ELECTERIC RESPONSE AUDIOMETRY – PRINCIPLE AND ITS APPLICATION

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An Independent project submitted in partful –

fillment for the degree of M. Sc. (SP & Hg)

of

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CERTIFICATE

This is to certify that the Independent Project entitled "Electric Response Audiometry, Principle and its Applications" is the bonafide work in part fulfillment for M.Sc., 3rd semester, in Speech and Hearing, carrying 50 marks of the students with Reg. No. 7.

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CERTIFICATE

This is to certify that this independent project has been prepared under my guidance.

GUIDE

DECLARATION

This independent project is the result of my own work undertaken under the guidance of Mr. P.J. Kumar, 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.

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CHAPTER – I

Introduction

Hearing thresholds are used to measure the hearing sensitivity of the ear. Before the 20th century, hearing tests were performed with percussion, string and wind instruments, among them the monochord and the whistle were common (Mynder's '79). Then came the use of spoken and whispered voice and finally tuning forks. The most respected and widely used of all these various methods have been the tuning fork tests. Tuning forks were used because they produce tones very near to puretones. But the tuning fork does not maintain a constant amplitude, and its output is difficult to control. It decreases with time.

The application of electroacoustic principles to study the hearing has made it possible to standardize the measurements. Audiometer is one of such instruments which came into existence based on electroacoustic principles. Audiometer can be defined as "an instrument which produces acoustic signal at varying frequencies and intensities at our will" (Heller, 1955).

At various stages of its development, audiometer has been known in several names, like, Acumeter, Acoumeter, Audiometer and Sonometer. The word Audiometer in its present form was coined by an English physician Richardsen in 1879. The development of telephone by Alexander Graham Bell in 1875, marked the beginning of a new ear for research and development in hearing testing equipment.

Credit for the earlier application of the electro-acoustic principles to hearing tests rests between 2 investigators, Hartman and Hughes (1878, 1879). The basic principles employed in all electrical hearing test instruments between 1878 and 1914 was to use to tuning fork placed in the primary circuit of an indication coil interrupting the circuit at regular intervals. The interruptions thus induced in alternating current in the secondary circuit, of which the telephone receiver was a part. The receiver reproduced a tone corresponding to that of the vibrating tuning fork, regulated in intensity by a rheocord of sliding induction. This era in audiometric history might be called as “electric tuning fork era”. But these instruments were not used more widely because:

(1) The amount of information gained by doctors from these early audiometers was not very great because the equipment was limited in what it could do;
(2) The maintenances of the equipment;
(3) The expense (Mynder’s, 1977);

The secondary phase in the development of audiometers was marked by the invention of the electric generators from 1914 to 1919. This invention changed the dimension of audiometric design. In 1914, Steffani constructed an electric generator, that produced an alternating current of compete range of frequencies.

The third period of development of audiometer can be traced in the "vaccum tube era". In 1922, Fowler and Wegal produced the first commercial electrical audiometer i.e., the Western Electric I.A. Audiometer.

However, the serious developmental problem, that resulted in the proliferation of manufacturers, was the absence of a uniform zero reference level for all audiometers.

The International Organisation for standard (ISO) after 1962 recommended international reference zero levels for puretone audiometers. These new zero levels result in a threshold contour and it is endorsed by the American Academy of Ophthalmology, the American Otolaryngology, the American ontological Society and the American Speech Language and Hearing Association, then ASHA.

In 1947, a unique principle was introduced, into the development of audiometers, by Dr. George Van Bekesy. The principle was the automatic, self recording audiometer that gave a tracing of the patient's hearing at threshold level.

In conventional audiometry, to measure the threshold of hearing, puretones are used. Puretone sensitivity can be measured by Air Conduction and Bone Condition. Here hearing sensitivity at each frequency is measured. The graph which shows the hearing sensitivity for Air Conduction and Bone Conduction is called as an "Audiogram".

It is critical that the audiologist test each ear without the participation of the other ear if he expects to say anything about the hearing of either ear individually. It is a known factor that, AC sounds may reach sufficient energy levels to stimulate the skull and the non test ear directly (BC) at 40 to 50 dB MTL depending upon the frequency of the sound. Thus, at level about 40 dB HTL, AC sounds may be intense enough to vibrate the skull sufficiently to stimulate the more sensitive cochlea irrespective of which ear the earphone is covering. Therefore, in both air and bone conduction puretone testing, making noise is employed to prevent the nontest ear from participating when the sensitivity of the test ear is being measured. Most of the time, plateau method is used to find out the masked threshold.

In children below 5 years of age, it is difficult to ascertain exact hearing threshold, using masking procedures. In children, most of the time, speech audiometry is used to assess the approximate threshold of hearing. But the use of speech audiometry requires the patient to have to knowledge and reasonable usage of the words with which he is to be tested. Using speech audiometry, responses of the patients with speech and language defects may be misinterpreted. Speech audiometry has its own drawbacks. Most of the talk back systems on many speech audiometry are often of very poor quality, which creates an additional problem in interpreting of responses.

A number of audiological tests have been devised to yield differential information regarding the function of an impaired auditory mechanism. These developments have occurred because auditory behavior observed during certain audiologic measurements can be of assistance in localizing that site of lesion underlying a hearing disorder. Many of these measures yield different results depending upon particular types of involvement.

Peripheral auditory test battery are one such group, which are used to gather information about types of involvement. It can be used to differentiate conductive from sensorineural hearing impairments. Some of the tests further aid in localizing a SN lossto either the cochlea or to the 8th nerve.

Certain auditory tests are used to measure the lesion in the central nervous system. Such tests are called as tests of central auditory disorder.

Still another battery of auditory tests procedures was designed to document pseudohypocusis. But a battery of auditory tests does not yield information by which a hearing disorder can be attributed to any one specific etiology. In the same vein, selected tests may identify pseudohypocusis but they cannot be expected to differentiate malingering from psychogenic hearing problems.

The findings from any audiologic study should be viewed as only contributory to, but not as a substitute for a multidisciplinary diagnostic work. The final diagnosis should be based an results of all tests in a battery.

Tests which help to differentiate between sensory Vs neural lesions are:

1. ABLB – Alternate Binaural Loudness Balance Test, given by Fowler (1937);
2. MLB – Monaural Loudness Balance Test, given by Regar (1952);

3.Tone Decay Tests, different procedures of Tone Decay tests given by:

1. Carhart (1957)
2. Rosenburg (1958)
3. Green (1960)
4. Olsen and Noffsinger (   )
5. Oulen's Tone Decay Test (1964)
6. Jeger's Supra Threshold Adaptation Test (1975)

3. Bekesy automatic audiometer – given by George Von Bekesy (1947). Different types of Bekesy patterns are describe by Jerger (1960);
4. Sensorineural acuity level given by Jerger;
5. Rainville test;
6. Impedance audiometry – Most important work done in this field by Feldman (1974, 1976b) and Jeger (1972);

Impedance audiometry measures and detects any pathology in the middle ear. Using impedance audiometry we can find out the patency of the Eustachian tube, we can predict the degree of hearing loss. It helps to differentiate between cochlea Vs retrocochlear and helps to findout hereditary deafness also. But this test also has its own disadvantages.

Speech is an unique achievement of the human species and development of overt speech is one of the young child's major developmental milestones. The unimpaired function of the hearing organ plays an important role in the development of language and consequently, in the mental and emotional development of the human personality. There is a growing evidence indicating that hearing loss in young children, even when of a mild of fluctuating type, may contribute to later learning difficulties. This confronts the Audiologist with three principal tasks (1) the prophylaxis of congenital or infantile hearing disorder, (2) The detecting of such disorders at the earliest possible stage, and (3) Their surgical treatment, if indicated or the institution of amplification and early hearing and speech training.

In the vast majority of cases, hearing loss can be speedily and accurately be assessed by using conventional audiometric methods. Sensory stimuli used in standard audiologic tests are puretones or speech. The sensation is determined by the subjective statement of the patient. Naturally this requires the patient's attention, intelligence and cooperation, which cannot be expected prior to the age of 5 or 6 years in normal children. In children with brain damage, an accurate and critical evaluation of sensory manifestation is hardly possible even beyond this age. Subjective audiometry has its limitation in these cases when in certain basic requirements are not met. Moreover, even when al requirements are completely fulfilled, the evidence of subjective audiometry is restricted by the fact that several tests only represent heuristic methods of investigation, which mean that subjective findings and supposed alterations are only hypothetically linked. When such problem arises in assessing the hearing by means of conventional audiometry, electro physiological tests can be very useful in clarifying the situation.

The discovery of the presence of electrical potentials in the auditory system during sound stimulation, has led for an intensive research in the area of electrophysiological measurements. At the peripheral stage, within the cochlea itself two types of potentials have been identified.

1. Alternating potentials.
2. Direct current potentials.

The significance of electrophysiological measurements is manifested by our present ability to determine at what level or levels in the auditory system there is a deficit. Additionally a statement can be made not only about when the deficit or deficit occurs but also, in many instances, as to the amount of function which is present. Thus, the utilization of these electrophysiological measures allows for both a quantitative and qualitative assessment of the auditory system.

Electrophysiological audiometry differs from behavioral audiometry in that the response to acoustic stimulation manifests itself by some change in the observed electrical properties of the person under test, while in behavioral audiometry the response is some overt bodily reactions. The overt responses can some overt bodily reactions. The overt responses can be voluntary or involuntary, but the listener has little or no control over his electrophysiological responses. Electrophysiological audiometer has often been called “Objective” because the response mechanism is not under the subjects control.

The purpose of the present writer is to make a detailed state-of-art-report about the electric response audiometric procedure used to assess the hearing function based on these electrophysiological principles.

In this paper, reviewer has tried to compile as much information as possible in the following area of electric response audiometry:

1. Electro cochleography.
2. Averaged evoked response audiometry
3. Brain stem evoked response audiometry,

CHAPTER – II

Principle of electric response audiometry

The evaluation of hearing is imperative in order to understand individuals communication ability, and enables appropriate medical referral and treatment (Skinner, 1972). Conventional audiological assessment does not provide exact information about the site of lesion in the auditory system. The advantage of electroencephalic response audiometry is that it provides an objective technique, free of noxious stimuli, which can be used regardless of age or intellectual limitation.

Study of EEG for the determination of hearing was done by Derbyshire et al (1956, 1958) in normal hearing and hearing impaired pre-school children (Skinner, 1972).

When individual is quiet and relaxed there will be a definite brain wave activity in electroencephalogram. There will be a change in pattern of EEG activity when there is a change in external stimuli i.e., visual, auditory tectile etc., This change in the response for an individual stimulus is negligible. This is usually done in background activity. As the change is very small, this individual response cannot be indentified clearly.

Responses to auditory stimuli more frequently observed in the EEG of subject, but, in general were not obtainable consistently. This inconsistency resulted from the fact that the small evoked cortical potentials produced by sound stimulation often were observed by the greater voltage of the ongoing, spontaneous cortical activity. Discovery of the summing computer made it possible to overcome this difficulty. The principle of changing to extricate consistent changes from a background of random noise is straight forward.

Summing computer averages the time locked responses. If a given stimulus produces a constant change (positive or negative) in the cortical potentials at a fixed time delay after stimulus onset, and this information is stored or preserved by a computer, the algebraic sum of these changes or responses should in increased amplitude as the number of responses is increased. In order for the response to be extricate from the ongoing EEG, this background activity must have essentially random polarities and amplitudes so that they would sum to zero, so when larger number of sensory stimuli are used, there will be a greater reduction in background EEG activity and there will be a greater summation of response amplitude. It is necessary to produce sufficient number of sensory-stimuli so that the signal to noise ratio will permit detection of the auditory evoked response. (Skinner, 1972).

So all electric response audiometric tests uses the principle of average summing computer in order to detect the exact site of lesion in the autditory system.

Classification of electric auditory responses

There are different electric responses produced by auditory system on its stimulation. Most of these arises in the central nervous system but others are generated in the ear itself and still others are reflex responses in muscles.

These potentials can be classified based on the electrode placement. In all cases one or two references electrodes are placed on the ear lobe or mastoid process or the post agricultural region. The group of potentials where active electrodes is at or near the top of the head (vertex) are called as vertex potentially or V potentials (Davis and Zerlin, 1962). The other group of potentials where the active electrodes are placed within the ear cancel or middle ear are called as elecrocochleograms.

Continuing response Vs on-effect

The first distinction among evoked potentials is anatomical, on the basis of electrode placement, ear Vs vertex. A physiological distinction is helpful, namely whether the potential is AC or DC or instead, an en-effect.

Continuing potentials are:

1. Cochlear microphonic (CM) a continuing AC response generated chiefly by the external hair cells in the organ of corti. Described by Wever and Bray (1930);

   Van Bekesy (1952) divided the cochlear microphonics into primary and secondary cochlear microphonics;

   The primary microphonics can be originated in hair cells. The secondary microphonics could be originate at various points within the cochlea;

2. **Summating potentials (SP):**

   A continuing DC response also generated in the organ of corti, first described by Davis (1950);

3. **Frequency following response (FFR):**

   AC response generated in several nuclei of the brain stem;

4. **Sustained cortical potential:**

   Generated in the auditory cerebral cortex;

5. **Contingent negative variation (CNV):**

   A very late DC shift that develops in certain situations between a warning signal and an expected "imperative" stimulus;

On-effects, latency and polarity:The on-effects can be subdivided and named on the basis of their latencies. Four major responses are classified.

according to the latencies are:

1. Fast responses – latency between 2 m sec and 12 m sec;
2. Middle components – latency between 12 m sec and 50 m sec;
3. Slow responses – latency between 50 and 300m sec;
4. Very late responses – latency between 250 and 600m sec. There will be a DC shift.

   Another type of classification are,

   - (i) Stimulus related;
   - (ii) Resting potentials;

Stimulus related and potentials are:

1. Cochlear microphonics and
2. Summating potentials

Resting potentials are:

1. Endocochlear potentials
2. Negative potential within the organ of corti

Davis (1958) gave two types of summing potentials:

1. Positive summating potentials;
2. Negative summating potentials.

Positive summating potentials are produced by the outer hair cells (Davis et al 1958), while negative summating potentials are produced primarily by the inner hair cells. For greater specificity a particular wave is indicated by P if it is vertex positive or N if it is vertex negative.

Instrumentation for eclectic response audiometry

The apparatus needed for ERA is complex and expensive. The instrument consist of two parts, one part is to record the responses and another one is to produce the necessary sound to evoke the responses. The part which records the responses are electrodes, amplifier filters, display and permanent recording device and another part which produces the necessary sound to evoke the response are audiometer with loudspeaker, earphone or baseconductor. Test environment is also important while testing patient using these instrument (Ruben et al. 1978).

Test environment

Following conditions will be able to create in ideal environment for the administration of electric responses audiometry:

1. Sufficient space for performing the testy, the subject and for equipment;
2. Two room situation with a window to observe the patient;

3. Sound proof chamber in order to carry out all tests;
4. If the work is mainly clinical, it will be of great importance to have the apparatus close to the place where the patients are seen;
5. If anesthesia and sedation are necessary, then it should be close to the operation theatre;

The Stimulating Apparatus

Stimuli

An ideal stimulus for electric response audiometry must meet there requirements:

1. It must be exact in timings so that the latency of the responses is clear:
2. It must be frequency specific, and
3. Its intensity must be known (Gibson and Rube, 1978).

A. Clicks

Clicks are easily produced by sending brief rectangular electrical pulses through a transducer. It provides a precise stimulus for timing purposes. It produces a large, clear evoked responses as it stimulates the whole basal portion of the cochlea. It is not frequency specific. In brainstem responses, myogenic responses and even in middle latency responses, click stimuli are used. In order to get frequency specific information, masking noise may be used simultaneously as in electrocochlegraphy.

2. Tonal stimuli

Tonal stimuli allows exact frequency specificity. In cortical response and contingent negative variation, tonal stimuli are used.

3. Filtered clicks

A click may be passed through high and low pass filters to eliminate all frequency except those within a limited band width.

4. Tone pipe

A more satisfactory method of producing a frequency specific stimulus involves passing a single sinusoidal wave which starts and stops at zero crossings through the high and low pass filters.

5. Tone bursts

Using tone bursts, larger duration stimuli may be produced by passing more than one sinusoidal wave through the high or low pass filters.

6. Masking voice

Narrow band masking conferred on the frequency of the stimulus can be used (Gibson and Ruben, 1978).

The Amplifier

Amplifier should have the same frequency response as the preamplifier.

The Attenuator

By attenuating the input and the output of the power amplifier, we can present the signal at varying intensities.

The Recording Apparatus

The recording apparatus consists of the electrodes, amplifier, filters and display.

Electrodes

Different kinds of electrodes are used. The form of the electrode varies according to the position where it has to be placed on the subject. Usually monopolar recordings are taken. An active electrode is place nearest to the source of potential. A reference electrode is placed at neutral point such as the earlobe in transtympanic electrocochleography. The earth electrode is placed at a further neutral point.

Monoploar recording are best for recording of evoked potential as it produces less distortion than bipolar recordings (Giblen and Ruben, 1978).

Standard silver/silver electrode EEG disc varieties are used to reduce the skin resistance. Before applying the electrode to the skin, acetone solutions are used to remove any greases or make-up the skin, specialized electrodes are used if needed as in electrocochlegraphy.

The preamplifier

Preamplifier are necessary because most of the electrophysiological responses to be measured are of small amplitude. Two important features of the preamplifiers are:

1. Common mode rejection, and

2. The input impedance common mode rejection

A three conductor electrode array is the usual hallmark of a common mode rejection system. The common mode rejection is usually frequency sensitive, as the frequency rises, the effectiveness of the common mode rejection generally falls. Acceptable common mode rejection at 60 Hz is in the 80 to 100 dB range (Berlin, 1974).

Input impedance

Input impedance should always higher than the electrode resistance, as this effectively "closes the gate" for the admission of extraneous electrical interference.

Filters

The amplified signal from the patient will contain a wide spectrum of frequencies which is limited only by the characteristics of the amplified itself. It is necessary to use filters. Amount of filtering the signal depends upon the type of electric response being measured.

Digital Averager

If a small biological voltage is to be measured in the presence of interference (noise), the additive function of a digital computer can be used to help improve the signal to noise ratio (Berlin, 1974).

Display

It is important to be able to examine the results of avenger at the time of testing and before a permanent record is taken. So oscilloscopes are used to display the recording.

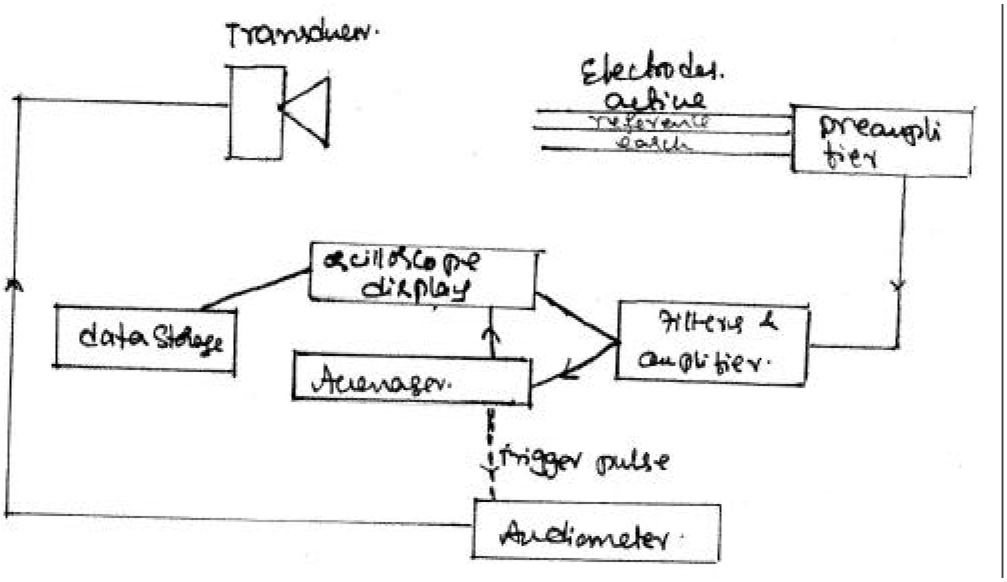
Data Storage

The permanent storage may be achieved either by using the memory or a computer type. Two types of permanent recordings are:

1. Pen recording - it is provided by the X-Y plotter;
2. Photographic methods – using an oscilloscope;

Storage of Raw Data

Raw data can be stored using magnetic type or floppy disc (Gibson and Ruben, 1978).



Block Diagram of Electric response audiometer apparatus

Terminology

Action potential – A change in voltage measured on the surface of a neuron when it is stimulated.

Average evoked response audiometry – Is one which records the potentials from cortex.

Brain stem evoked response audiometry – It is a kind of average evoked response which obtained from Brain stem.

Click Stimuli – Is one which contains fast onset and decay time, resulting in good synchronization of the neural impulses.

Cochlear microphonic – A measurable electrical response of the hair cell of the cochlea.

Contingent negative various – A slow de shift in the EEG seen 300 M Sec or so, after a warning signal is presented.

Elecrocochlegraphy – It is a method of recording of the electrical activity of the cochlea and first order, eighth nerve fibers in response to acoustic stimulation.

Filtered clicks – The click may be passed through high and low pass filters to eliminate all frequencies except those within a limited band width.

High frequency hearing loss - It is a kind of S.N. Hearing loss where hearing loss is seen after 2 khz.

Habituation

Reduction in amplitude wave form due to prolonged stimulation of the auditory stimulation.

H - Curve – This curve is observed at high intensity level, It is reflects activity of the inner hair cell.

Latency – Is time elapsed between arrival of the stimulus and the response.

L- Curve – This curve is observed at low intensity level i.e., 30-40 dB SPL. This reflects the activity of the outer hair cell.

Middle component response – It is a kind of average evoked response. The latency of this response very from 8 to 60 M Sec.

Slow cortical response – It is kinds of average evoke response. It is also called as K- complex or vertex potential. Its latency varies from 50 – 300 M sec.

Summating potential – It is a stimulus related de electrical response recorded from the cochlea.

Temporary threshold shift – Presence of shift in the hearing threshold after exposure to noise which is temporary in nature.

Whole-nerve action potential – It is the sum of the Aps of many individual neurons, which are fining nearly simultaneously within the auditory never.

CHAPTER III

ELECTROCOCHLEOGRAPHY

The electrocochleography is a test which notes, records and measures the averaged electrical responses which are set up between the bony promontory of the cochlea and ear lobe in response to very short acoustic stimuli of alternately positive and negative phase.

Electrocochleography permits investigation of the most peripheral part of the auditory system and thus makes it possible to study the cochlea and first auditory neurons in normal and pathological ears.

Electrocochleography is proving to be one of the most valuable electric response audiometry techniques. The potentials recorded are not affected by sedation and no masking of the contralateral ear is necessary. It is possible to test objectively the cochlear function of any child, even in the presence of multiple handicaps, providing that child is able to undergo a general anesthesia.

The potentials which are recorded from the cochlea are cochlear microphanic (CM) and summating potential (SP). Cochlear microphaic was described first by Weher and Bray (1930).

Saul and Davis (1932) were the first to distinguished the action potential (AP). Summating potential was described by Davis Fernandez and McAuliffe (1956) and by Bekesy (1950). Portman Le Bert and Aran (1967), Yoshie, Ohashi and Suzerki (1967) and Sohmer and Feinmener (1967) described the measurement of these potentials in man with minimal surgical interventions.

The cochlear transducer mechanism

The mechanical vibrations of the basilar membrane effect a discharge of neural impulses in the cochlear nerve. The travelling wave distorts the basilar membrane on which the hair cells lie. The hairs of the outer hair cells are embedded in the tectorial membrane which being unaffected at one end, is not distorted and the hairs are bent due to the shearing action between the basilar membrane and the tectorial membrane. The hairs of the inner ear are displaced by movement of the cochlear fluids. The bending of the hairs is known to be related to the earliest of electrical potentials observed in the cochlear, the cochlear microphaic (Gibson and Ruben, 1978).

The cochlear microphonic

The source of the cochlear microphonic is the hair cells. There are certain properties of the cochlear microphonic which helps us to understand the role of cochlear microphaic in hearing.

1. Individual hair cells are not frequency specific. The hair cells in the basal coil of the cochlea not only generate CM to high frequency stimulation but also to lower frequency stimuli passing up to the more apical regions.
2. The amplitude of the “Summed” CM is a resultant of the CM for many individual hair cells which are generating CM at different electrical phases.
3. CM are related to the instantaneous displacement pattern of the basilar membrane in the region where the recording electrodes are situated
4. When the sound is a sinusoid, then the CM response reflects its time pattern. Cochlear 2 microphaic mimics the wave form of the eliciting sound.
5. CM produced by the outer hair cells is proportional to the displacement of the cochlear partition, but the inner hair cell produced CM is proportional to the velocity of the partition (Dallos et al 1972b Dallos, 1973).

Summating potential

The summating potential (SP) is normally present at high stimulus intensities. Summating potential is a multi-component response which arises from various nonlinear mechanisms within the cochlea. These non-linearities are enhanced at high stimulus intensities. Summating potential is characterized by a DC shift in the baseline of the response, generally in a negative direction, and occurs for the duration of the stimulus.

Characteristics of summating potential are:

1. It results from a non linear vibration of the basilar membrane (Withfield and Ross, 1965);
2. At high intensities the SP may exceed the CM in amplitude (Davis et al, 1950);
3. Summating potential reflects the signal envelope of the eliciting sound;
4. The scala tympani SP is negative in electrical polarity when it is derived from hair cells lying on that part of the basilar membrane which corresponds to the up-slope of the travelling wave, and it is positive when obtained from hair cells active by the down slope of travelling wave (Dallos et al, 1972).

Davis et al (1958a) concluded that the asymmetry normally generating a negative SP, is such, that the basilar membrane vibrates more upwards and towards the scala media than downwards. When the pressure in the scala tympani is revised the upward movement of the basilar membrane is limited and it vibrates more downwards than up wards. In conditions characterized by endolymphatic hydrops

The downward vibration would be limited since the membrane is being stretched in this direction and so the normal up-going asymmetry is enhanced, leading to a negative SP of an increased amplitude.

Action Potential

The action potentials of the cochlear nerve may be either recorded directly from the nerve or from individual never fibres. The AP recorded during electrocochleography is the sum of many individuals APs along the length of the basilar membrane. The term "whole never AP" is used, when the AP is evoked by a click as evidence suggests that it represents neural activity from the whole length of the basilar membrane.

Characteristics of AP response

There are two prominent negative waves N1 and N2, separated by a small positive deflection. The peak of the N1 shows a latency of about 1 M sec with respect to the CM1 and the peak of N2 is about 1 M sec later (Eldredge, 1977).

Pure tone bursts of short duration can be used to evoke the AP and the latency of the AP than for tone bursts (above 2 KHz) evoke an excellent AP.

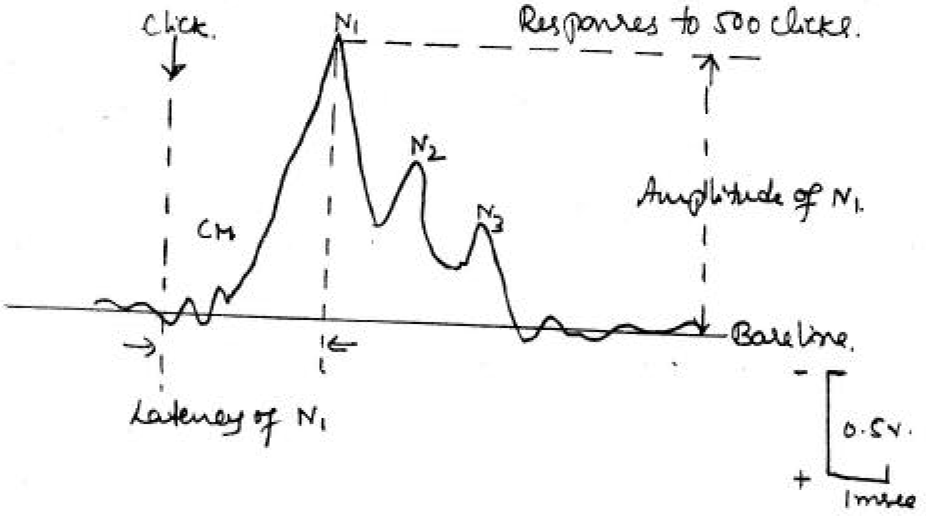
Altering the intensity of stimulation affects the amplitude latency and configuration of the WNAP.

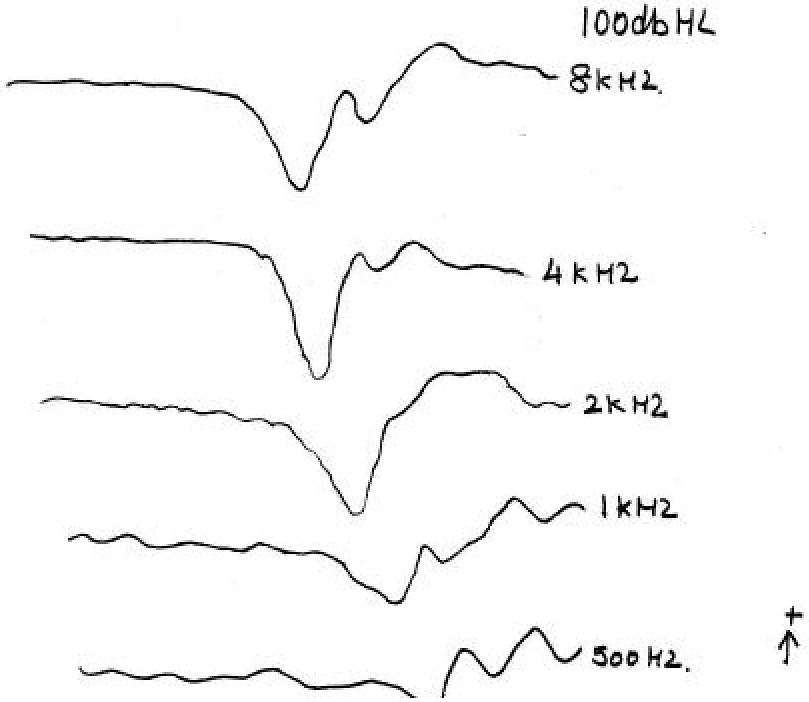
The AP of the entire auditory nerve are recorded in man as the main component (N1) of the electrocochleography. The impulses are all or none and are followed by a refractory period of the order of a millisecond. With acoustic stimulation by a tone of approximate frequency, the average rate may be increased for a small fraction of a second to about 800/sec, but adaptation is rapid and with continued stimulation at moderate levels the average rate of discharge is not much over 100 impulses/second. The dynamic range over which the rate increases with intensity is very small (Davis 1976).

The degree of synchronization of the first response of the individual never fibres depends largely on the rise time and intensity of the stimulus. AP recordings can be used effectively to investigate the frequency selectivity of the cochlea (Spoor and Eggerment, 1971).

With increasing stimulus intensity the AP latency decreases, the latency shift being largest for lower frequencies. At high stimulus intensities the AP latencies are nearly the same for tone-bursts of frequencies from 2 to 12 KHz, but at threshold value the latency depends on the tone frequency (Eggermant and Spoor, 1973).

A typical summed waveform of the Action Potential





Compound APs obtained using various short tone burst stimuli

Apparatus for electrocochleography

The apparatus for electrocochleography consists of two parts, one being the recording system and the other is the stimulation equipment.

Stimulus generation

The stimulation apparatus consists of several parts. The normal stimulus is a tone burst i.e., a sine wave with a trapezoid shaped envelope.

The shape of the tone-burst can be defined by the rise and fall times and the duration of the plateau. The stimulus intensity can be given as the intensity level of a continuous tone with the same since wave amplitude. The phase relationship between sine wave and envelope can be fixed (Spoor, 1974).

The stimulus repetition rate used clinically of often a compromise between the adaptation of the AP resulting from fast rates and the time taken to accumulate individual responses to yield a clear cut averaged AP.

Stimulus transducer

Loudspeaker or earphones can be used as stimulus transducers.

While using earphones, it should be enclosed in metal to prevent the recording of electromagnetic artefacts. A stimulus intensity is usually graduates in 5 dB steps (Gibrar & Ruber, 1978).

Stimulus calibration

Signal may be calibrated using SPL meter.

Recording apparatus

Amplification – Preamplifier

A differential preamplifier placed in the room with the patient is used for the amplification of the electrical signal. The signal ended output of the preamplifier is led through the wall of the room to the main amplifier.

Main amplifier

The subsequent amplification is provided by a main amplifier built with IC circuits. The output of the main amplifier is connected to the average and the other parts of the data recording system.

Averaging of the response

Data Retrieval Computer can be used to record the data. The data retrieval computers measures the amplitude of successive small time portions of the signal containing the response and store the results in successive data points of its memory. This is repeated for every repetition of the stimulus, and result is the arithmetical sum of al the responses.

Elimination of CM and SP

In elecgtrocochleography, the response to be detected is composed of the potentials of CM, AP and SP. The CM follows the sign of the stimulus. If the sing of the tone burst is alternatively reversed in the series of stimuli, the CM response too the average cancels this response. In this way the arranged response containing only the AP and SP. A useful condition for this cancelling of the CM is that the sine wave in the tone burst is time-locked to the start of the burst. If the response are also alternatively sign reversed before being fed to the average, the AP and SP are cancelled by subtraction and the CM is summed (Spoor, 1974).

Latency Measurement

To measure AP latencies, the time of arrival of the sound stimulus in the ear must be known. To facilitate the measurement of AP latency, the arrival time can be marked on the signal trace that will be analyzed be the average and will thus appear on the recording (Spoor, 1974).

Electrodes

Two types of Electrodes are used:

1. Transtympanic electrocochleography

Usually a thin steel wire which is insulated except at the very top and the opposite end at which it makes contact with electrode holder.

2. Extratympanic Electrocochleography

The surface electrode usually rests on the posterior-in-ferior rim of the drum. Electrode which pierce the surface of the meatus yield better response as the electrode/tissue impedance is much lower. Coabs and Dickey (1970) used a wire electrode similar to that used in transtympanic testing (Ruben and Gibsan, 1978).

Data recording, X-Y Recorder, Tape Recorder, Oscilloscope

The data stored in the memory of the average are recorded on paper by an X-Y recorder.

Recording and stimulation technique

Recording of the AP, CM and SP are obtained from locations near the generators of these potentials, the evoked response association with them are quite large. As the recording electrode is moved away from the generator site, the amplitude of the response decreases dramatically.

Based on electrodes and recording sites used, electrocochleography can be classified into three types. They are:

1. Transympanic electrocochleography;
2. Intratympanic electrocochleography;
3. Surface recording technique

1. Transtympanic electrocochleography

The transtympanic membrane technique was developed by Portman, Lebert and Aran (1967) and by Yoshie, Ohashi and Susuki (1967). Transtympanic membrane electrodes are usually 3 to 6 inches in length and are insulated throughout except at the point and the other end. Hence the electrodes make contact with the promontory of the cochlea. The point of the electrode contracts the promontory after the needle id passed through the posterior/inferior quadrant of the tympanic membrane.

The electrode is placed after the administration of a

Local anesthetic to the ear cancel of a co-operative patient. Children under the age of 12 years are usually tested under general anesthesia, while adults are tested under local anesthesia.

Yoshie (1973) fixed the electrode in place with medical grade cement applied to the tragus, while others supported the electrode with elastic bands which in turn, are attached to a circumaural ring (Portman and Aran (1971), Eggerment and Odental 1974b, Nauhtan and Zerlin (1976b). The circumaural ring is held on the patient's head by a large elastic band placed around the head. A small metal cap attached the preamplifier lead provided a cap for the outer end of the electrode. These electrodes are used with a reference electrode attached to the earlobe on the same side and ground electrode placed on the forehead.

Extratympanic electrocochleography

Alternative to the transtympanic membrane approach involved the use of electrodes placed within the external meatus near the tympanic membrane (Yoshie and Ohashi, 1969, Cullen et al 1972, Coatis, 1974). It consisted of a small insulated wire which had a balled end and which is fitted to an 0.005 inch thick piece of acetate that had formed into an open spring.

The electrode/spring combination is passed into the external meatus with the aid of an otoscope and middle ear forceps until the electrode is approximately 2 to Le mm from the tympanic membrane. When released the acetate expanded to contact the walls of the external meatus, thereby holding the electrode against the skin surface. The electrode may be placed without any anesthesia or sedation in a co-operative patient. This electrode is used with a reference electrode placed on the earlobe, and a ground electrode attached to the forehead as in transtympanic approach.

Surface recording techniques

Surface electrodes outside the ear include those which are clipped to the earlobe (Sohmer and Feinmener, 1967) or fitted to a device which holds them in contact with the hard palate (Keides, 1971) are of the disadvantages of the surface techniques arose from the fact that they yielded relatively small evoked responses. The response amplitudes for moderate to high signal levels were 0.1 to 2 volts (Sohmer et al 1972, Cullen et al 1972, coatis, 1974). Small response amplitudes could contribute to erroneous threshold estimates, when the intrameatal and surface techniques were compared with the transtympanic technique, it seemed that the intrameatal and surface recording might be obtained only a screening procedures. Using transtympanic technique, if AP response threshold can be obtained in the range of 0 to 20 dB for a given patient, are might safely assume that no hearing impairment exists (Schmidt and Spoor, 1974, Mantandon et al, 1975a, 1975b).

Identification of the responses

The identification of AP at intensities of 40 dB SL or above is a simple matter. The latency is approximately 1.2 to 2 m sec. The CM and SP are similarly easy to identify. The case of identification of the responses is one of the main attractions of this method of electric response audiometry.

Isolation of CM from APs and APs from CM

The cochlear responses recorded from promontory technique or extra tympanic method using a short burst of puretone pip or click, is mixture of the CM response, the whole nerve AP and S response. In order to obtain information either as to the whole-nerve AP response or the CM response, or the SP response, differential electrode recording technique is used.

The action potential may be isolated by alternately reversing the phase of the acoustic stimulus during averaging. This is called as an “averaging principle” on which the CM response can be averaged out to zero. The CM alters phase in keeping with the alteration of the phase of the stimulus, so that the sum of the CM to an equal number of condensation and rarefaction stimuli is approximately zero. The whole-nerve AP response is independent of the polarity of stimuli. It always occurs as a negative potential and sum of the AP evoked by rare-faction and condensation stimuli is an AP of approximately twice the size of the AP evoked by a single stimulus.

The CM may be isolated by using alternating phases of stimulation and by subtracting the result of one phase (Eg: condensation) from the opposite phase (Eg: rarefaction). In this manner the CM obatained in both phases is added together while the AP as a negative potential is added to itself displayed as a positive potential and therefore approximates to zero. (As quoted by Gibsen and Ruben, 1978).

Isolation of SP from CM and APs

The SP obtained by electrocochleography is enhanced in certain pathological conditions such as Meniere's Disease. The SP does not adapt even at very fast interstimulus internal. If a fast stimulus presentation rate is used (Eg: 150 per second), The AP is drastically reduced in its amplitude while that of SP is unaffected. At these fast stimulus presentation speeds the wave form contain a relatively large contribution from the SP. To obtain subtract the potentials obtained at a fast stimulation rate (mainly SP) from the potential obtained at a slower rate which is AP and SP. The SP being identical in both traces, is removed so that the potential remaining is the difference between the AP at the two speeds of stimulation. The subtraction displays an AP slightly reduced in its amplitude and diphasic in shape.

This method which is described above is a clinically useful technique since one can quickly determine the extent to which the SP or a similar potential is altering the wave form of the AP in pathological conditions (Gibsen and Ruben, 1978).

Factors affecting the stimulus and response in electrocochleography

Prolonged or repeated stimulation (habituation) – The amplitude, latency and waveform of the AP are constant despite prolonged or repeated stimulation and there is no evidence of habituation. The cochlear microphaic and summating potential are not affected by habituation provides that the electrode is placed accurately, these functions remain remarkably constant from day to day in the same individual.

Stimulus presentation rates – Eggerment and Spoor (1973a) gave an excellent description of the results of equilibration (adaptation) experiments in guinea pigs. They observed decreased interstimulusinterval (ISI altering the amplitude latency and wave form of the AP and having no noticeable effect on the CMS SP. The ISI is a measure of the time elapsing between the end of one stimulus and the beginning of the next. The stimulus rate is the number of stimuli delivered usually per second. One can relate the ISI and stimulus rate if one knows the length of the stimulus. These effects are due to the fact that the AP depends on the firing of individual nerve fibres and that each nerve fibre require a short recovery period after each firing before another neural impulse is questioned. The equilibrium value for any of the functions at a given ISI interval is generally reached after 5 stimuli, and after this period the pattern of firing of individual fibres reaches a steady state. The findings of Eggerment and Spoor (1973a) are as follows:

1. The amplitude of the AP remains approximately 100% of its value for rates upto 7% (ISI, approximately 140 me sec) and alters fractionally at rates upto 14% (ISI, approximately 70 m sec);
2. The latency of the N_1 component of the AP increases with shorter ISI;
3. The width of the N_1 component of the AP increases in a manner comparable to the increase in latency;

Sedation

Sedatives, including general anesthetic agents, appear to have no effect on the functions of the cochlear responses AP, CM, SP. Aran (1971a, b), Aran et al (1969) and Portmann and Aran (1971) succeeded in determining the input-output and intensity-latency relations of the AP using promantoly recording under light general anesthesia (Ketamine administered intra muscularly).

Sohmer et al (1972) carried out the AP measurements in infants with a simple earlobe electrode under sedation reduced with chloral hydnate rectally. The use of sedation or general anesthesia seems to be necessary for clinical electrocochleography in preschool children and infants. It is also favorable in nervous adults. Natural or sedated sleep, regardless of stage of sleep and age of subject, was very effective in increasing the signal to noise of the AP to the ongoing muscular activity.

According to Aran et al (1969) and Aran (1971 a, b) electrocochleography with unco-operative children, very young children, and infants, should be carried out under sedation or general anesthesia.

Frequency specificity of the responses

The CM obtained by transtympanic electrocochleography is not frequency specific as it only relates to a small area of the basilar membrane close to the round window. The hair cells in this position respond to all frequencies but give the largest CM amplitude to low frequency stimuli.

Ruben and Gibsan (1978) considered tone bursts as excellent stimuli for evoking compound AP at specific frequency. They evoked a compound AP which is certainly specific for frequency between 1 KHz and 8 KHz, especially at stimulus intensities below 65 dB Hz and accurate estimation of the audiometric threshold may be made at these frequencies (Eggerment and Odenthal, 1974a).

At stimulus levels above 65 dB HL and AP evoked by tone burst is altered by bands top masking at the same frequency (Eggerment and Odenthal, 1974a). The explanation is that all the units lying within the broad area of the FTC are contributing to the response.

Making noise

Eggermant and Spoor (1973b) describe the effects of continuous masking noise on the AP. The mechanism by which masking affects the amplitude, latency and width of the AP is the same as that responsible for adaptation. In effect, the masking noise make the nerve fibres fire at a maximum rate and it does not allow them to have a sufficient refractory period.

The effect of masking is especially important when electrocochlegraphy is performed in areas which are not sound proofed. The low frequencies, especially, are easily masked, making threshold information impossible in noisy circumstances.

