tone special equipment is however required so that the same frequency may be presented simultaneously to both ears at different intensity. This may be accomplished either with a modified Bekesy or standard audiometer. The tone is presented to the control ear at a level of 5 dB above the previously determined threshold. At the same time same tone is presented to the test ear beginning with a suprathrehold level and continuing until the subject reports about a change in sound localization in the control ear. That point determines the inferred threshold in that ear.

12.4. The Bekesy Ascending - Descending Gap.

Cherry and Ventry (1976) evaluated the ascending-descending gap at 1 and 2 KHz at threshold and at suprathreshold level (MCL) by a modified methods of limits and by BeKesy audiometer. BeKesy audiometry followed the BADGE procedure of Hood etal. For modified methods of limits each ascending serves began at -10 dB HL and each descending series began at 100 dB HL. Normal hearing subjects either simulating or not simulating a hearing loss and subjects with sensorineural losses from 30 to 70 dB and without any evidence of functional hearing loss, were used. Thresholds and suprathreshold A-D gap were greater than threshold gap. The A-D gap exceeded 10 and 4 dB in the method of limits and in BeKesy audiometry respectively for subjects responding at MCL or simulating a function hearing loss. It was concluded that a functional hearing loss should be suspected if A-D gap is greater than 4 dB by BeKesy audiometer and 10 dB using method of limits.

Bauman and Ventry (1983) demononsrated the effect of experimental manipulation on the A-D gap reduction in the A-D gap occurred after simply allowing the subjects to listen over a 70 dB hearing range for 28 sec. It appears that brief exposure to an intensity range that is likely to encompass MCL can reduce the A-D gap considerably. They proposed that MCL is under-estimated in descending technique which results in AD gap of 11 dB. Procedure is important for careful interpretation. This was done at 1000 Hz attenuation rate of 2.5 dB/sec. Speech and other frequencies should also be included.

13. RAISER INTRACRANIAL PRESSURE.

In case of raised tntracranial pressure, significant hearing loss is seen (John, Kacker & Tandon;1979) Hearing acuity of the patients were studied using a BeKesy audiometer both pre-operatively and post-operatively when the raised intracranial pressure was controlled. Only low frequencies of 125, 250 and 500 Hz showed a reversal of hearing loss which was statistically significant. The type II pattern of BeKesy audiometry changed to Type I and type IV and V patterns had a tendency to change to BeKesy I or II, on control of raised intracranial pressure.

14. PHONOPHOBIA:-

It is generally accepted that phonophobia (an abnormal sense of discomfort evoked by suprathreshold sounds) is caused by paralysis of stapedius muscle. Hansen (1965) evaluated this condition in cases of facial nerve paralysis, cerebral vascular residuals, chronic otitis media and following stapedectomy by using BeKesy audiometry where in subjects reduce tonal intensity when it becomes uncomfortable. The author concluded that phonophobia should no longer be considered a complaint of neurotic patients.

15. SPEECH RECEPTION THRESHOLD (SRT)

Lezak, siegenthaler and Davis (1964) utilized a Bekesy type audiometry to obtain speech reception threshold (SRT) tracings on 24 normals young adults. A tape recorded copy of Technisonic TICD record of continuous discourse was substituted for pure tone oscillator in the BeKesy apparatus. The tracings obtained were analyzed by time segments over the 3 minute test - No significant differences were found among mean thresholds for time segments. The overall SRT was 18.6 dB ref.0002 bar. The overall standard duration of the distribution of thresholds among the subjects was 6.5 dB. The mean length of excursion among the subjects varied about 3 dB among the tone periods, but was found to be significant only between the first and the second minute. The overall mean length of excursion among the subjects was 6.6 dB. Although the obtained mean SRT using BeKesy Technique produced a threshold value at a lower intensity than reported for the regular TICD, obtaining SRT using a Bekesy type apparatus appears to be feasible.