Rise time of the signal

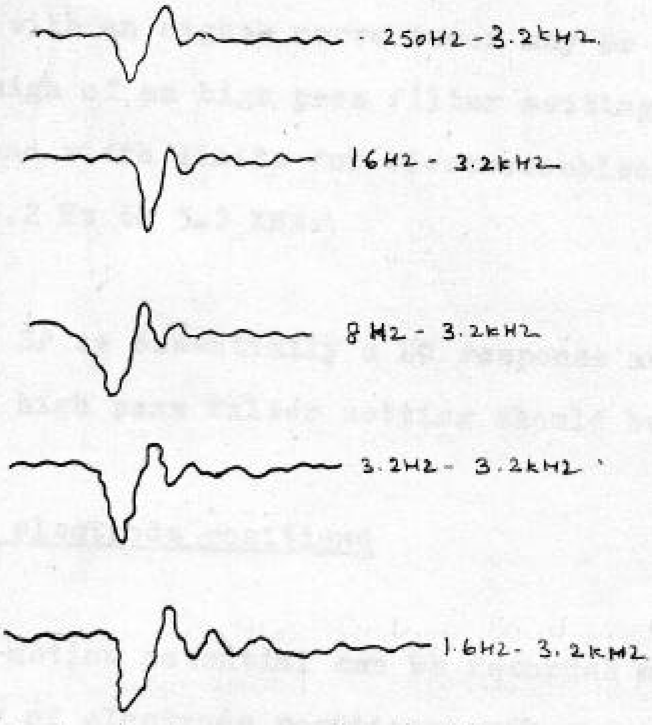
It is conventional to measure latencies of AEP from the start of the electric pulse, corrected for acoustic delay, to the peak of the AEP response. In tone bursts and filtered clicks, the rise time of the stimuli contribute to the important components of the latency, particularly near threshold when stimulation does not occur until the intensity has risen nearly to maximum or even later. A long rise time will exaggerate the increase of latency that occurs with reduced intensity. If the rise time is relatively long ray 4 m sec. the more excitable units will respond a little earlier and the most marginal units a little later than the rest of the group and thus be synchrony is lost. This may lead to an estimation of threshold that is higher than the true threshold (Davis, 1976).

Altering band width recording limits

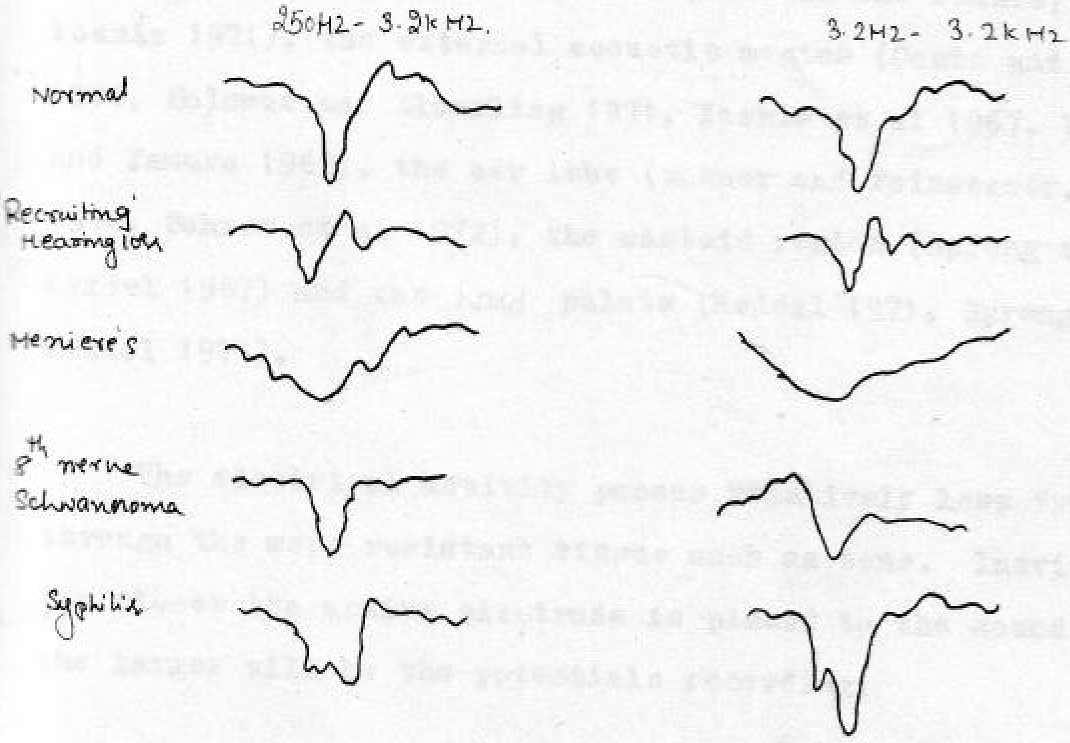
Analysis of the AP reveals that majority of the energy lies between 600 Hz and 1.2 KH, but there are contributions from outside this frequency range, The use of too high setting for the high pass filter leads to a differentiation of the normal AP which appears sharper and more diphasic, from other frequency band width.

The recording of low frequency contributions to the AP is especially important in abnormal cases.

The effect of records AP from a patient with a cochlear hearing loss using various band width



The effect of limiting the bandwidth on the characteristic AP wave forms encountered in certain pathological conditions.



The classic broad wave form of the AP obtained from a patient with an eight never tumor may be completely lost if too high of an high pass filter setting is used. The usual band width limits for electrocochlegraphy are approximately 3.2 Hz to 3.2 KHz.

The SP is essentially a DC response and ideally a very low of a high pass filter setting should be used.

The electrode positions

The action potential can be recorded nonsurgically from a variety of electrode positions such as promentoly (Aran et al, 1969 Aran and Lebert, 1968, Aran 1971a, Portman et al 1967, 1968, Portman and Aran 1971, Yoshie and Yamura, 1969, Yoshie 1971), the external acoustic meatus (Coats and Dickey 1970, Soloman and Elberling 1971, Yoshie et al 1967, Yoshie and Yamura 1969), the ear lobe (Sohmer and Feinmeaser, 1967, 1970, Sohmer et al 1972), the mastoid region (Spreng and Keidel 1967) and the hard palate (Keidal 1971, Spreng and Keidal 1971).

The electrical activity passes relatively less freely through the more resistant tissue such as bone. Inevitably the closer the active electrode is placed to the sound window, the larger will be the potentials recording.

Placement of an electrode an the promontory or in the wall of the meatus seem to offer two major advantages:

1. AP voltages in the order of one of several are obtained. This improves the signal to noise ratio and reduces the effects of movement artifacts;
2. APs can be obtained for stimulus intensities below the maximum output of most mall speakers, thereby permitting generating of latency or response amplitude curves as a function of stimulus intensity (Cullen at al 1972)

Yoshie (1973) remarked that the AP threshold is an average 17.6 dB lower when recorded directly from the promontory than that recorded the ear canal. He stated that promontory recorded AP “threshold” were in good statistical agreement with subjective threshold of the subject to the same stimuli.

Khechinashrili and Keranishrili (1968) studied elecrocochleography by placing an active electrode on the ear drum Result showed that the ALP led off from the tympanic membrane were due to intra-cochlear activity and could not demonstrate the spread of the evoked responses from the retrocochlear activity structures. The response led off from the ear drum, different from those recorded by electrodes placed on the ear lobs showing more complex patterns of activity (Sohmer and Feinmesser, 1967).

Simmar (1972) compared the result of 3 commonly used recording sites. His results favored the promontory type of recording.

The choice between external auditory meatus and promontory N_1 recordings in a clinical environment is clearly in favor of the promontory approach, for an audiologist with manual skills it takes 30 to 40 minutes fro the beginning of anesthesia to complete a recording.

External auditory meatus techniques are shorter by about 10 to 15 minutes if the electrode remains in place and if the positioning is optimal.

Responses from the promentory approach seem to be much more reliable, whether an N_1 wave form is present or absent, a threshold elevation is usually significant. Extra tympanic approach recording are capable of yielding almost as sensitive threshold as promentory approach can give, but it seemed rarely to do so. Threshold sensitivity is considered as one of the most important criteria in selecting a recording technique. But it is not the only criteria, but it is intrinsic in extending the range of N_1 measurement to its maximum. This response range is important in abnormal ears because of recruitment and small differences in response latencies on N_1 input-output functions reflect major cochlear abnormalities.

If N1's can be obtained only at moderate and high stimulus intensities, recording will be correspondingly limited, promontory recordings meet this sensitivity and the clear subrathreshold wave form requirement are obtained more consistently than in the extra tympanic recordings.

Promentory recording is admittedly more hazardous than extratympanic recordings because sooner or later an electrode may slip and enter the cochlea via the round window or the oval window, or ossicles may be fractured or dislocated as it happens while using myringotomy kinves or Eustachian tube infections may occur or pinpoint perforation may fail to close. Improved methods and operator skills will be able to overcome all these disadvantages alteast to certain extent. (Simmen, 1972).

Eggermant and Odenthal (1974b) have presented the following data after reviewing the literature:

1. The amplitude of promontory AP to high intensities of stimulation is 10-30 PP (Peak to Peak value);
2. The amplitude of promontory AP to 10 dBSL stimuli is 0.2 PP;
3. The amplitude of ear canal AP to high intensities of stimulation is 1.2 PP;
4. The amplitude of ear canal AP to 10 dBSL stimuli is 0.1 PP;
5. The amplitude of mastoid or ear lobe AP (N_1 of BSER) to high intensities of stimulation is 0.6 – 1.1 PP;

Thornten (1975a) reported that it is not always possible to indentify the AP from mastoid or ear lobe recordings at levels of less than 40dBSL as the responses cannot be differentiated from the background activity or noise.

Examination of data revealed that the attenuation varies with the intensity of stimulation in each case and that the low intensity evoked. AP travels relatively more easily to distant sites than that of the high intensity evoked AP. The ability to detect the AP at threshold levels depends on the level of background activity and the extent to which this may be negated by averaging techniques.

Elberling (1976a) has estimated the background noise at each site of recordings:

(A) The background noise level for prommentory recordings is approximately 6.8 PP;

(B) The background noise level for ear canal recordings is 3.4 PP;

(C) The background noise level for ear lobe recordings is 20.3 PP;

The level of the background noise depends both on the impedance between the electrode and the underlying tissues and on the ability of the active and reference electrodes to receive potentials from extraneous sources (Eg: muscles, EEG etc.,). The promontory electrode has a high impedance of approximately 60 KΩ but with the reference electrode placed on the Ipsilateral ear lobe, little extraneous noise is encountered. The electrode embedded in the external acoustic meatal skin has a low input impedance, probably less than 3 K and is placed almost as favorably as a promontory electrode as regards the extraneous noise. An ear canal electrode which does not penetrade the tissues has a far higher input impedance approaching than that of the promontory electrode and picks up much more noise. The ear lobe or mastoid electrode may have a low input impedance but with the reference electrode placed on the vertex a considerable amount of background noise is included in the recordings.

The wave form and functions of the AP recorded from the ear canal are essentially identical to those of promontory recordings although there is a minor difference due to a low frequency filtering effect occurring as the response passes through the more resistant tissues (Elberling, 1976a). The function s of the AP recorded fro the ear lobe/mastoid are similar and often reveal the 'H' and 'L' areas of the amplitude-intensity graph. Often a high level of a high pass filter is chosen (250 – 500 Hz) to alter the AP wave form.

Procedure

The subject is made to sleep in supine position on a comfortable bed which was segmented to permit adjustment to a suitable contour. The electrode position depends upon the biases, professional training and expertise of the b tester as well as the subjects permission. Simmons (1975) has concluded that the most dependable, accurate, and sensitive site is the promontory of the cochlea.

It patients do not agree for trans-tympanic placement, external auditory meatus recording technique can be used accurately.

Acoustic stimuli used are the clicks and tonepipes, with center frequencies of 2000, 4000 and 8 KHz. The tone-pips are puretones generated by an oscillator and passed through an electronic switch. The electronic switch should give a 1M sec rise-decay time and a 3.5 M sec. duration. The intensity of air-conducted stimuli is expressed as peak-equivalent sound pressure level. It should be changed by steps of 5dB with the help of an attenuator. The acoustic stimuli are presented to the subject at intervals of 125 M.sec at a repetition rate of 8 stimuli per second from loud-speaker placed one meter in front of his head. Bone conducted stimuli are delivered with a bone-conduction vibrator placed on the subject's forehead.

When transympanic technique is used, the stimuli should be presented 200 times and in external auditory meatus recording techniques, stimuli should be presented 1000 times. Some times, the number averaged for the promontory recording are varied from 100 to 500, according to the signal to noise ratio of the response in the ongoing background activity. Two channels of the recording systems can be used for the purpose of simultaneous recording of the cochlear responses obtained from both ear. These responses are amplified with pre-amplifiers and frequency analyzers with an overall frequency response to 1 to 9000 Hz.

The wave form of the averaged cochlear responses to time-locked tone-pips or clicks will be a mixture of both cochlear microphonic, action potential and summating potential.

Place of electrocochleography in clinical audiometry

Electrocochleography (ECOG) is the recording of stimulus related potentials generated in the cochlea, including the first order neuron viz., the CM, AP and SP. First recording of a stimulus related potential was done by Wever and Bray (1930) from animals cochlea. This phenomenon was found in man a few years later by Fromm et al (1935).

Electrocochleography is a form of electric response audiometry which provides an objective measurement of hearing function. Although the AER audiometry is widely used than electrocochleography, AED has definite disadvantages when compared to electrochleography. In AER, the auditory evoked response is influenced by a number of factors which is not under the control of investigator. AER are mainly affected by the drugs which are used in case of children and by attention of the patient. As AER produces poor reproducibility, it has low reliability. In AER, the whole auditory system is investigated from its most peripheral part to the cerebral cortex, on electrocochleogrphay, the investigation is confined to the most peripheral part of the system. In addition, the measurement is restricted to the examined ear, which can be important in cases where masking of the better ear is difficult or impossible (Schmidt and Spoor, 1974).

Electrocochleogrpahy provides critical information about the hearing threshold of the following:

1. Young children and neonates
2. Mentally Retarded cases
3. Communication disorders children

4. Children with autistic
5. Neurologically handicapped children
6. Brain damaged children
7. Difficult to test children
8. Multiple handicapped children
9. Epileptic children
10. Aphasic children
11. Non-organic cases
12. More than one pending diagnosis
13. Retrocochlear lesion cases
14. Congential deformity

In adults electrocochleography provides critical information about (Davis and Beagley (1969)

1. Non-organic hearing conditions
2. Pre-operative cochlear evaluation with auditory masking dilemma cases
3. Mutism
4. Retrocochlear cases

Application of electrocochleography

1. Hearing evaluation in children who are bhyperactive and multiple handicapped
2. Threshold measurements in young child
3. To confirm the ERA thresholds, electrocochleography can be used

4. Identification of retrocochlear impairment and location of site of lesion.
5. Identification of the better ear in hearing impaired children.
6. Electrocochleographic measurement helps to differentiate different kinds of pathology.
7. Abnormal adaptation can be tested using electrocochleography.
8. Cochlear pathology can be found out with the help of electrocochleography.
9. We can assess the degree of air-bone gap with the help of bone conduction electrocochleography.
10. Difficult diagnostic problems can be solved.
11. Electrocochleography can be used to assess the cochlear function pre-opertively.
12. Auditory masking problems can be overcome using electrocochleography.

Disadvantages of electrocochleography

Besides all the advantages and applications, electrocochleography has a number of disadvantages.

1. In case of promontory approach, in order to pierce the tympanic membrane local or general anesthesia is needed. Some consider this procdure too aggressive to justify its use as adiagnostic procedure;

   Schmidt and Spoor (1974) have observed only one case of temporary dizzinon due to the application of local anesthetic and middle ear infection developing after electrocochleography;
2. Electrocochleographic procedure is time consuming to obtain frequency-specific thresholds and one or more suprathreshold parameters such as input-output and amplitude latency relationships. This requires about 2 hours;

   This time can be shortened considerably by using a sound stimulus composed of a series of tone bursts with increasing intensity with fast administration. However, accurate latency measurements require a more complex averaging system.

3. Electrocochleographic producer requires the co-operation of medical engineer, an ENT specialist and an anesthesiologist and an expensive equipment.
4. Examination is rather more experience and even more when hospitalization is necessary;
5. Elecgtrocochelography records information only about the basal end which is responsible for high frequency signal.
6. Information regarding low frequencies i.e., frequency below 1500 Hz cannot be obtained using electrocochleography;
7. Electrocochleography records the peripheral response of the auditory nerve. If electrocochleography shows no that person has got normal hearing as lesion may be there beyond the cochlea;
8. Low frequency stimuli are difficult to use in electrocochleography because:
    a) The point of maximum excitation on the basilar membrane is remote from the active electrode;
    b) The firing among neural elements is less synchronized (Davis, 1976) and
    c) Stimulus artifact are most often encountered.

Clinical applications of electrocochleography

Electrocochleography is a method of recording of the electrical activity of the cochlea and first order, eighth never fibres in response to acoustic stimulation.

Elecrocochleography is now being utilized to evaluate the peripherial-auditory function of patients when ordinary behavioural audiometric tests are not possible to the carried out with them (Portman and Aran, 1971). By using filtered clicks or tone bursts of different frequencies, it may be possible to get a tone topic evaluation of hearing loss at different frequencies i.e., and "action potential audiogram" (Portman and Aran, 1971). Information about the type and site of the hearing disorder may also be obtained using electrocochleography.

Electrochleography provides two distinct information. Firstly it provides a reliable indication of the cochlear output which is not affected by sedation or by masking problem. Secondly, it offers a unique insight into the physiology of the cochlea and may be used to learn more about the nature of particular causes of hearing dysfunction.

As a measure of auditory acuity

Electrocochleography measures the threshold of the auditory mechanism at the level of the first order cochlear neurons. More control lesions can affect the hearing without affecting the electrocochlear. The vast majority of children with hearing losses suffer from peripheral disorders and if the electrocochleograhpy reveals a reduced cochlear function it can lead us to concluded that the child might be suffering from a hearing loss.

Click stimuli evoke a whole nerve action potential the entire length of the basilar membrane but the largest comparent of this response is derived from the basal coil. The threshold of the WNAP usually indicates the auditory acuity within 10 dB of the mean level of thresholds obtained using pure tone audiometry for frequencies between 2 – 8 KHz (Aran et at, 1971).

The compound AP evoked by frequency specific stimuli provides an indication about the auditory threshold at the corresponding frequency and this may be compared directly with the pure tone audiogram. It is fairly simple to make accurate measurements of the thresholds at frequencies between 1 and 8 KHz, where as 500 Hz stimulus do not always evoke identifiable responses closers to the psycho-acoustic threshold and a gap of 1-40 dB is usually observed.

In addition to threshold estimation, electricochleography offers a sophisticated means in determining the nature of the hearing dysfunction.

There are three parameters that can be used for clinical interpretation:

1. The latency of the response;
2. The amplitude and
3. Its wave form;

Electrocochleographic wave also be used as an aid in the neuro-otological diagnosis.

Characteristics of normal cochlegoram

1. The threshold of detection of the AP response is within 10dB of the individual perceptual threshold for total stimulation in the 2 to 4 KHz region.
2. The absolute amplitude of the AP may vary over 2 or 3 orders of magnitude among recording situations and individuals. The rate of change of amplitude with changes in stimulus intensity remain fairly constant. This will be 0.5 to 1% per dB for stimuli upto 60 dBSL in normals. This change in rate of growth corresponds to Yshie's (1968) L and H portions of the amplitude growth functions

which are relatively slow or flat near the threshold and relatively steeper at higher intensities.

3. The peak latency of normal component of AP response is dependent on the intensity of the stimulus. In normal subjects it will be in the region of 4 M Sec at threshold and it decreases to less than 1.5 M Sec at 90 dB.

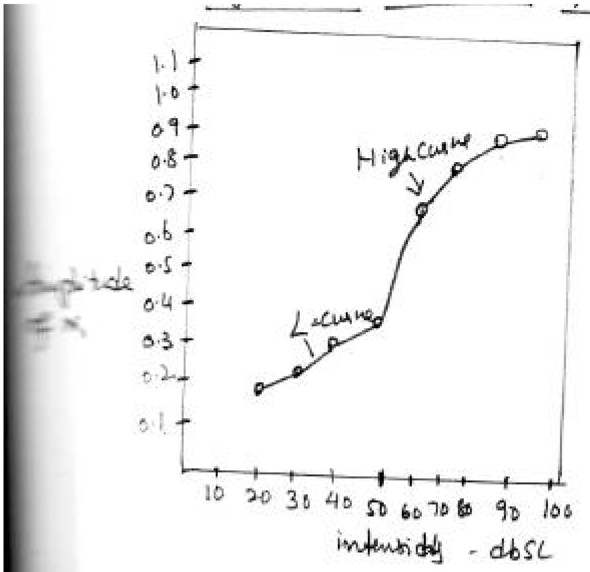
According to Gibsen and Ruben ('78), characteristics of normal cochleogram are as follows.

"The WNAP obtained from the normal ear shows a characteristic monosphasic wave form at high stimulus intensity levels, the amplitude/intensity functions may be divided into "H" and "L" areas and the latency alters from approximately 1.2 M sec at 110 dBML to 4-6 M sec at near the lends."

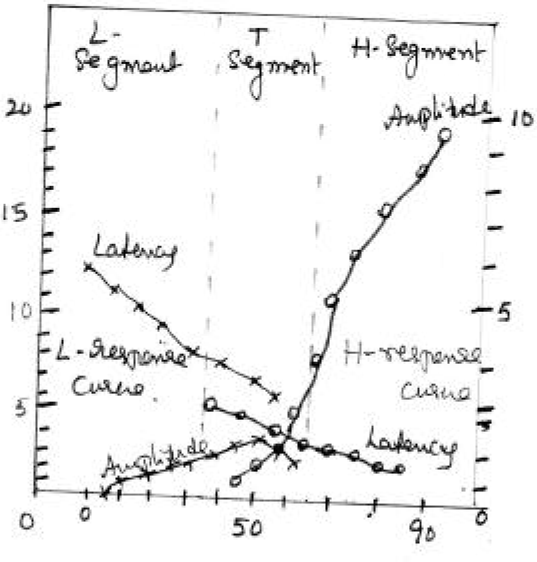
The compound AP has an onset latency which progressively lengthens and has a width which increases as the intensity of stimulation is reduced.

The CM in the normal ear various considerably but is usually of sufficient amplitude to be identifiable down to a level or pseudothreshold of approximately 60 dBSL. At intensities of 110 dBHL, the amplitude of the CM to click stimulation usually

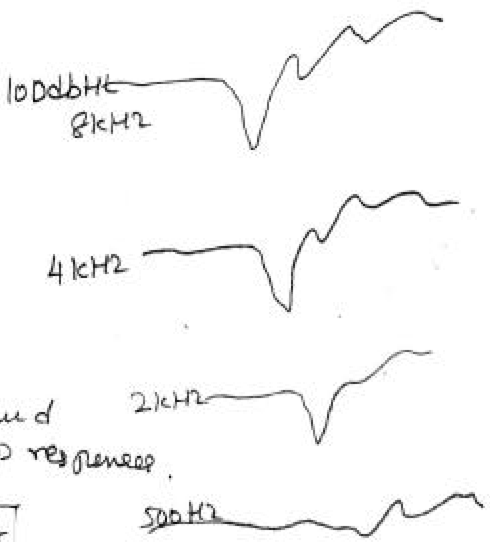
Output-Output relations of N1 in wave to clicks



normal pattern of the input-output and intensity-latency relations of the AP responses.



Compound APs obtained using short tone bursts



Normal cochlear microphonic wave

approaches the amplitude of the WNAP. The magnitude of the CM evoked by low frequency stimuli invariably exceeds that of the corresponding compound AP.

The Sp. in normal ears is usually identifiable as a small negative trough on the descending limb of the AP. Sp rarely affects more than one quarter of the length of the descending limb. At low frequency, such as 500 Hz, the Sp contributes more to the AP and broadens the waveform; by using the subtraction technique to remove the Sp, the 500Hz AP is much more easily identified.

Portmann, Aran and Larougrve (1973) have described characteristic waves seen in normals. Normal cochleogram usually characterized by,

1. A pattern of response which is diphasic at low and medium intensities and monophasic at high intensities;
2. A latent interval range of 4 to 5 M sec at threshold and by a decrease in latent interval with increasing in intensity;
3. An increased amplitude of the response with increasing intensities;

Yoshie (1971) has discussed the normal pattern of the input-output relations of the compound AP response, which involved both the intensity-amplitude and the intensity-amplitude and the intensity-latency relations. It is obvious that the pattern of the wave forms of the N_1 comparants depend greatly on changes in the stimulus intensity. The magnitude of the N_1 grows with the increase in the stimulus intensity.

Three kinds of responses pattern can be distinguished in relation to the stimulus intensity. They are:

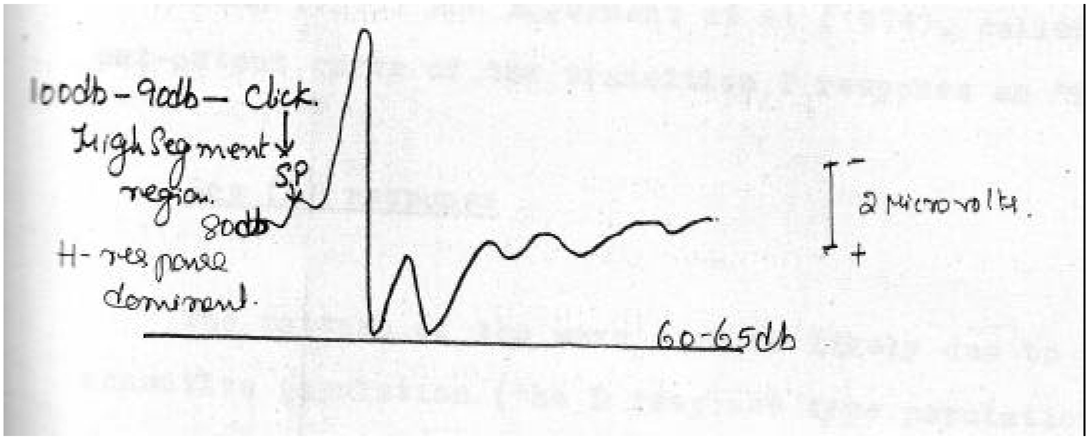
1. High (H) response;
2. Transitional (T) response;
3. Low (L) response;

High (H) Response

This kind of response is observed in the high-intensity region of the stimuli from 60 or 65 dB HL to 100 dB HL. The wave form of the response is characterized by a relatively sharp and significantly large negative deflection. Some times, N2 comparant appears with a time delay of about 1 M sec from the N_1 peak latency. The N_2 mostly results due to repeated firing of the less sensitive sensory units, but it is not attributable to the contribution of the more sensitive sensory units (The low response-type population). The segments of the Input-output curves both for amplitude and for latency correspond to the high-stimulus intensities. These are designated as High or

M Segments

In the M segment, usually the low response is inhibited almost completely.

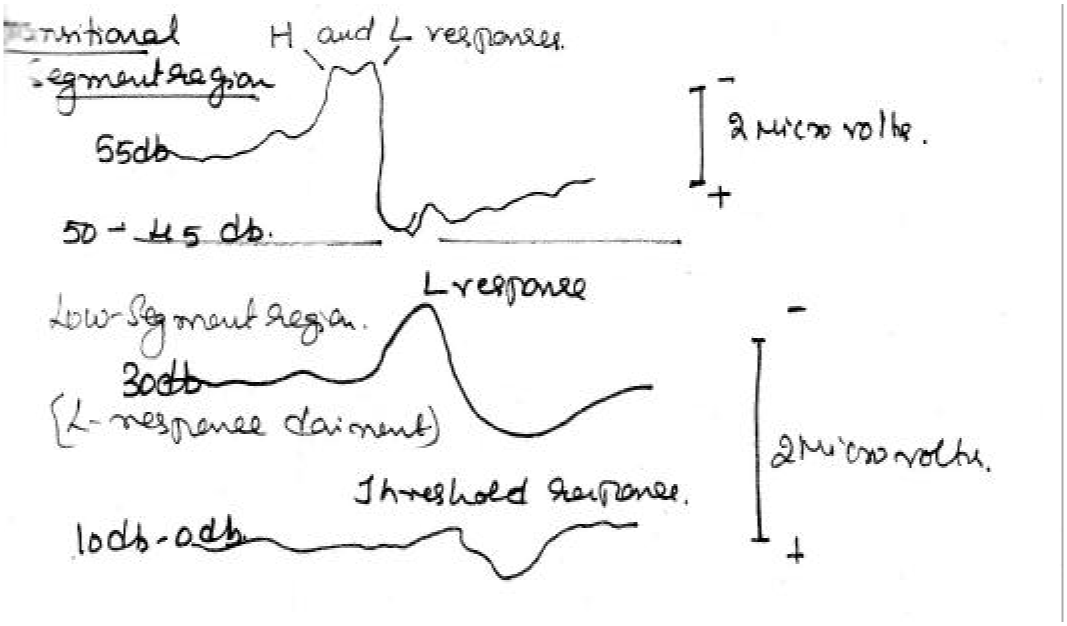


Transitional (T) response (Mixed response of the L & M responses)

Elberling (1973) and Eggerment et al (1974) have pointed out that the appearance of a double peak or a doubled N_1 component, is the most prominent feature of the wave form for the compound AP response to the stimuli with intensities from 45 to 65 dB HL. The first peak of the doubled N_1 component is attributable to the less sensitive population (H) response type population) and the second peak of it, is attributable to the more sensitive population (L-response type population) but it is neither due to the M response type nor due to L response type. The T response is a mixture of the L and H responses. Yoshie (1973) confirmed a discrete point on the curves or a transition which was comparable with the result obtained by Elberling (1973) and Eggerment et al (1974), called the Input-output curve of the transition T response as “T segment”.

Low (L) response

The pattern of the wave form is likely due to the more sensitive population (the L response type population), which can be respond to such a stimulus intensity as weak as a subjective threshold level of hearing. The segment of the Input-output relations corresponding to low stimulus intensities and which appears between ? and 45Hz is called the Low or “L segment”.



Electrocochleography in conductive hearing loss

The electrocochleography obtained from a subject with a conductive hearing loss resembles the normal electrocochleography pattern. The action potential pattern will not differ essentially from those in normal hearing, since the cochlear partition is not involved in the pathologic process. The actual stimulus level in dB HL required to evoke the action potential is greater in conductive hearing loss cases and so the amplitude/intensity and the latency intensity functions were shifted to the right side. One should suspect a conductive hearing loss if the AP at 100 dB has a normal configuration but a latency of over 1.6 M se (Ruben 1978).

Action potential wave form and conductive hearing loss

Partial removal of pathological liquid from middle ear contents (Glue) results in a shift of all AP parameters without alteration of the AP wave form itself. The AP wave form at 65 dB HL before removal of the glue is essentially the same as the AP at 55 dB after partial removal of the middle ear contents, indicating some 10 dB improvement in the conduction mechanism (Eggermant et al 1974).

Input and Output curves

In conductive hearing loss cases, the input/output curve is shifted to the right as compared with the normal curve.

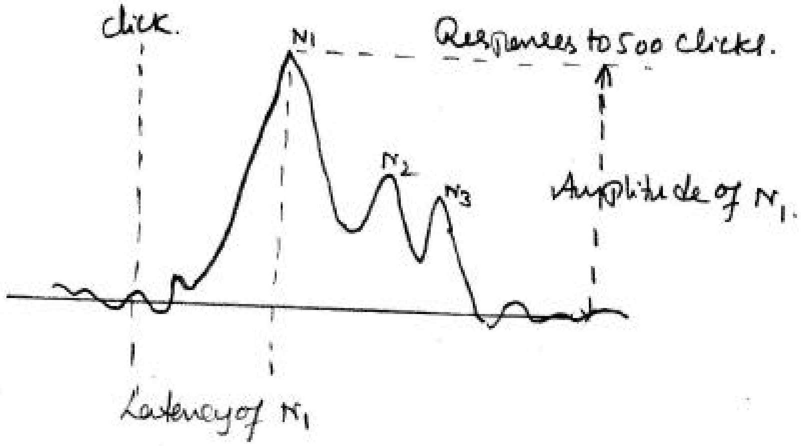
The latency-intensity curves

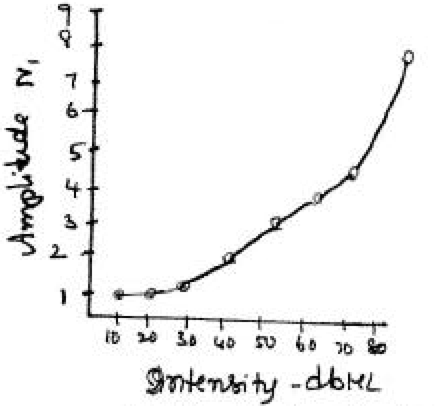
In case of conductive hearing loss, latencies are roughly identical to that of normals, but there seem to have a slight tendency towards larger latencies at high intensity levels and the curves are shifted upward by 20 to 35 dB. The latency-intensity curve is shifted to right side with the amount of hearing loss. This means that latencies are not different from normals, which intensity is expressed in terms of sensational levels. (Eggermant and Odenthal, 1974).

According to Portmann and Aran (1971) pure conductive deafness gives a characteristic picture on the electrocochleogram. The degree of the shift of latency intensity curve is and indication of the degree of conductive deafness.

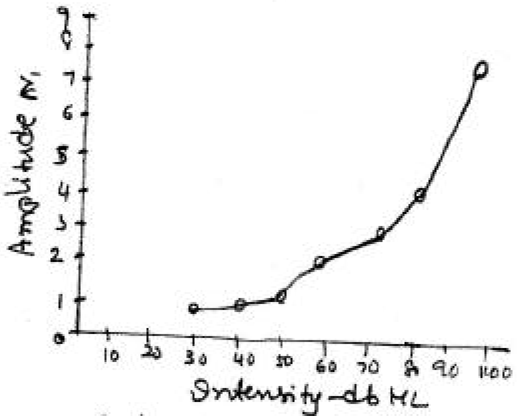
The cochlear micropha-ics in conductive pathologies is generally of a small amplitude despite the fact that the hair cells are unaffected. The summating potential is usually reduced in amplitude in conductive hearing loss cases. (Gibsen and Ruben, 1978).

Normal Action Potential Wave

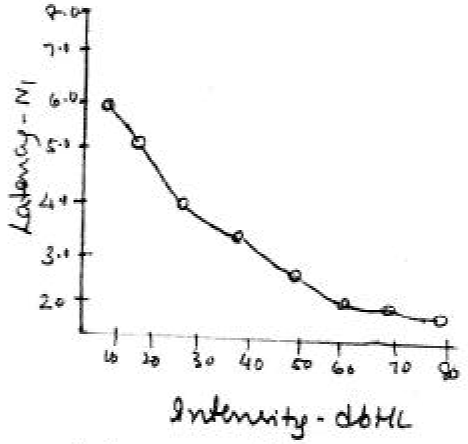




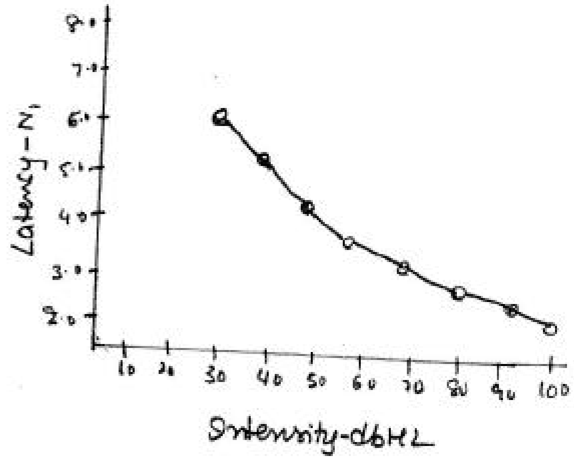
Normal intensity-amplitude curve.



Intensity-amplitude curve in conductive loss



Intensity-latency curve in normal ear.



Intensity-latency curve in conductive hg loss.

Electrocochleography with SN hearing loss cases

Hair Cell Loss – Many cochlear pathologies result in damage to the hair cells. In cases of hair cell lesions which is confined to the outer hair cell, a different between the normal AP wave form and AP wave form of the pathological cochlea may be expected.

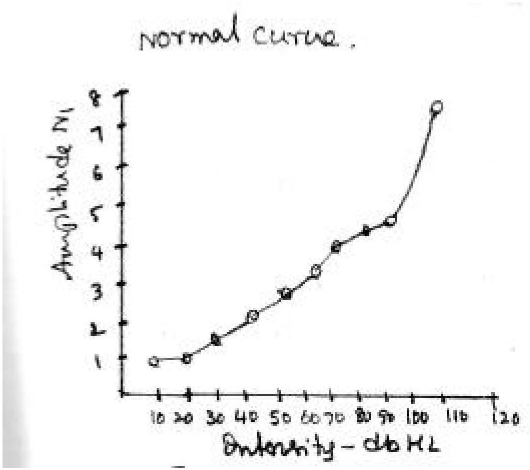
According to Ruben and Gibsen)1978) “recruiting hearing losses yield a diphasic WN AP wave form. The amplitude/intensity functions fall sharply to the threshold and the latency alters only slightly. These findings are explained by Evans (1975a) as resulting from damage to the “Second filter” within the cochlea. The amplitude/intensity functions are much steeper than in normal ears as the latency at near threshold levels is shorter.

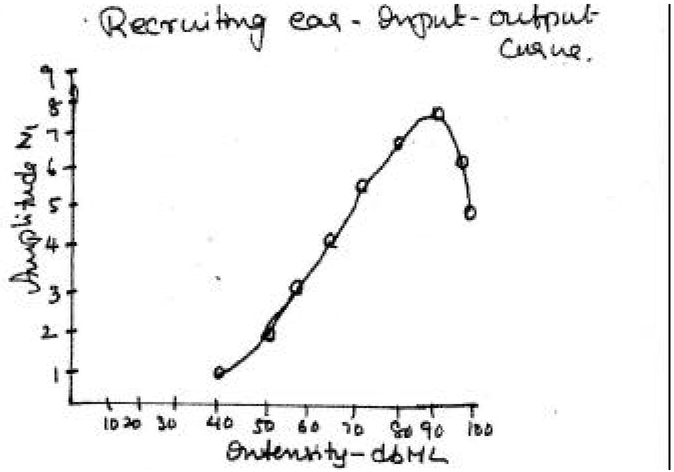
Odenthal D. W and Eggermant (1974) have compared cases of high frequency hearing loss with normal subjects in terms of action potential wave forms, Input/Output curves and amplitude latency curves. They have grouped the abnormal patterns in 3 categories.

1. Action potential wave form

At high intensities, both amplitude and latency are the same for both normal and recruiting ears. At lower intensities there is absence of N1 (II) in recruiting ears.

Input-Output curves

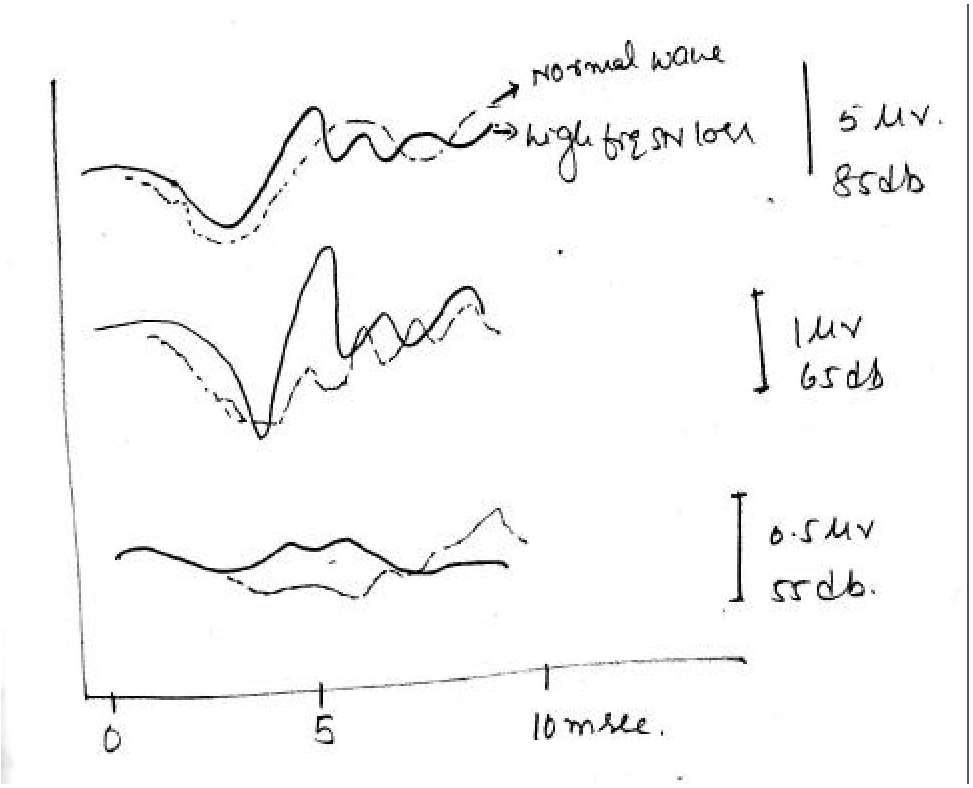




In cases of sensory hearing loss with recruitment, the relation of the action potential amplitude and AP latencies differ fundamentally from those of the normal cochlea. The shallow part which is seen in normal ears is missing in recruiting ears and threshold value is usually elevated. In the high-intensity range, in some cases, the amplitude of the AP reaches normal or supra-normal values, mostly owing to the presence of recruitment.

When the amplitude intensity data are compared a rapid increase of amplitude is seen at intensity values just above the threshold. The slope of the curve is twice as compared with that of the normal curve and it shows a tenfold amplitude increase for a 10dB intensity increase. As the threshold

Ap waveform in normal and recruiting ear, At high intensities both amplitude and Latency are the same for both responses. At lower intensities the absence of the N1 (II) is noted in case of recruiting, mediating the absence of a contribution from population II nervous to the compound responses.



level is reached, the latency value tend to be shorter in recruiting ears when compared with the latency values in the normal ear.

The AP width-latency wave form of recruiting ear when compared with that of normal AP width latency, AP width latency was minimum is cochlear hearing loss while the maximum latencies wave came in both cases. This leads to the conclusion that a certain part of the compound AP is absent in cases with cochlear hearing loss.

According to Odenthal and Eggermant (1974) the amplitude latency curve represents the validity of two populations of neural units in the cochlea. In high frequency hearing loss the second negative deflection of the double peaked AP is always missing. The first peak has a threshold of 40 dB whereas the second peak has a lower threshold and a longer latency. If the second peak is absent, the threshold is usually elevated and latency remains short, even at this level. This results in abnormal amplitude latency function as seen in high frequency hearing loss. This reflects the selective loss of one population of neural units i.e., of outer hair cells.

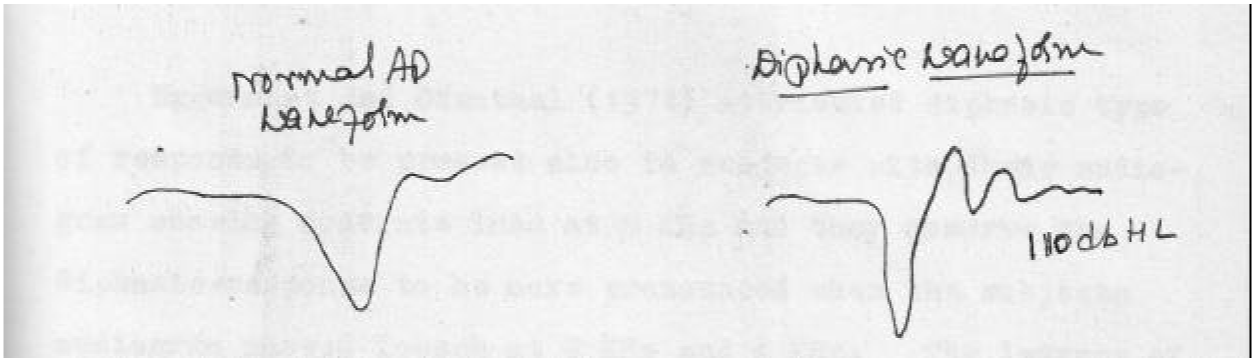
According to Ruben and Gibsen (1978), the CM varies in amplitude but is generally smaller than seen in normals. The summating potentials are also smaller in recruitment.

Portmann, Aran and Larougrue (1973) have described characteristic wave forms seen in recruiting ears. According to them, the response may be labeled "recruiting" when the following three characteristics are present simultaneously. They are:

1. A short latent interval (about 2 M sec at the threshold which is always sound above 40 dB Hz. A latent interval of this order is found at the same level of intensity in normal subjects.
2. A diphasic (positive and negative) response pattern at all sound levels.
3. An amplitude which increases rapidly with increasing click intensity, without a plateau and with occasional high readings at high sound levels.

The amplitude catches rapidly with that of a normal subject at the same level of intensity. Above threshold it increases within 10 dB as much as it would be in a normal subject within 50 dB.

It is suggested that in normal ears, the input-output curve is composed of both L curve and H curve representing the output of two different hair cell population (Yoshie, 1968) In recruiting ears, the L curve having a low threshold appears while the H curve (40 dB Hz) remains unaltered. In recruiting ears, steep input-output curve is seen (Eggermant and Odenthal, 1974).



Eggermant (1977) has drawn relationship between slope of the compounds AP input-output curve and shape of the response area that relates the electrocochleography findings. From the latency-intensity relations, are can infer, which part of the cochlea makes the largest contribution to the whole nerve AP, whereas the latency-function determining the position of the best responding region along the basilar membrane as a function of stimulus level.

The wave form of the compound AP depends both on the types of stimulus used and the state of hearing organ.

Portman et al (1973), using wideband click stimuli, determined a “recruiting respond” by a diphasic wave form at all levels.

Eggermant and Odenthanl (1974) attributed diphasic type or response to be present alos in subjects with their audiogram showing moderation loss at 8 KHz and they observe the diphasic response to be more pronounced when the subjects audiogram showed losses at 2 KHz and 4 KHz. The latency of the response itself indicates the contributing fibers to belong to the basal part of the cochlea. In some cases, a diphasic response is broad with relatively large latency range. This is seen in cases with slightly increasing threshold at higher frequencies. This indicates that the shape of the compound AP depends on the type of audiogram and the type of cochlear dysfunction than on the presence of recruitment. Portman and Aran (1971) classified perceptive deafness into simple perceptive deafness and complex perceptive deafness. In single perceptive deafness, cases with recruitment are included. In complex perceptive deafness, Meniere’s disease cases are included.

Their findings in recruitment cases are those, that:

a) The threshold is raised (60 dB);

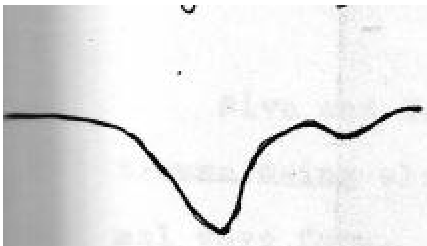
b) The presence of diphasic response even at high intensities and;

c) The presence of no plateau on the amplitude curve and an increase in amplitude with increasing click intensity;

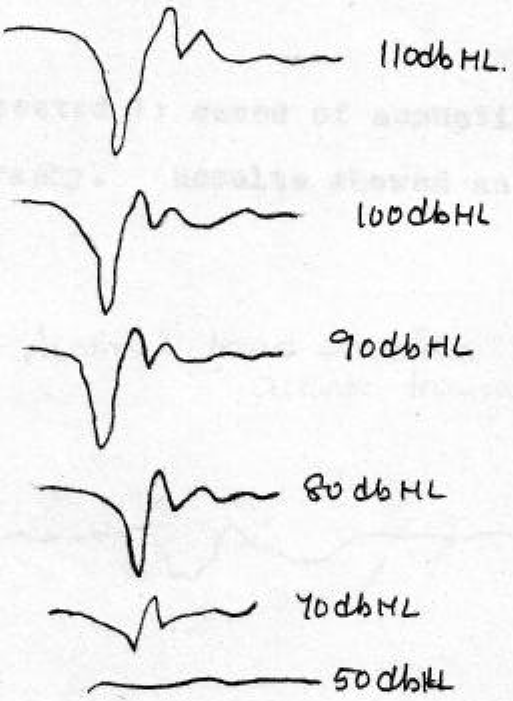
Norther and Down reported electrocochleography wave form pattern in recruiting ear. Their findings correlated with the findings of Portman and Aran (1971).

Aran and Sauvage (1971, 1973), classified abnormal AP response seen in pathological cases into 6 types. They found significant difference in wave form when compared both the normal and recruiting ears.

Normal Ap at high intensity



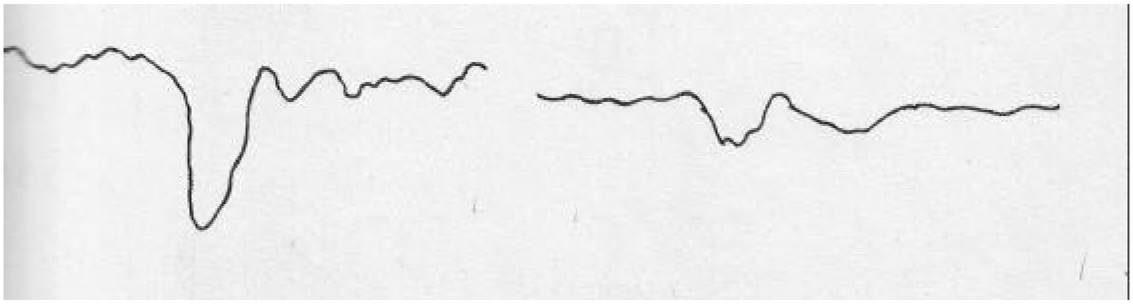
A diphasic WNAP in recuting hearing loss



Electrocochleography in acoustic trauma cases

Cases in whom the hair cell damage is confined almost entirely to the basal coil of the cochlea, the WN AP shows a characteristic late W waveform. The explanation lies with the observation, that the wave form of the WN AP represents the neutral activity from the entire length of the basilar membrane (Elberling, 1974). The part of the WN AP derived from the basal coil, at high intensities is the N_1 which is reduced in its amplitude while the later components of the WN AP derived from the middle coil of the cochlea are normal. The combined effect results in the characteristic late W waveform. The CM in this condition is usually of minute amplitude presumably because all the outer hair cells close to the round window are affected.

Niva and Tamaka (1978) tested 11 cases of acoustic trauma using electrocochleography. Results showed in an abnormal wave form.



Normal AP wave form Abnormal broad waveform in acoustic trauma

“Dead Ear”

A patient with total loss of cochlear function in one ear is occasionally in misdiagnosed using subjective audiometric tests. The patient may be suspected as having a severe conductive deafness since the sound applied to the skull near the damaged ear can travel to the unaffected ear. It is a surgical embarrassment to operate on a ‘dead ear’ expecting a conductive pathology.

Eelectrocochleography provides here as the only tests of cochlear function in which no masking of the contralateral ear is required and provides a definite tool of indication of residual cochlear activity (Ruben and Gibson, 1978).

Electrocochleographic classification of sensorineural defects

Sensori-neural hearing losses can be classified using electrocochlegrophic wave forms. It helps as to obtain objective diagnostic information as to the site, the extent, and the stage of auditory defects in the cochlea.

Functional classification of auditory defects

Functional classification include, sensory unit, subtractive loss and sense-organ malfunction. Davis (1962, 1970) has advocated these terms. Using these terms, it is possible to understand abnormal wave forms seen in sensori-neural hearing loss cases.

Sensory unit

According to Davis, the sensory unit is defined as "one afferent auditory neuron and the hair cell or cells which it innervates". Sponendlin (1966, 1971) named two types of sensory units (a) Inner hair cell-type II neuron system and (b) Outer hair-cell type II neuron system. These two distinct population of the sensory units are designated as systems for high threshold and low threshold respectively (Aran 1972; Dallor, 1973; Davis, 1961; Eggermant et al 1972, 1973, Portman, et al 1973; Yoshie, 1968, '69, '73).

Two types of the Sensor units in man

Ecoch Anatomy (Spoendline)	“Low” - Response type population OMC type II Neuron System	High – response type population OMC – type I Neuron System.
Ecoch patterns by transtympanic Electrode (Normal N_1 Response)		
Input-Output pattern	“Low” – curve	“High” – curve
Max. output (db ML)	45 – 55	Above 90 -100
Response threshold	0 dbML – 10 dbML	40 dbML – 50 dbML
Latency (m sec)		
Min.	2.0 – 2-5	1.0 – 1-3.
Max.	5.0 – 6.0	2.3 – 3.5

Subtractive Loss

The concept of the subtractive loss, means a permanent or temporary (reversible) loss of the sensory units in a qunatal farlion (Davis, 1961). There are two kinds of subtractive loss depending on whether the subtraction of sensory unit is permanent or temporary, namely “permanent subtractive loss” and “reversible subtractive loss”.

According to Davis (1962), four functional patterns of subtractive loss could be distinguished in sensorinerual defects depending upon the anatomical distribution of the defects. They are as follows:

1. Total subtractive loss in the basal turn, possibly associated with abrupt high tone deafness;
2. Graded subtractive loss, which is progressively greater towards the basal end and probably associated with a

gradual high-tone hearing loss.

3. Random subtractive loss, possibly resulting from old age or acoustic tumours; and
4. Selecting subtractive loss of the most sensitive sensory units throughout the length of the basilar membrane, probably related to recruitment, and possibly resulting from Meniere's disease.

Sense-organ malfunction or dysfunction

Sense-organ malfunction is usually seen in Meniere's disease. It may be attributed to a mixture of hyper excitability of the nerve endings and over activity of the sensory cells which elevated threshold.

Abnormal electrocochleography responses in SN hearing losses.

In sensory-neural hearing loss, two basic types of abnormal patterns of electrocochleography can be seen, namely, "type A" (Sense-organ malfunction type) and "type B" (subtraction loss type). These types can be mixed with each other in any combination. The mixed type is called as "type C" (complex type).

Electrocochleographic classification of sensorineural hearing losses

Functional classification (Davis 1962)	Electrocochleographic classification of Sensarineural Hearing loss	
Dysfunction of the sense-organ (sense-organ malfunction)	Type A (Sense – organ Malfunction Type) Dominant SP Response.	Meniere's Disease.
Subtraction of sensory units.	Type B (Subtractive loss type) Subtype I. "High Response H – Response Recruiting Response.	Stage 1. Normal N1 amplitude Stage 2. Significant reduction in amplitude of N1. Stage 3. Response Not
	Subtype II. Separating Response. Loud H- Response. Dissociated response.	Subtracting loss.
	Subtype III. "Low" response Slow response.	
Mixed Defects. (Subtractive loss in combination with sensor-organ malfunction)	Type C (Complex type) Subtype I. Complex Response of type B and Dominant –SP responses.	Meniere's disease
	Subtype II. Complex Response of type B And Dominant +SP response.	Acoustic tumor. Progressive subtractive loss, tempral bone fracture

(complex type).

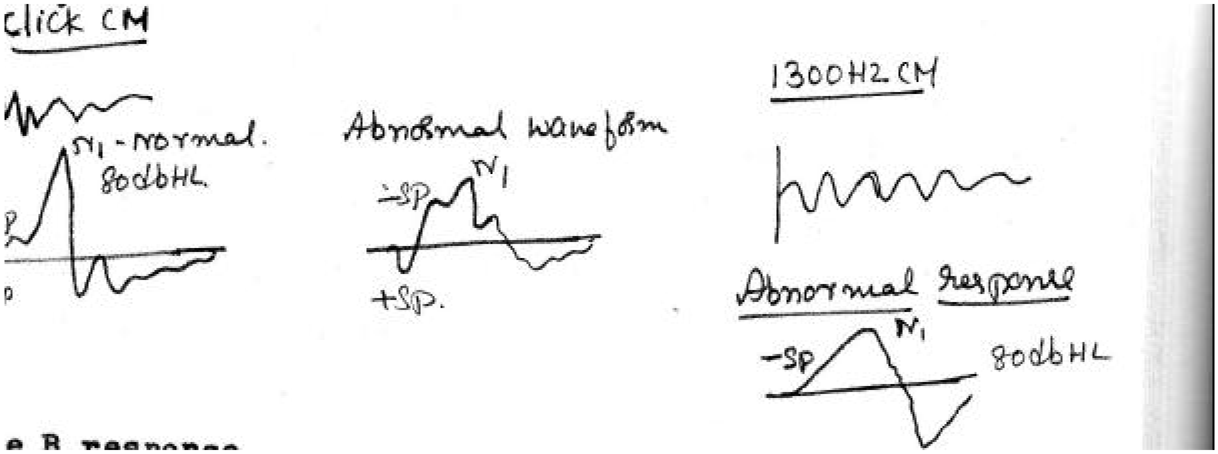
Figure –see page 80a

Type A response

Type A response corresponds to a pathological pattern of the SP response found in a pure form of the sense-organ malfunction. It is usually seen in Meniere's disease. The characteristic feature of the type A response is the dominant magnitude of the SP response recorded from the promontory.

In Meniere's disease, the magnitude of the negative SP response very often exceeds that of the N1 peak of the AP response. Magnitude of the negative SP increases with a more rapid and steeper slope than that of the compound AP response of the same ear, and the magnitude of the negative SP is affected more in diseased ear than in the better ear. Such is affected more in diseased ear than in the better ear. Such a dominance of the negative SP response is a common or garden-variety phenomenon in the sense-organ malfunction. Type A response may have some relation to exaggerated asymmetry or distortion in the process of producing the receptor potentials.

Waveforms of the dominantly negative SP and CM suspense in the sense-organ malfunction due to Meniere’s disease.



Type B response

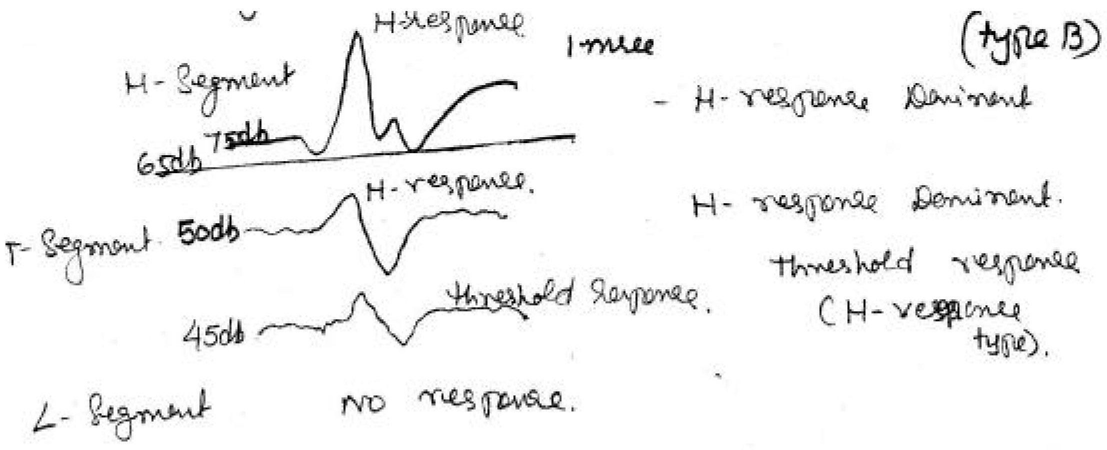
This is due to a pure or simple form of subtractive loss. This is an abnormal pattern of the compound AP response. It is possible to differentiate three kinds of type B responses.

1) High (H) or Type B II response

This is the most typical pattern seen in subtractive hearing loss cases.

Aran (1972, 1973) and Portman et al (1973) have described such a response in recruiting ears. The M response is deduced from a total or server subtractive loss of the low-threshold population throughout the length of the cochlea. This pattern was almost always association with the audiometric patterns of the so called pancochlear and the server cochleoapical types.

The figure represents the abnormal H-response pattern



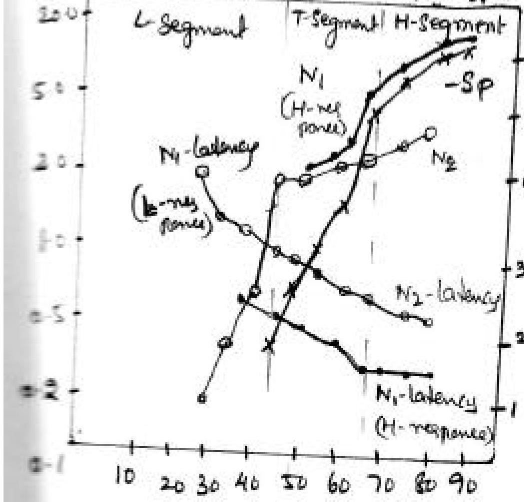
ii) Separating response

The separating response is a mixed type of the H and L responses. This pattern is usually seen in cases of high tone hearing lose with abrupt onset. The separating response may reflect the subtractive loss of the loss of the sensory units is total across the sense-organ and extends for some distance from the basal end (Davis, 1962). This is same as the dissociated response described by Aran (1972 & 1973).

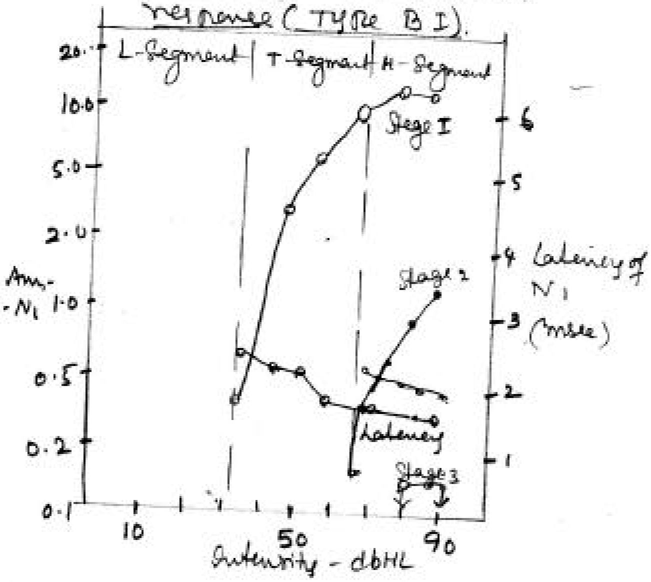
iii) Slow response

This pattern of the abnormal response involves many problems. The latency of the slow response is

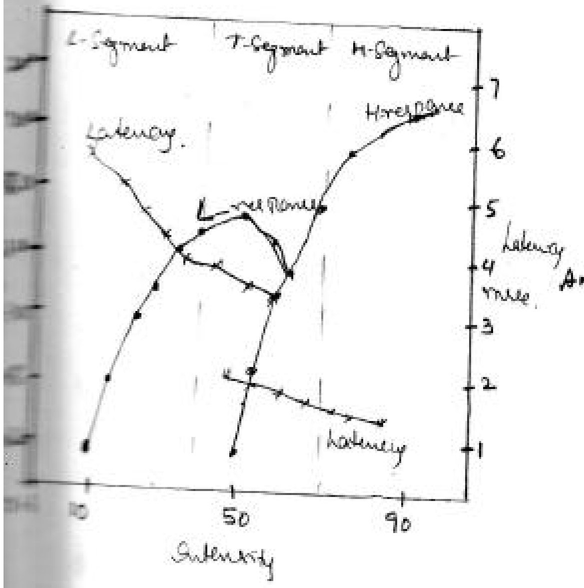
A- Input-output and intensity-
relation of the Ap &Sp response



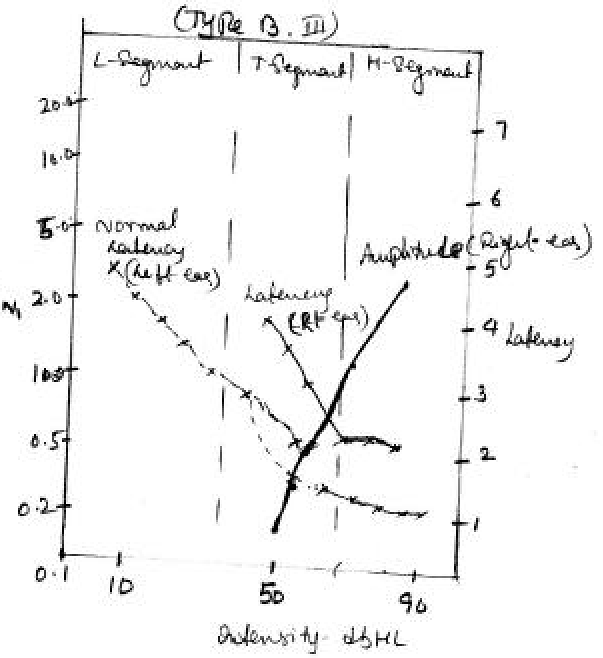
Input-output & Intensity-latency
relation of the abnormal H-
response (TYPE B I).



Input-output and latency-intensity.
relations of the separating
response (typeBII)

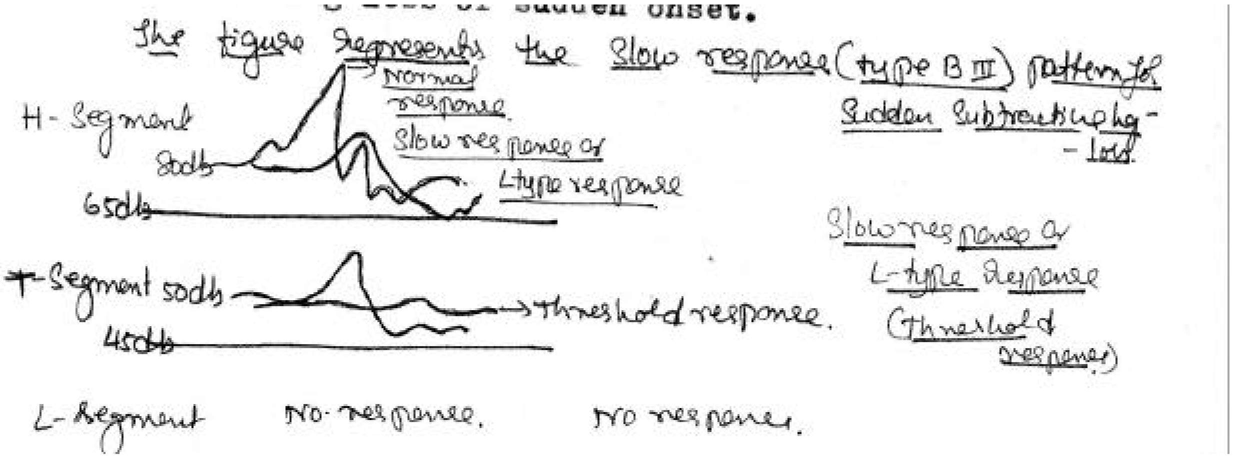


(TYPE B. III)



Input-output and Intensity-latency
relation of the slow response (type B III)

prolonged significantly in the H segment intensity region when compared with the normal response. This kind of situation is observed in the course of recovery from the total hearing loss of sudden onset.



The figure represents the Slow response (type B III) pattern of Sudden Subtractive hg-loss.

Type C or complex response

This is a mixed or complex response of the subtractive loss and the sense-organ malfunction.

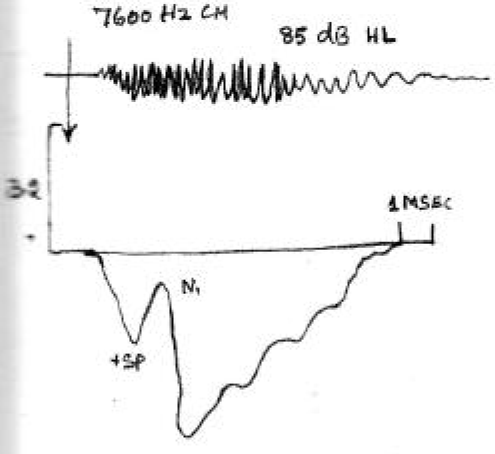
There are two types of type C responses, are associated with the dominant negative SP response and the other with the dominant positive response.

Dominant negative SP response is seen in Meniere’s disease with subtractive hearing loss so that the behavior of the SP response was in essence the same as the type A response.

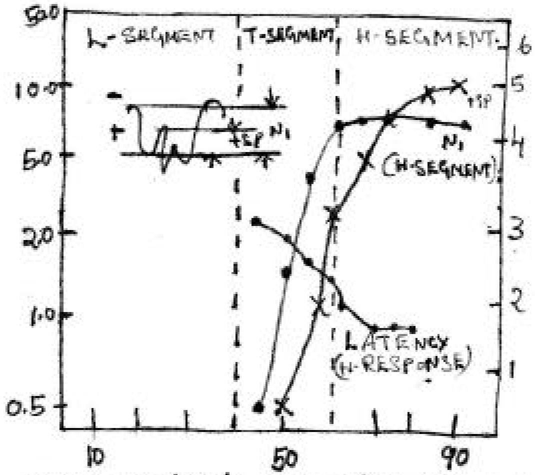
Dominant positive SP response is characterized by an exaggeration of the positive SP response to the higher frequencies. It is usually seen in progressive sensori-neural haring loss or malign stage – such as acoustic tumor and unilateral progressive sensorineural deafness of unknown etiology. In these cases, the positive SP response is so exaggerated that the magnitude of it exceeds that of the N_1 peak.

In contrast, in normal hearing and simple subtractive hearing loss, the magnitude of the positive SP response to the higher frequencies is less prominent and very often it is negligible in comparison with that of the negative SP response.

In Meniere’s disease the negative SP response was so dominant that the positive SP response was reduced or eliminated as a consequence of electrical subtraction or cancellation from the records of electrocochleography.



response in acoustic neurinoma.

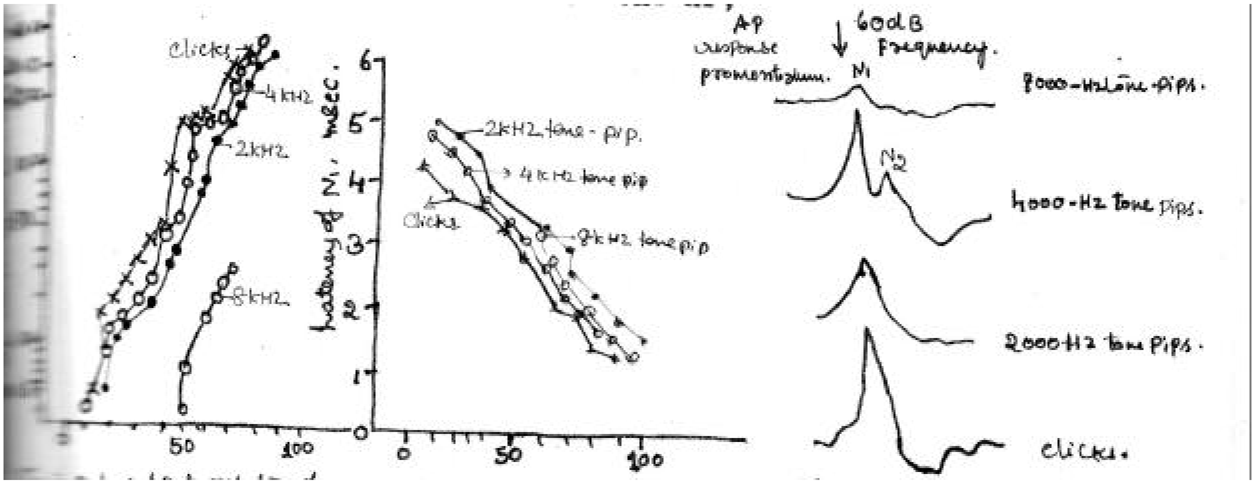


Input - output intensity latency dominant +SP and abnormal AP responses to 7600 Hz tone - bursts in acoustic neurinoma.

Correlation of electric indices of the AP measurements with pattern of subtractive loss (Yoshie, 1973)

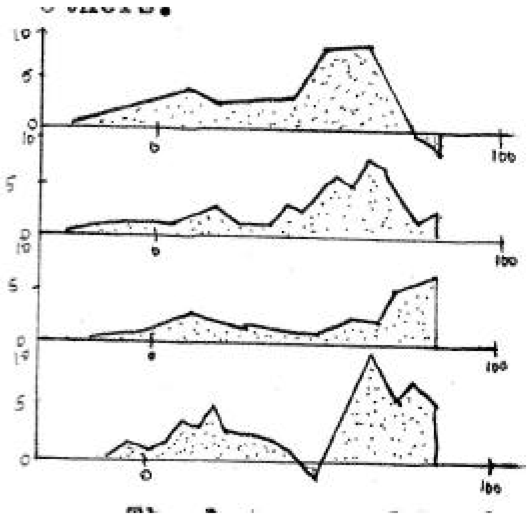
Five kinds of the AP measurements were made as electric indices of SN hearing loss:

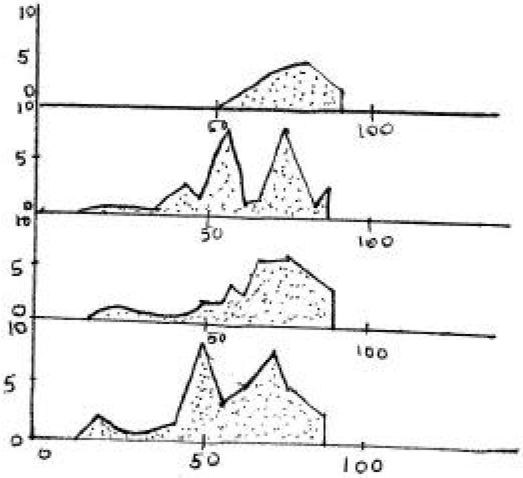
1. The threshold of AP;
2. The input-output relation of N_1;
3. The increments of amplitude of N_1 as a function of the intensity;
4. The intensity – latency relation of N_1 and
5. The wave form of the AP;



This figure represents the electrical indices obtained from a patient with an abrupt high tone hearing loss. The input-output functions of N1 of the highest frequency (8 KHz) differed significantly from those obtained for the other frequencies. Such a form of input-output curve observed for the highest frequency comes under the category of the “H curve” which is characterized by an elevated response threshold, a steep slope, a narrow dynamic range, and a reduced amplitude of response (Yoshie, 1968; Yoshie and Ohashi, 1969).

An alternative to the input-output curve is the amplitudes increment curve. Davis (1961) assumed that the increments in voltage of the AP are proportional to the numbers of neural activated. The increments of the N1 amplitude for 8 KHz tone-pips are greatly depressed when compared with those for the others.





The latency of N_1 is not dependent on the behavior of the amplitude of N1 in case of SN hearing loss.

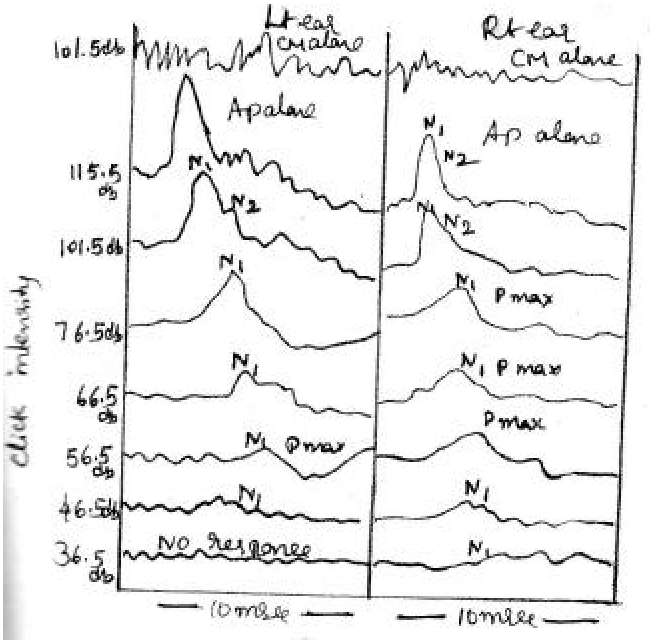
On the basis of observations on the AP measurements for sensorineural hearing loss, 3 conceptual populations of sensory units are hypothesized by Yoshie (1973).

1. The more sensitive population of sensory units capable of discharging well-synchronized impulses with lower thresholds;
2. The loss sensitive population of sensory units capable of discharging well synchronized impulses with higher thresholds, and
3. The more sensitive population of sensory units capable of discharging less synchronized or dispersed impulses with lower thresholds;

Electrocochleography in subcortical deafness

Koga K (1971) reported a case of subcortical neurological examination showed a left hemiplegia, hyperactive tender reflexes on the left side.

A battery of audiological test was administered to this case. Battery of tests includes cortical-evoked potentials, electrocochleogram and impedance audiometry. Results of the electrocochleograpic examination showed normal response, where as no cortical-evoked potential was observed or recorded. These results suggest that the combination of objective hearing tests, such as electrocochleography, ERA and others may be useful in diagnosis of patients with central deafness.



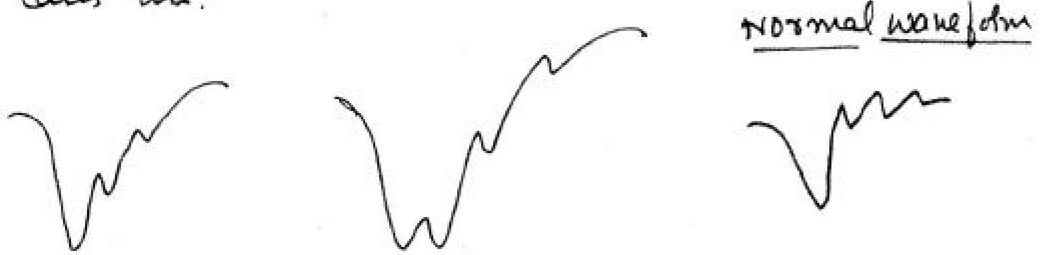
Electrocochleographic response to
200 tone pips recorded from
promontory
Lt and right ear represents
normal responses.

Electrocochleographic findings in presbycusis cases

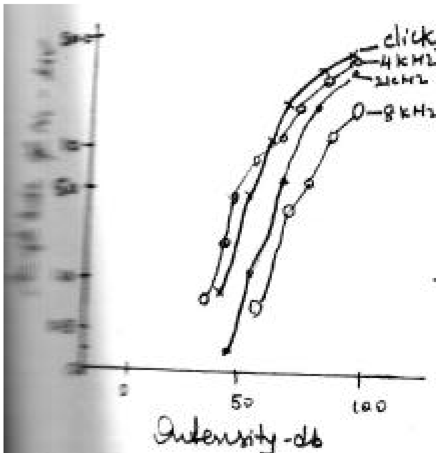
Bergholtz and Hooper (1977) studies a group of patients with presbycusis, noise induced hearing loss and sensorineural hearing loss of unknown etiology etc., They studies latency amplitude and wave form of the AP in each group. Patients with presbycusis, noise induced hearing loss and sensori-neural hearing loss without recruitment showed the same type of amplitude intensity and latency-intensity pattern is slowly sloping amplitude –intensity curves, sometimes with a tendency towards a plateau. The latency of the AP wave form was longer than that of normal wave form latency. They concluded that using electrochleography information about the site and type of the hearing disorder can be obtained objectively.

Types of Action potential wave form seen in presbycusis

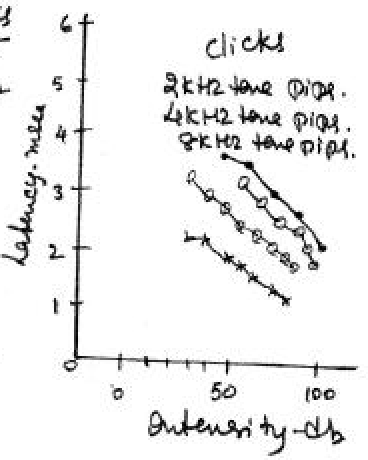
Types of Action potential wave form seen in presbycusis
Cases are:-



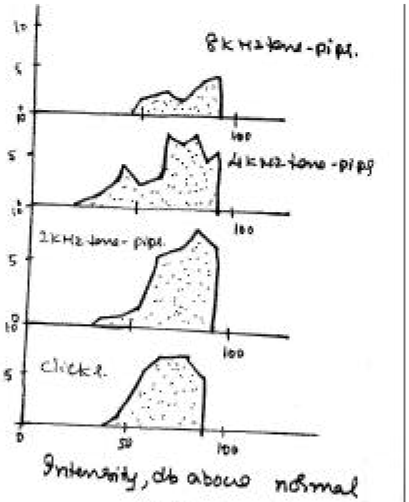
Yoshie (1973) described a kind of random subtractive pattern resulting from old age with a flat or gradual high-tone hearing loss. All the electrical indices except the intensity-latency relation showed the pattern of subtractive loss. The increment of the N_1 amplitude revealed that only the less sensitive population of sensory units with higher thresholds could be activated, because the more sensitive population of sensory units with lower the was no longer active. This means that random subtractive loss might occur rather diffusely throughout the entire length of the cochlea. In this case, the intensity-latency relation remains normal. It seemed that the latency of N_1 was not increased by random subtractive loss due to old age.



[illegible] amplitude relation seen in presbycusis



Intensity-latency changes in presbycusis.



The increments in voltage of the N_1 component/5 db increase in intensity.

Temporary-threshold shift and electrocochleograhpic findings

When a subject is exposed to noise of sufficient intensity and duration, his hearing is found to be affected for a period of minute, hours or even days following exposure. The shift may be temporary or permanent in threshold of hearing.

IN chinchillas, no change was observed in endocochlear potential, wile changes in the cochlear microphanic were recorded from the region of the cochlea corresponding to the frequency of the noise showed a best numerical correlation with the behavioral threshold shift in the same animals. The compound AP of the auditory nerve showed a greater change than other measures (Benitz et al 1972).

When the stimulus intensity was decreased by the amount of TTS, a large reduction in CM amplitude was observed even through the TTS of that amount was not accompanied by a reduction in CM amplitude.

Sohmer and Pratt (1975) studies the responses of the auditory nerve and brain stem auditory nuclei in human subjects by means of electrocochleography, before, during and after exposure to white noise intensities which produced TTS It was observed that neural decrement was expressed by decreased N1 amplitude and increased latency. The later waves generated in the brainstem auditory nuclei were much less affected.

The N_1 amplitude decrease can be due to a decrease in the number of fibers actuated and/or to a decrease in the synchrony of firing (Benitez, 1972).

Pierson and Minot (1980) assumed that noise has a detrimental effect when the cochlear receptor is overloaded and more specifically when the cochllar microphaic fails to increase linearly with intensity. Result of their study of their study showed that the fatigability is greater when there is a large negative asymmetry or a large negative SP. The changes of symmetry were provoked by asphyxia or by introducing solution of Kd into the perilymph. Thus changes were well correlated with the fatigability.

Series of experiments were done by Benitez et al 1972 shows that the surface recorded CM potential of human subject is not affected by noise exposure which nevertheless give rise to TTS. Action potential will change during TTS both in latency and in its amplitude.

The absence of amplitude changes of the CM indicate that there is no impairment of sound conduction to the inner ear, eventhough, this increases the latency of the auditory never action potential (Sohmer and Coher, 1976). The site affected by the noise exposure must be beyond the site of generation of the cochlear microphaic, but before the site of generation of the compound AP.

Bergholtz and Hooper (1977) tested cases with noise induced hearing loss, presbycusis and SN hearing loss without recruitment. They observed some kinds of response patterns in these three cases. All of them exhibited slowly sloping amplitude-intensity curves, sometimes with a tendency towards a plateau. The latency of the AP threshold was longer than found in normal.

Electrocochleography and Adaptation

Patterns of the eighth nerve action potential (AP) responses to click stimulation have been shown to yield a great amount of information on the supraliminal functions of the normal and pathological human cochlear. It is of great value for the objective differential diagnosis of hearing loses (Aran 1973a, Aran et al 1971, Eggermant et al 1974, Portman & Aran 1973, Yoshie 1973, Yoshie and Ohasi, 1969).

The objective electrophysiological method was used to examine the adaptation of the auditory nerve. The study of abnormal adaptation helps to differentiate Meniere's disease from that of acoustic neuroma.

In 1935, Davis was the first one to observe the decrease of the amplitude of the action potentials during continued stimulation. The decrease of the amplitude of the AP of the auditory nerve is best demonstrated by giving a series of acoustic clicks to the ear. If 10 clicks are presented in series, at the end of the fourth click a decrease in the amplitude of action potentials will be seen, If the clicks are combined with white noise, the AP grows smaller. If white noise is presented the AP of the clicks that have not grown smaller by adaptation decrease first, when the masking effect of the noise is as great as the adaptation, the adapted potentials grow still smaller.

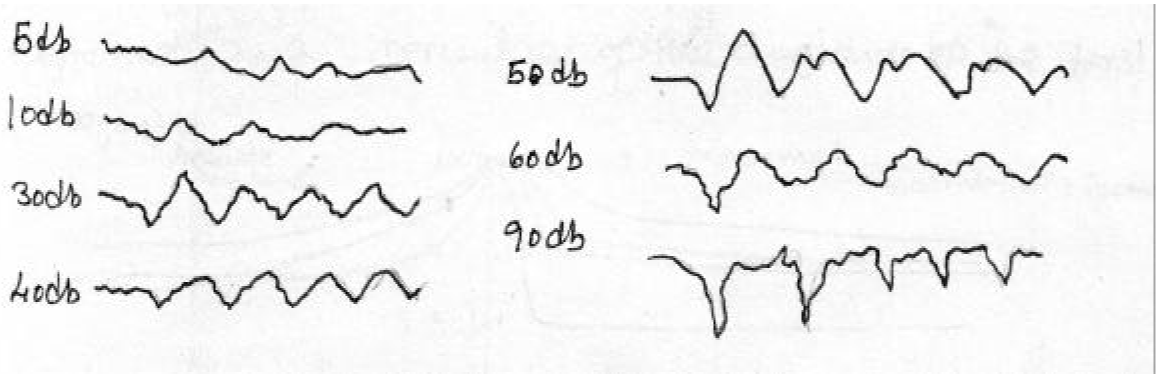
Rondenburg, Nijmegen (1978) observed adaptation of the AP up to the fourth click. The adaptation is not abolished by the interruption of the efferent bundle. They concluded that adaptation must be localized peripherally and it is not due to the activity of the efferent bundle. Sauvage and Aran (1974) studied abnormal adaptation in pathological cases using electrocohleography. Rapid adaptation was studies within a few milli seconds involving the dynamic character of the auditory nerve fibers. The normal phenomena is related to the structure and physiology of the nerve fibers and the way in which they are stimulated by the hair cells.

The fact is that as soon as the inner ear or the eighth nerve, affected, fast adaptation is less pronounced than in normal ears. Fast adaptation is a very basic and sensitive phenomenon. It is less pronounced and significantly different in eighth nerve cases from that of the normal subjects and cases with sensory outer hair cells affections. This can be inferred from the pattern of AP responses.

Studies have suggested that rapid adaptation is closely related to the high sensitivity units population (Eggerment and Odental, 1974) or Second filters (Evans, 1974).

Maximum adaptation occurs only normal ears and around 60 dB HL. That is when the high-sensitivity mechanism is maximally solicited this is altered or absent in pathological ears have adaptation is less pronounced.

Response to the five clicks of the train at different intensity levels, recorded in normal ear.

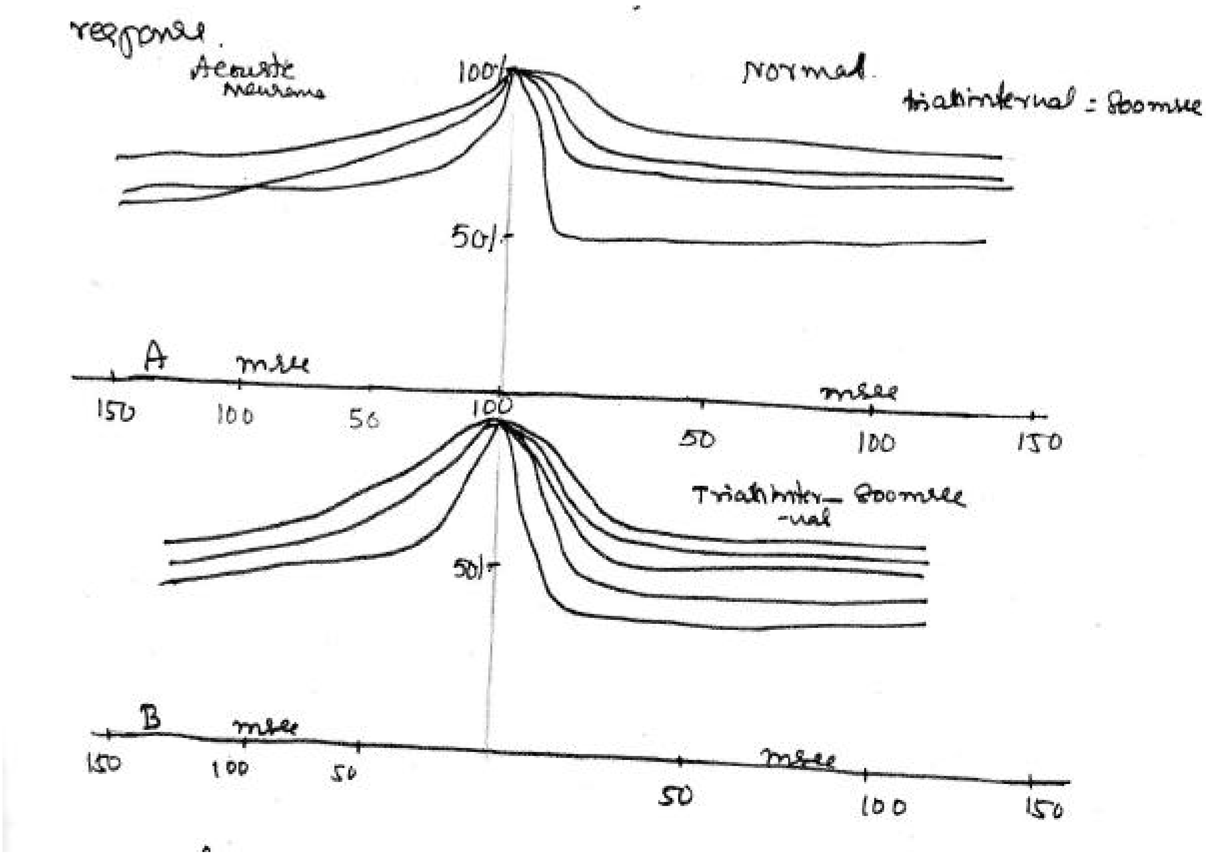


Yoshie (1971) studied abnormal adaptation is acoustic neuroma cases. He reported the following results:

1. The time course of the fast adaptation differs from that of normal hearing subjects when compared with SN Hg. loss due to acoustic neuroma.
2. Besides the abnormal pattern of auditory adaptation the patterns of electrocochlegorams (AP and CM) showed characteristics of sensori-neural defects.
3. The dynamic range of fast adaptation was narrower for the acoustic neurinoma patients than for the normal

subjects. He concluded that, electrocochlegoraphy is useful in diagnosing and measuring the adaptation in acoustic neuroma cases.