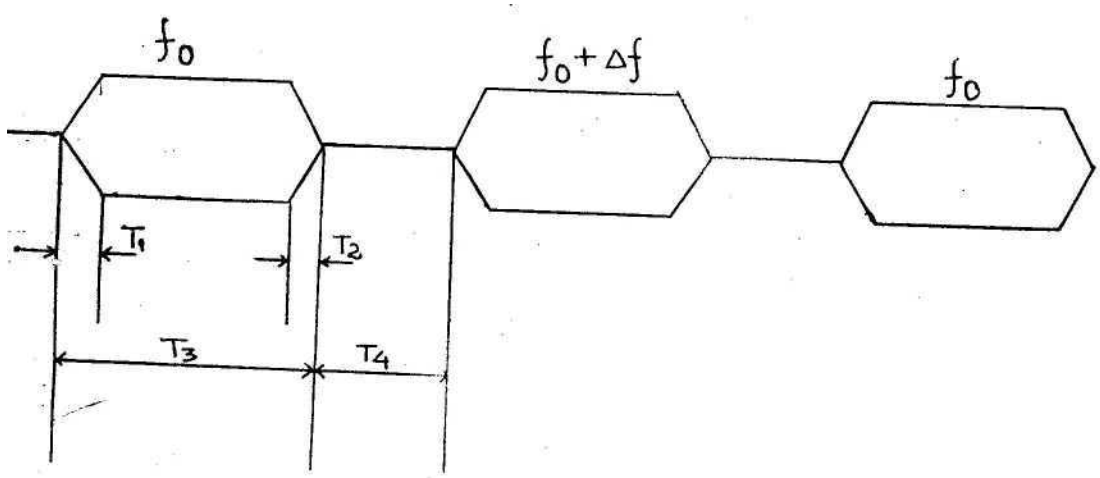
16. AN AUTOMATIC TEST FOR FREQUENCY DISCRIMINATION

Grisanti (1987) proposed an automatic test for frequency discrimination using the Bekesy audiometry. This test is used to determine the threshold of frequency discrimination. The test is performed by means of a modified automatic audiometer at fixed frequencies, each administered for a duration of 60 sec. The test involves the stimulus of a series of pairs of tone bursts of 500 ms duration the frequency of one of the tone bursts (fO) is constant, while the other (fO + f) gradually increases and decreases according to subjects response. The tracings obtained facilitate the evaluation of the discrimination capacity of the subject.

Equipment - The test is performed using a modified automatic audiometer at fixed frequencies (500, 1000,3000, 4000,6000 Hz) each administered for a duration of 60s. Modification implemented on the Amplaid 225 audiometer are as follows.

(a) The continuous attenuator provided in the standard equipment has been replaced by a manual attenuator range (0-90 dB HTL)

(b) An electronic circuit supplying VCO driver with a voltage continuously synchronized with Y displacement of the pen - recorder has been developed. In this way, the



$T_1 = T_2 = 50$ msec. $T_3 = 500$ msec

$T_4 = 200$ msec.

FIG.12. Sequence Of Tone Bursts.

oscillating frequency undergoes a fractional change f/f proportional to the pen displacement.

(c) A timing circuit to apply the stimuli tone burst at f0, and tone burst with f in sequence has been installed.

The test involves the stimulus of a series of pairs of two tone burst of 500 msec at each of the test frequencies at an intensity of 40 dB sensation level, each with a silent interval of 200 msec. (Fig .12)

The intensity of tone burst is controlled by an attenuator, from 0 dB HTL to 90 dB HTL maximum. The frequency of one of the tone burst (f0) is constant while the other (f0 + f) gradually increases. (eg. 1000/1020, 1000/1040, 1000/1060, 1000/1080. . . . . .)The frequency variation rate f/f0/t is 1% per second upto 20% maximum.

The percentage of frequency variation of the second tone burst is controlled by a push button operated by the subject who must push the button every time he perceives a frequency difference between the two tone burst and release the push button as soon as he realises that frequency of two tone burst is the same.

The tracing of the plotter facilitates the evaluation of discrimination capability of the subject at different frequencies.