Fast adaptation causes between normal hearing and abnormal due to acoustic neuroma. In this fig, the time course of the relative amplitude, egressed as a percentage of the amplitude the first response.



A; ? T = 16msec P=10, train interval=800msec

B; ? T = 8msec P= 20, Train interval = 800msec.

Sudden Hearing Loss

A sudden hearing loss may result due to different causes ranging from profound anemia to congenital syphilis, from multiple sclerosis to viral infection, from labyrinthine drops to vascular lesions of the brainstem and cochlea (Morrison and Booth, 1970). The electrocochleographic findings in these cases re as diverse as the multiplicity of etiology would suggest. Iwata et al (1976) have investigated many cases of sudden deafness. One of their most interesting findings was that those patients with relatively large negative SP contributions to the SP/AP complex had a significantly better prognosis than those patients with monophasic or diphasic waveforms. This finding would suggest that patients with labyrinthine hydorps fair than those with other disorders, which has been suspected clinically for some years.

Nishida, Kumagani, (1976) studied the usefulness of electrocochleography in the estimation of prognosis of sudden deafness. In subjects with normal hearing, the various wave form pattern of AP N_1 and SP responses obtained compared with various waveforms of sudden hearing loss. Different kinds of wave forms seen in sudden hearing loss are:

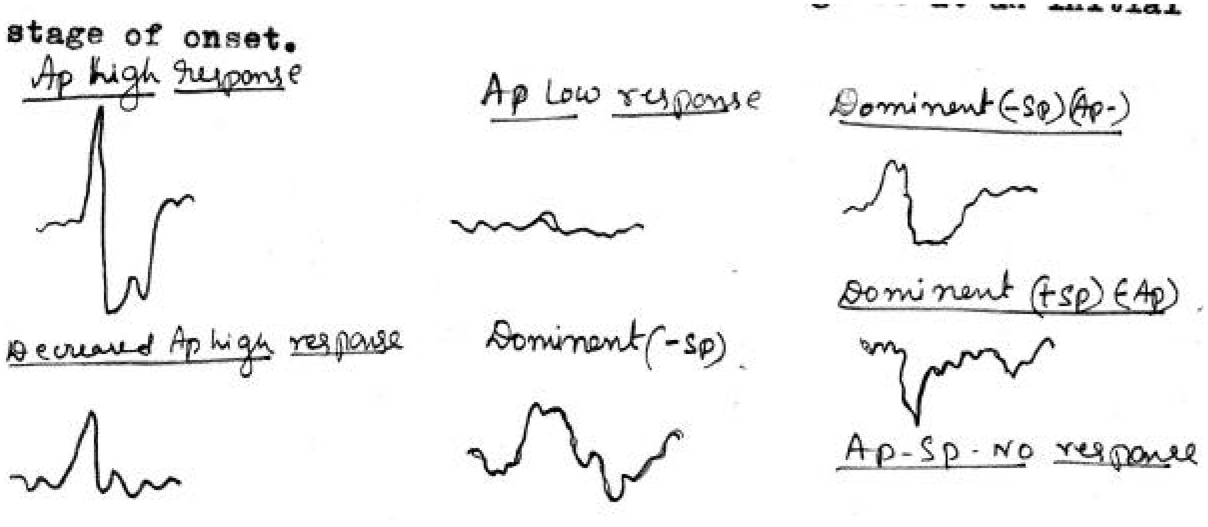
1. **AP high response** – The wave form of AP response have an

intensified amplitude and a loss of the L part. The increment of N1 amplitude is steeper, with increasing intensity in input-output functions.

2. **Decreased AP high response – The wave forms of AP** response have decreased AP amplitude in the H part and a loss of the L part. The increment of N1, amplitude is minimal with increasing intensity.
3. **AP low response** – The wave forms of AP have a notably low voltage and delayed latency at a sound intensity of 90 to 100 dB HL that is same as the amplitude recorded from the L part in subjects with normal hearing.
4. **Dominant SP** – The dominant SP has an amplitude almost equal to that of AP or a voltage much higher in the H part than that of the normal subject.
5. **Positive SP or negative SP** – The wave forms of only the SP response have a positive or negative deflection that develop immediately after the starting of cochlear microphonics. No. AP response is obtained.
6. **AP and SP no response** - The wave forms show no AP and SP response, even at the maximum sound intensity.

Patients with sudden deafness, those who showed dominant SP or AP high response wave forms in the electrocochleography performed at an early stage of onset demonstrated complete recovery or remarkable improvement within one month. In the cases in which there was not 38 response in puretone audiometry, the electrocochleography response to a sound intensity of 90 to 100 dB Hz failed to demonstrate a sufficient difference in pattern to allow for an estimation of the prognosis. However, the cases in which AP high response and dominant SP negative forms appeared in the electrocochleography at a later date, after the hearing loss had slightly improved, resulted in remarkable recovery.

The patients who had electrocochleographic wave forms that indicated unsatisfactory prognosis hardly showed any change in their hearing loss from the time of no response in puretone audiometry. The dominant negative SP and AP high response wave forms that indicated a satisfactory prognosis resembled quite closely the electrocochlegoraphic findings at the time of an attack of Menieres, disease. The fining of dominant negative SP or AP high response seem to indicate some functional change of the endolyne phatic space. It was estimated that in such a condition, the neurosensory epithelium or the cochlear nerve being affected temporarily in its function. Change of the endolyn phatic space was in a condition similar to the physiologic block that is observed in the type of peripheral facial never palsy that has a satisfactory prognosis. Nishida Kumagani (19) conclude that electrocochleography could be used as a means to estimate prognosis of suddent deagness at an initial stage of onset.



Yoshie (1973) has described a kind of selective substantive loss of the most sensitive sensory units seen in unilateral sudden hearing loss. The wave form of the AP recorded from the worse ear was different from those recorded from the normal ear of the same subject. The input-output relation of N_1 in sudden hearing loss represents the H curve pattern, but the pattern of the input-output curve of N_2 is eventually identical to that of the L curve for the normal ear. The depression and recovery of the wave forms of the AP may be related to reversible subtractive loss of the most sensitive units in the basal turn.

Electrocochleographic results in mumps disease

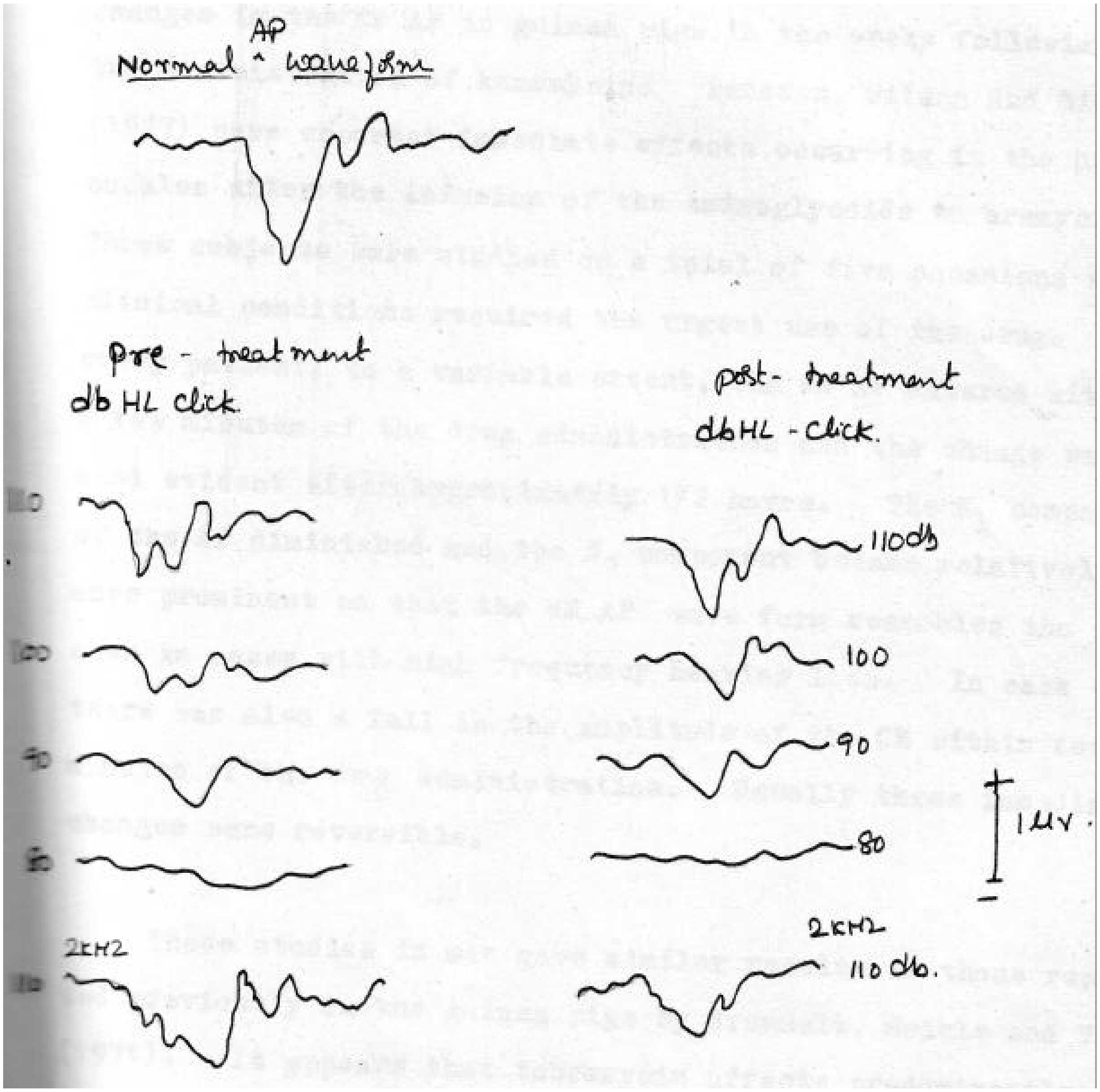
Mumps is a viral disease that is mostly seen in infants and it also affects organs other than the parotid gland. Sawada (1979) performed electrocochleography on 16 affected ears of 15 dear patients whose deafness had rustled from the memps. Although puretone audiometry showed no response in each ear, the cases of mumps deafness can be classified into the following 3 types of cochlear impairment according to the CM response (1) No AP response but a well developed CM response, with impairment at the neural level and probable functioning of the cortis organ. (2) Absence of both the neural and corti's organ (3) No AP response but a decreased CM response, with serve impairment of the neural regions and partial impairment of corti's organ.

Syphilitic hearing loss

In this condition the endolymphatic hydrops is more masked than in Meniere's disorded and, in addition, there is an extensive hair cell loss especially in the hasal turn of the cochlea, with retrograde neural degeneration involving the spinal gauglion.

Ramsden, Moffat and Gibsen (1977) investigated a series of 30 ears mostly with the rate onset congenital form of the disease. They reported that the CM was invariably minute. The AP was of small amplitude and often diphasic. In 77.7 percent of cases, the SP affected more than one quarter of the descending (negative –going) limb of the AP, but, the SP rarely affected the upgoing limb as it so commonly does in Meniere's disease. The enhanced negative SP may possibly be explained by a shift of the Basilar and Reissners membranes owing to the end-dynphatic hydrops which characterize the pathology. In syphilitic hearing loss, only few hair cells remain intact,. This related to the difference in hair cell damage occurring in the two conditions.

The Electrocochleogram obtained before and after penicllive and steroid theory in a patient with congenital syphilis. [Ramsden, R. T. et al. 1977)



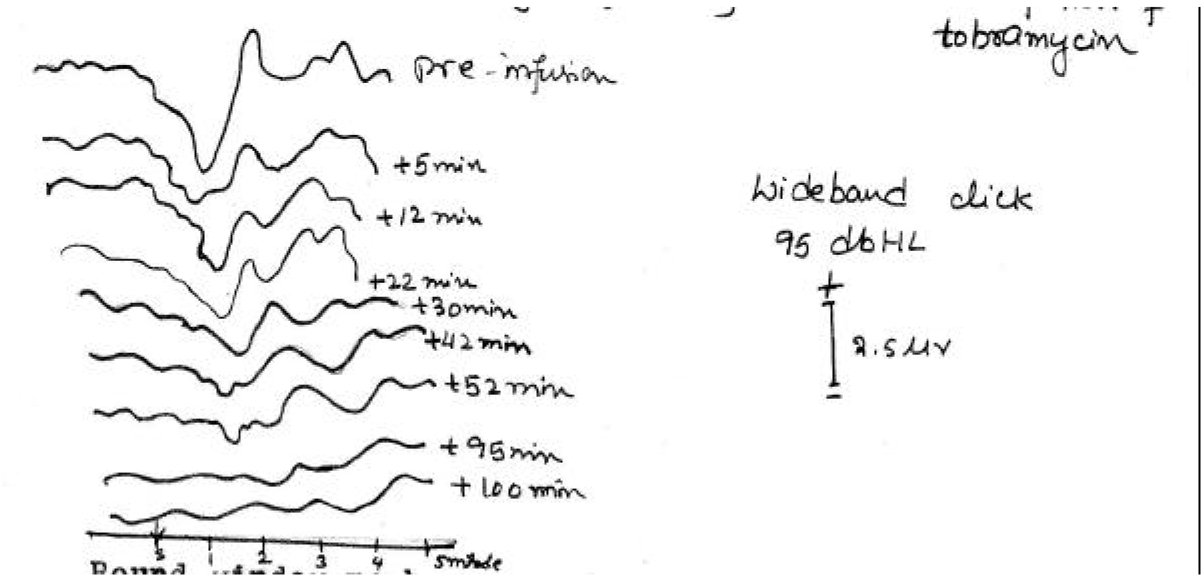
Ototoxic cochlear damage

Aran, Darouzet and Errel (1975) have noted specific changes in the WN AP in guinea pigs in the weeks following the administration of kanamycin. Ramsden, Wilson and Gibson (1977) have reported immediate effects occurring in the human cochlea after the infusion of the aminoglycoide to bramycin. Three subjects were studies on a total of five occasions were clinical conditions required the urgent use of the drug. In every patient, to a variable extent, the WN AP altered within a few minutes of the drug administration and the change was most evident after approximately 1 1/2 hours. The N1 component of the AP diminished and the N2 component became relatively more prominent so that the WN AP wave form resembled the form seen in cases with high frequency hearing loss. In each case there was also a fall in the amplitude of the CM within few minutes of the drug administration. Usually these immediate changes were reversible.

These studies in man gave similar results to those reported previously in the guinea pigs by Brummelt, Meikle and Vernan (1971). It appears that tobramycin affects predominantly the outer hair cells within the basal turn of the cochlea.

Ramsdan (1977) studied a patient who received gentamycin drugs. In no case was there any change apparent during a 2 hours period after the infusion. A comparative study in the guinea pig has shown gentamycin to be more ototoxic than tobramycin (Brummett et al 1972). This illustrates the difficulty in determining the ototoxicity of substance in man from animal experiments. Electrocochleography may be of great value in offering an opportunity of assessing the early effects of a drug in the individual patient.

The immediate Ecoch changes following intravenous infusion of tobramycin



Ruben and Gibson have tested 2 cases affected by rupture of the round window membrane. In each case the CM was vrtually unobtainable and there was a slightly enhanced negative SP. The WN AP showed some recruitment in its functions and had a diphasic pattern. The finings that the CM was unobtainable would support the belief that the CM obtained by transtympanic electrocochleography is obtained only from hair cells situated on a limited area of the basilar membrane close to the round window membrane

Lermoyez's syndrome

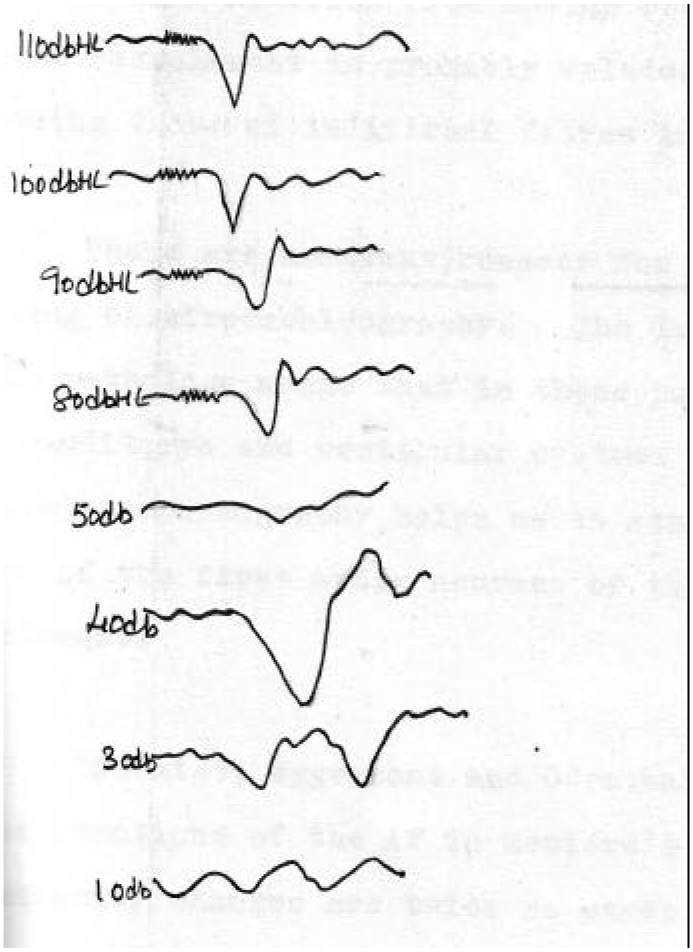
Lermoyez's syndrome (Lermoyez 1929), is a variant of Meniere's disease rather than an independent entity (Bailie 1956, Harrison and Naflalin, 1968).

Schmidt, Odenthal, Eggermant and Spoor (1975) investigated a case of Lermoyez's syndrome by tone burst electrocochleography in both a period of almost normal hearing and of impaired hearing. They have compared results obtained on the subject with 22 Meniere's disease patients. They observed, abnormal steep input/output curves for the AP (2) normal amplitude-Latency curves, except for 8 KHz. According to them, the case of Larmoyez's syndrome is closely related to Meniere's disease as far as the cochlea is concerned.

Tinnitus and electrocochleography

Giblan and Ruben (1978) tested several young adults, each suffering mainly from tinnitus. They complained also that their hearing was of poor quality eventhough puretone audiometry failed to show any hearing loss. In each case the electrocochleography revealed a massive CM in the affected ear which was superimposed upon the AP despite the use of stimulus phase alternation. The functional significance of this finding is unknown but one may surprise that some disorder has affected the cochlear efferent activity.

The figure represents the Electrocochleogram of an ear affected by tinnitus and Massive CM in the affected ear



Meniere's disease

Meniere's syndrome is characterized by symptoms of vertigo hearing loss and tinnitus, and occurs commonly in many pathological conditions including vertebra basilar insufficiency, congenital syphilis, autoimmune disorders etc., In Meniere's disease hearing fluctuates, especially in the lower frequency range, and this is a result of a endolymphatic hydrope which prevents the basilar membrane from moving freely. The presence of loudness recruitment is probably related to deterioration in the tuning curves of individual fibres induced by cochlear ischemia.

There are numerous reasons for studying Meniere's disease using electrocochleography. The labyrinthine localization of the pathology means that in these patients the peripheral part of auditorya and vestibular systems is of special interest. Electrocochleography helps us to study function of the cochlea and of the first order neurons of the auditory system in Meniere's disease.

"Schmidt, Eggermant and Odenthal (1974) have investigated the functions of the AP in Meniere's disease. The amplitude/intensity changes are twice as steep in Meniere's disorder when compared with the normal cochlea. These changes indicated the presence of recruitment. The latency/intensity functions differ from those obtained in cases with hair cell loss; the span of latency is similar to normal, but abrupt transition in the latency value around 55 – 65 dB occurs in frequently.

In 1974 Odenthal and Eggermant tested 5 patients of Meniere's disease using electrocochleography. They divided the whole group of Meniere's disease into 2 groups:

1. Early stage of Meniere's disease;
2. Advanced stage M.D. electrocochleography was performed on each case of early and advanced stage of Meniere's disease.

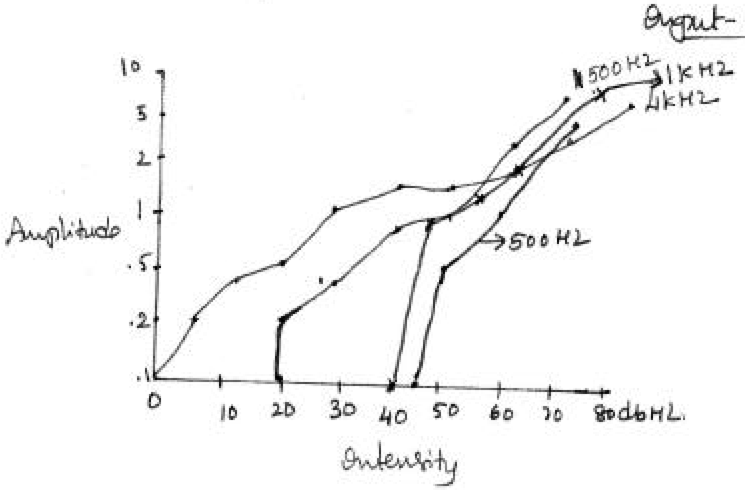
Early stage of Meniere's disease

Input-output curves at various frequencies show much steeper curve than found in normals. This is due to the presence of (recruitment (Eggermant et al 1974). In early stage of Meniere's disease, normal latencies were obtained at thresholds level.

Advance and stage of Meniere's disease

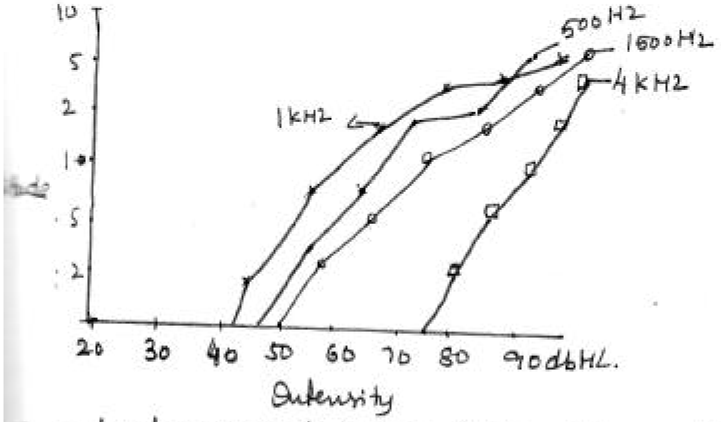
There will be threshold elevation at high frequency in addition to the typical loss for the lower frequencies. The AP wave form is very different from the normal, and a rather pronounced SP occurs at high intensities despite a considerable

Early-stage of Meniere's diease Action potential wave form and Output-Output curve



Shallow part of the 4KHz curve is not found for the lower frequencies and lower part of the low-frq curves are much steeper, due to Recruitment.

Advanced-Stage of Meniere's disease



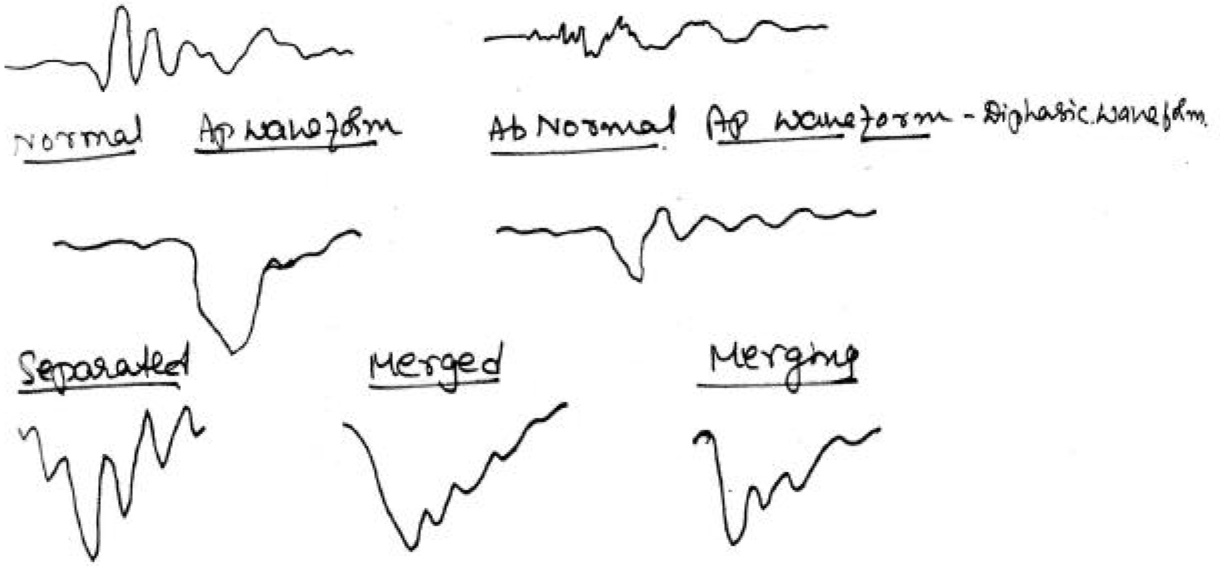
-output curves at hi frqs in the advanced case of Meniere's disease.

of these curves lack the shallow part.

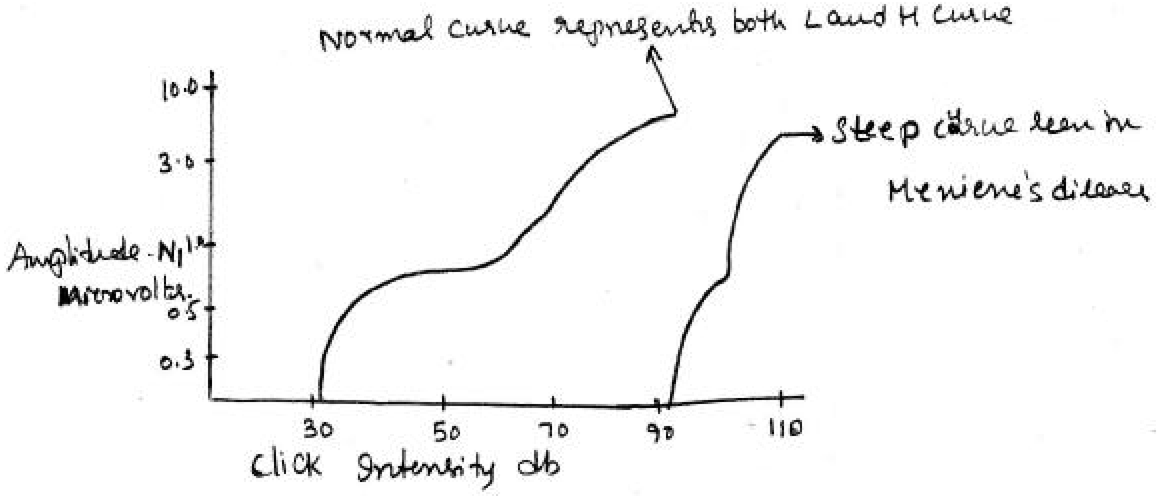
threshold elevation in the basal turn of the cochlea. The latency at the threshold at this frequency is relatively short in this case.

Gibson, Moffat and Ramsden (1977) found that the more certain the clinical diagnosis of Meniere's disorder, the most striking feature was to be widening of the SP/AP wave form. The presence of an abnormal SP may be related to the endolymphatic hydrops as Moffat (1977) has shown that the SP amplitude decreases after the administration of glycerol to the patient. Schmidt, Eggermant and Odenthal (1974) did extensive study in Meniere's diseases cases using electrocochleography. They have grouped the results as abnormal pattern obtained in cases of Meniere's disease.

Electrocochlegraphy in Meniere's disease [Gibsan W.R et al 1976]

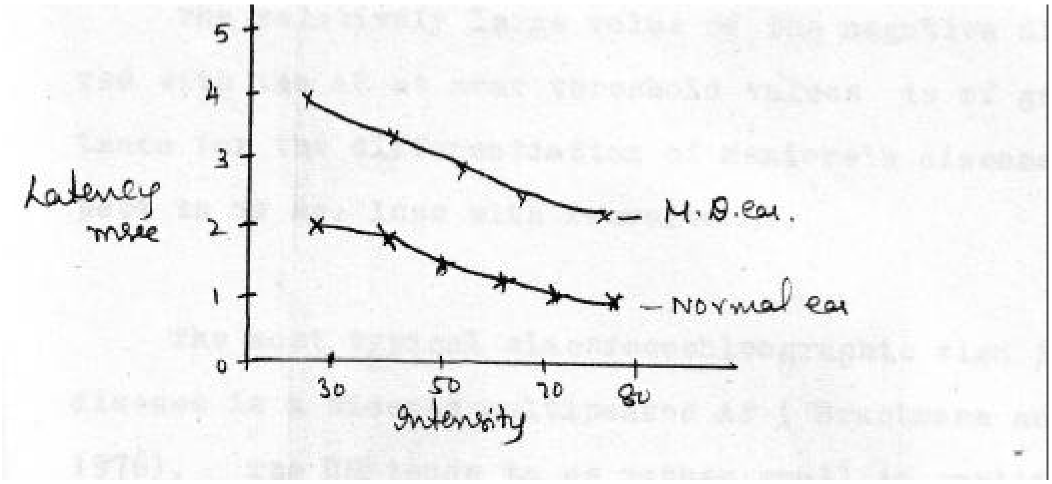


Input-Output properties of the Meniere's disease Action potential



It was noted that the threshold is elevated compared to normal cochlea. The output at about 90 dB Hg level is generally higher than in the normal cochlea. The slope of the input/output curves for the AP in Meniere's disease is found to be the same as the slope of the high frequency hearing loss and is twice as steep as the slope found in normal cochlea.

Latency, in general, in Meniere's disease is larger than in normal hearing at the same intensity and smaller than for normal hearing at the same sensational level.



Summating potential

The summating potential can be distinguished from the AP by its lack of adaptation. Unlike the AP, the AP, being a presynaptic potentials does not show an amplitude change as a function of stimulus interval.

In Meniere's disease, negative SP output can be of the same order of magnitude as the AP. This clearly differentiates Meniere's from that of high frequency hearing loss. At some intensity level, the negative SP is about 5 times larger in Meniere's disease than in high for hearing loss. The mean value of the negative SP in Meniere's disease does not differ significantly from that found in normal hearing subject, due to the elevated threshold, however, the value of the negative SP relative to the AP near the threshold is much larger in M.D than in normal hearing.

The relatively large value of the negative SP as compared with the AP at near threshold values is of great importance for the differentiation of Meniere's disease with respect to SN hg. loss with recruitment.

The most typical electrocochleographic sign in Meniere's disease is a widened multipeaked AP (Brackmann and Selters 1976). The CM tends to be rather small in amplitude and distorted and there is usually a well masked negative summating potential as Eggermant showed (1976a). Occasionally there is a positive spike immediately before the negative AP peak (Aran and Portmann, 1976) which has been attributed to a positive SP; this may indeed be so especially where there is a loss of basal hair cells.

Recruitment in Meniere's disease

1. The SISI test in relation to AP input-output curves for amplitude-modulated signal

Eggermant and Odenthal (1974) investigated to see the presence of recruitment in Meniere's disease cases. They have compared SISI test scores with AP input-output curves. AP amplitude was given as a function of the intensity increment super imposed on a continuous tone of 20 dB SL. The intensity increment envelope was the same shapeaned duration as that of the short bursts, cases who had high SISI scores showed steep N_1 AP amplitude and cases who showed low SISI scores had flat AP N_1 wave form.

Eggermant and Odenthal (1974) concluded that the SISI score is related to the AP output in response to amplitude modulated tones, which depends only on the intensity of the continuous tone.

Amplitude-latency relations in Meniere's disease

The slope of the amplitude latency curve is almost independent of frequency in the Meniere's disease cases. In Meniere's disease, in contrast to high frequency SN hearing loss, the amplitude latency curves, for 1500 and 2 KHz are not significantly different from those found in the normal cochlea. For 4K and 8 KHz at near threshold values latencies are some what shorter than found in the normal cochlea but it generally exceeds 3 M sec. If normal or near normal amplitude latency relations are seen in Meniere’s disease cases, it means that there is no selective outer hair cell loss to imply that in Meniere’s disease, atleast for frequencies upto 2000 Hz, recruitment is not due to a selective loss of outer hair cells (Schmidt, Eggermant and Odanthal, 1974).

The cochlear microphaic in Meniere’s disorder tends to be smaller and distorted Gibsen et al (1977a) found that the CM evoked by a click stimulus of 110 dB HL had less than 2 hr. peak amplitude in 58% of their cases.

The presence of a broad SP/AP wave form and a small CM provides an objective confirmation of the clinical diagnosis of Meniere’s disorder. It is possible to use these abnormal responses as a means of monitoring the immediate effects of drugs. Gibson, Ramsden and Moffat (1977) by injecting a vasodilator (Naftidrafurye) intraneously observed a little change in electrocochleography in normal cases and reported that the abnormal responses often altered. The amplitude of the cochlear microphaic increased within a few minutes of the infusion and gradually, over several minutes, the amplitude of the negative SP decreased. These changing may provide evidences to support a vascular etiology in Meniere’s disease.

Aran and Sauvage (1974 reported that characteristics of broad AP response in Meniere's disease indicate the presence of hair cell loss and the nerve fiber activity.

According to Odenthal and Eggermant (1974) the most striking features of Meniere's disease are steep <u>input-output curves, relatively long threshold latencies</u>, and <u>normal amplitude latency</u> curves and relatively large SP values near the AP threshold.

Diagnosis of Acoustic Neuroma and Small tumors

The acoustic tumor develops from the neurilomma of the auditory never, usually in the superior vestibular division, but occasionally in another division or even in the cochlear nerve itself presence of the tumor especially when laterally placed in the internal auditory meatus (IAM) courses a neural type of hearing loss, and other cochlear effects due to vascular changes.

Acoustic neuromas fall into 2 main categories:

1. Laterally placed in the IAM cause early unilateral audiometric changes and should be detected early; and
2. Tumors which are placed medially in the cenebellopontine angle, tend to be more silent in the early stages and show symptoms of cenebellopontine angle tumor with brainstem compression (Beagley and Giblan, 1976).

Electrocochleography plyas an important role in diagnosing the cases of acoustic neuroma.

With the help of input-output curve, latency intensity curve and AP wave form we can diagnose the acoustic neuroma cases.

Portmann (1973) demonstrated a delayed conduction time of the action potential (AP) in response to “clicks” in patients with acoustic neuroma.

Beagley and Gibson (1976) observed 4 distinct patterns in electrocochleographs in acoustic neuroma cases.

1. The first pattern consisted of absence of AP or diminished AP with a large CM in A Neuroma cases, there may be no AP at maximal intensities or it may have a high (above 90 dB) but the CM tray be clearly visible at 60-70 dB. The CM will have larger amplitude. These findings suggest a presence of neuroma which is suppressing the AP generation nerve fibers, but sparing cochlear hair cells to produce a microphaic potential.
2. Second important pattern was the absence of subjective hearing but the presence of an evident AP. This mostly happens because tumor causes a complete neural block at some point along the cochlear nerve preventing the AP being transmitted centrally. As it cannot pass along the auditory tract, it is not detected by the patient as an audible stimulus when using a subjective hearing test. But peripheral to the neural block the cochlear nerve continues to functions as shown by the presence of a typical

Ap. In these cases, it is necessary to rule out the presence of a non-organic hearing loss using AER.

3. A third important characteristic electrocochleography pictures is that the electrocochleography threshold is lower than the subjective threshold. Electrocochleography shows greater auditory acuity than the conventional puretone audiogram in cases with acoustic tumor.

   Gibson and Beagley (1976) reported that 19 (27%) of the 71 ears with A.N. showed electrocochleography thresholds to be atleast 15 dB more sensitive than subjective audiometric thresholds.
4. Fourth distinct pattern electrocochleography pictures is that of a widened and distorted AP. It was frequently observed in early laterally placed neuromas. The presence of widened AP may be as wide as 5 to 20 M sec and it was consistent with the presence of an acoustic neuroma.

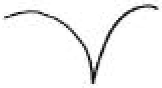
Teas et al (1962) reported the generation of AP to be due to the combined activity of the cochlear nerve fibers both within the modiolus and within the I.A.M.

Beagley et al (1977) have indicated experimentally that

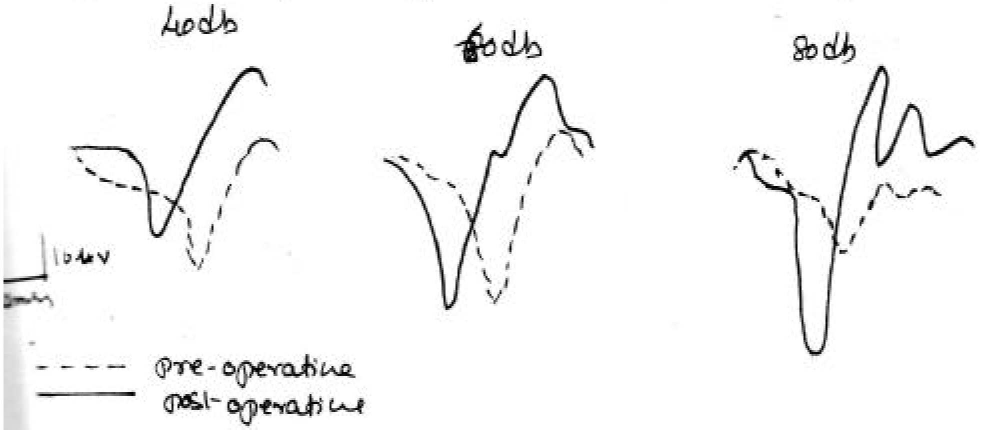
Action potential waveform in Acoustic neurama canal

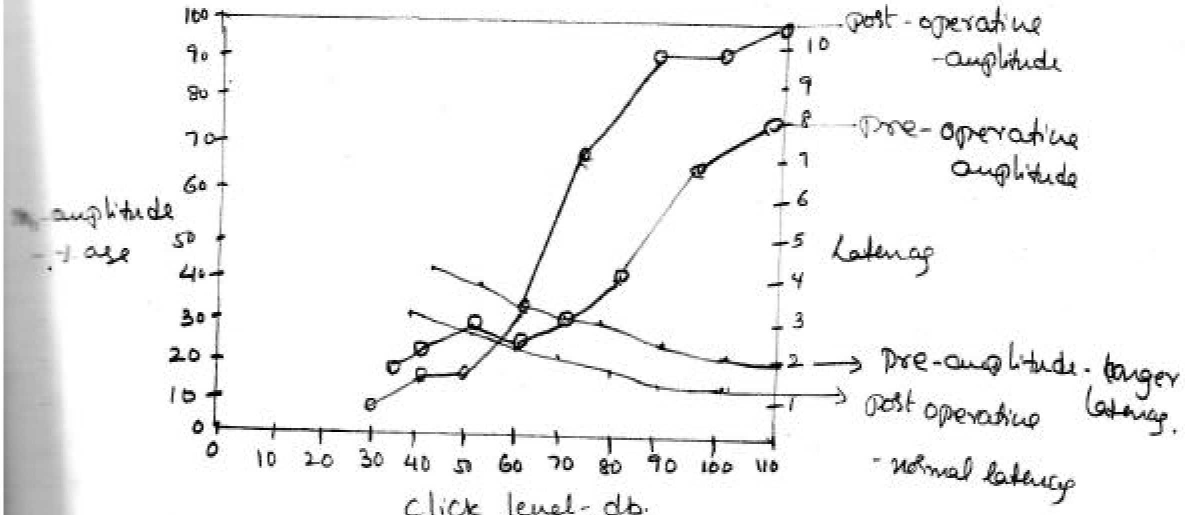
Normal AP waveform

Abnormal AP wave form



pre & post operative wave forms showing return to normal form postoperatively in acoustic neurama. [Brackman & Selters 1973)





pre- post operative findings showing normal latency and increased amplitude post operatively.

deactivation of the cochlear fibers at the IAM caused. Widening of the AP response.

Brackmann and Selters (1973) tested 25 cases with acoustic neuroma. In 9 of the 25 cases, they were unable to obtain APs. All of them had server high-tone loss on behavioral audiometry. In 16 cases in whom APs were obtainable, the loss was within 10 to 20 dB of the audiometric threshold at 4 KHz. Threshold latency was, reported to be shorter than found in normal ears. The values varied from 1.7 to 4.9, with a mean of 3.1 me sec (in normal ears it varied from 2.9 to 4.3, with a mean of 3.7 m sec). At high intensities the latency was normal in 12 cases, whereas it was prolonged in four. The values varied from 1.3 to 2.9, with a mean of 1.7 m sec.

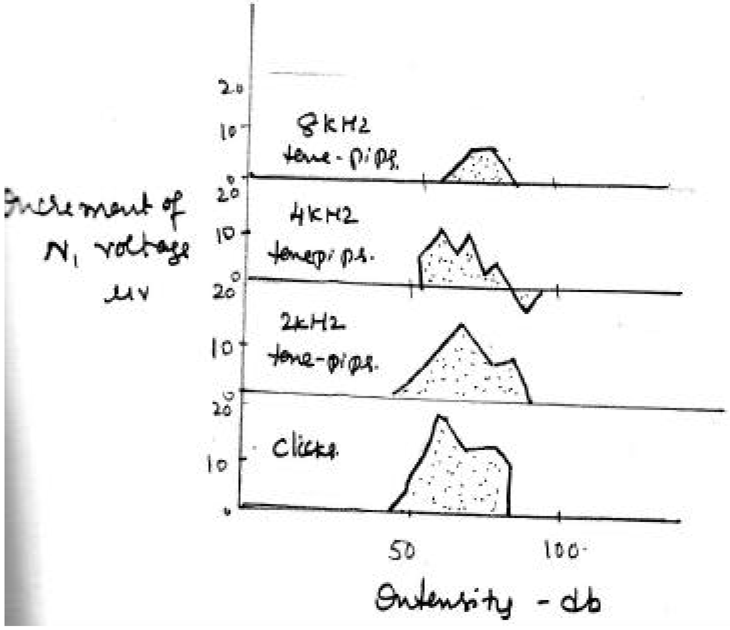
There was a small diminution in the maximum amplitude of AP in tumor cases when compared to normal ears.

Odenthal and Eggermant (1976) examined the AP derived using high pass masking in cases with eighth nerve tumours and reported that the wave form was often manophasic. This is a most useful observation as it aids considerably in the differential diagnosis between Meniere's disorder (diphasic deviced AP) and retrocochlear pathology (menophasic AP). The monophasic shape of the derived AP may be due to conduction defect in the passage of the nerve impulse (Beagley et al 1977).

The broadening of the SP/AP wave form may be explained by the convolution of menophasic unit potentials. Gibson and Beagley (1976b) have suggested that the broadening is due to the superimposition upon the AP wave form of an SP like potential. The SP/AP wave form was widened by over 4 m sec in 71% of the patients with tumors.

On many of the patients with eights nerve tumors, there is a brief positive wave preceding the broad negative SA/AP wave form. This wave probably represents a positive SP component which may be related to hair cell damage close to the round window membrane.

Yoshie (1973) described a kind of random subtractive loss seen in acoustic tumor. According to him,



This fig represents the Increments in voltage of the N_1 Components/5db Increase in Intensity.

The input-output curves for all the frequency were approximated similar to that of 'H curve' pattern, but the outputs showed the maximum voltages attained. At the maximum value the amplitude of N_1 formed a plateau. The amplitude increment relation provides alternative information to the input-output relation. It suggests that there may be a random subtractive loss due to disproportionately large amount of neural defects. In this case the latency of N_1 was increased considerably with a decrease in intensity.

Differential diagnosis of Meniere's disease and acoustic neuroma

The problem of differential diagnosis are maximal when one is faced with a widened manophasic AP in one ear only, which could be the result due to an early acoustic neuroma and/or due to a unilateral meniere's disease. It is usually found that careful inspection of the wave forms gives most of the information required to differentiate between them.

The differential diagnosis between early Meniere's disease and early cases of pontine angle neurinana can be based on at least two electrocochleographic findings:

a) The relatively pronounced SP amplitudes at high stimulus intensities in Meniere's disease, and
b) Extremely long AP latency values at low-stimulus intensity values in pontine angle neurinana.

To assist in differentiating between the two conditions, Eggermant (1974) proposed two separate techniques, using adaptation and high-pass masking. The techniques of narrow-band analysis by successive high-pass masking offered the best theoretical possibility of clinching the diagnosis where there was a widened AP in acoustic neuroma. In this condition there was almost certainly a marphasic unit response instead of a diphasic unit response as a result of the absence of the central contribution from the cochlear nerve fibers. When the morphasic unit responses were convoluted the widened AP typical of acoustic neuroma was seen. Successive high-pass masking by Eggermant's method gives a good idea of the underlying unit response and this should be monophasic in early neuroma cases.

The use of adaptation of the AP to separate – SP is particular valuable in Meniere's with multipeaked wave forms. When total adaptation is achieved, the normal AP remains very clear. However, in complete adaptation may occur an objectionable artifact on subtraction causes cases, namely a falsely diphasic AP and no reliance be placed this finding. The essential problem remains as to differentiate a conspicuous – SP from the widened AP of acoustic neuroma. One important observation relates to the time of onset of the negative deflection. If it is a true SP it should start with the onset of the cochlear microphonic and be practically conterminous with it when tone-burst stimulation is used. A rather low frequency, tone-burst Eg 8 cycle of a 2 KHz sinusoid, seems to be the best stimulus to elicit a SP in Meniere's disease, probably because it will cause its maximal deflection at a wider and more lax part of the basilar membrane than would be high frequency tone-burst such as 8 KHz cause. If the SP can be removed by the adaptation technique and a normal AP can be seen.

It is postulated that the widened notched wave form is due to SP and the clearly separated N_2 and N_3 peaks are the result of the hydrops impending the travelling wave so that the successive peaks tend to be seen individually rather than being in incosporation more closely with the N_1 peak.

Other pathologies affecting the eighth nerve

Any lesion affecting the eighth nerve affects the electrocochleograph in the same manner as a Schwanoma (Beagley and Gibson, 1976). Intracochlear neurofibromatosis, a condition in which the tumor affects the nerve at the modiolus, usually results in a very wide SP/AP wave form.

Basilar artery ectasia (Gibson and Wallace, 1975) does not produce much widening of the SP/AP wave form. The more medial the site of the pathology, the less likely it is to produce widening SP/AP wave form and more likely to produce an objective electrocochleography threshold that is more sensitive than the psychophysical hearing threshold.

Brainstem leniar and electrocochleography

Aran and his colleagues (1971) described the electrocochleography findings in cases of kerniocterus and a condition in which the basal ganglia of the brain are damaged by bile staining in the presence of high bilirubin lavels in the blood. This is most commonly occurs in cases of haemolytic disease of the newborn which is due to rhesus incompatiability between the baby and its mother. Usually kernicterus cases have lesion in the brainstem nuclei.

Elecrocochleographic findings in kernicterus cases yield a broad SP/AP wave form often with a sharp positive peak at its onset. Aran et al (1971) describes this wave form as ‘anormale’.

Lesions which affect the brainstem above the level of the cochlear nuclei may not affect the electrocochleography. Electrocochleography alone cannot differentiate between medially placed tumours and non-organic hearing loss, but if it is combined with other methods of ERA, such as BER or CERA, the site of the lesion may be determined with certainty.

Objective Bone Conduction audiometry using electrocochleography

Cody et al (1968) were the first to design AER to determine bone conduction thresholds objectively one of the disadvantages of determining bone conduction using AER is that it needs masking of the contralateral non-test ear.

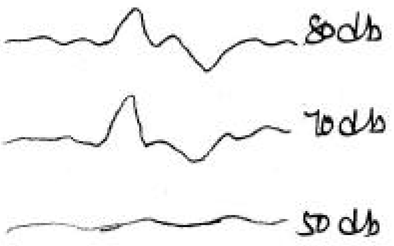
In contrast, to this AER technique, electrocochleography needs no masking for the ear which is not under test. The preliminary investigation of bone conduction electrocochelography was carried out by Yoshie et al (1973). They used clicks or tone pips as bone conducted stimuli to elicit the AP from the cochlea in man. Comparisons were made between the air and bone-conduction AP responses in normal hearing subjects. The input-output and intensity-latency curves of N_1 for 4 KHz tone pips by bone conduction were almost identical to those of air conduction. There was a relatively good agreement between bone conduction AP threshold and bone conduction subjective thresholds, but the agreement was not better than that for the air conduction AP measurements.

An air-bone gap was determined objectively by comparing the input-output and latensity-intensity relations of the bone-conduction AP and the air conduction AP. Conclusion drawn by Yoshie et al (1973) was that, the promontory recorded AP measurements by bone conduction will be very useful to determine the degree of air-bone gap.

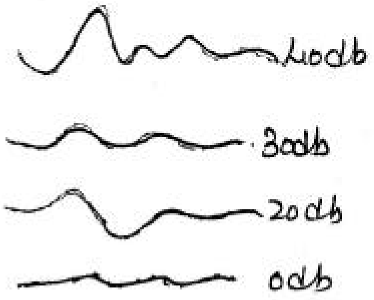
They compared 15 patients with conductive hearing loss and 10 patients with SN hearing loss. They found a good agreement between BC threshold of AP wave form and conventional BC threshold.

Typical promontory record AP response to Ac and Bc stimuli

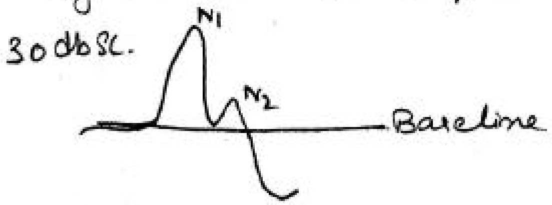
Ac Electrocochleography



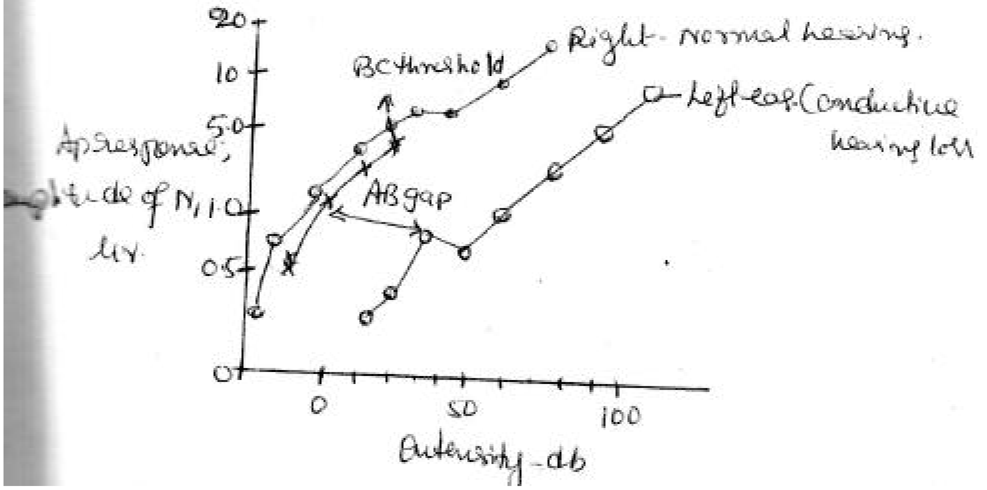
Bc Ecoch



Typical Bc response (yoshie 1973)



objective estimation of air-bone gap c̄ the help of Ecoch



Assessment of Air-bone gap in young children using elecrocochleography

Berlin et al (1978) reported that long standing conductive losses led to dystrophies in the cochlear nucleus and medial nucleus of the trapezoid body. They used BC electrocochleography in young children, to find it expedient to use BC electrocochleography in infants under 18 months and to bypass the need for traditional audiometry, masking etc., This helps in early detection and quantification of conductive losses in children. Thus, the electrocochleography diagnostic procedure to determine cochlear response often by coupled with a therapeutic procedure.

Application of BC electrocochleography in adults

Berlin et al (1978) illustrated 2 cases in whom the auditory masking dielema was present. In those two cases, BC electrocochleography helped to confirm the essential integrity of both cochlear.

Problem seen in BC electrocochleography

BC electrocochleography presents a major problem with respect to calibration of the acoustic signal like clicks and tone pips. The output of a bone conduction vibrator is subject to much more distortion that of a loudspeaker for the same signal.

The wave forms of vibratory bone-conducted clicks were relatively dull, but the air conducted clicks were very sharp.

Conclusion

Electrocochleography is considered as one of the main objective test as it fundamentally measures the peripheral auditory function which helps in the diagnosis understanding and treatment of sensoryneural hearing loss.

CHAPTER IV

AVERAGE EVOKED RESPONSE AUDIOMETRY

Discovery of perceptual fluctuation of the electrical potential in the animal cortex was made in 875 by Catan. He described tham as “feable currents of the brain”. First recordings from the human brain were made in 1924 by Mars Berger (1929). He used the term electroencephalogram (EEG) to describe these potentials. Berger (1929) established that these potentials originated from the neuronal tissue and that the potentials changed with sensory stimulation.

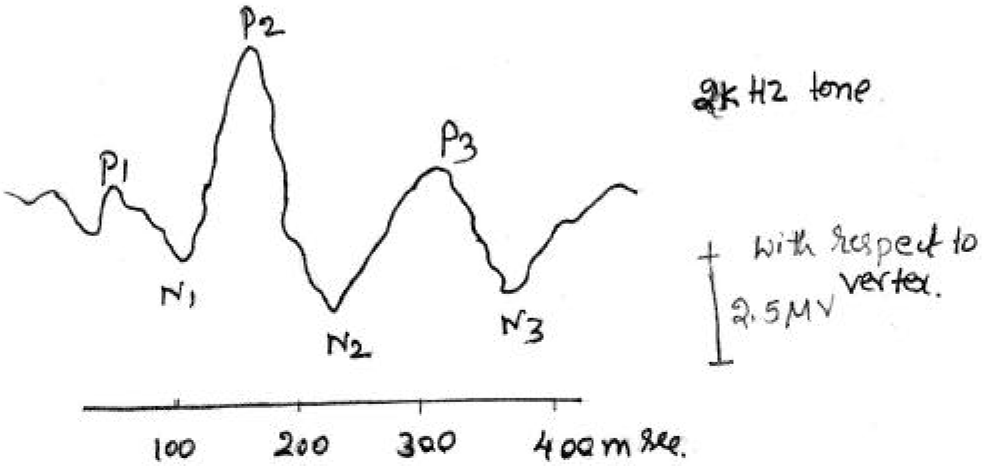
The responses evoked by auditory stimuli are maskedly attenuated by surrounded tissue and the signals were difficult to be separated from those of ambient noisy. This inseperable barrier of recording human evoked responses has been surmounted by the recent development of electronic computers. The averaging techniques using a computer has made it possible to identify small evoked responses which are otherwise masked with electrical background activity (Suzuki, 1969).

Nature of the auditory electroencephalographic response

The auditory electroencephalic response (AER) can be divided some what arbitrarily into four classes of responses on the basis of latency, different properties, and presumably different anatomical sources. They have been identified by their latencies from the onset of the signal as:

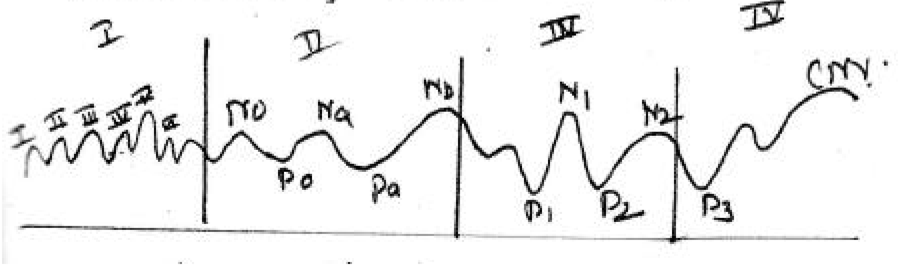
a) early components when latency varies from 4 to 8 m. sec;
b) as middle component when latency varies from 8 to 50 m. sec;
c) as late component when latency varies from 50 to 300 m. sec;
d) as very late component when latency varies from 300 m sec to several seconds (DC shift);

The early response is comprised of a series of "very fast waves" (100 to 200 Hz) which presumably arise from the brainstem (Jewett and Willisten 1971, Lev and Sohmer, 1972). The middle response comprised of a series of "fast waves" (5 to 100 Hz) which primarily arise from the primary cortical projection area (Goldstein, 1969). The late AER is comprised essentially of slow waves (2 to 10 Hz) (Appleby, 1964, Scott, 1965) which presumably arise from the primary cortical projection and secondary association areas. "Very late" responses have been described as the expectancy wave which is the last peak in the late response and the contingent negative potential (De shift). This response presumably arises from the frontal cortex (Walter, 1964).



A typical adult Response.

Representation of the 4 classes of AER.



Classes of Avenaged evoked response

Classification	Origin	Waveform	Lating	Amplitude
Early	Brainstem	Fast[100-200Hz]	4-8 msec	50µv-1µv
Middle	Primary cortical projection area	Fast [5-100Hz]	8-50 msec	0.7-3 µv.
Late	Primary cortical projection area& 2nd association areas	Slow [2010Hz]	50-300 msec	8-20 µv
Verylate expectancy & CNV	Prefrantal cortex & 2nd easy association areas	Slow Dc	230-360 msec 300+msec	10-20 µv 10-30 µv

Influencing factors in evoked response audiometry

Intensity

The stimulus parameter that exerts greatest influence on the response wave form is intensity. As the loudness of the test stimulus increases, the amplitude of the evoked response usually becomes greater.

The relationship between signal intensity and amplitude of early and middle components is not definitive (Skinner, 1978). In general, response amplitude increases monotanically atleast at low intensity levels, but components may very in amplitude at moderate and higher intensity levels. The relationship is confounded among the early components by the relative influence of the emergence and growth of various wavelets.

Glattka (1975) and Starrand Achor (1975) indicated no consistent relationship between intensity and increase in amplitude. Davis and Zerlin (1966) pointed out that the Input/Output relationship is not a linear function. The sensation of subjective loudness grows at a much faster rate than does the amplitude of the evoked response. Wolfe et al (1976) found a monotonic relationship. Latency of the various peaks of the early response consistently diminished with increased signal intensity and provided the most stable, stereotyped characteristic (Hecox and Galambos, 1974; Glattke, 1975; Wolfe et al 1976).

Moore and Rose (1977) showed that amplitude of the evoked response does not increase at levels above 70 to 90 dB SL.

Studies done by Rapin, McCaudlen and Best (1966) Rose and Ruhm (1966) and McCaudlen and Lentz reported a systematic prolongation in the latency of the evoked response components with lowering sensation levels. Skinner and Antinoro (1969b) and Antinoso et al (1969) reported a linear relationship between the signal intensity in dB and AER amplitude in microvolts at low and middle frequencies.

Clinically the effects of the stimulus sensation levels on the response are of utmost important in deciding whether an evoked response is present or absent. Near threshold level it is contingent on understanding how the stimulus sensation levels alter the response amplitude and latency.

Rise time

A critical stimulus parameter affecting the evoked response is the rise time of the stimulating sound. Difference in response latency can, indeed, be seen between a click having almost instantaneous rise time and a of similar intensity having a rise-time of 25 to 30 m. sec tone pipe or bursts with rise times shorter than 2.5 m sec do not elicit an early response (Cobb, Skinner and Burns, 1977).

There is a significant effect of rise time on the middle responses of AER. Lane and Kupperman (1969) reported that the AER to puretones is not a clear as the AER to clicks. Skinner and Antinoro (1970b) studied the effects of signal rise time on the middle response using fast, 0.5, 2.5, 5, 10 and 25 m sec. rise times. The responses were consistently elicited with a stable wave form at a fast rise time, but indicate that one must rely on the use of a very fast signal rise time in order to elicit clear and stable early and middle response wave forms of the AER.

Skinner and Jones (1968) and Onishi and Davis (1968) reported similar findings while studying the effects of signal rise time on the late AER. Onishi and Davis (1968) indicated the AER amplitude of the primary peaks to fall off gradually with increase in rise time upto 30 m. sec, where a more distinctive amplitude, reduction occurred. With rise times 5 m. sec to 5 m. sec, Skinner and Jones (1968) found a more distinctive drop in AER amplitude at about 25 m. sec rise time. No interaction between sensation level and rise time was observed from 30 to 90 dB SL. A rise time of

25 to 30 m. sec is optimal, since it is gradual enough to produce a pure tone sufficiently abrupting a clear AER.

Stimulus Duration

It is well known that stimulus duration is related to perceived loudness of an auditory signal. Zwislocki (1960) showed that threshold at 1000 Hz improves 10 dB for a 10 fold increase in duration upto about 200 m. sec. Temporal summation revealed by increased perceived loudness is essentially complete after durations of about 200 m. sec at 1000 Hz. Shorter durations at this frequency will result in decreased loudness or poorer threshold values.

The early and middle responses are apparently the “on effect” responses produced by the onset of signal and are unrelated to signal duration. The effects of signal duration on the middle components were studies by Lane and Kupperman (1969) and Skinner and Antinoro (1970b).

The effects of signal duration on the late AER components have been investigated by Skinner and Jones (1968) and Onishi and Davis (1968). They used a fast rise signal (10 m. sec) and observed a slight tendency for the AER amplitude to increase with signal durations upto 25 to 50 m. sec. Further increase in signal duration upto 150 m. sec had no effect on the AER amplitude.

Rose et al (1966) reported that at 40 dB SL the stimulus durations makes no significant difference in the response amplitude. At threshold level increasing stimulus duration from 10 to 100 m. sec, increase the response amplitude corresponding to a subjective increase in loudness.

Frequency

The abrupt signal rise times which are required to elicit the brainstem evoked response (BSER) produce wide energy dispersion across frequency. Hence it is suggestible to use tone pips or filtered clicks to limit energy dispersion and gain information on the frequency response of the hearing mechanism. Antinoro and Skinner (1968), Antinoro et al (1969), and Rothman (1970) reported a significant interaction between amplitude of the late AER and signal frequency, particularly at high frequencies. They reported a continued decline in AER amplitude from 250 to 8 KHZ at 30 and 60 dB SL. The differences in amplitude of AER relatively smaller at 250, 500, 1000 and 2000 Hz.

Types of auditory stimuli

Good responses can be elicited using a variety of stimuli. It is a known fact that clicks produce good responses and with the help of filtered clicks frequency specific information can be get. Puretone can also be sued as stimuli because they can be produced and calibrated according to standard audiometric reference levels. Speech, bands of noise, or other auditory stimuli may also be used to elicit an evoked response (as cited by Rose, 1978).

Number and rate of stimulus presentation

The relative success of the encephalographic response technique depends upon the efficiency with which the evoked potential can be visualized or can be “read from the background activity”. The averaging process depends on the concept that time locked stimuli grow in direct proportion to the total number of stimuli (N). The signal to noise ratio is improved by the square root of the number of stimuli in averaging N samples. Approximately 50 stimuli appear to be sufficient to produce a visible response in most subjectsm even when the stimulus is near threshold (Rosenblith, 1957).

The evoked response from a population of neurons follows many of the same physiological principles common to all neural tissue. When stimulated at an increasing rate, single neural and groups of nerves may reach a point at which they have insufficient time in between stimuli to recover or to permit continued firing. The neural tissue responsible for the slow components of evoked response behaves in some what the same fashion; that is, if stimuli are prevented at sufficiently fast repetition rates, the responses tend to be reduced in terms of amplitude.

The early response (4 to 8 m. sec) can be obtained at very high stimulus repetition rates but optimally using 5 to 10/sec and it requires 1000 or more stimulus samples Glattke repetition rates of 8 to 10 pr. second and it requires 500 or more stimulus samples (Karlovich and Goldstein, 1969). Apparently, the early and middle responses to not habituate or adapt as a function of signal number or rate. Several studies (Keider and Spreng, 1965, Davis et al 1966, Nelson and Larrman, 1968) have demonstrated an increase in the AER amplitude of the late response with decreasing rates of signal presentation.

Leibman and Graham (1967) and Rose and Ruhm (1966) indicated that 100 or more signals may be used without any risk of inhibition. The least number of runs which have been reported as adequate for AER resolution, are from 32 (Davis et al 1966) to about 50 (Cady and Bickford, 1965), Leibman and Graham 1967, McCandless and Best, 1964; Price and Goldstein, 1966).

Age

The influence of subject's age on the evoked response is also important.

Price et al (1966) found greater response amplitude in children over 10 years than in adults. Suzuki and Jagnchi (1968) found children under 14 years to have consistently smaller amplitude response than adults. McCaudlen and Best (1966) Davis and Zerlin (1966) concluded that the evoked response is highly variable at all ages, between subjects and with in the same subject on test and retest.

Sedations and AER

The use of sedation with very young children has been reported to be advantageous and while doing AER imperative. The major purpose of sedation is to permit evaluation of uncooperative or uncontrollable patients. Sedation usually reduces the compounding effects of movements and myogenic artifacts. In addition, sleep may enhance, however, may ablate or obscure the AER. The benefits to be derived depend partly upon the sedatives used and, more importantly, on the class of components under study in that the effects of sedatives vary accordingly.

It would appear that the use of sedatives might prove to be very advantageous in studying the early AER. It has been reported by Picton et al (1974), Wolfe et al (1976) and Davis (1976) that the early response can be recorded more clearly in sleeping subjects since sleep may reduce myogenic artifacts by reducing the tension of the scalp musculature. Galambos (1976) reported that the early response was recorded successfully in pre-school subjects under sedation.

Skinner and Shimoto (1975) studied the middle response under a variety of sedatives, using adult subjects, as their own control, and found response detectability at 40 dB SL to reduce under the effects of all the sedatives used. The reduction was more when barbiturates were used. Kupperman and Mendal (1974) reported of AER thresholds approximately equivalent to behavioral thresholds with adult subjects who were sedated using barbiturates. According to Herz et al (1967) administration of sedative to very young children is unsatisfactory because the responses both made natural sleep and under sedation become longer in their latency and wave length when compound to the responses recorded when the subjects are awake.

General criticism about the several sedatives including chlorpronlazinehytn chloride, diazepam and chloral hydnate, is that the sleep was too light or do not last long enough. The dominant component of the back ground activity of young children during sleep most frequently lies in the frequency range of 3 to 8 Hz which is just are to cover the frequency range of the evoked response and signal to noise ratio is not improved during sleep. The shape and latency of the vertex potential in response to sound varies with depth of sedation and anesthesia (Herz et al 1967).

Beagley and Gorden (1972) used phenergan as sedative and found no specific deprenant effect on the evoked response amplitude.

According to Lloyd (1973) any medication which affects the ongoing EEG activity is likely to affect the evoked response. The AER is adversely affected by some barbiturate activity. In particular, later components of the response (beyond 100 m.sec) are obscured when the patient is restated with pentothal (Price and Goldstein, 1966). Rapin and Graziani, reported good results when children were sedated using chlorpromazine.

Special consideration of AER

AER with children

The determination of hearing levels by AER has proven to be very successful with more mature subjects. An objective audiometric test, however, is more urgently required for those young children who cannot be assessed with certainly using subjective or behavioural tests. The determination of hearing levels in very young children by the AER technique is very difficult task and lacks the objectivity implicit in the procedure. The most relevant problems encountered are:

1. Maturation of the potential

Subject maturation is the most important variable in AER since it is well known that response stability and detectability are excellent in mature subjects. During the first few months of life profound morphological changes occur within the CNS. This maturation is reflected to some extent by changes in the slow cortical potentials. Younger the age of the subject smaller the amplitude of the response, and larger and more variable the latency of the components (Engel and Young 1969, Ferris et al 1967).

Davis and Onishi (1969) reported their findings according to conceptual age. The vertex potential was recorded first at 23-29 weeks when N_1 had a latency of 180-270 m.sec and P_2 had a latency of 600-900 m. sec. After 35-37 weeks, the P_2 component became most prominent with a latency of approximately 300 m. sec. At 40 weeks, the P_1 and N_2 components were desirable but, at 45 weeks, the N1 became indistinct again and the P2 remained the largest component with a latency of approximately 250 m sec. Further, decrease in the latency of the components occur chiefly over the ensuing four months. Until the age or 7 or 8 years is reached the late components of the response predominant, but after this age the adult wave form is attained and it becomes much simpler to identify the response (Beagley & Kellogy, 1968).

Neitzman, Graziani and Duhamel (1967) have suggested that the different patterns of the slow cortical responses could be grouped according to gestational age and so be used to obtain an estimate of CNS maturation. It is known that progressive myclinization occurs in the auditory nervous systems of infants (Langworthy, 1933), This process often is postulated as the basis for variability in AER latency and poor "time locking" between signal and response in very young subjects.

High voltage background EEG activity

According to Davis et al (1967) the records of very young children are difficult to evaluate because the spontaneous background EEG activity is of high voltage. This intensifies the problem of extricating the response from the "biologic noise".

Appleby (1964) suggested that the amplitude of the response decreases with increasing background EEG activity. But this is not confirmed by Davis et al (1966). Some children even generate a peculiar type of interference consisting of large DC shifts which appears at irregular intervals with no apparent curve. The problems are most apparent on testing children with brain damage, and epilepsy, who often display a delta EEG rhythms. Various attempts have been made to limit and reject artefacts from the recordings and most systems rely on a time delay before each response is fed to the averager, during which higher amplitude artefacts can be recognized (Satterfield 1966, Shephered, Wever and McCaeren 1970). Improvement of signal to noise ratio does not necessarily improve with an increase in the number of signal presentations (Shimizu, 1966).

Sedation will prevent the loss of subject co-operation and lessen muscular artefacts but it does have masked effects on the EEG which often results in revising the background noise.

Subject Co-operation

Young children are commonly apprehensive about AER and many refuse to co-operate sufficiently to permit the procedure. Even the most co-operative children present problems. Their abrupt movements introduce muscle potentials which may obliterate a neural response or displace electrodes introducing artifacts. Handicapped children are in general even more difficult to control, presumably in past because of greater anixety owing to poor communication ability (Skinner, 1978).

Instability of the wave form

The wave form of the response in young children shows marked variability and rapid changes due to sudden alternation of the psychological state of the subjects (McCaudlen and Best, 1966). Davis et al (1967) reported more stability in wave form patterns after the age of 8 years. If severe deafness is suspected, it can be confirmed by using a tactile stimulus. Even this situation is complicated because of lack of repeatable responses and expertise to judge the presence or absence of a response.

Subject State

The early BSER and middle components are remarkably stable responses and appear to be relatively unaffected by subject's state i.e., waking or sleeping states. The early response, can be recorded more reliably in relaxed or sleeping subjects since there potentials are of very low voltage and may be observed easily by myogenic potentials. Dramatic changes are known to occur in the wave form of the late response from walking to sleeping states in some subjects (Skinner, 1978).

Skinner and Antinoro (1969) found the response to be clearer when obtained from the sedated child, and they attributed this finding to a reduction in the voltage of the ongoing EEG activity.

Cohen et al (1971) reported the recognition of responses to be most difficult when the EEG activity was desynchronized, during the REM stage of sleep.

The clinical application of AER

AER provides useful information regarding the auditory system in some instances (Rapin and Graziani, 1967, Davis 1966, Price and Goldstein, 1966). It is considered as an objective test of hearing in selected children in whom a diagnosis cannot be firmly established by conventional audiometric methods (Rapin, 1964).

The EEG patterns are generated in the cerebral cortex. The EEG response to sound might be modified by disturbances,

(i) in the peripheral ear
(ii) in the neural pathways between the ear and the cortex
(iii) within the cortex itself.

It is generally agreed that these changes in EEG are the result of activation of the reticular system at the level of the brainstem and thalamus. Following interpretations are used to diagnose the cases:

1. Abnormality of basic EEG pattern which signifies a cortical or cortico thalamic disturbances;
2. Lack of response to sound and vibration in one are signifies a local cortical or subcortical disturbance;
3. The combination of absence of auditory responses and presence of normal vibratory responses signifies a peripheral disturbance in ear or auditory pathway at the medulatory level.

AER in children and adults

Suzuki et al (1962) Appbeby et al (1963), Davis (1964) Mc Caudlen et al (1968) obtained cerebral evoked response, or vertex potential, with auditory stimulation at 10 dB to 25 dB SL in normal adults. Suzuki et al (1965) showed that the detectable response was obtainable in 70% of normal adults with stimulus intensity at 10 dB SL and 100% at 20 dB SL. Davis (1966) reported an approximate difference between evoked response threshold and behavioral threshold for normal adults ranging from 7.5 to 12.5 dB. Behavioral thresholds were reported to be approximately 10 dB higher than the behavioral threshold for each age category of 1 to 4 years.

For hard of hearing children the relation between the evoked response thresholds and behavioral thresholds were quite different from that of normal subjects Rapin (1964) compared the evoked response threshold and the subjective threshold of 36 children having hearing losses of 50 dB or more. In 19 of 37 children the two thresholds were within 10 dB of each other.

Davis (1966) reported a good agreement between behavioral and AER threshold in deaf children between 4 and 13 years of age. He concluded that this technique be very helpful with M.R. (Rose and Rittmani (1966) and brain damage children (Rapin and Graziani, 1967).

Average evoked potentials in Mentally Retarded cases

The use of average EEG data in the assessment of auditory function depends upon spontaneous activity of the cortex and is not dependent upon motor activity. For this reason, this technique would appear to be of potential value in the clinical assessment of auditory function of mentally retarded.

Hogan and Grahan (1967) performed Average evoked response audiometry in mental retarded cases. The results indicated that average evoked response audiometry can be administered to retarded adults of moderate functioning level. The average evoked responses of the mental retarded subjects have found, an average, to be larger in latency than that of the normal group and that the response amplitude and wave form features of the data from M.R. adults were mostly similar to those obtained with normal adults. M.R. adults did not exhibit evoked response with extremely long latencies extending to 4 sec.

Rose et al (1968) investigated mildly to moderate M.R. subjects with normal hearing to emphasis that the evoked response computer can be used with same degree of accuracy as a clinical test for determining threshold. Baenet and Lodge (1967) reported that their mongoloid subjects had many more extremely large response amplitudes than their normal subjects.

Taguchi and Goodman (1970) considered amplitude of wave form to be a more variable factor in evoked response in mentally retarded cases.

Hearing aid prescription and average evoked responses

JBassa (1972) performed AER on 119 children aged 1 month to 12 years. In hypocusis children hearing aids were adapted using AER to words or phonemes as a measure of hearing. He observed an increase in amplitude as the intensity of sound stimulation increased till a level at which the AER beginned to diminish. This was clinically associated with a sign of auditory discomfort. He tried, 3 or 4 hearing aids in each children at different frequency response curves. The hearing aid which gave largest AER was prescribed. He concluded that AER can be used to prescribe the hearing aid in hard of hearing children.

Averaged evoked response in aphasics

Cortical damage in certain locations causes an inability to process and use speech. The result is aphasia, which is characterized by impaired retrieval in all language modalities of a learned code (Schuell, Jenking and Jimarez, 1969).

Studies using the averaged evoked response to linguistic and non-linguistic stimuli in normal subjects have revealed different neural response for such stimuli (Matsumiya et al 1972). When aphasics were presented with clicks or tones, their averaged evoked responses wave described as abnormal and often in consistent. The amplitude of the evoked potential was most affected on the side of the lesion (Sorford, Sances, and Ramker, 1966). In addition, indications abut some relationship between certain evoked potential characteristic and the severity of the aphasia are available (Kolman and Shinizu 1970 and Liberman, 1966).

The average evoked response component latencies of aphasics appear to be related to their ability to process speech and language. Although the general analysis showed that there was a significant difference between hemispheres in the component latencies. Further analysis demonstrated that this difference in the latencies was present only in those subject who had severe communication difficulties. Those with severe impairment displayed shorter component latencies of the responses recorded from the left hemisphere (Greenberg and Metting 1974). This difference between the hemispheres is a reflection of the damage to the left hemispheres which is outwardly affecting the subject's communication behavior.

Williamson, Goft and Allisen (1970) found a correlation between amount of clinical loss and the samatosensory-evoked response (SER). They found that subjects with severe cerebral impairments demonstrated SERs with shorter late2ncys components from the left hemisphere and maskedly reduced amplitudes when the affected side was stimulated. Patients with milder impairments showed a normal response or attenuation of all components. Sanford, Sances, and Baker (1966) found differences in the amplitude of the response depending on whether shock stimulation was contralateral or ipsilateral. Greenberg and Metting (1974) did not find any significant difference between ipsilateral and contralateral presentations but the stimuli were presented auditorily and required the subject to integrate the word or noise.

Koleman and Shimiza (1970) reported a relationship between scores of their aphasic subjects on the Minnesota test for the differential diagnosis of aphasia and the obtained AER component amplitudes. Larger amplitudes were associated with patients who were able to repeat four or more digits. This showed a significant association between AER components and short-term memory span, since it was also found that it was necessary to increase tonal duration and sound pressure level to elicit larger amplitudes from the severely impaired subjects. They stated that this indicated a problem with the aphasics temporal integration.

Liberran (1966) found a correlation between severity of aphasia and the resultant SER (Samatosensory evoked response) Most of this severely impaired aphasic subjects had absent or serverely depressed evoked potentials on both ipsolateral and as did normal subjects, continued to elicit responses when forced to attend the auditory stimuli.

Greenberg and Metting’s (1974) study revealed that hemispheric differences were present in the averaged evoked responses of aphasic subjects when presented with speech and non speech stimuli. Those subjects with severe communication difficulties demonstrated significant AER differences between hemispheres.

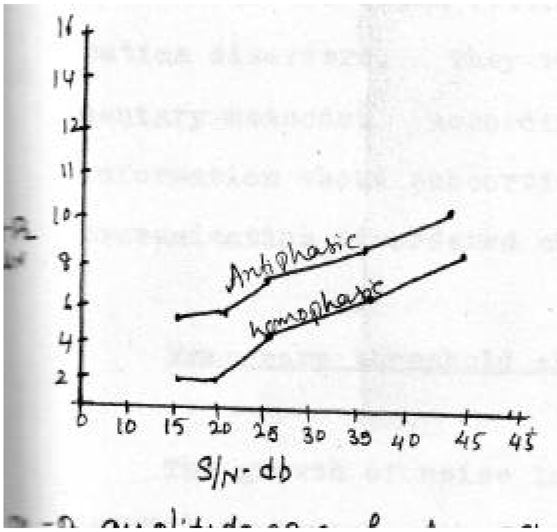
Kolman and Shimizu (1972) used averaged evoked response to monitor the general recovery of aphasic patients. When language skills were severely involved, average evoked responses were not discerniable although normal hearing sensitivity could be established. As average evoked responses became discerniable improvement in language functions was noted, and as language skills continued to show improvement, average evoked responses approximated to those seen in normals. Differences in average evoked response configuration appeared when each ear was stimulated individually with references to site of lesion, contralateral stimulation resulted in an AER consisting of increased latencies and decreased amplitudes when compared to those obtained a ipsilateral stimulation.

Evoked potential correlates of interaural phase reversals

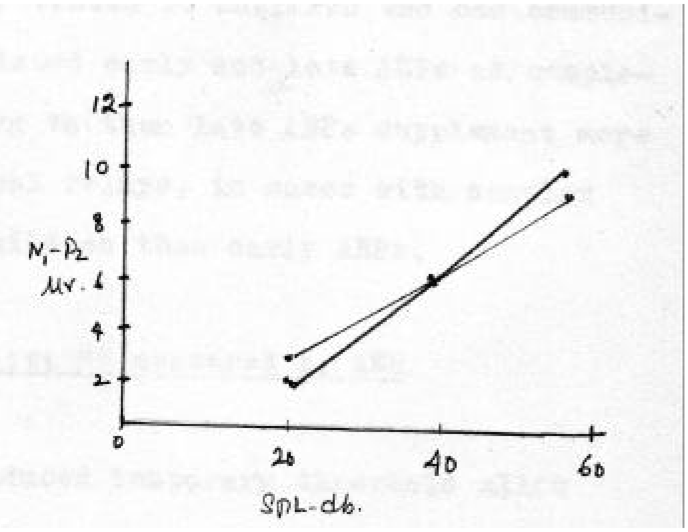
Hirsh reported that the threshold for a low frequency signal (200 Hz) in the presence of high intensity noise is reduced approximately 15 dB when the tone is presented out of phase (S_π) and noise in phase (N_o) relative to the situation where both stimuli are presented in phase (S_o N_o). This is called as masking level difference which is based on a behavioral measure.

The cortical evoked potentials evoked by sound is without doubt relevant to the process of hearing. A close correspondence in stimulus intensity, for example, exists between that required for behavioral threshold and that required for the threshold of the evoked response (Davis, 1965). Computer averaged auditory evoked potentials produced by acoustic signals presented in the context of an masking level difference experiment have been reported (Edward, 1971). Edward (1971) found that the amplitude of the $N_1 – P_2$ component of the average evoked potential reflected the MLD at threshold. N_1 - P_2 was largest for the N S_o condition followed by N_o S_m and N_o S_o Evoked potentials were not recorded in the N_o S condition. Since $N_1 – P_2$ amplitude is usually larger for louder signals (Davis, 1968) are exglaration for the $N_1 – P_2$ difference observed by Boulter and Kluskens (1971) may be that S_π signals sound louder than So signals, They found $N_1 - P_2$ amplitude to be larger for S signals for S_o signals and for low frequency tones this does not appear to be related to loudness, for there was no backward noise and that the signals were well above the threshold. Edward's finding that relatively larger $N_1 - P_2$ amplitude are evoked in the antiphasic N S_o condition may be related to loudness. Since Edward (1971) presented tones against a noise back ground and that the observations were made at threshold. Interaural stimulus phase difference, were reflected at the level of diffusely generated potential recorded at the vertex. In the presence of noise, $N_1 - P_2$ amplitudes varied with stimulus conditions with varying loudness estimates, provided a restricted range with low S/N ratios. Thus $N_1 - P_2$ amplitude seemed to be an appropriate physiological correlate of loudness over the stimulus range from near detectability upto about 20 dB above that level. At high S/N ratios or in the absence of an external masker, there was a fairly constant difference between $N_1 - P_2$ amplitudes in hemophasic and antiphasic conditions. For low frequency signals presented in a background of noise (N_o) both loudness and lateral-lization varied in phase the antiphasic stimuli produced the lowest, most lateralized images and also produced the largest vertex responses. However, the $N_1 - P_2$ difference persisted for signal energies well above those producing HLDs or loudness difference. The loudness difference was greater for antiphasic than for hamophasic stimuli, reflecting the loudness difference reported by others at low signal to noise ratios. At higher signal to noise ratios or in the absence of an external noise maker where loudness difference disappears, however, a difference between $N_1 – P_2$ amplitude evoked by lans and anti phasic stimuli persisted.

These findings (Butler and Kulskens, 1971) may furnish a lead to the electrophysiological mechanism underlying masking level difference viz., a signal which elicits a greater electrical potential simply requires a correspondingly grater intensity of noise to achieve masking at the neurological level.



N1-P2 amplitude as a function of S/N
Ratio for hamophasic (No So plus SpNp
And antiphasic (SpNo plus NpSo) stimuli
Signal for is 250 Hz.



N1-P2amplitude evoked by 2KHz
inphase (So) and out of phase (Sp)
tones in the quiet.

AER in children with communication disorders

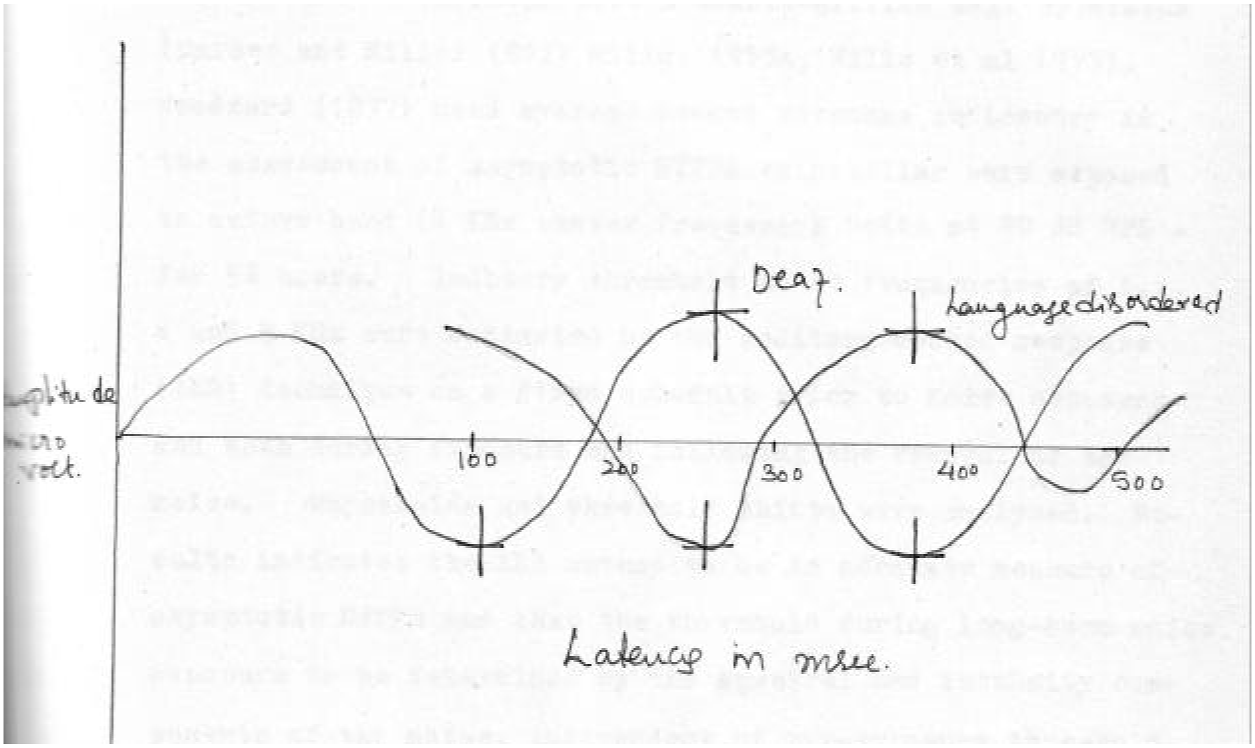
Wilson, Sutta and Rodda (1972) investigated the feasibility of AER technique in assisting the differential diagnosis of dearness and specific language disorders in children. Their results indicated the presence of increased latencies of the AER in cases of specific language disordered child when compared to those obtained with originally deaf children. They also indicated the auditory inhibition and the level of cortical arousal to be important factors in children with a language disorder to imply that the effect is more likely to be associated with an inhibition of auditory input rather than some pathological involvement of the auditory pathway.