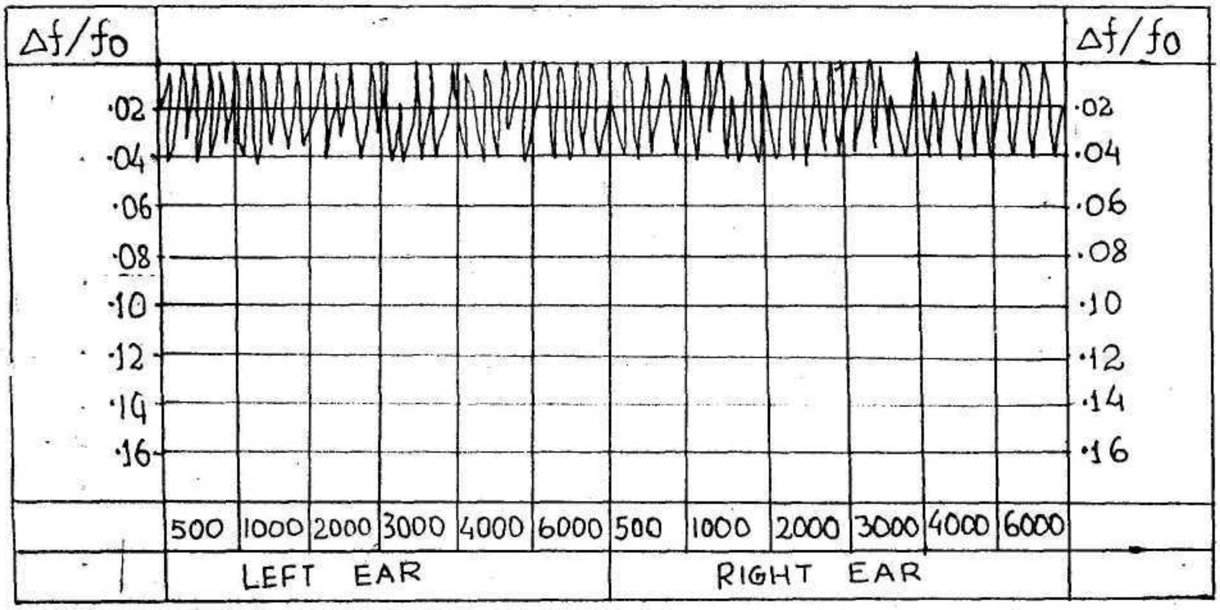


FIG.13. Pattern Showing a Normal Frequency Distribution.

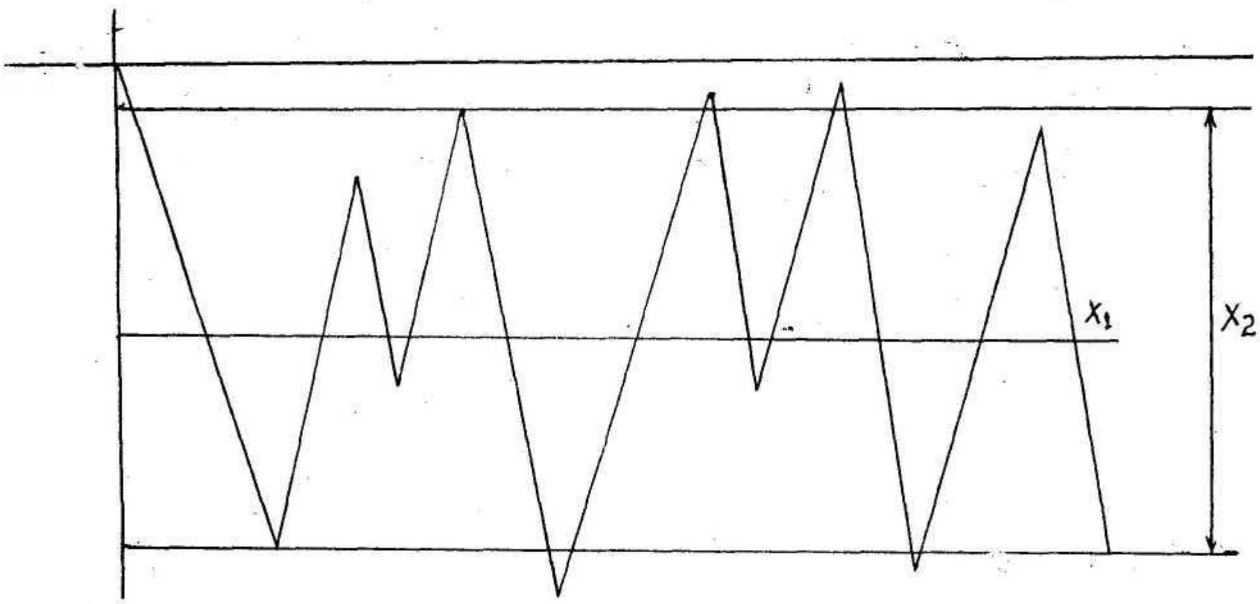


FIG.14. Basic Parameters Of Pattern: X_1, Mid-point, X_2, mean amplitude.

Method and Results:- In the present study the tracings, in the majority of cases, uniform characteristics and that the amplitude of excursion rarely exceeds the limit of f/f0 = 0.04. (Fig. 13)

In examining the tracings, it is seen that some parameters can be used to characterise the response shown in all tracings. For every tracing number of upper and lower peaks are considered thus determining the number of excursions in each frequency range. It implies that the more numerous the peaks, the move accurate is the frequency discrimination of the subjects. Another parameter is the 'mean amplitude' of the excursion: the peak to peak amplitude of excursions has been measured. So that the arithmetic mean of values in each frequency range may be calculated. Another parameter has been identified in the ordinate f/f0 (mid-points) which is centred on the amplitude of every excursion. The arithmetic mean value of this parameter has been calculated in each frequency range.(Fig. 14)

Discussion and Conclusions :- The parameters considered before and identified as variables are X_1 = the mid point, X_2 = the mean amplitude X_3 = the number of upper peaks. X_4 = the number of lower peaks. The analysis of correlation co-efficient indicated the most important variables are X_1 and X_2 and X_3. How ever there are strong variability among the subjects, the cause of which are at least of three kinds.