Cohen and Rapin (1978) tested 26 children who had communication disorders. They viewed early and late AEPs as complementary methods. According to them late AEPs supplement more information about subcortical relays, incases with complex communication disordered children than early AEPs.

Temporary threshold shift as measured by AER

The growth of noise induced temporary threshold shift (NITTS) is linear with the logarithms of time of exposure (Ward, 1963). Magnitude of asymptotic NITTS has been determined

Average evoked response in communication disordered children



predominantly by a behavioral method using a conditioned avoidance paradigm with a double-grilled cage apparatus (Carder and Miller 1972) Mills, 19073a, Mills et al 1973). Woodford (1977) used average evoked response audiometry in the assessment of asymptotic NITTS chinchillar were exposed to octave band (4 KHz center frequency) noise at 80 dB SPL for 96 hours. Auditory threshold as at frequencies of 1, 2, 4 and 8 KHz were estimated by the auditory evoked response (AER) technique on a fixed schedule prior to noise exposure and both during exposure and following the removal of the noise. Thresholds and threshold shifts were analysed. Results indicated the AER method to be an adequate measure of asymptotic NITTS and that the threshold during long-term noise exposure to be determined by the spectral and intensity components of the noise, independent of pre-exposure threshold.

AER and Malnutrition

Barnet and Weirs (1978) measured AER in infants who were hospitalized due to malnutrition. They observed abnormal wave form in these infants. AER wave form remained abnormal as the infant's somatic growth improved during treatment. So they concluded that abnormalities in AER reflect a long lasting effect of nutrition on brain function.

Evoked response audiometry evaluation of BC Oscillator placement

Cody and Bailey (1973) used evoked response audiometry and conventional audiometry to determine the sensitivity of the BC threshold, at the frontal and mastoid positions, both methods revealed that BC threshold determined at the frontal position to be less sensitive than those determined at the mastoid position.

AER and Recruitment

There is a relationship between the characteristics of sound as an auditory stimulus and the auditory sensation produced by this stimulus, with reference to intensity. this is an intimate and direct relationship in normal hearing and conductive hearing loss subjects between the intensity of the auditory stimulus and the clarity of the perceived sensation. Certain types of deafness, this linear relationship is lost or disturbed (as in case of recruiting ears). Abnormal growth of loudness with increase of sound intersntiy is characteristics of disorders of spiral organ.

Knight and Beagley (1969) showed that in recruitment there was an abnormally fast increase in the amplitude of the evoked response, until a level comparable to that of a normal is reached at high intensities.

Marco (1972) tested a case of Meniere’s disease and observed an exaggerated amplitude of the AER response that did not correspond to the intensity of the stimulus used and there was a loss of linear relationship between the intensity of stimulus and the AER amplitude.

Clayten and Rose (1970) found no significant difference between the amplitude of the response for normal and recruiting ears. Keidel and spreng (1965) showed that the amplitude of the AER varied as a power function of intensity.

From the above studies which support the view of linear relationship between intensity and amplitude wave form, we can conclude that AER can be used to demonstrate such abnormal results.

Use of AER in the study of audiotory discrimination

The AER is a widely used method for assessing hearing sensitivity individuals who cannot or will not participate satisfactorily in behavioral audiometry. The presence of an AER is taken as evidence that the test stimulus produced a disturbance within the peripheral hearing apparatus which in turn results in cortical excitation. The presence of an AER indicates that at some level the listener differentiated between the stimulus and the background noise around him. Then AER can be viewed as an evidence of auditory discrimination. Auditory discrimination can be studied using the AER which places few constraints on the types of stimuli which can be used. This approach is based on the concept of stimulus novelty. When the same stimulus is repeated in a predictable manner, AER amplitude decreases over time due to short term and long term habituation (Fruhstorfer, 1970) Weber, 1970). If a stimulus is prevailed in a more novel (less redundant) manner, larger AER amplitudes result. the erects of stimulus novelty on the AER amplitudes result. The effects of stimulus novelty on the AER have been demonstrated by randomly presenting frequency changes within a stimulus run (Barnet and Lodge, 1967) and by using a variable interstimulus interval (Replin, 1964, Vaughaa and Ritler, 1970). These findings can be released to the study of auditory discrimination.

AER in non-organic loss cases

Bochenok and Bochenok (1971) tested 5 patients of non-organic hearing loss. They compared the results of subjective audiometry and the AER. They found that in non-organic deafness the AER threshold reflected more accurately than the subjective audiometric threshold. They concluded that the AER is the optimal technique in diagnosing cases with non-organic hearing loss.

AER in eighth nerve lesions

Early diagnosis of an eighth nerve lesion wuch as a newroma is one of the biggest challenges that audiologists and neuro-otologists face because of its life threatening nature when it develops from an “ear tumor” into a brain tumor. AER can be used to meet this challenge. Shimiza (1968) observed delayed peak latency with either the same or smaller amplitude on the side of the eighth nerve lesions. He observed longer latencies, and peak latency at the same sensation level. This result was in contrast to the findings in Meniere’s disease cases, which showed an increase in amplitude and short latency owing to the presence of recruitment.

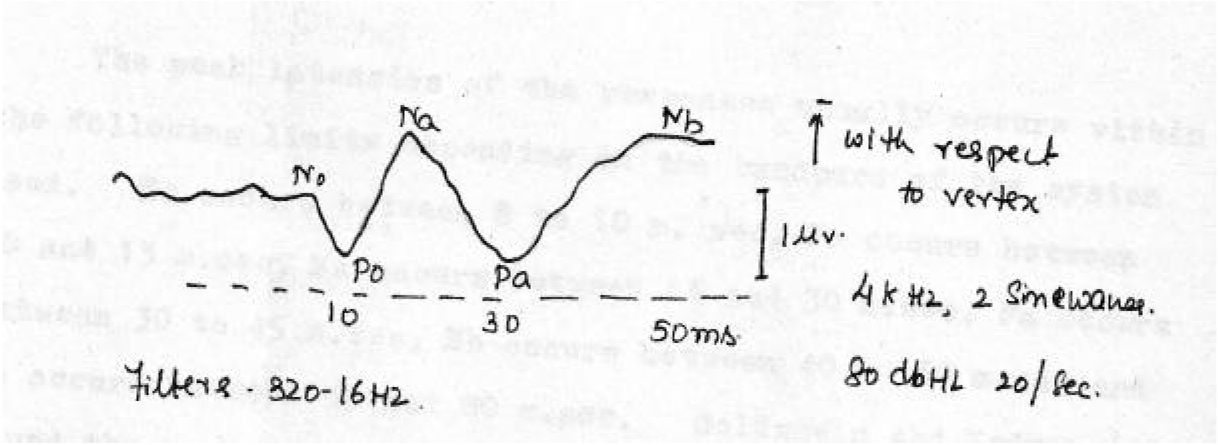
Middle latency response

The middle response was revealed by the work of Geisler, Frishkopf and Resenblith (1958) which was among the earliest studies in which the summing computer was used. they concluded that this response was on neurogenic origin. Bickford, Jacobson and Cody (1964) indicated it to be myogenic. It is now accepted that the acoustically evoked responses (latencies from 8 to 40m. sec) derived from placing the active, of monopolar, electrode directly over the post-aural region of over the Inion are almost entirely myogenic. Geisler (1964) suggested that the middle response represented cortical potentials whose amplitude are dependent on muscular tension.

The origin of the middle response when recorded post auricularly was evaluated by Kiang et al (1963) and by cody et al (1964), They concluded that the response recorded from that location was myogenic. Mast (1968) reported short latency response recorded from parietal and vertex electrode placements. The latencies were shorter than those of the Inion of post-auricular responses. The responses recorded from the cortex were consistent in the presence of muscle contraction and indicated that they probably consisted of both neurogenic and myogenic components. Borsanyi and Blanchard (1964) Lowell (1965), Goldstein (1965) have supported a neurogenic origin of the middle response when recorded from the vertex.

Terminology

Mast (1963, 1965) originally named the series of evoked potentials with onset latencies of less than 60m.sec “the short latency responses”. It is also named as “fast of early responses”. The latencies of the middle response varies from 8 to 60m.sec.



The neurogenic middle responses to early auditory volleys. they are generated in the primary and nearby secondary auditory projection areas. It is quite possible that upper brainstem responses of thalamus also contribute to the early part of the middle responses, but there is no experimental evidence in humans regarding this (Davis, 1976).

Response configuration

The wave form of the response is described as consisting of two major positive peaks and three major negative peaks Goldstin and Rodman (1967) labeled these peaks N_o,P_o,Na, Pa, and Nb to avoid confusion with the symbols N_1, P_1,N_2,P_2 etc., to describe the slow cortical response.

The peak latencies of the responses usually occurs witin the following limits depending on the bandpars of the system used. No occurs between 8-10m. sec, P_0 occurs between 10 and 13 m.sec, Na Occurs between 16 and 30 m.sec, Pa occurs between 30 and 45 m.sec, Nb occurs between 40 & 60m.sec abd Pb occurs between 55 and 80m.sec. Goldstein and Rodman (1967) found the combination of Na Pa to provide the best means of identifying the responses.

Characteristics of the middle latency response

1. This response tests the audiotory system upto, but not beyond the first response of the audiotory cortex;

2. This response, combined with the slow cortical responses and the brainstem responses, is a considerable potential in localizing midbrain leviar of the auditory pathway;

3. Complete muscular relaxation is essential and is best achieved by natural sleep or sedation, but the response is not modified by these changes (mendal and Goldstein, 1969, Mendel, 1974a, Kupperman and Mendel 1964).

4. Hypoxia, hyperventilation and boduy acceleration increased the latencies and reduce the amplitude of the response components (Freeman, 1965);

5. No frequency dependence has been demonstrated. Most of the studies have employed unfiltered clicks and very brief tone bursts as stimuli and have obtained fairly good frequency specificity town to 250Hz.

6. The sensitivity of this method is fair. The threshold of recognition is about 20dB above the behavioral (Davis, 1976);

7. The time requirements are the same as for the slow cortical responses. The time for each collection is one to 2 minutes. The overall time limits are by sedation (Davis, 1976);

Testing procedure

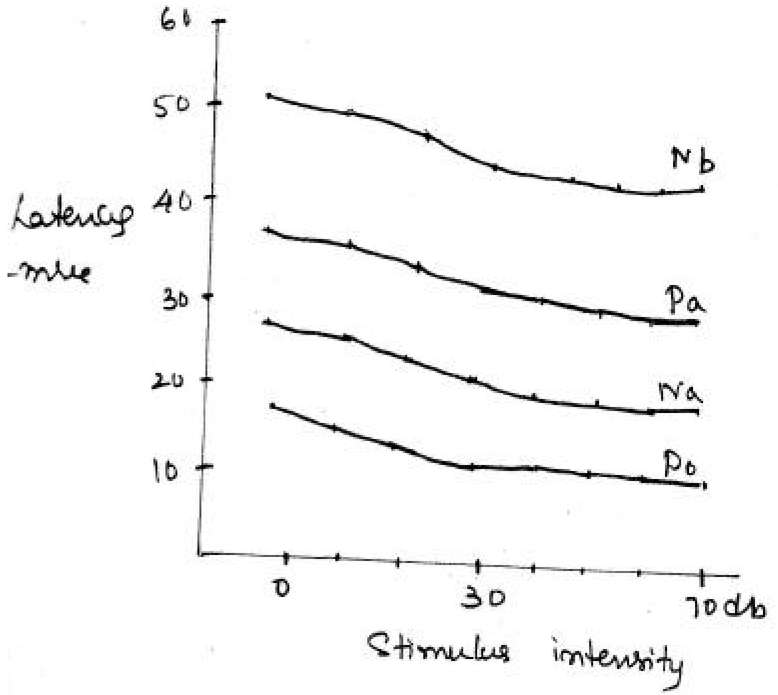
Adult subjects and older children may be tested, while lying on couch or while sitting with their neck supported. Young children are to be tested under sedation.

The electrodes are placed on the vertex of the scalp and on the contralateral mastoid process with the earthing electrod placed usually, on the forehead. The stimuli are delivered from all ear phones. The determination of threshold at several frequencies often requires a 2 to 3 hour test session (Gibson and Ruben, 1978).

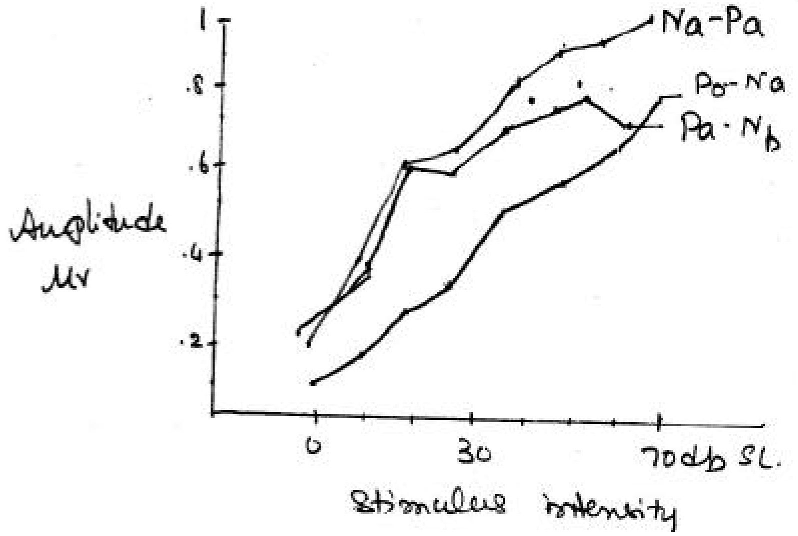
Clinical application

Goldstein and Rodman (1967) published and first report showing a close correlation between the behavioral auditory thresholds and the thresholds of the responses. Middle component can be elicited in neonates with 1 KHz tonal stimuli peak latencies and point to point amplitudes were found to vary as a function of stimulus intensity. Neonatal AERs recorded from the side of the head ipsilateral to the ear stimulated were more recognizable than their contralateral counterparts. This asymmetry has not been reported in adults Mendel et al (1974) evaluated the response in 18 infants and the latency intensity functions of the components of the middle latency responceses (Madell and Goldstein, 1972).

The Latency Intensity functions of the components of the middle latencies response [Madell and Goldstein, 1972]



The amplitude- intensity functions of the components of the middle latency responses [Madell and Goldstein 1972)



Obtained identifiable responses within 15 to 30dBHL in most cases. Lowell (1965) and Davis and Hirsh (1973) observed the middle latency responses to be difficult to evaluate in yound children. As a means of neuro-otological diagnosis, the middle latency responses could have real value. Robinson and Rudge (1977) observed latency abnormalities but not amplitude abnormalities in patients with multiple selerolis.

Advantages of middle latency responses

1. The middle latency responses are stable in different states of the subjects, from waking to light sleep to deep sleep, either natural or induced by barbiturate sedation, and
2. The absence of serious limitations of frequency in obtaining good middle latency responses. Offer the best hope for clinical determination of low-frequency thresholds by AER in difficult subjects.

Disadvantage

The disadvantage of the middle response is its susceptibility to interference by the muscles. This cannot be overcome by filtering but artifact rejection techniques fo over this (Davis 1976).

The contingent negative variation (CNV)

The contingent negative variation was first described by Walter (1964). He described the contingent negative variation as an electroencephalographic phenomenon consisting of a slow potential shift of negative polarity with an amplitude of 5-30ur, which was highest at the vertex (with a reference electrode on the mastoid).

The contingent negative variation response appear as a slow DC shift in the baseline EEG activity following are stimulus. As a result of conditioning a subject expects a second stimulus to which he may be required to perform some task. The task which subject is going to perform may be physical or mental. The first of these pained stimuli is a “warning” and the second an “imperative”. These stimuli may be separated by an interval of between 0.5 sec and 4sec. The wave occurs between the evoked between the evoked responses of the first and second stimulus, and almost certainly represent a state of “readiness” of the subject to perform some action.

Walter (1964) described the CNV to be a shift of the apical cortical dendritic potentials in the direction of depolarization to ‘primo’ the cortex for action. This reduction of the excitability threshold facilitates the ability of the cortex to respond, enhancing the efficiently of the over activity.

Slow cerebral potential shifts were first reported in animals following the development of stable, high input impedance DC amplifiers. Kohler and his colleagues (Kohlar, Held and O'connell, 1952, Kohler and o'connell, 1957) demonstrated a slow potential shift that accompanied prolonged auditory and visual stimulation in cats, monkeys and humans. This DC perstimulatory shift has been examined further in humans by keidel (1971a). They (Kohler et al 1952) found the maximum negative shift to be at the vertex rather than as they had expected at the primary cortical areas.

Rowland (1961) reported slow potential shifts that occurred in cats after conditioning, they were initially more positive before becoming negative in polarity. they occurred during ten second intervals during which clicks signaled a forthcoming electric shock. A similar slow potential shift was reported by urtx (1966) which occurred in rats after electrical reinforcements following conditioning signals.

Another slow potential shift was, first observed by Kornhuber and Deecke (1965), appeared to be a readiness potential preceding voluntary movements and had its greatest amplitude over the contra lateral Rolandic cortex. It is known as the “Bereitschaft potential” (BSP). Mc adam and Scarle (1969) reported an increase in motivation to increase the amplitude of the BSP and CNV appear to be closely related except for the different scalp distributions and motivation.

Walter et al (1964) gave the first important description of the CNV response in man. The CNV was observed only in response to an initial (conditional) stimulus when the firest stimulus was assoiciated with a second (imperative) stimulus. The conditional stimulus evoked a primary response in the non-specific frontal cortex which was followed by a CNV leading up to the response of the imperative stimulus. The CNV reflected the expectancy of signal association by the subject and was independent of the intensity of the conditional stimulus. Its amplitude and consistency were related to the semantic content of the imperative stimuli if they were meaningful to the subject and required some decision or action from the subjects (Walter, 1964). The cognition and in this respect is a very important finding.

Much interest was aroused by the discovery of the contingent negative variation and soon several laboratories were investigating this response. Cohen and Walter (1966) demonstrated a CNV to an imperative stimulus consisting of pictures without an need for physical operant response such as proving a button. CNV responses have even been recorded with subjects who were merely required to “think now” as the operant response.

Irwin et al (1966) and Cant and Bickford (1967) showed the amplitude of the response to increase with the amount of effort required to press the bar as the operant response. The CNV amplitude was significantly greater when it was necessary to exert K pounds of pressure father than 2 pounds of pressure. Large CNV amplitudes can often be associated with the degree of certainty with which the subject expects the oncoming imperative stimulus (Hillyard et al 1971). McAdam (1966) however, reported that this factor to be not related directly to CNV amplitude.

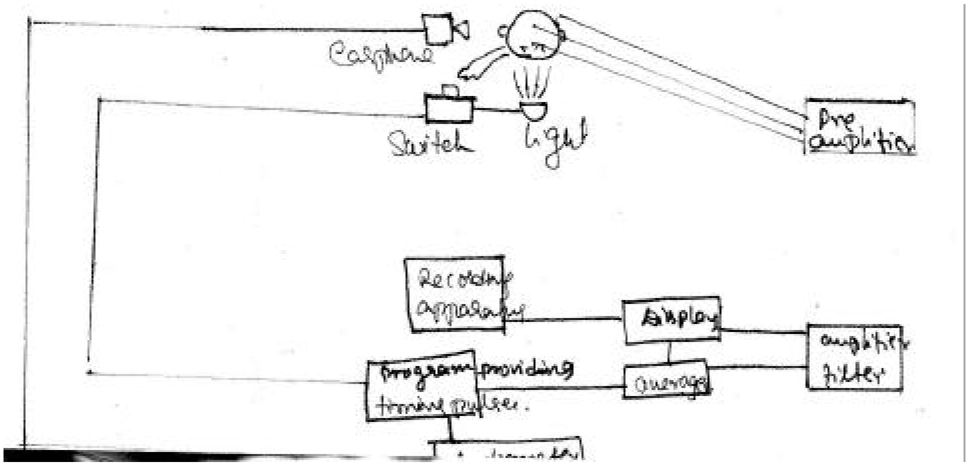
Terminology

The effects of conditioning in man and animals have been investigated by electrophysiological methods, and under certain conditions, EEG modifications have been observed. Two very late responses have been discovered to be conditioned responses.

The first of these, responses is revealed by particularly large and reliably increased amplitude of the P_{300} peak. This peak is component of the late response, arising from the primary projection and secondary association areas. It is termed the expectancy wave (Davis, 1973).

The second response is a very slow negative potential which is actually a DC shift. It is termed as contingent negative variation by Walter (1964). Both types of responses can be related to specific conditioning stimuli to test certain cognitive or psychological operations in children as well as in adults.

Instrumentation



Test environment

Subject should be tested in a sound proof chamber and subject should sit comfortably with the neck supported. the chamber should have the preamplifiers into which the electrode leads are inserted, close to the subjects head; the ear phones or loudspeaker, a switch for the operant response and a light, directly in front of the subject, giving the imperative stimulus.

The stimulus generation

Two separate stimuli must be provided and each must receive a trigger pulse which is time locked to the sweep analysis. The first is the conditioning stimulus which occurs after a short pre-stimulus analysis delay of 0.5 – 1.5 sec. The second stimulus or imperative stimulus, is generally a weak flash of light lasting 0.5 sec which occurs between 0.8 and 1.6 sec after the conditioning stimulus.

The conditioning stimulus may be of any frequency which is audible to the subject. The intensity of the stimulus is varied in 10 dr 5 dB steps so that the threshold intensity can be determined the absence of a CNV response in most cases, indicates the subject's psychological hearing threshold. Masking facilities may be needed.

The Recording Apparatus

Electrodes – the cerebral electrical activity can be recorded by chloride silver cup shaped electrode filled with electrode jelly (Prevec and Loker 1974).

Amplifier – The amplifiers must be DC coupled and built to low noise biological specifications.

The averager – A small computer or a purpose built average may be used.

Prevec, Loker and Cernelc (1974) used the TMC CAT 1000 averaging computer to average 45 consecutive responses.

The monitoring oscilloscope

Because only a few trials are averaged, artefacts can easily lead to misinterpretation if unwittingly included into the averaged response recording. A careful watch should be made of the ongoing electrical activity so that any sudden change can be noted.

Permanent recording of results and analysis

CNV testing is a prolonged procedure. In order to get full advantage of that it is necessary to use FM magnetic tape recorder instead of conventional tape recorder.

Testing procedures

The subject must be awake and attentive. Movement of the head and neck must be limited to prevent the generation of electrical artefacts. The subject should sit comfortably with the neck supported. Before applying the electrodes it is essential that all traces of grease are removed from the underlying skin. It is necessary to wait for 10 - 15 min. after applying electrodes and before beginning the testing. Active electrode is placed on the vertex, reference electrode is placed on the mastoid process and earch electrode on the forehead.

Subject's instructions

The subject has to be told the relevance of the various stimuli and instructed as to when he has to make the operant response. He has to be told that he will hear a pure tone signal, which may be extremely faint, and this will warn him that the light is about to flash on. Then he has to be told to extinguish the light by pressing a button as quickly as possible.

By repeating this procedure several times, establish the conditioning process. The subject begins to expect the arrival of the imperative stimulus and it is this expectancy which is related to the slow potential change known as the contingent negative variation. While measuring the puretone threshold the intensity of the pure tone stimulus may be reduced until patient can no longer hear the sound and so no longer expects the flash.

Instruction to the subject changes according to the particular test to be performed.

Characteristic of the response

The distribution of the response – Walter (1964) believed that the CNV was derived mainly from the frontal areas of the brain. Later studies using manopolar and bipolar electrodes placed in various wscalp positions showed that the CNV was centered near the vertex (Cohen 1969, Vaughan 1969). Bickford (1967) found that the topical distribution of the CNV altered under different test conditions. They reported that the presentation of a noxious stimulus following the operant response increased the amplitude of the CNV in the central and parietal regions, but when the subject was given the option of avoiding the noxious stimulus by making the operant response quickly within a set time limit, the CNV amplitude was increased mainly in the frontal region. It may be concluded that the maximal CNV amplitude is usually obtained by using an active electrode placed near the vertex and that the reference electrode may be sited over the mastoid process. The amplitude of the response is reduced in frontal regions, it is further reduced in parietal areas and it is very small in occipital and posterior temporal positions.

The amplitude of the response

Amplitude of the CNV, usually 20 – 25 uv, seems unrelated either to stimulus modality or magnitude (Walter, 1964; Low et al 1966a). In adults, the mean amplitude of the CNV as ecorded fro the vertex is 21.4 uv with a standard deviation of 4 ur (Cohen, 1969). Low et al (1966a) have reported CNV amplitudes as great as 50 uv in subjects younger than 12 years of age.

Factors affecting the amplitude

The amplitude of the CNV is affected by fewer external test factors than other evoked potentials and the major factor appearing to affect it is the psychological state of the subject himself. The following test factors can affect the amplitude.

(a) Stimulus factors – One fundamental difference between CNV audiometry and other methods of ERA is the requirement for two separate stimuli, the conditioning stimulus and the imperative stimulus. The characteristics of this stimulus are not critical and often a 300 m sec tone burst with a gradual rise and decay are used as this allows for a good frequency specificity but clicks and words may also be employed.

The nature of the imperative stimulus is not critical provided it can be perceived by the subject and usually a flash of light is used during CNV audiometry. If the subject is blind, an audible click may be used.

The operant task which makes the imperative stimulus significant, may effect the CNV amplitude, as it probably alters the degree of motivation of the subject. Certainly the CNV amplitude is increased when the subject has to perform a motor task such as pressing a button (Gibson and Ruben, 1978).

(b) The inter-stimulus interval – The time elapsing between the conditioning stimulus and the imperative stimulus is important. Mc Adam, Knott and Robert (1969) found that CNV amplitudes were significantly larger if the interval between these stimuli was between 0.8 and 1.6 sec.

(c) Amplitude during the whole testing period – The acquisition, maintenance, and extinction of the CNV has attracted attention. Mc Adam et al (1969) showed that the amplitude of the CNV develops to its maximum during the acquisition trial and later decreases during the practice trials. Walter et al (1964) reported that the CNV response could be maintained indefinitely provided the subject retained the interest, and that the interest was best maintained by having the subject perform an operant response. CNV develops more quickly when an interesting operant task is required (Low et al, 1966a).

When the subject is not warned, the CNV disappears progressively over approximately 30 trials once the imperative stimulus is omitted (Walter et al 1964). On warning the subject Walter et al (1964) reported that the CNV was extinguished immediately when the imperative stimulus ceased, but Low et al (1966a) found that it disappeared more slowly over 6 – 12 trials.

When an imperative stimulus follows the conditioning stimulus no more than 40 – 45% of the time, the CNV amplitude is reduced (Walter et al 1964). The CNV can still be obtained in patients high intelligence when reinforcement by an imperative stimulus occurs only in 30% of the trials. Walter (1966) has suggested that if the CNV persists even when the probability of reinforcement is low, the subjects are seekers of stress and when the CNV cannot be obtained even with a high probability of reinforcement, the subjects are anxious and neurotic.

Prevec, Loker and Crenele (1974) have concluded that the amplitude of the CNV partly depends on :

1. Changes in parameters of stimulation, such as intensity (Irwin et al 1966, Lowetal 1967, Rebert et al 1967), duration of the second stimulus (Peters et al 1970), the information content of the second stimulus (Walter 1965, Cohen and Walter 1966, Pictan and Low 1971), or extinction of the second stimulus (Walter et al 1967; Tecee and Scheff 1969);

2. Accurate perception of the stimuli (Mc Adam and Ruben 1971);

3. Interval between the two stimuli (Mc Adam et al 1969;

4. Changes in the response; Eg. type of action (Donchin et al 1972) and motor effort (Rebert et al 1967); reaction time (Mc Adam 1966);

5. Individual differences (Knott and Irwin, 1967)

6. Changes in some physiological functions (Naiten et al 1971);

7. Motivation (Irwin et al 1966) and (8) attention (Teces 1972)

Latency of the response

The latency of the onset of the CNV potential is difficult to measure since it develops amongst potentials which are late components of the evoked potential to the conditioning stimulus. Robert and Knott (1970) found that the CNV did not commence until atleast 400 m sec. had elapsed following the presentation of the conditioning stimulus. The latency of the maximum amplitude of the response is variable and usually lies within 450 – 900 m. sec.

Place of contingent negative variation in clinical audiometry

The contingent engative variation (CNV) has beenused to design objective test of the threshold of perception of a simple acoustic stimulus.

Advantages of contingent negative variation response

1. The most important advantage is its use of the CNV as an audiometric test. It can be used as an objective method to determine the threshold of subjective perception of an acoustic stimuli;
2. Another advantage of the CNV as an audiometric test when compared to the electric response audiometry is that its

amplitude does not decrease when the intensity of the stimulus is decreased to the threshold. CNV, tends to be higher when the stimuli are nearer to the threshold of perception, and

3. CNV, is a objective proof of the perception of stimulus changes and is useful for exact determination of differential threshold for frequency or intensities;

4. It can be used as "objective speech audiometry" in cases of aphasic and non-organic cases;

Disadvantage

1. Contingent negative variation method cannot be used in cases of small infants;

2. It cannot be used in severe mental retardation cases.

Clinical application of contingent negative variation

The contingent negative variation has been used to design an objective test of threshold of perception of a simple acoustic stimulus. If offers a direct audiometric measure.

Prevec, Loker and Gernelc (1974) evaluated the use of CNV for the estimation of the pure tone audiometry threshold of adults. They reported that 10% of normal healthy subjects fail to develop a recordable CNV. In contrast to the findings with other methods of ERA, the amplitude of the response does not decrease as the stimulus intensity is diminished (Prevec et al, 1974; Rapin et al 1966). The CNV infact, is often larger when the stimulus is near the threshold of perception Prevec et al, 1974; Rapin et al 1967. This may due to an increase in the concentration of the subject when we can barely hear the warning sound.

Language evoked response audiometry

Burian, Gestring, Gloring and Raider 1972 used contingent negative variation as a method of examining the verbal discrimination and comprehention in aphasic patients. They called this method as language evoked response audiometry (LERA).

Verbal comprehension in aphasic subjects may be examined objectively by using electric response audiometry are possible way would be to correlate electrophysiological data with the comprehension of spoken language. Although electric response audiometry (ERA) `Burian et al 1969a) supplies objective data about the hearing level of a subject, it is of little value in determining the existence of receptive aphasia and the existence of primary hearing defects may be ruled out. The latency and shape of the acoustically evoked potential of aphasic children does not seem to differ significantly from the wave form and latencies of normal hearing children of comparable ages (Beagley, 1971).

Burian, Gestring, Glaring and Haider (1972) conditioned the aphasic subject in such a way that he associates only meaningful words with the presentation of theimperative light stimulus and not the meaningless words which may be presented. They tested two adult patients with aphasia (Burian et al, 1972) one patient, aged 46 years, was severely aphasic following a neurosurgical removal of an astocytoma, soonafter the operation, no difference in the CNV response to meaningful or meaningless words could be demonstrated but several months later, after he had recovered, he was able to discriminate and only developed a CNV response to the meaningful words.

Second patient, aged 44 years developed severe and long lasting aphasia after haemorrhage. He was agrammatic, using telegraphic speech, dysprosody and word-finding difficulties. In language-evoked response audiometry, the patient demonstrated in the first trial normal discrimination between meaningful and meaningless words. But in the severe test situation (the flash shifted from the meaningful to the meaningless word) he `perseverated' the first situation developing the CNV after the meaningful item. In this way contingent negative variation can be used to that verbal discrimination and verbal comprehension in aphasic subjects.

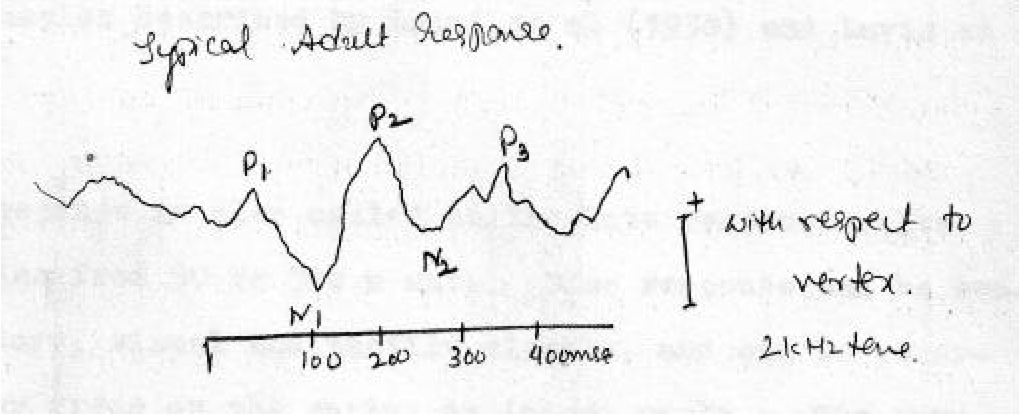
As a means of neuro-otological diagnosis

The contingent negative variation could provide a fascinating diagnostic tool for psychiatrism and psychologist who are concerned with higher cortical functions. Psychopathic subjects have great difficulty in establishing a CNV. Conflicting reports have been published regarding CNV amplitude in patients with anxiety neurosis.

Knott and Irwin (1968) found smaller amplitudesin patients manifested anxiety states, Walter (1967) has deported that in intelligent patients, the CNV can be maintained even when the imperative stimulus only follows 30% of the conditioning stimuli, whereas, in patients of lesser intelligence and those that are “seekers of stress” the CNV cannot be obtained unless the probability of reinforcement is high.

Cortical electric response audiometry

Slow "vertex" potential – Late response or K complex



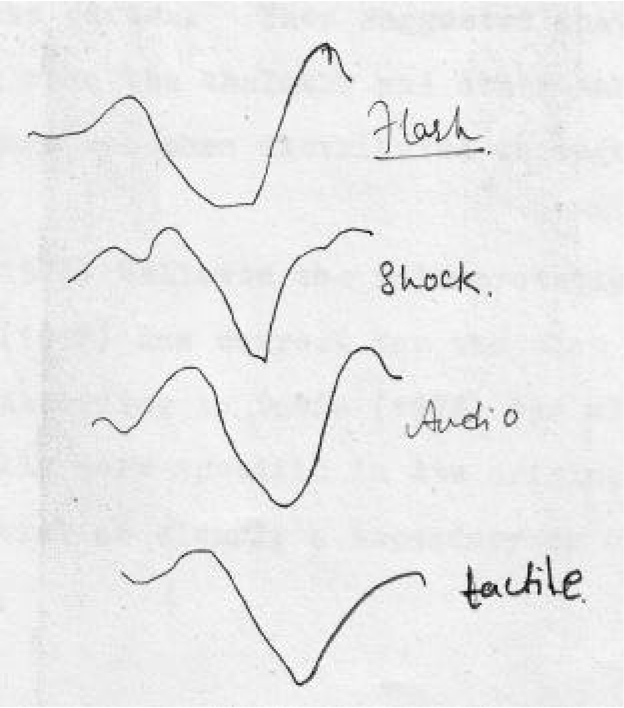
The typical adult response shows a small inconsistent positive peak (PI) at 50 – 75 m.sec, a large negative peak (NI) at about 100 – 150 m.sec and a large positive peak at about 175-200 m sec. The polarity in each case refers to the vertex electrode with respect to the mastoid. Usually this is followed by a low second negative peak (N_2) at 200 – 250 m.sec which is inconsistent in the adult but may be very prominent in young children. A slow positive wave then follows at about 300 m sec which has been associated with the CNV.

Bloch and Paillard (1953) and Gostant (1953) suggested the term `V' potential (Vertex potential) as the anatomical distribution of the slow potential is centred around the vertex. The slow response was described by Mc Candlen and Best (1964).

Derbyshire and Mc Candlen (1964), Walter (1964) and Davis et al (1964). This response is generally accepted as a neurogenic response and in sleeping subjects probably gives rise to the familiar K amplex described by Loomi et al (1938) and Davis et al (1939).

Slow response is also called as the late response. Its latency varies from 50 to 300 m sec. Slow response can be evoked by auditory, visual and tactile signals, and can be recorded from many areas on the cortex or intact scalp. The wave form differs among sensory modalities. The largest amplitude occurs to auditory stimuli (Walter, 1964).

Cortical responses to flash shock, auditory, and tactile stimuli [Davis et al 1964]



Source

The source of the slow vertex potential in individual who is awake is almost certainly the cerebral cortex. Evidence suggests that it is chiefly originated in the primary cortical projection area for each modality and also in the immediate surrounding secondary projection areas.

The late response appears to be a secondary discharge.Forbes & Morison (1938) described this first time as a nonspecific an effect with relatively long latency with variable components and subjected to habituation (reduced by repetitive) stimuli). They noted the long delay between the primary and secondary responses and the synchronization of appearance in various regions of the cortex. They suggested that the afferent discharge acted upon the thalamus and other subcortical centers and that the change was then distributed throughout the cortex.

Davis (1976) believes the interpretation done by Forbes and Morison (1938) has correct for the slow cortical response in sleep. According to Davis (1976) the slow waking response is anatomically more specific in its origin, and considers the vertex potential as clearly a secondary or even tertiary cortical response.

The wave form of the late response has been described by skinner (1969) as polyphasic with vertex positive peaks at about 75 to 200 m.sec and vertex negative peaks at about 150 to 275 m.sec. The primary peaks of the late response in fully conscious subjects are first negative and then positive which range in amplitude from about 8 to 20 m. volts.

Instrumentation

Test environment – Subjects should be tested in a comfortable relaxed position. Infants and sedated subjects are usually tested while lying on a couch under close supervision. Test should be carried out in a sound proof room.

Stimulus generation

Stimulus envelope – Pure tone stimuli are used. Rise and decay time of 25 – 30 m. sec with a plateau of 25 – 50 m.sec are to be used. The largest response amplitudes are obtained using the lower audiometric frequencies (0.25 – 2 KHz).

Stimulus repetition rate

Due to the slow recovery time of the slow response, it is not possible to use fast repetition rate. A rate of one stimulus every one or two seconds is to be used.

Number of stimulus presentations

be presented. It takes between half a minute and 2 minutes to collect the necessary number of responses.

Transducers

Adults and older children can be tested using a pair of earphones. Masking noise can be used at high intensities. Young children may be tested using a free-field loudspeaker if they show signs of mico-operativener to wear earphones.

The recording equipment – Electrodes

Surface electrodes are required commonly silver/silver chloride deme electrodes are to be employed.

Amplifiers

Low noise biological amplifiers are essential.

Auarafer, monitor oscilloscope, actafactrejection and permanent recording methods are used as recording equipment (Gibson and Ruben, 1978).

Testing procedures

Adults are usually easy to test, but young children can be very difficult.

Adults are usually co-operative and are tested while sitting comfortably in a chair with the neck relaxed against a pillow. They should not move their heads during the averaging period of each response or trial.

In case of young children, sedation can be used. It is very helpful in hyperactive and emotionally disturbed cases. Pure tone can be used as stimulus. Its rise and decay time should be less than 25 m sec. In order to get best response, stimulus should be presented once in 10 second. Surface electrodes should be placed on the vertex near the anterior fontanel (active electrode), reference electrode should be placed to the right mastoid area and ground electrode should be on the left mastoid area.

Identification of threshold

The threshold of a potential in CERA is detected by first starting the test using a stimulus intensity, well above the audible threshold. The stimulus intensity is then reduced from trial to trial in 20 dB steps until the threshold level is reached where the slow potential is absent. If more accurate level is required, intensity may be changed in smaller steps of 5 – 10 dB. Threshold which is determined at 500 Hz and 1000Hz and 2 KHz gives a good indication of the hearing in the important frequency range.

Characteristics of the slow response

The stimulus modality – Slow response from the region of the vertex may be evoked by stimulating the brain virtually using any sensory input. Davis et al (1972) have shown that each of the slow response is derived from the primary cortical projection area of the sensory modality concerned.

The tactile slow response is helpful in establishing a base-line response. If a subject is tested and no auditory responses are obtained, one is forced to draw a conclusion that the subject is deaf. If a clear tactile response is obtained, then the diagnosis of severe hearing loss is reached with an increased reliability.

The frequency range of the response

The main spectral energy of the slow response is concentrated within the frequency range of 4 – 6 Hz. It is therefore possible to use a narrow band pass filter which helps to exclude disturbance caused by the mains power frequency (50 Hz) and by some of the muscle artefacts.

Johannsen (1971) investigated the filtering of the slow response and has suggested that the optimum filter settings are 1.6 Hz high pass filter to 13.6 low pass filter. Use of a low cut-off frequency of 1.6 Hz enhanced the amplitude of the response.

Stimulus characteristics

Some of the important stimulus characteristics which influence the AER are described already. In this section, stimulus characteristics which are responsible only for slow vertex otentials are described.

Intensity

Suzuki and Taguchi (1965), Keidel and Spreng (1965) Rapin et al (1965), and Rose and Ruhn (1966) have reported an increase in the peak amplitude of each component and reduction in the latency. Antinoro, Skinner and Jones (1969) with increasing stimulus intensity showed the relation between stimulus intensity (in dB) and the amplitude to be linear for low and middle frequencies.

Stimulus duration

It has been reported that the slow response does not reflect temporal summation (Skinner and Jones, 1968, Onishi and Davis, 1968)

There is a slight tendency for the amplitude to increase with signal duration upto 25 – 50 m sec and remains at further increase in the same level with signal duration upto 150 m.sec.

On-effects- and off effects

Like most of the other AEPs the slow cortical response is an on effect. It appears in response to clicks or tone pips and also at the onset of a sustained pure tone. Brief rise-times not over 20 m. sec are desirable, but a rise time of 20 m. sec is very nearly as effective as one of the 3 m.sec as measured by amplitude of N_{90}, - P_{180}. Furthermore, a tone of 30 m. sec is as effective as a longer tone. A change in the intensity or in the frequency of an ongoing tone evokes a v potential which is equivalent to almost that happens from the transition from silence at the onset of a tone. A decrease or an increase in intensity is effective (Davis 1976).

At the end of a long tone burst there is an evoked response of the same pattern as at the onset. This “off-effect” is less reliable than the on effect and is usually about one third of its amplitude (Keidel, 1970). The latency of the off-effect measured from the start of the fall of intensity, is about 15 m.sec. shorter than the latency of the on-effect. The importance of the off-effect for AER is its possible interference with the on-effect if the stimulus is a brief tone burst (Keidal, 1976). If the burst is about 75 m. sec in duration the N_1 wave of the off-effect superimporsan the P_2 wave of the on-effect and reduces its amplitude.

Sprang (1969) showed the short duration stimulation to lead to a superimposition of two (on & off) resonse types. “On response” is the predominant activity when short duration stimuli are used; partly due to the slow recovery period of the response.

Binaural stimulation

The amplitude of the response is enhanced if the stimulus is delivered to the two ears simultaneously. The $N_{90} - P_{180}$ wave is about 20% larger than for stimulation of either ear alone (Davis, 1976).

Interstimulus interval

A parameter of stimulation that is very important for AER is the interstimulus interval (ISI). Davis (1964) found the slow cortical response (V potential) to require a very long ISI (more than 7 sec) to yield the maximal amplitude of responses. A common practical question forwarded by many authors is that what ISI (or repetition rate) yields the greatest summed total voltage in one minute of collecting time. Answer to this question by Davis is that any value from one to two seconds larger or shorter intervals are less efficient. If the ISI are varied in a random or a pseudorandom sequence, avoiding intervals less than 0.5 and more than 4 sec, but keeping the average interval consistent, the average evoked potential is a little larger (10%) than if the intervals are all the same (Rothman, Davis, Hay, 1970). This advantage is thought to be due to the avoidance of "Habituation.

Interposed stimuli

The amplitude of the V potential is a function of both intensity of stimulus and of ISI. For a constant ISI, the effect of a strong first stimulus on the response to the second stimulus is greater than the effect of a weak first stimulus.

Interposed stimuli have less depressing effect if they are delivered to the contralateral rather than to the same ear. If the conditioning stimulus resembles the test stimulus then it depresses the secnd response more. The homolateral interaction is not detectable (Butler 1968; Butler 1972).

Regular V/S irregular stimulus repetition rates

It is found that if an irregular stimulus repetition rate is used, the amplitude of the response is consistently larger (Tyberghein and Forrez, 1969). Randemization of the stimulus application, aids the average in suppressing any regular source of interference, such as the EEG alpha rhythm and also by increasing the attention of the subject (Davis, 1976).

Contralateral masking

The amplitude of the slow response to a left ear stimulus is the same, allowing for subject variability, regardless of whether the recording is made from the right side of the head or from the left. It is not possible to determine which ear has been stimulated merely by comparing the recording from the left side with that of the right. Therefore, if one ear is to be tested alone, it is essential to mask the contralateral ear. But in case of average evoked response audiometry, it is very difficult to determine the correct masking level when the hearing level of the subject is unknown.

Subject variability

There is considerable inter-subject and intra-subject variability in the slow response (Davis and Zerlin, 1966). Some of the responsible factors such as attention and habituation, are known to affect the slow response.

1. Habituation

Davis and Yorlis (1963) noted that the slow responses to be larger at the beginning than at the end of the recording session. Davis and Zerlin (1966) described the effects of habituation to be due to prolonged stimulation.

2. Attention

Davis (1964) reported the amplitude of the slow response to increaseif the subject was given with task requiring a decision. No change was detected when the decision was made simple. Most and Watson (1968) observed the slow potentials evoked by near threshold auditory stimuli, to be maskedly enlarged when the subject actively listened for the stimulus. Although the earlier components of the response increases (Picton and Millyard, 1974), the augmentation of evoked activity with attention is most pronounced as a positive wave, extending from 200 – 450 m.sec.

Squires, Hillyard and Lindsay (1973) observed the N_{100} – P_{300} components to represent different aspects of the decision process. The N_{100} signifying the quantity of signal information received and the P_{360} reflecting the confidence of the subject in performing the task correctly. They found a substantially larger N_{100} comparent when a subject was asked to pay more attention to the stimulation in one ear and ignore the stimulus in the other. Hence, it can be concluded that attention is a very important factor that is affecting the AER.

Slow cortical responses during sleep

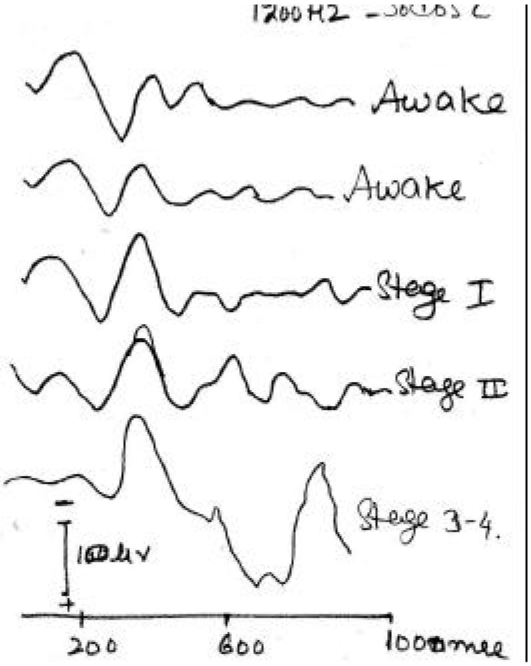
It is often necessary to test young children during sleep, as they are too active or unco-operative when they are awake. However, it is clear that the slow response in sleep differ in many respects from those obtained from the awake subjects. These differences are related to the depth of sleep and to the age of the child. The level of sleep can be assessed from the EEG pattern.

According to Davis (1976), AER response in sleep is different both physiologically and in anatomical origin, from the waking responses, even though the first part of the sleep response bears a superficial resemblance to $P_{180} – N_{250}$ of the waking response. One reason for believing that they differ significantly is the close relation between the waking and the sleeping responses to the very different patterns of ongoing EEG activity. Another is the appearance of a late component in deep sleep with a large negative to positive swing that crosses the zero baseline, at a very close to 600 m.sec after the stimulus.

Gibson and Ruben (1978) classified EEG activity during sleep. According to them “when a subject falls asleep the EEG undergoes distinct changes which can be classified according to the depth of the sleep.

Different ECG rhythms encountened
During Sleep Stages

Slow cortical response recorded at
different stages of sleep



Stage ω.

I t corresponds to the waking stage. There is a low voltage mixed frequency EEG activity. Some subjects exhibit continuous alpha activity while others may show little or none of this rhythm (alpha, Beta, Theta and Delta).

Stage – 1 : It occurs during the transition between the waking stage and the deeper sleep stages. It usually losts for less than ten minutes. It is characterized by low voltage, mixed frequency EEG activity of mainly 2 – 7 Hz but as stage 2 approaches

12 -14 Hz although during the early stages some slow, rolling eye movements may occur.

Stage 2 : It is characterized by the presence of sleep spindles and often K complexes. Sleep spindles are bursts of 12 – 14 Hz activity lasting over half a second. K complexes occur in response to sudden stimuli including auditory stimuli (Davis et al, 1939). High voltage activity seen in later stages does not occur.

Stage 3 : It is defined by an EEG in which more than 50% of the record consists of waves slower than 2 Hz which have amplitudes of oher 75 uN. Stage REM – It is a stage of rapid eye movements. This stage can be related to periods of dreaming.

Williams and associates (1973) observed first the waveforms to change as the subject goes to sleep and to change further as the subject shifts into deeper stages of sleep. the most significant changes appear to be a depression of P_1 and N_1, an accentuation of N_2 and frequently the appearance of a later positive wave (P_3). The entire response appear to be depressed during a light stage of sleep (low voltage stage) and can be evoked only at intensities considerably above the subjective threshold of hearing when the subject is under moderate stage of sleep (high-voltage), the vertex response again becomes prominent (William et al 1973).

Aserinsky and Kleitman (1955) Roffwang et al (1964) and Weitzman et al (1965) stated that the new born infant has two stages of sleep, a quiescent and an active phase. Quiescent sleep shows high voltage, slow wave EEG activity and active sleep has a characteristic low voltage fast EEG activity. In adults there are significant changes in amplitude and latency of the evoked response components during different stages of sleep (Weitzman and Kreman, 1965; Williams et al 1962, 1964). In infants the chages seem to be basically the same as in adults (Suzuki and Taguchi, 1968; Weitzman et al, 1965).

Barnet and Goodwin (1965) stated that larger amplitudes and longer latencies were often associated with deeper sleep, but this effect was observed to be less in infants than in adults. Taguchi, Picton, Orpin and Goodman (1969) did not find any difference in response amplitude between light and deep sleep in younger age group and but found significant difference in older infants.

Natural sleep covered little alteration of the response characteristics (Skinner and Antinoro, 1969).

Gibson and Ruben (1978) stated that it is not surprising that slow response potential under sedation can lead to difficulties in identification of “true” responses. Davis (1973) summarized the current views regarding the use of sedation. He stated that for some young and hyperactive children sedation provided the only possible means of completing the test procedure.

According to Gibran and Ruben (1978) latency of response as a whole increases during sleep and later waves predominant over earlier waves as depth of sleep increases.

The clinical application of slow vertex potential

Slow potential may be used as a means of estimating the auditory acuity and direct comparison can be made with the results of conventional pure tone audiometry.

As a means of measuring hearing threshold

Cortical evoked response audiometers is a careful audiometric technique in adults and older children. It is useful in the following cases :

1. Confused or uncomprehending subjects who are unable to follow the instructions for conventional audiometry;
2. Unreliable subjects who give varying subjective thresholds. Cortical evoked response will indicate the true threshold;

3. Suspected "hysterical" or "non-organic" hearing loss;

4. In medico-legal cases to confirm the subjective audiometric results;

In children under the age of 6 years many difficulties are encountered using cortical evoked response audiometry to estimate the auditory acuity. The following conditions are contraindications to the use of cortical evoked response audiometry in children;

1. Epilepsy;

2. Muscle fics or spasms i.e., athetosis. These two conditions are usually associated with numerous electrical artefacts which make interpretation of the response made difficult;

3. Cases who needs sedation;

Slow vertex potentials in conductive hearing loss cases

Slow vertex potentials evoked by using a vibrator placed on the mastoid area can be recorded. Cody, Griffing and Taylor (1968) examined slow vertex response audiometry bone conduction thresholds in 28 normal ears at frequencies of 500, 1K and 2KHz and reported that the thresholds obtained were within 15 dB of the subjective BC threshold in 95% of the cases. In patients with a severe sensori-neural hearing loss, it was possible to evoke a response by a tactile than by an auditory pathway (Townsend and Cody, 1970).

Cochlear disorders

Pathological conditions which affect the cochlea are often characterized by a phenomenon of recruitment (Dix, Hallpike and Hood, 1948).

Clayton and Rose (1970) found no differences between the amplitude and latency function of CERA responses to the same loud stimulus when it was presented to normal hearing ears or to the ears with suspected cochlear hearing losses. Knight and Beagley (1968) have showed the amplitude/intensity functions of the slow potential to rise abnormally steeply in recruiting types of hearing loss and this resemble with the subjective Fowler's ABLB test.

Meiere's Disorder

Townsend and Cody (1970) and Bhimizu (1968) reported that groups of Meniere's disorder cases have an average, a shorter response latencies than the groups of normal hearing subjects.

Best and Tabos (1968) examined the recovery function of the P_2 (P_{200}) component using pained stimuli at varying inter-stimulus

stimulus intervals (ISI). They reported that the normal subjects and patients with conductive hearing losses showed a dip in the recovery function at 800 m sec but patients with cochlear disorders exhibited a dip at 400 m.sec ISI and patients with retrocochlear lesions had a dip at 200 m sec ISI. Townsend and Cody (1970) noted a dip in their recovery functions at 200 m sec ISI in many patients with Meniere's disease.

Eighth nerve disorders

Shimizu (1968) after testing 4 patients with eighth nerve disorder observed the latency of the response increase and its amplitude to diminish in them. Townsend and Cody (1970) could only confirm this findings in one of their 6 cases.

Conclusion

The slow cortical response and other cortical responses provides an accurate prediction of the puretone audiogram in adults and in older children. Disadvantages of this technique may be overcome, when it is associated with other electric response audiometric techniques (Ecoch, BSER).

CHAPTER – V

BRAIN STEM EVOKED RESPONSES

AUDIOMETRY – BSER

Within the wider field of electric response audiometry (ERA) the technique known as Brain stem evoked response audiometry (BSER) has been found to be particularly useful in recent years. BSER are obtained from surface electrodes by a completely safe and non-traumatic technique. In comparison with electrocochleography, BSER has the advantage of not requiring any form of surgery and it can thus be performed by non-medical staff.

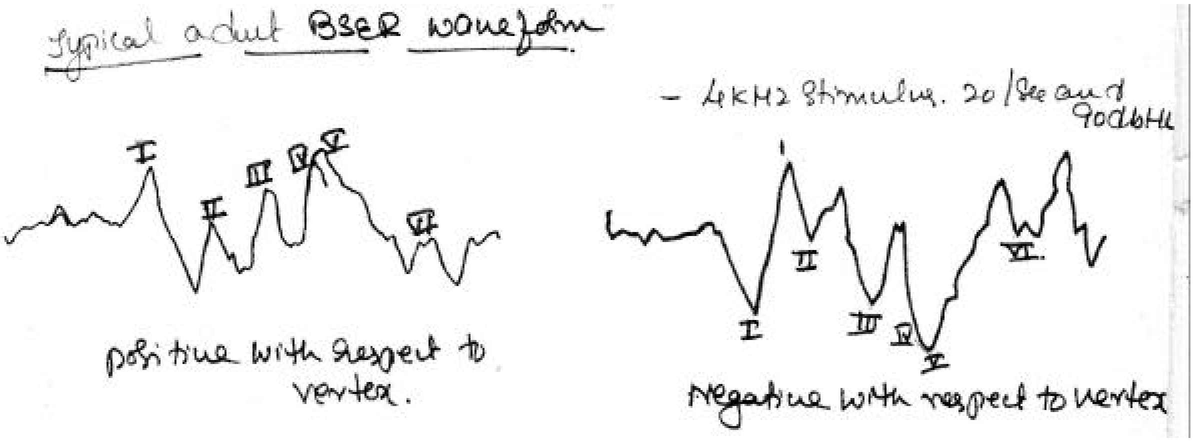
Interest in the fast potentials was first aroused by Sohmer and Feinmesser (1967). They recorded the eighth nerve action potential (AP) from the earlobe. A response of 0.5 uv was evoked by a click of 115 dB SPL. Experiments on the cat conducted by Jewett (1970) showed that the early neurogenic responses thus obtained were the result of potentials generated by several levels of the auditory pathway.

Jewett and Willston (1971) showed that acoustically generated “early” potentials could be detected from a wide area of the skull. They distinguished between two parts of a volume conducted field; the near field and far field. Transtympanic electrocochleography is a near field technique as the position of the active electrode is very crucial and BSER is considered as far field technique as the position of the active electrode are not so crucial.

Comparative studies in man and animals by Jewett and Williston (1971) indicated that the first of these potentials (N_1) is generated at the cochlear nerve. Lev and Sohmer (1972) used superficial and intracranial electrodes to obtain simultaneous recordings in the cat. They reached the conclusion that the wave sequence was produced by the cochlear nerve (N_1), the cochlear nucleus (N_2) the superior olivary complex (N_3) and the inferior colliculus (N_4 and N_5).

Sohmer (1972) has proposed the following anatomical correlation for the series of neurogenic responses typical of the brain stem;

			Jewett classification
N_1	-	The first order fibres of the acoustic nerve	NI
N_2	-	The cochlear nucleus	NII
N_3	-	The superior olivary complex	NIII
N_4 (a&b)	-	Lateral lemniscus and preolivary region with equal contributions from crossed and uncrossed fibres.	NIV
N_5	-	The inferior colliculus mainly activated by crossed projections	NVI



All these responses in brain stem evoked responses occur in the first eight m sec. following the presentation of the stimulus. These peaks (vertex positive) separated by approximately one m. sec. are labeled with Roman numbers I through VI by Jewett (1970). These wave forms are constant, especially those of waves I II and III. According to Don et al (1979) the first 6 components are clearly detectable and labelled. Out of all the 6 components the largest and the clearest wave is wave V. Much attention has been focused on this wave because it is traceable near threshold values of the click stimulus (Hecox and Galambor, 1974).

The wave form which occurs at about 7 m.sec after the stimulus onset is called "Frequency-following response". It is particularly good area of the BSER wave form for estimating threshold levels.

Instrumentation

Instruments which are used for AER are also used here. But there are some special requirements for BSER.

The stimulus generation

Stimulus repetition rate – It is advisable to use a stimulus repetition rate of 50/sec. When BSER is to be employed as a neuro-otological tool, it is essential to use 2000 stimuli.

Stimulus transducer – An anechoic test chamber is essential if loudspeakers are used (Thorntan 1975a).

Masking noise – The apparatus must include provision for the application of masking noise to the non-test ear if monaural information is required. Clicks contain a wide spectrum of frequencies so wide band masking is required.

The recording equipment

Filter settings – The high pass filter is commonly used with a 100 – 500 Hz out off frequency.

Recording side of equipment must contain, electrode, amplifiers, filters, the averager, monitor oscilloscope and artifact rejection facilities. Output can be recorded permanently using permanent recording circuit (Giblan and Ruben, 1978).

Procedure

The procedure varies according to whether the subject is a co-operative adult or a young child or baby. The subject can be either awake or asleep, since the BSER response is essentially unaffected by sleep stage and most drugs. The target and comparison electrodes are usually placed at the vertex and earlobe respectively with a ground electrode at the forehead. Rise and decay time of the stimuli should be rapid i.e., 0.1 m. sec with a duration of 0.1 m. sec. Stimuli should be presented between 2Y2 and 10 times per sec.

Young children are difficult to test satisfactorily without the use of sedation. Sedatives such as trimeprazine, promathazine and chlorpromazine can be used (Burian 1975). It is necessary to start the test with loud stimulus (Eg 80 dBHL), so that the BSER can be obtained clearly. The stimulus intensity is then reduced in regular steps to cause the BSER to diminish. The level at which BSER diminishes or disappears, is considered as the threshold or near threshold of the subject.

The most easily identifiable response in BSER is the fifth wave (NV) that is usually merged with the fourth wave NIV). The NV response occurs with a latency of about 6-7 m sec in adults and 7.6 to 8.6 m. sec in babies. It can usually be identified after only a few 100 stimuli have been delivered.

Characteristics of the response in Brain stem evoked response audiometry:

Electrode positions

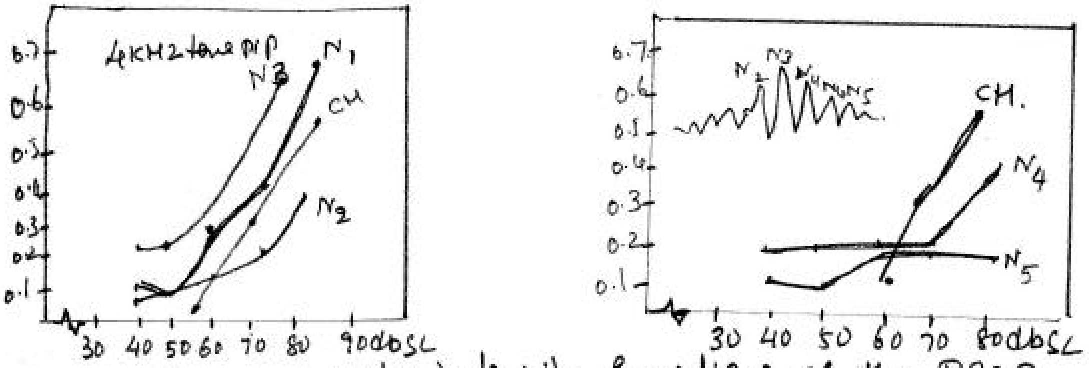
The optimum electrode positions are not yet known. Since brain stem evoked response audiometry is a far field technique small difference in electrode sites are not critical. Sohmer and feinmener (1973) have demonstrated the variations of the responses obtained from different electrode sites in human subjects. Many workers have used bipolar electrode technique with one electrode placed at the vertex and the other placed either over or near the ipsilateral mastoid process. Sohmer and Feinmener (1973) have used a clip electrode attached to the ear lobe as this avoids some of the larger muscle potentials. Hecox and Galambos (1974), Thorntan (1975a) and Suzaki (1975) placed an electrode over the mastoid process and Terkiedson (1975) advised, positioning the electrode on the neck, a few inches behind the ipsilateral masoid process.

Davis and Hirsch (1977) positioned the active electrodes over the mastoid process and on the forehead, immediately below the hairline, and the earth electrode on the chin. According to them, placing an electrode on the vertex is not necessary. Inspite of the differences in positioning one of the electrodes the wave form of the BSER remains basically unaltered.

Amplitudes of the BSER

The BSER are minute and the peak to peak amplitude of individual waves rarely exceed 1 uv. with increasing stimulus intensity, the amplitude of the first wave increases in a similar manner, as it is seen with the AP of transympanic ecoch. except that it is 20 times smaller. In a normal subject, it is usually possible to identify a “plateau” between the “H” and “L” curves of the graph. The amplitude of thelater waves from the brain stem nuclei increase little with increading stimulus. Intensity and at high intensities the amplitude occasionally decreases.

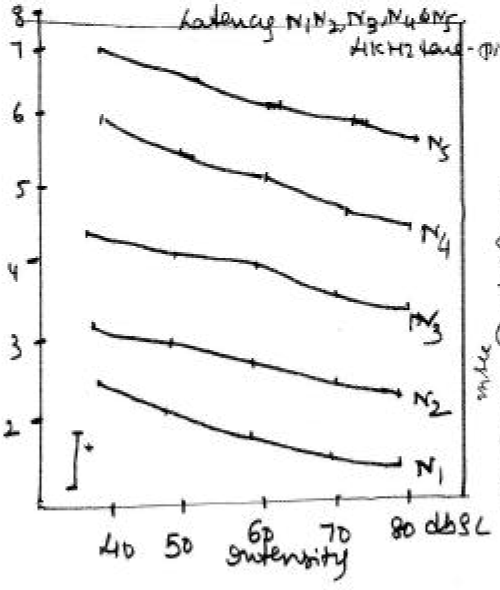
When stimulus intensities of less than 25 dB SL are used, the first wave N_1 is usually not identified. The second wave N_2 has the smallest amplitude of all the BSER waves and can rarely be identified at low stimulus intensities (Gibson and Ruben, 1978).

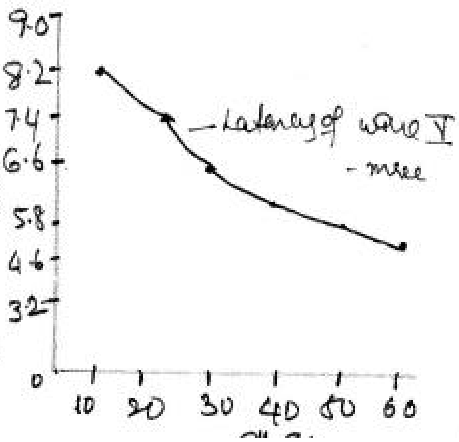


The amplitude-intensity function of the BSER.

Latencies of the BSER

The latency of each of the BSER peaks, using the similar stimuli is remarkably constant among adult subjects. The latency of each of the waves, decreases by almost similar amount as the stimulus intensity is increased. The NV wave almost invariably follows NI after 4 m.sec (Gibman and Ruben, 1978).





Latency-intensity function of the BSER

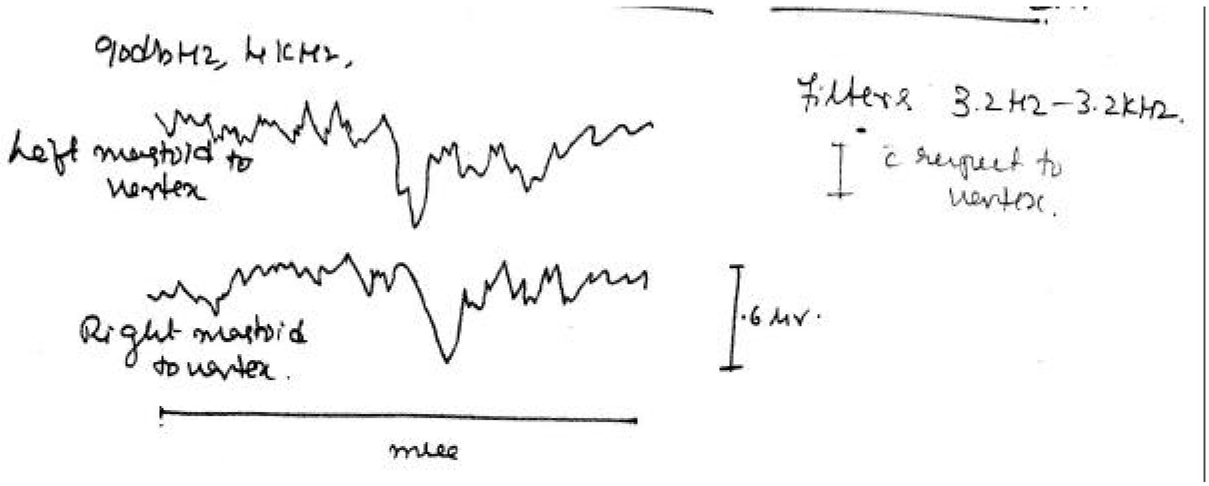
With increasing stimulus presentation rates, there is no alteration in the latency of NI but the latency of the later waves increases slightly (Pratt and Sohmer, 1975). The latency change of each wave is greater than that of the waves preceding it (accumulative effect).

The latencies of the BSER are prolonged in neonates (Mecox, 1975). The NV (N4b) in a one day old baby has a latency ofapproximately 7.6 – 8.6 m sec at 60 dB SL.

Ipsilateral and contralateral responses

Terkildson and his associates (1973) showed the variations in the responses to a unilateral stimulus depending upon whether it is recorded from the ipsilateral or contralateral mastoid.

The Ipsilateral BSER and the Contralateral BSER.



Gibson and Ruben (1978) recorded BSER wave form from the ipsilateral and contralateral mastoids. The BSER wave form obtained from the ipsilateral mastoid showed a familiar profile where as the recording from the contralateral mastoid though found to be similar in many respects didn’t found tobe similar in many respects. Thornton (1975b) reported his findings that the first negative peak on the contralateral recording which is equivalent to the N II is often large.

The absence of the NI in BSER when using high stimulus intensities must always raise the suepicion that the stimulus is being delivered to a deaf ear in a subject with a unilateral hearing loss. The true situation will be revealed if masking of the opposite ear is properly accomplished.

It is likely that analysis of the ipsilateral and contralateral recordings provide useful information (Thornton and Hawker, 1976a). The difference were 1 m.sec between the NV of the two recordings only occur in subjects with hearing is normal hearing when pathology, such as demyclination is present.

Factor affecting the brain stem evoked responses

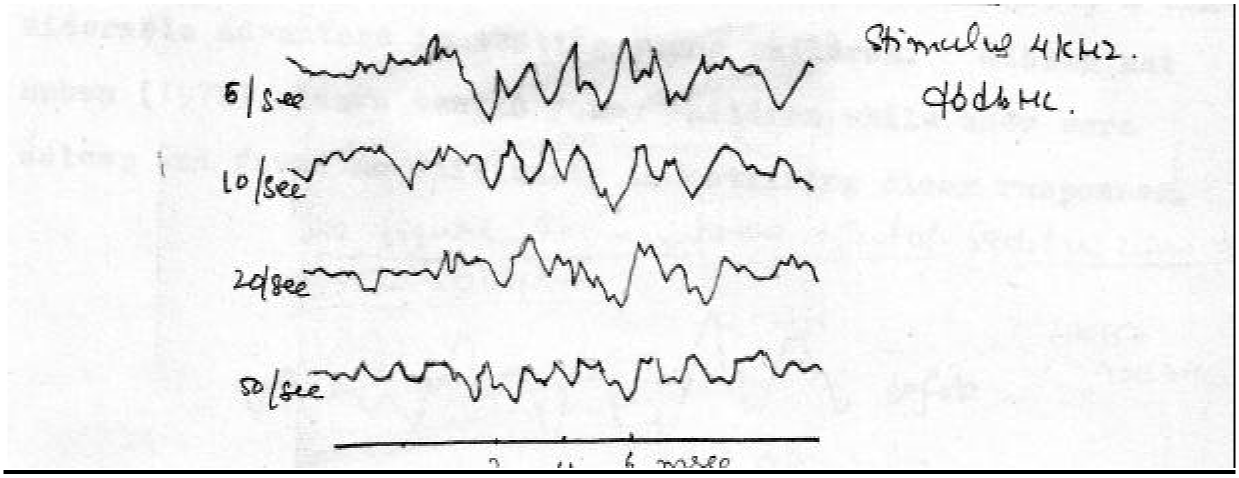
There are certain factors which are directly or indirectly affecting the brai stem evoked responses.

Stimulus presentation rate.

Stephans (1976) studied the effect of stimulus presentation rate on the various components of the cochlea and early brain stem responses. Two experiments were conducted. When stimulus rate was higher than 2/sec, there was a steady reduction in peak to peak amplitude of the N_1 P_1 response. Increasing the stimulus rate from 2 to 20/sec had no significant effect on the amplitude of any of the later waves of the complex. When the stimulus rates were further increased, over the range 18 to 50/sec, there was a significant decrease in the amplitudes of all the waves of the complex. The overall pattern of this decrease is similar for N_1 P_1, N_2 P_2 & $N_{3\ \text{with}}$ a monotonic reduction in amplitudes for rates higher than 12/sec. For the later waves N_4 P_4 and P_4 N_5 there was no reduction in amplitude until rates higher than 30/sec were used. The general pattern of the results for the earlier and later waves were also eflected in the latency changes.

The N1 response diminishes with shorter interstimulus intervals. It begins to decrease at stimulus presentation rates of 10/sec and it is difficult to identify in brain stem evoked response over 50/sec. The amplitudes of the later waves, appear to be little affected, even at faster rates of 50 – 100/sec (Praft and Soher 1975) Terkildson, Osterhammel and Huis In't veld, 1976) but Gibson and Rubin (1978) notes that NIV and NV have tendency to merge at faster rates of stimulus presentation.

The figure represents the BSER wave form resulting from different rates of stimulus presentation

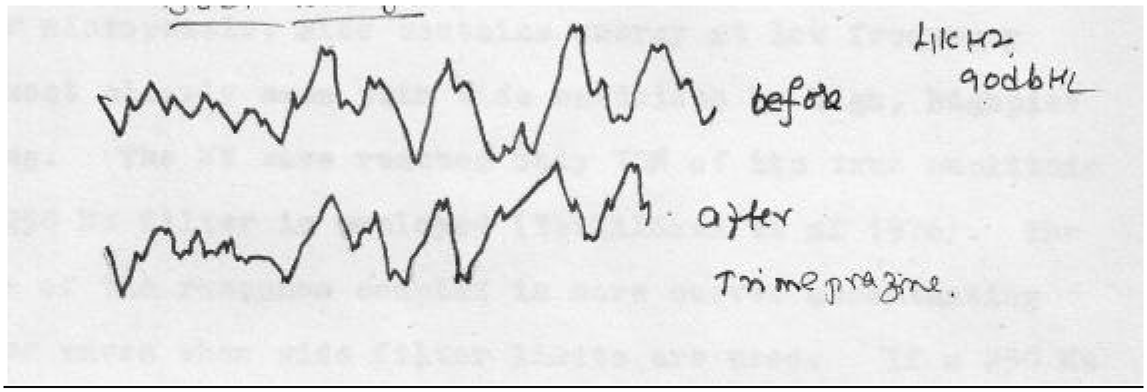


Fujikawa and Weber (1977) tested 3 groups of 8 subjects each consisting of infants, adults and young adults respectively, using routine brain stem evoked response technique 4 different rates of clicks. They measured the three latency shift score for each of the 3 fast rate of clicks at 33/secs 50/sec and 67/sec. Analysis of the data revealed greater shifts for infants and gexiatric adults than for young adults. They concluded that the imposition of a fast rate of click presentation offers a promise as a clinical tool for the discovery of brain stem differences.

Sedation

The brain stem evoked response audiometry appears to be not affected by sedation, or even by general anaesthetic agents and relaxants. Bryant (1976) investigated the effects of two different sedations in six normal subjects. After administering diazepam and tripneprazine, he found no significant alterations in the BSER wave forms. This gives a considerable advantage in testing young children. Gibson and Ruben (1978) always tested young children while they were asleep and found no difficulty in obtaining clear responses.

The figure represents the effect of sedative upon the BSER waveform

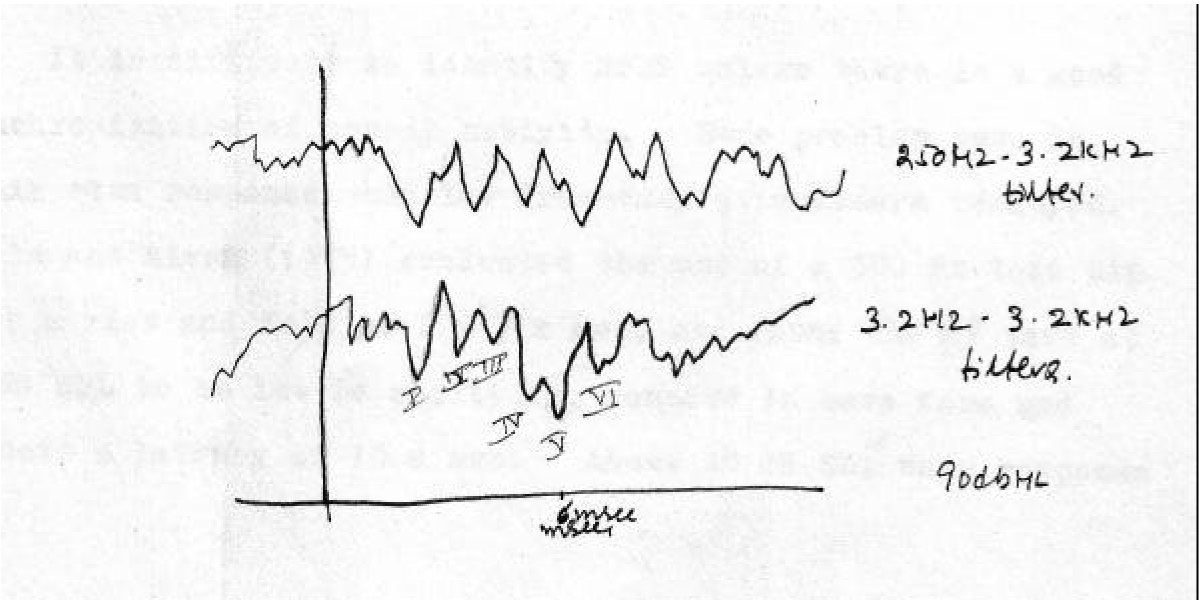


Prolonged or repeated stimulation (habituation)

The amplitude and latency functions of BSER are remarkably constant on repeated or prolonged stimulation. Thornton (1974) and Thornton and Coleman (1975) reported no significant variations in six normally hearing subjects who had four replicates of four stimulus levels during two test sessions.

The bandwidth of brain stem evoked responses

Fourier analysis of the brain stem evoked response shows that most of their energy lies in the range of 800 – 1200 Hz. Use of narrow band width filtering does lead to some distortion of the responses. The NI response in certain circumstances contains low frequencies, so, if a high, pass filter (over 100 Hz) is used, the NI responses will not show the same characteristic wave forms, as that of the transtympanic APs. The cochlear microphasic, also contains energy at low frequency and is most clearly seen with wide bandwidth by high, highpass filtering. The NV wave reaches only 70% of its true amplitude when a 250 Hz filter is employed (Terkildsen et al 1976). The baseline of the response complex is more curved accentuating the later waves when wide filter limits are used. If a 250 Hz high pass filter is introduced the response base line becomes almost flat.



The advantage of employing a high – high pass filter is that low frequency artefacts which may disrupt the response making identification of the peaks hazardous, are excluded The filters used by various clinical groups vary between 100 – 500 Hz (high pass) to 3-5 KHz (low pass). The effectiveness of the filters depends, greatly, on the sharpness of their cut-off frequencies.

The frequency specificity of brain stem responses

It is difficult to identify BSER unless there is a good synchronization of neural activity. Some problem seen in brain stem response when low frequency stimulimare employed. Davis and Hirsh (1975) evaluated the use of a 500 Hz tone pip with a rise and fall of 2 -3 m sec, and found the MV wave at 30 dB SOL to be low in amplitude, rounded in wave form and to have a latency of 10 m sec. Above 40 dB SL, this response was obscured by a larger, earlier response, Davis and Hirsh (1977) have shown that BSER can be used to estimate thresholds at 500 Hz although the response threshold is atleast 15 dB above the behavioral threshold.

Another possible method of increasing the frequency range of BSER is to use high pass masking techniques. Using these techniques Eggermant and Don (1977) have reported a dominant V wave using a 500 Hz stimulus with excellent frequency specificity. Osterhammel and and Huis In't veld (1975) studied the effects of frequency at 1.2 and 4 KHz in a masking study to determine frequency specificity of the brain stem auditory evoked responses. They indicated that the response reflects activity in the cochlear which is characteristic for each signal frequency.

Frequency selective masking of tonal stimuli

Terkildsen, Osterhammal and Huis In't Veld (1975) have performed a series of selective masking experiments. They noted changes due to masking in the recordings when masking noise was contended at or above frequency of the stimulus. The NI wave showed a shift in latency and the following peak was enhanced.

Place of brain stem evoked response in clinical audiometry

The brain stem evoked response technique is extremely promising in the assessment of acoustic function in paediatric population. Most of the workers agree that the fifth wave in the series is the most useful one for audiometric purposes (Eg. Sohmer and Feinmesser, 1970, Hood 1975; Davis 1976; Galambor 1976, Meunier and May 1976). Brain stem evoked response is useful in assessing the hearing function of both infants and adults for a number of reasons.

1. Abnormalities ma aid in neurlogic as well as audiologic assessment;
2. Anesthesia, while not necessary, apparently does not affect the response;
3. Because surface electrodes are used, none of the expense, anesthetic, or other risks inherent in trans-tympanic electrocochleography are involved.
4. When a normal fifth wave is seen, information is presumably transmitted to the level of thalamus (medial geniculate bodies)
5. The response is stable and repeatable over time (Sohulman Galambor and Galambor, 1975).
6. Brain stem evoked response audiometry helps to assess the carefulness of hearing aid.
7. Using brain stem evoked response, improvement after surgery can be assessed.
8. It helps to diagnose the cases of acoustic neuroma.
9. We can construct audiogram using brain stem evoked response which closely corresponds with the puretone audiogram.

10. Bone conduction brain stem evoked response audiometry helps to assess the degree of airbone gap present in conductive and sensorineural hearing loss cases.

However, there are draw backs to the exclusive use of brain stem evoked response with children:

1. At the level of the fifth wave, the observer is really never sure which ear has contributed to the response. If the stimulation is at high intensity or if the transcranial transmission has taken place then, spurious interpretations may be drawn.
2. Bone conduction, while possible, yields similar problems unless masking is used, and then certain decisions must be made about masking parameters that require unavailable audiometric thresholds.
3. Electrode shielding, common mode rejection, muscle artifact, and ambient electrical activity problems can either obscure any good recordings and/or confound the easy identification of the key responses.
4. Since both sides of the auditory system are being stimulated at levels above the cochlear nucleus, it is conceivable that in certain cases, out of phase responses from either side can interact and confound the interpretation of the recordings. Thus having a single source followed by multiple generators along the auditory pathway may preclude simple interpretation.

Clinical application of brain stem evoked response audiometry :

Application of brain stem evoked response in children:

When dealing with hearing deficiencies in very young children the main question to be resolved by the audiologist is concerning the early rehabilitation and early identification. In this regard the recording of the auditory nerve and brain stem responses appear to be helpful diagnostic tools. The test will show if peripheral auditory function is grossly normal, abnormal or seriously impaired. In children with neurological disorders and mental retardation, paediatricians and neurologists want to know if deafness is an aggrevating facts.

Mokotoff and Galambor (1977) combined impedance audiometric and Brain stem evoked response measurements as aids in assessing hearing in children between six months, and four years of age. They recorded, latency of the brain stem wave V prior to obtaining impedance measure. When combined the results indicated that these procedures to have clinically effectiveness in audiological assessment of children, especially with those with whom it is difficult or impossible to use conventional procedures.

1. As a measure of hearing acuity

This test measures the threshold of the auditory response at the level of inferior colliculus and higher lesion may upset hearing without being detected by Brain stem evoked response methods.

The first wave of 6 ms response (NV or N4b) to a click or high frequency tone pip is an excellent audiometric indicator using a 4800 Hz tone pip. Davis and Hirsh (1975) reported that the threshold of detectability to be usually at or below 10 dB SL, Davis (1975) routinely used brain stem evoked response for the hearing evaluation of children. Schulman, Galambor and Galambor (1977) stated that Brain stem evoked response is recordable almost without exception in adults and in infants as young as 33 weeks gestational age. Yamada (1975) showed how patients with a conductive loss could be distinguished from normal subjects by the intensity/latency function of the fifth nerve. Patients with cochlear lesion often showed an abnormally rapid change in both intensity/latency function and intensity/amplitude function which may be related to recruitment.

2. Brain stem evoked response audiometry is an objective method for the quantitative evaluation of hearing. Brain stem

responses can be used in middle ear surgery in order to get direct objective information about middle and inner ear function on the course of reconstruction. The procedure was first described by Jewett et al and later clinically by Gerull et al (1972), Brain stem evoked response audiometry can be applied to middle ear surgery as follows.

(i) Control of sound conducting mechanism in tympanoplasty

Recordings of the BSER is to be done before and after tympanoplasty comparison of the two latencies will indicate improvement or deterioration of sound conduction. Optimal placement of the graft is indicated by the shortest latency;

(ii) Measurement of the mobility of the ossicualar chain

Vibrations of the ossicular chain, produced by click stimuli via this acoustic system, evoke reactions in the brain stem. This mobility of the ossicular chain can be measured indirectly;

(iii) Potential avoidance of inner ear damage

BSER audiometry can be used to determine the inner ear function during removal of the stapes or fenestration of the foot plate.

3. BSER in children with otitis media

Brain stem response may serve as a useful tool in identifying potentials at risk for hearing loss due to middle ear abnormalities. This technique may prove particularly applicable to pediatric population where otoscopic or tympanometric findings may fluctuate or require confirmation. In case of children latency of wave I provides preferable diagnostic criteria for age independent testing of infants and children. Otitismedia in children usually linked with delayed acquisition of language skills and hearing loss due to otitis-media in children who are going to schools can be objectively identified using BSER. In these children prolongation of BSER component latencies with decreasing stimulus intensity (Mendlson et al 1979).

The figure represents the BSER waveform in children with otitis media, before and after treatment

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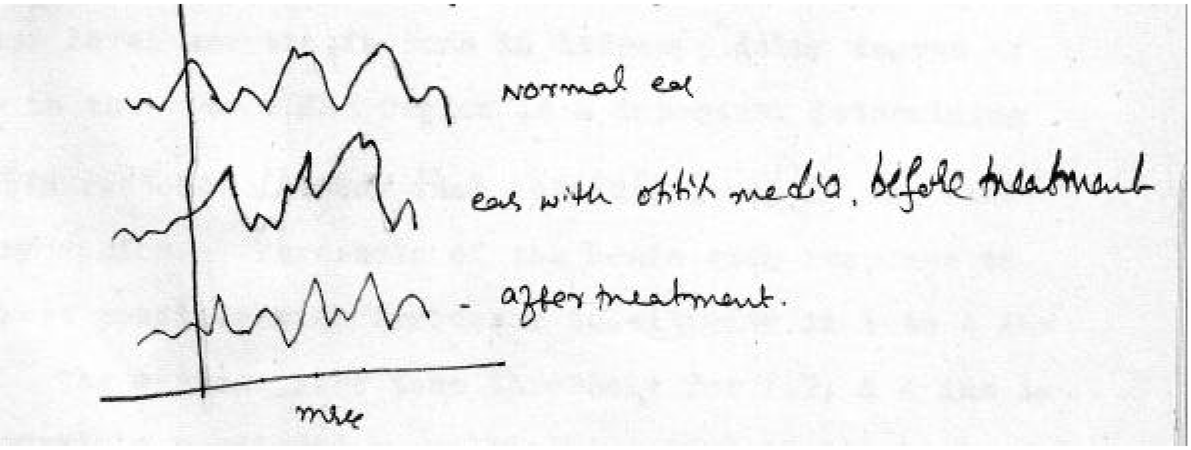


4. Prediction of SN hearing level for BSER

BSER can be used to predict the degree of hearing loss from the BSER threshold and latency data.

Coats and Martin (1972) and Moller and Belgrad reported that the brain stem evoked response thresholds to correlate best with high frequency (HC) hearing levels (2 to 4 KHz). In addition wave V latency is reported to be directly related to audiometric configuration. Latency in flat hearing loss tends to be shorter than latency in high frequency slopping loss.

Jerger (1978) tested normal hearing subjects and patients with high frequency sloping audiograms. In subjects with normal hering, BER latencies at 70 to 90 dB HL ranged from 4.9 to 6.5 m sec. In cases of high for loss patients these latencies were slightly prolonged. although both audiometric shape and level are the factors in latency, delay degree of contour in the 1 to 4 KHz region is a important determining Brain sten response latency than absolute level in the same frequency region. Threshold of the brain stem response to clicks best predicts high frequency sensitivity in 1 to 4 KHz region. The average pure tone threshold for 1, 2, & 4 KHz is most accurately predicted by multiplying BSER threshold by 0.6 Latency of the brainstem response in the 70-90 dB HL region increases by about 0.2 m sec. for a 30 dB increase in the audiometric contour between 1 and 4 KHz.

5. Multiple sclerosis

Multiple sclerosis is a fairly common disorder affecting mainly young adults. Vertigo is very common whilst deafness is rare.