1) Biological variability among subjects
2) Variability of sampling.
3) Variability due to the precision of apparatus.

Results are effected by tracing of subjects. Repetition of the test cm the same subjects produces an increase in the number of excursions and a diminution of the amplitudes.

The application of this procedure in clinical practice is being evaluated by extensive studies on patients with defective audition (Cusimano and Maggio, 1980)

17. BEKESY AUDIOMETRY IN CHILDREN

Price and Falck (1963) investigated the application of BeKesy audiometry to normal hearing hildren. The procedure was found clinically useful with children of average intelligence, with at least 7 years of age. Ninetythree percent yielded type I tracings. Only 5 out of 9,6-year - olds were able to complete the test satisfactorily. The results of a study by stark (1965) comparing thresholds obtained with conventional and BeKesy audiometry also suggested that the usefulness of automatic audiometry in normal and hearing impaired children is dependent on age.

Almost one-third of 6-year-old subjects didnot produce clinically useful tracings which almost all of the 7-to 10-year-old group did.

Hearing-impaired children also generate BeKesy configurations similar to adults. Each pattern except the type III was observed in children (Stark, 1960; Swisher and Stephens; 1968) A sizable number of hypacusis children yielded Type I tracings (stark, 1966), reflecting; perhaps pathology similar to the large segment of subjects with sensorineural losses of unknown etiology in the Jerger (1960) study. Olsen and Buckles (1979) reported that children of 6-7 years are capable of tracking threshold, successfully in a brief tone paradigm.

18. HIGH FREQUENCY BEKESY AUDIOMETRY

Recent improvements in acoustic instrumentation have facilitated a revived interest in High frequency (HF) audiometry units said to produce and measure high frequency tone both reliably and validly were constructed and used to investigate changes in High frequency auditory sensitivity which were suggestive of some pathology.

Various application of HF audiometry have been demonstrated pertinent to both research oriented and clinical audiometric concerns. Rosen et.al., (1964), Rosen and Olin (1965) and Rosen and Rosen (1971) demonstrated the utility of HF audiometry in the study of presbycusis. Fletcher and loeb (1967) investigated temporary threshold shift across the human pitch range, while other investigators (Downs et.al., 1968; Flothorp, 1973; Fousti et.al., 1979, 1981; Corliss et.al., 1979; Erickson et.al., 1980; Dieroff, 1982) reported studies of permanent noise induced hearing loss (NIHL) in young adults, predictable or detectable only by way of HF audiometry. Sataloff et.al., (1967) applied HF audiometry to NIHL in older subjects. Differences in HF sensitivity significantly identified different stages of meningitis (Fletcher et.al., 1967) while traditional audiometry did not. Jacobson et.al., (1969) used HF audiometry to detect drug ototoxicity 1-2 months before the changes were detected by conventional audiometry was correlated with residual HF sensitivity. These investigators concluded that HF audiometry has the potential of yielding valuable diagnostic information.

Recently a cost-effective HF audiometer has been described based on the Grason-stadler E-800 Bekesy audiometer in the fixed frequency mode. Preliminary results have indicated highly acceptable reliability and validity of thresholds Gauz and Smith (1985) studied 20 men and 65 women, all normally hearing young adults (170 ears) presenting with negative otoaudiological histories produced HF ac thresholds from 8-20 KHz Excursion. Widths of the pen tracings compared favorably with those of earlier reports in HF audiometer studies. The composite function (both sexes, both ears) was flat through 12 KHz/ with progressively greater SPLs required for higher frequencies. Neither gendernor ear related differences were seen. It was concluded that the simplified HF E-800, or an analogous unit could be used as a viable clinical fool, surpassing the cost effectiveness of a number of different HF audiometric system.

19. SUMMARY

This study was aimed at reviewing and evaluating the clinical applicability of the Bekesy audiometry with the current informations available.

The chapters 2,3,4 and 5 deal with the instrumentation, test parameters, general clinical procedure, the diagnostic features of the Bekesy audiogram and the different factors affecting the test performance.

The chapters 6 and 7 describe the conventional Bekesy Procedure, the Jerger's classification of Bekesy tracing and their usefulness in differential diagnosis of different types of hearing loss or coasting the site of lesion.

In chapters 8, 9, 10, 11, and 12 the different modifications of the conventional Bekesy procedure and their results have been classified on the basis of their relative importance in diagnosis of different types of hearing loss, e.g. conductive, cochlear, retrocochlear, Functional hearing loss and also central auditory disorders.

The chapters 13, 14, 15, 16 deal with some special applications in case of raised intracranial pressure, phonophobia, in finding out the speech reception threshold and an automatic test for finding the threshold of frequency discrimination.

Chapter 17 deals with the application of Bekesy audiometry in children and chapter 18 with that of the high frequency Bekesy audiometry.

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