Robinson and Rudge (1975) studied 30 patients with multiple sclerosis and none of the subjects revealed any hearing loss. 22 of the group of 30 patients showed an abnormal delay of the later waves of the BSER. McDonald and Mushin (1972) have shown a latency delay of the visual evoked response in cases of multiple sclerosis. Douek, Gibsen and Humphries (1975) demonstrated similar changes using their “crossed acoustic response” which recorded the post-aural myogenic responses from both sides of the head. Thorhten and Hawkes (1976b) reported that virtually all the patients they tested with definite multiple sclerosis according to schumacher’s criteria gave responses which fell outside the normal amplitude/latency limits. Robinson and Rudge (1977) believed that pairs of clicks stimuli 5 ms apart presented at a fast repetition rate stress the auditory system and make the abnormality of the V wave masked I multiple sclerosis. The pattern is characterized by a prolonged N_1 to P_4 conduction time with the maximum lag occurring enroute the superior olivary amplex to the lateral laminiscal and the inferior colliculus areas as well as by the absence or masked decrease of N_2 and N_5, at times associated with increased amplitude of N_4. A broad, bulky N_4 and a plateau like P_4 may also be observed.

Logic behind this result

Prolonged conduction fits logically with the process of domyelinisation. According to pratt ( ) increased N4 in brain stem lesions may suggest a damage in the more centrally situated levels limiting the area participating in eliciting the potentials. Thus, the wave preceding the damaged area appears sharp in its contours and high in amplitude.

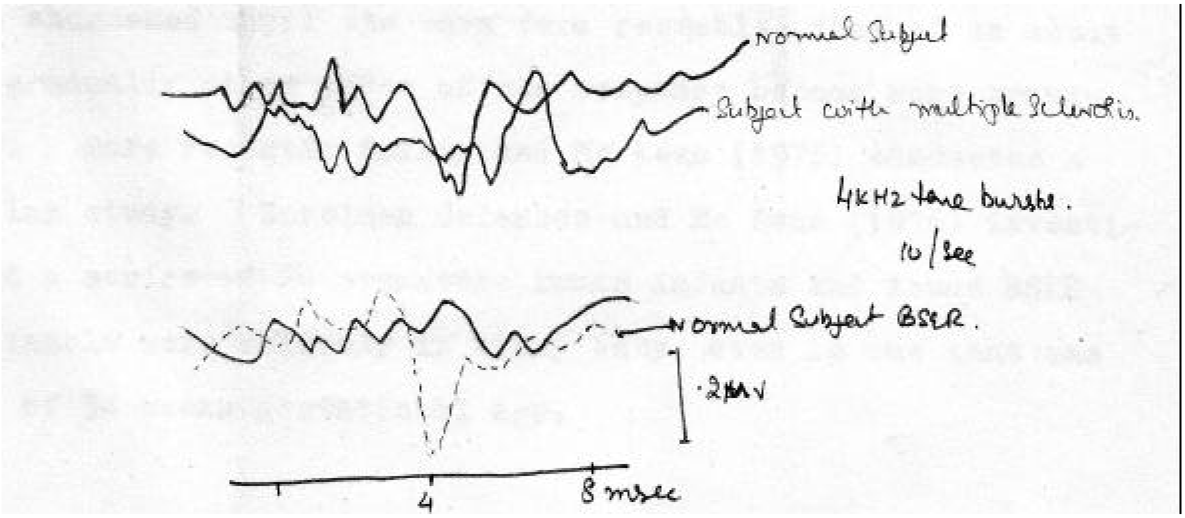
A broad wave may possibly represent a disturbance in synchronization of the fiber response as a result of demyllination. The contour of the wave may reflect the number of the oxans affected and the degree of the pathological process.

Frochet and Soudant J (1978) used BERA to find the exact location of neurologic disorders. They investigated the possible difference between normal subjects and patients with multiple sclerosis when the auditory stimulus was increased from 10 to 50 Hz. Findings from 15 normal subjects were compared with those findings obtained from 6 patients Results revealed no adaptation phenomena in the brain sten. The patterns which characterized M.S. are :

(a) Augmentation of the peak to peak delay;

(b) No synchronization between peaks such that it was very difficult to recognize each peak, and

(c) the peaks were easier to recognize at 50 Hz than at 10 Hz. This dysynchronization at the compression and rarefraction of the click is one important factor which is seen in multiple sclerosis;



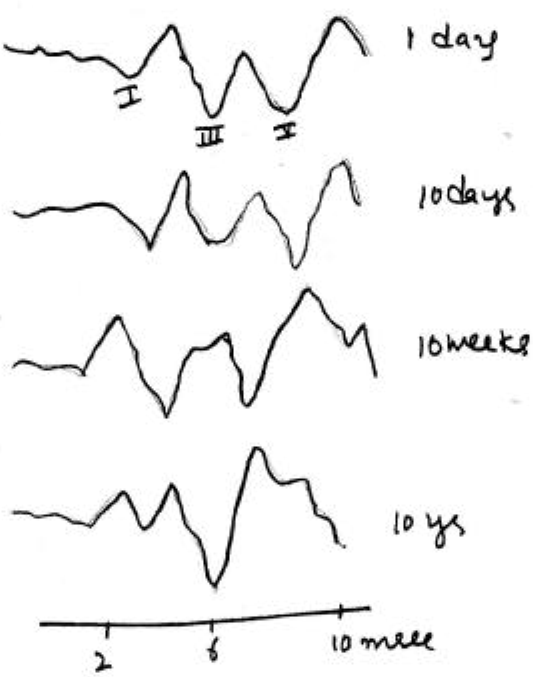
The figure represents the and BSER record from multiple selerotic care

6. The maturation of the auditory pathway in premature infancy and neonates

BSER provides an interesting electrophysiological correlate of auditory development. Jewett and Romano (1972) reported in rats and cats the gradual change in the profile of BSER responses from birth over following weeks till the adult wave form is reached in 1 – 2 months. Similar work was performed by Buckwald and Huang (1975) in cats. Since BSER are obtained by a non-inuasive technique, they may be recorded from human neonates without any fear of legal or ethical problems. Hecox and Galambos (1974) described the development of BSER in human subjects and showed how the wave form altered during the first few weeks of life. At birth, the latency of the later waves was progressively more delayed when compared with the adult BSER wave forms and the third and fifth waves were prominent. Over the next three months, the latency of each of the latter wave shortened until the wave form resembled that of a adult and gradually other waves of the response become more prominent. More recently Salamy and Mc Kean (1976) conducted a similar study. Schulman Galambos and Mc Kean (1976) investigated a series of 24 premature human infants and found BSER obtainable were reliably in every baby, even in one that was only of 34 weeks gestational age.

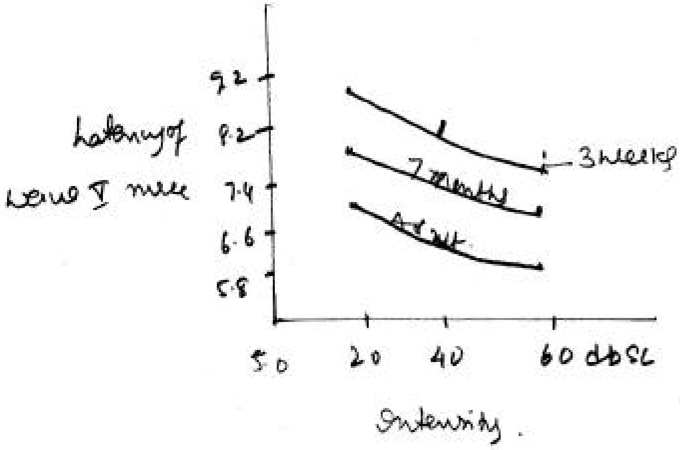
Schulman Galambos and Galambos (1975) observed that a

The figure represents typical BSET pattern recorded at different ages



with respect to vertex.

60dbsc click.
33/sec



The figure represents the latency-intensity curve recorded at different ages developmental decrease in fifth wave latency with increasing gestational age in a group of premature infants. They concluded that the response is not subject to fatigue or sleep stage and it is useful in evaluating auditory function in high risk newborn infants.

7. BSER in Hearing Aid Selection

Brain sten evoked response technique provides a means for determining optimal maximum power output requirement of the instrument used by a hearing impaired. Hecox, Breuninger and Krebs (1975) demonstrated the effects of hearing aid amplification upon brainsten responses. They observed differential responses of the brain sten when a hearing aid was worn. It might also be possible to define many of the acoustic parameters of the hearing aid which result in improved intelligibility for the user. BSER can be an extension of objective procedures in making judgements about approximate hearing aid selection. It does not require patient’s judgement or analysis, nor are the responses are appreciably altered by the patients physiologic state (Saudlin, 1975). Morgan and Salle (1980) used brain sten evoked response audiometry with premature habies. It reveals the following four points. Auditory function matures as follows – non filtered clicks and 4 KHz frequency develops in a parallel fashion. The 2 KHz frequency seem to be delayed. The latency figures for the Jv. wave diminishes as hearing matures but the premature does not have the same latencies at full term as a new born baby. AP – Jv wave also diminishes as maturity nears, principally because of the reduction in Jv latency, but also to a certain extent because of the modifications in Jv latency, which oddly enough seems to lengthen. BSER appears to be a good method to survey premature babies in thenoise of the lucubator or/and with ototoxic treatment.

Starr, et al (1977) recorded the Brain sten potentials from scalp electrodes in 42 infants ranging in gestational age from 25 to 44 weeks. The latencies of the various potentials components decreased with maturation. Wave V was evoked by 65 dB SL clicks, changed in latency from 9.9 m. sec at 26 m sec of gestation to 6.9 m sec at 40 weeks of gestation. Central conduction times in the auditory pathway also decreased with maturation from 7.2 m sec at 26 weeks to 5.2 m sec at 40 weeks. The effects of brain sten and cochlear disorders on auditory brain sten potentials were noted in several abnormal infants. Application of thistechnique could permit an objective definition of both normal and abnormal sensory process in new born infants.

8. Brain sten response in Down's syndrome

Yellin and Lodwig (1980) compared Down's syndrome children and normal children by varying the inter stimulus interval as BSER. Results showed that, auditory evoked brain potentials amplitude as well as latency measure to increase with the lengthening of inter stimulus interval. But in case of children with Down's in normal syndrome AEP peak latencies and amplitude went longer than those found in normal group.

9. Combination of optometry with Brain sten evoked response audiometry

Otometry has been introduced as an "objective" method in hearing aid selection. The method is based on subjective loudness measurements with and without hearing aid. Van Wedel (78) combined optometry with brain sen evoked response to investigate whether this combined method gave a hearing aid fitting method that might also be useful with non-co-operative patients. This combination gave useful results for demped waves with high frequency (above 3 KHz). This gave fruitful result when the damped wave signal of optometry was replaced by another signal suitable for both optometry and brain sten audiometry.

10. Brain sten evoked responses in case of Acoustic tumor

There is an inverse relationship between the operability of acoustic tumors and their detectabiity. Usually, the larger tumors are difficult to remove, but easier to detect are the smaller ones are easier to remove, but harder to diagnose. The initial vague symptoms can delay the diagnosis till the tumor involves the nerve or vessels, increasing the risk to the patient.

Use of brain sten evoked response audiometers for acoustic tumor detection was first investigated by Selters and Brackman (1977) and later by elemis and Mitchell (1979). They observed the latency of wave V to be prolonged or unrecordable in 90% to 100% of ears with proven acoustic tumors. Latency prologation is probably caused by the presence of the tumor on the auditory nerve. It is thought that the pressure may slow down (Clemis and Miller (1978) Beagley (1970) desynchronize the nerve conduction, resulting in a response that is either delayed or so smeared that it is unrecognizable. Additional work by Beagley et al (1970) showed the chemical deplorization to alter the quality of action potentials. Thus a chemical or electrical change in the peripheral auditory system may also increase wave V latency values.

Wave V latencies may be assessed either by a comparison with a normative data values or by comparing the ear under investigations with the patients contralateral ear in cases of unilateral deafness for the purpose of tumor detection. An interaural latency difference (ILD) of greater than 0.3 m sec, when the pure tone threshold is less than 65 dB (0.4 m sec for losses over 65 dB) was considered by selters and Brackman (1977) may to be abnormal.

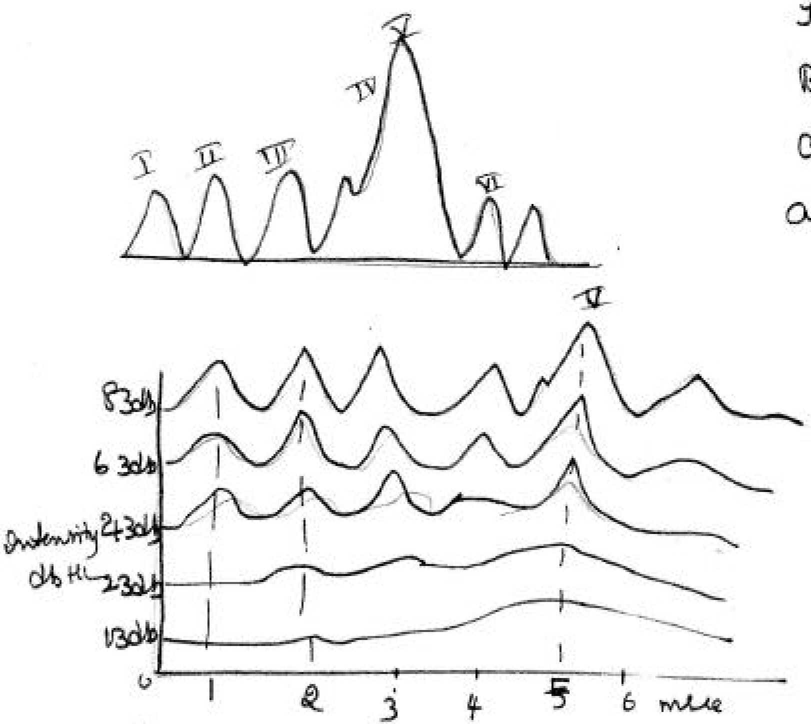
Clemis and Theresemc Gee (1979) tested patients with acoustic tumor using Brain sten response audiometry. Latencies showed one of the three characteristics:

1. Wave V latencies were significantly different from the normal mean;
2. The internal latency difference was greater than 0.3 m sec or;
3. No response could be recognized at sypra threshold levels.

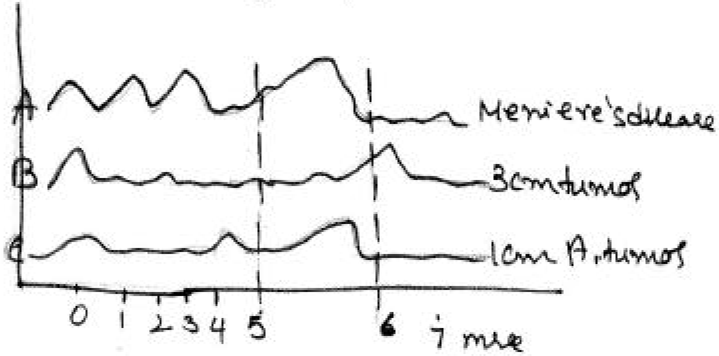
Patients with unilateral vestibular schwannomas has normal absolute latencies, but abnormal interaural latency differences. This suggests that ILD is an more sensitive measure than absolute latency. Tumor size and ILD are very much related. A patient with a relatively small tumor demonstrated rather a large ILD and for a patient in whom no response could be recorded, the tumor size varied widely. This suggests that it is not only the size of the tumor per se, but also the locas of the prenure of the tumor determines the magnitudes of the effect of on the physiological response,. A small strategically placed acoustic neuroma may cause as much latency shift in the presence as a larger tumor in a different locus. However, a larger tumor should exert greater pressure on the nerve than a small tumor. One of the main disadvantage of the interval latency difference measures is its inability to detect bilateral tumors. Clemis (1979) has reported a patient who had Von Reck hinghan's disease who had a 2.5 on tumor on the right side and 0.4 cm intra caricular tumor on the left. Subject showed an ILD of 0.8 m sec, with more delay in the right ear. The ILD values in this case allowed the identification of larger tumor in the right ear and smaller one in the left, but – that of the suggesting false negative result in left. Selter and Brackman (1977) also reported such a case and suggest comparing the latencies with normalitive data.

Thomson and Jerkidson (1975) tested patients with Acoustic neuroma using BSER. Their result showed Its to be of high diagnostic significance in the diagnosis of retrocochlear lesions. It caused a delay in the response or a change in the response configuration.

In 1977, Morokowa studied Auditory BSER with 5 patients having cerebellopantive angle tumors. The results on BSER audiometry with cerebellopontine angle tumor were compared with the acoustic tumor cases. In cases of acoustic tumor all 5 waves

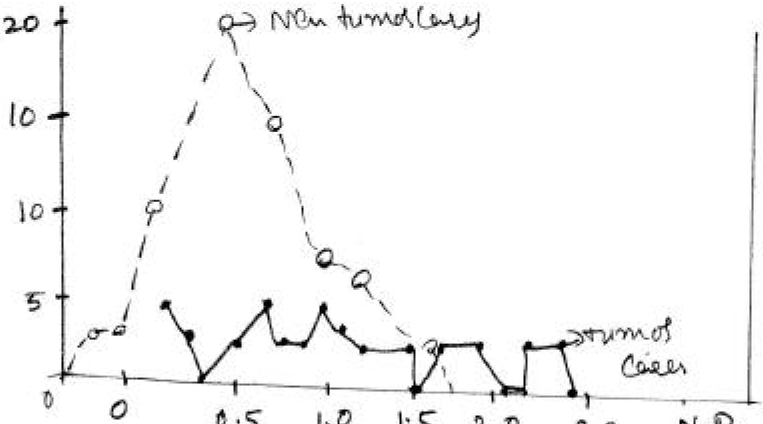


These figure represents BSER in normals. Change in wave form seen as the intensity is decreased.



This figure represen BSER waveform in Meniere's and Acoust. neuroma cases

Shift in latency of wave V observed



This figure represent the interaural differen of T5 latency (IT5) in groups of patients with non tumor cases and 46 tumor cases were unable to be recorded. In cases of other cereballopontine angle tumors not originating from the acoustic nerve, auditory brain sten response consisted of the initial 3 waves (I – III) when the unaffected ear was stimulated and only the initial wave I when the affected ear was stimulated. Four different brain stem responses have been reported to occur in patients with eighth nerve tumors (As given by Gibson and Ruben 1978)

1. **Loss of the BSER wave form following N I**

Sohmer, Feinmesser and Szabo (1974) reported that a stimulating the affected ear of a patient with an eighth nerve tumor, the BSER wave form could only be traced as far as the site of the lesion and the N2, N3, N4 and N5 peaks were absent Similar findings were reported by Starr and Hamiller (1976) Stal Selters and Brackman (1977) have investigated a series of 100 patients whose clinically suspected of retrocochlear disorders. Investigation showed that 36 had vestibulocochlear Schwan 10 had other retrocochlear tumors and forty four had other tumor. These authors reported that 46% of the tumor group gave poorly developed BER wave forms and an unrecognizable NV. On five records only NI was identifiable and all these patients had 3-4 cm tumors located medially in the cerebropontine angle. Four of the patients had excellent hearing on puretone audiometry to lead are to expected a smaller tumor size in them.

2. Latency delay of NV

Selters and Brackman (1977) noted that 54% of the tumor patients in their series had a recordable NV wave on stimulating the affected ear but this wave often showed a latency delay when compared with the NV produced on stimulating the normal ear. They used an 83 dB HL click stimulus and all the patients had puretone hearing the better than 75 dB average for 2.4 and 8KHz. A correction factor was often applied as the hering between the (n) and affected ears often differed. A latency delay of over 0.2 ms was believed to be significant if there was an auditory threshold difference of 0-50 dB, 0.3 ms. with a different of 50 – 65 dB and 6.4 ms with a difference of over 65 dB using these criteria, 96% of the tumor patients were successfully identified and 12% of false positive diagnoses were reached.

3. Difference between Ipsilateral and contralateral recordings

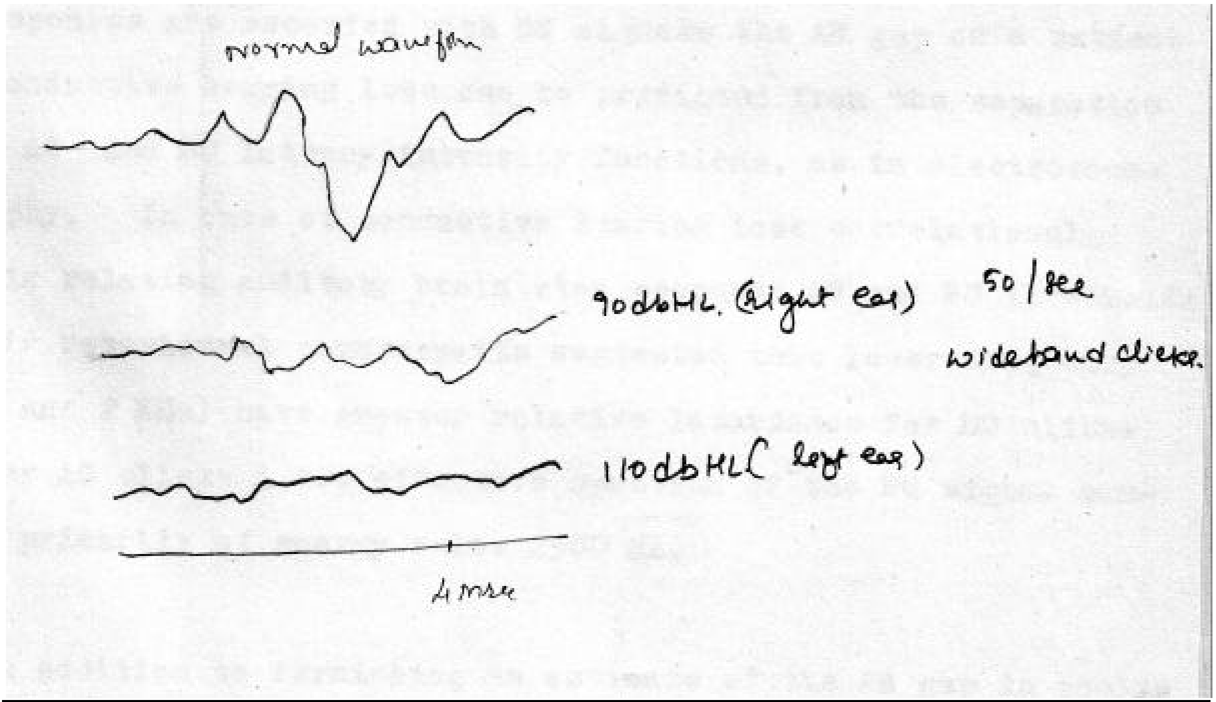
Thornton (1974) showed an abnormality of the first wave (N1) when recorded from the Ipsilateral side of the head using binaural stimulation and suggested that careful examination of the traces might indicate the stimulus entering only from the normal contralateral ear to travel unhindered upto the brain sten He postulated that by comparing the recordings of binaural and monaural stimulation, it may be possible further to localize the site of dysfunction.

4. Latency delay between the N III and NI peaks

Selters and Brackman (1977) measured the time elapsing between the N III and N I peaks and found significant delay only in those patients with large (over 3 cm diameter) tumors. Thus this can very well be used to precict the size of the tumors.

House and Brackman (1979) studied 98 percent of their patients with surgically confirmed acoustic neuroma using BSER audiometry. Latencies of wave forms on both ears wave measured and compared. All the patients showed either a delay or absence of wave V.

The figure represents the BSER recorded from a subject with large 8th nerve tumor affecting the left ear



Bone conduction brain sten evoked response audiometry

The use of bone conducted signals in electrocochleagraphy has been reported by Yoshi (1973) who indicated that the separation of the AC input-output and latency intensity functions from the analogous BC functions provide an estimation of the behavioral AB gap. In addition, Yoshie described a difference in wave form between the amount AP elicited by AC and BC signals. He also noted that the BC latency intensity function be somewhat different from that of the normal AC latency intensity function. In subjects with normal hearing, the latency of wave V was found to be 0.5 m sec longer for responses to BC clicks than for responses to AC clicks presented at the same sensation level. In cases of conductive hearing loss if the auditory brain sten evoked responses are recorded with BC signals the AB gap on a patient with conductive hearing loss can be predicted from the separation of the AC and BC latency intensity functions, as in electrocochleography. In case of conductive hearing loss correlational analysis relating auditory brain sten response AC and BC thresholds to their behavioral counterparts suggested that lower frequency (1 KHz and 2 KHz) have greater relative importance for BC clicks than for AC clicks i.e., effective spectrum of the BC signal consisted primarily of energy below 2500 Hz.

In addition to furnishing an estimate of the AB gap in adults with conductive hearing loss, auditory brain sten evoked responses ABR – Auditory brain sten response) by BC can contribute valuable information in certain difficult to evaluate cases where ABSER by AC is alone ambiguous.

Clemis and Mitchell (1977) described problems that arise from conductive hearing loss when ABSER is used in the diagnosis of acoustic tumours. Latency increases due to conductive hearing losses can be a source of false threshold in their application of ABSER. Use of BC signals offers a solution to this problem. For interaural latency comparisons the ABSER to BC clicks may be recorded separately for each for with the use of appropriate masking. The 2 latency intensity functions may be directly compared before or after latency correction. In addition the corrected BC latency intensity function on the ear in question may be compared with thelatency-intensity function of normal subjects.

Another area where ABSER by BC can be of great value is in the evaluation ofinfants. It is well established that wave V latency systematically increases as gestational age decreases. However, even in conductive hearing loss wave V latency increases. In infants with conductive hearing loss it may be difficult to separate the latency increase due to age from the latency increase due to conductive hearing loss. Such cases, valid estimation of AB gap can be accomplished only if BC signals are used in adition to AC signals.

BC signals may, in some cases, elicit only an observable response. In patients with a mixed hearing loss there is an elevation of the ABR threshold. The conductive loss will elevate the ABR thresholds further. The summed threshold elevations may exceed the output capability of the AC signal system and C signals are not affected. Because in the conductive hearing loss the BC signals need only an energy equivalent to cochlear threshold to elicit a response. The BC thresholds as they allow a prediction of cochlear sensitivity. This may be important in a young child with congenital atresia where other techniques fail in estimating cochlear function. Use of BC signals, in conjunction with AC signals increase the diagnostic and predictive capabilities of the ABSER.

Yamane and Yamada (1971) recorded short latency responses evoked by BC sounds from the scalp of humans. 1 cycle of sinusoidal wave was used as a stimulus for driving the BC receiver. The wave form of the responses evoked by BC sound was similar to BSER evoked by AC sounds. The BC BSER test was used with 20 clinical patients who had conductive, SN and mixed hearing losses. It was demonstrated that the BC BSER test was useful for differentiation of conductive SN and mixed hearing losses.

Limitations

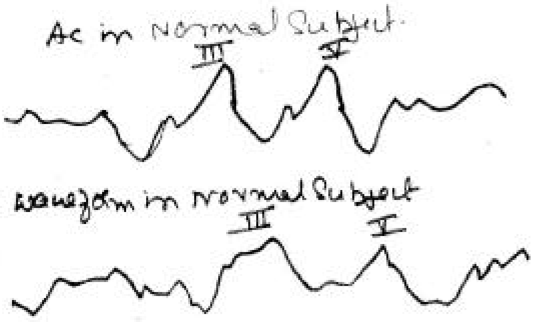
1. The wave V latency by BC is about 0.5 m sec longer than the AC latency at the same intensity. The maximum output latency for BC is less than AC. If the maximum ACoutput level is 100 dB HL, the maximum BC output level is 60 dB HL. This

limits the degree of cochlear loss in response by BC will be observed to a maximum of 40 to 50 dB. At high intensity levels by BC (50 to 60 dbHL) electrical artifacts from the signal transducer may present a significant problem. The use of forehead placement of the BC vibrates reduces but does not eliminate this problem.

2. With all BC signals ABSER signals delivered by BC result in binaural stimulation. To record the BC ABSER from one ear only, the non-test ear must be approximately masked.

3. In subject with normal hearing, the BC ABSER latency is approximately 0.5 m sec greater than the AC latency at a comparable intensity level. This increase in BC latency is due to the different spectra of BC & AC signals. The BC signal primarily is restricted to energy below 2500 Hz, when the BC latency intensity function is corrected for the latency increase, the average separation of the AC and BC functions predicts the average behavioral AB gap in the 1 KHz to 4 KHL. Further this ABSER threshold provides valid estimation of the behavioral threshold for AC and BC respectively.

Kanaugh and Beardsley (1979) tested 37 subjects using bone conduction brain stem evoked response audiometry. They found that the technique to be of limited value in differentiating conductive from neurosensory hearing disorders in all but severely affected subjects. It can, however, evaluate cochlear function in the presence of a known severe conductive hearing loss i.e., external ear atresia. In subjects with severe conductive hearing loss, air conduction elicited maskedly prolonged wave V latencies. Such a masked prolongation was not observed in individuals with peripheral neurosensory loss and when present signified that a patient had a major conductive component to his hearing disorder.



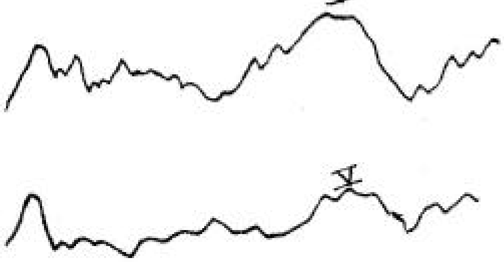
AC in Normal Subject.

BC waveform in Normal Subject

wave V latency of 5.36 msec
wave III latency of 3.51 msec

wave V latency of 7.02 msec
wave III ~~amp~~ latency of 5.04 msec

Figure represents the Bone Conducted BSER in a Subject with asymmetrical neurosensory hearing loss



wave V latency of 6.84 msec
[Contralateral ear masked)

wave V latency of 8.12 msec
(Contralateral ear not masked)

Brain sten response audiometry at speech frequencies

Auditory brain stem evoked response (Wave V) is careful in objective assessment of hearing threshold at higher frequencies (2 KHz and above) (Davis 1976). Yamane and Kodera (19) studied BSER at three speech frequencies (500, 1K and 2 KHz). Their result showed that, in normal subject, Brain stem evoked responses ranged from 10 to 20 dB SL at these 3 frequencies. In subjects with impaired hearing BSER threshold corresponded well with conventional pure-tone thresholds at each frequency in case of low as well as high frequency hearing loss. The BSER thresholds were higher by as much as 25 dB than pure tone threshold inhearing loss cases. They concluded that, the puretone threshold at each of the 3 major speech frequencies can be predicted with fair accuracy from the BSR.

Brain stem evoked responses in mid brain tumors

Starr and Achor (1975) and Starr and Mamilton (1976) have reported the brain stem responses findings in patients with various mid brain tumors. They found that the BSER wave form could usually be identified with the level of the site of dysfunction. For instance, with tumours above the superior olivary complex the waves NI, N II and N III were identified but not the waves N IV and NV.

Other central lesions

Thornten (1974) reported a case of driver in the Royal Navy who suffered from the "staggers" a vestibular form of decompression sickness during a deep dive using oxygen/helium mixture. The bubbler released from the blood, are thought to cause microlesions within the brain stem. When first tested, the patient had a 35 dB loss at 2 KHz and the BER showed an abnormally small N_3 response and an absence of the sixth wave (N V1 and/or NV) six months later, his hearing improved to 15 dB at 2 KHz than the N_3 was enlarged and the sixth wave was visible. One year later, his hearing loss was recovered to normal (5 dB at 2 KHz) his BSER than appeared to be within normal limits.

Comatored patients

Starr and Achor (1975) performed BSER investigations on 37 comatored patients with aetiologies that included drug overdoses hypoxia, diabetic coma, hepotic failure and status epilepticus. The BSER was not altered in respect of latency in any of the conditions.

Brain death

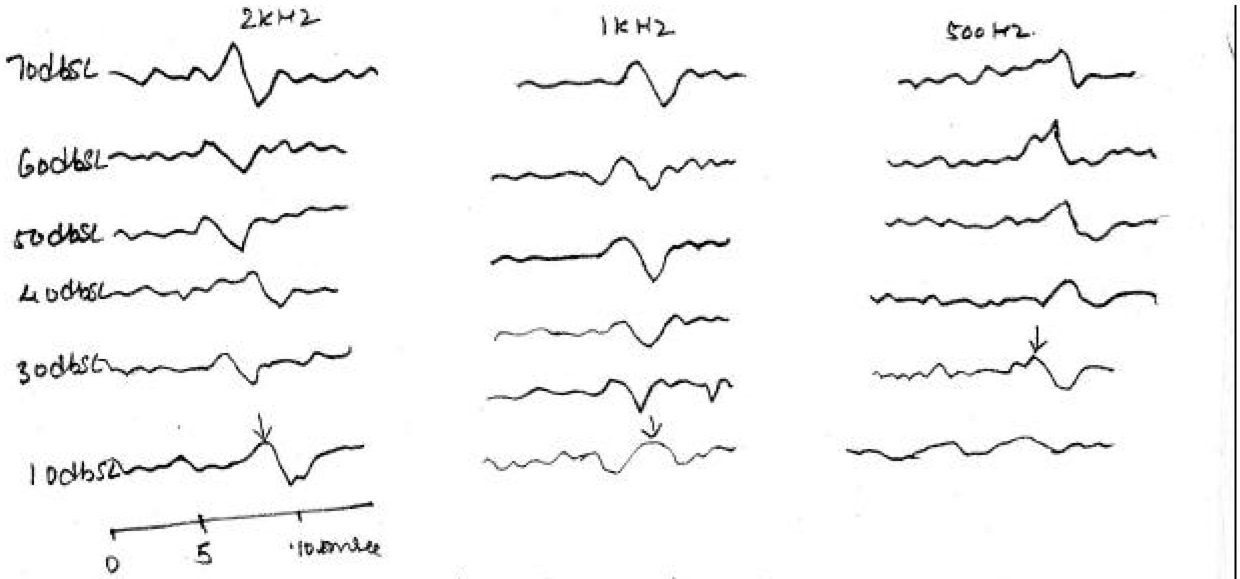
Starr and Achor (1975) used BSER to assess brain death in 20 cases. They found that typically only the first wave (NI) was obtainable.

Construction of the audiogram using brain stem evoked response

One of the major applications of brain stem evoked response audiometry is the determination of hearing threshold in infants and multiply handicapped children. Early detection of auditory problems would allow for early corrective measures, hearing aid selection and language acquisition. For the assessment of hearing threshold puretones are used. By using brain stem evoked response, we can determine the audiogram. It is reasonable to construct the audiogram using the derived brain stem evoked response obtained in high pass masking noise.

Two groups of subjects were tested by Don, Eggerment and Brackman (1979) (1) control group consisting of 10 normal adults (2) a group of hearing loss patients.

Results from normal hearing subjects



Derived responses from 2KHz, 1KHz & 500 Hz. Derived responses [illegible] region shows clear response at 30db

Results from normal hearing subjects are summarized as follows:

1. Contributions to the brain stem evoked response from clicks can be detected down to 30 dB SL for two cochlear regions, 8 KHz and above and 500 Hz and below.

2. Contributions to the brain stem response from 4, 2 and 1 KHz octave wide regions can be detected down to at least 10 dB SL.

3. Latency shifts occurs with intensity changes for wave V for a given octave, wide frequency region of the cochlea,

After defining the normal wave form, they tested hearing loss cases, in order to determine and construct audiogram using brain stem evoked response. They employed the brain stem response high-risk masking technique on patients with audiograms of varying configurations. They compared their derived responses with that of normals.

Specifically, the amount of hearing loss at a given audiometric frequency is defined by the following simple formula:

$$X(f) = L_p(f) - LN(f)$$

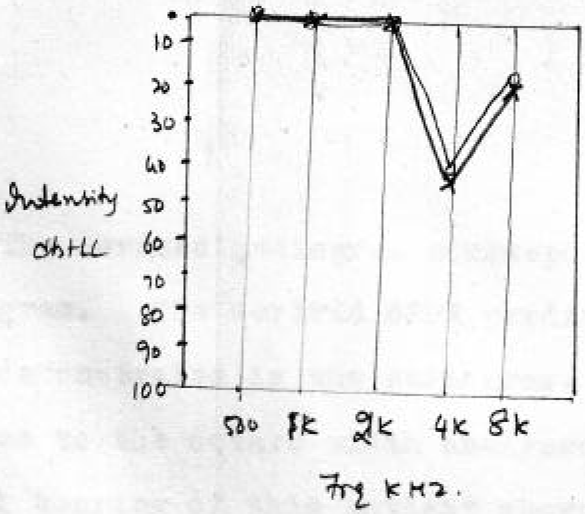
Where X (f) is the patients hearing loss at audiometric frequency f (in KHz);

Lp (f) is lowest click level (HC) where wave V is detected in the patients derived responses for frequency region f.

LN (f) is lowest click level (HL) where as the average wave V is detected in the patients derived responses for frequency region f in normal hearing subjects.

Hearing loss at one audiometric frequency

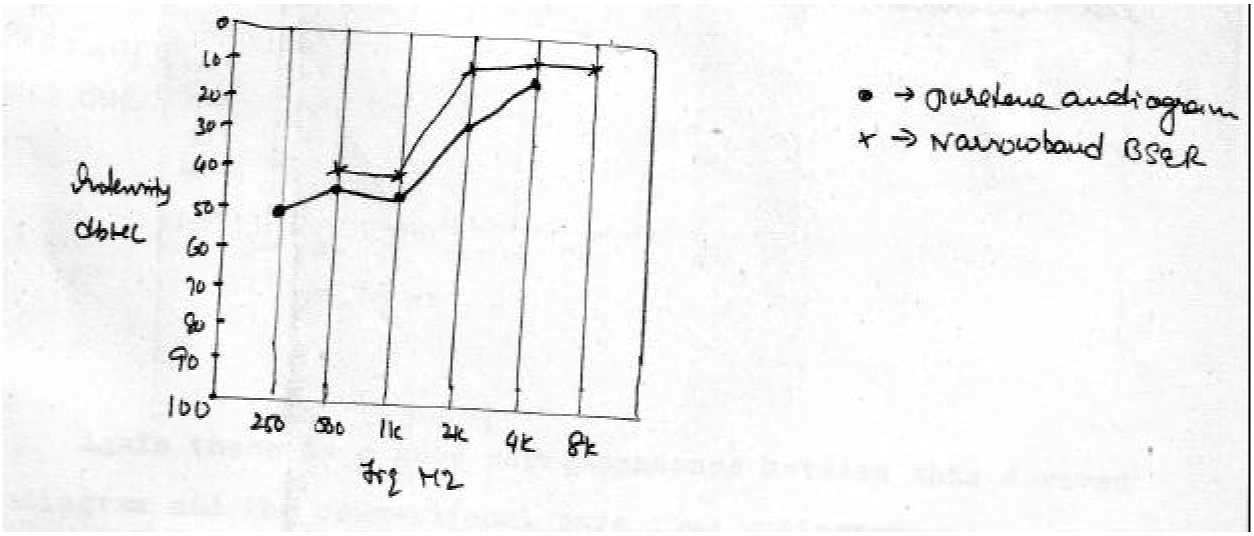
A patient with a " 4 KHz notch" hearing loss was tested in order to determine if this method was sensitive to detecting a loss confined to one specific frequency.



Audiogram showing the derived BSER and pure tone response.

The audiogram derived with the high pass masking technique corresponded with pure tone audiogram. Thus, a hearing loss at essentially one audiometric frequency was revealed by this technique.

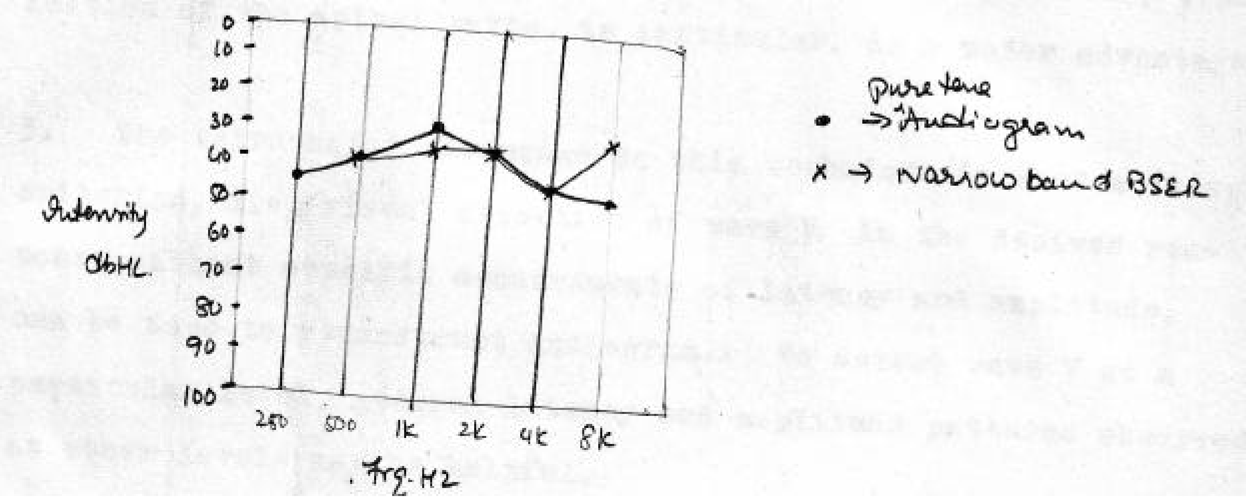
Low frequency hearing loss



The derived audiogram corresponded with that of puretone audiogram. The derived BSER predicted better response at 2KHz than demonstrated in the audiogram. this discrepancy may be related to the octave width analyses used and to the apparently normal hearing of this patient above 2 KHz. In other words, the responses observed in this region at the low intensity levels may have been initiated from the normal regions less than one half octave above 2 KHz.

Flat loss

Another type of hearing loss examined with the high-pass masking technique was the “flat loss”.



Again there is a good correspondence between this derived audiogram and the conventional pure tone audiogram.

The study done by Don, Eggermant and Brackman (1979) indicates the use of brain sem responses derived from a high-pass masking technique to reasonably allow for a accurate reconstruction of the pure-tone audiogram. It has three advantages over any other methods:

1. Click stimuli, which are best for eliciting detectable synchronous neural activity, can be used to obtain frequency specific information needed for reconstructing the audiogram. There has been some difficulty in eliciting well-defined brain stem responses with frequency specific stimuli such as tone bursts, when the

frequency is low i.e., 1 to 0.5 KHz.

2. The high-pass masking technique affords evaluation of specific parts of the cochlea at the various intensity levels, evaluation of the apical parts, in particular, is a major advantage.

3. The third major advantage to this technique is that a `simple' criterion, i.e., visual detection of wave V in the derived response without specific measurements of latency and amplitude, can be used to reconstruct audiogram. To detect wave V at a particular level, general latency and amplitude patterns observed at other levels may be helpful.

Effect of audiogram shape and lesion location on action potential and brain stem evoked responses

In an attempt to use the human compound auditory nerve action potential (AP) in clinical diagnosis, same investigators have ascribed localizing importance to peak latency, to wave form and to the amplitude latency relationship. Prolongation of brain stem auditory-evoked response latency and of the interval between the first AP peak and fifth brain stem response peak (V) have been suggested as retrocochlear lesions (Thornten and Starr, 1976).

Eggerment and Dollar (1976) suggest that AP latency and wave form may be influenced by audiogram shape independent of location of pathological condition, and if audiogram shape affects N_1

latency and wave form, it might also affect BSER latency and wave form. Therefore coats and Martin (1977) studied the effect of audiogram shape and lesion location on brain stem evoked responses. They simultaneously recorded auditory nerve action potentials (APs) and brain stem evoked response (BSERs) in order to correlate with audiogram shape and with location of pathological condition.

This investigation demonstrated that (1) action potential latency (at 108 dB SPL) is correlated with the amount of 4 to 8 KHz pure-tone hering loss and (2) AP threshold elevation and amplitude depression tend to be better correlated with lower-frequency (1 to 4 KHz) hearing levels. They found that as 108 dB AP latency increased with high frequency loss, the condensation rarefaction latency difference also increased. The results further suggested that there are two click action potential components, on early C-R in-phase component and a C – R out of phase component. The relationship between high frequency hearing loss and AP latency did not appear to be linear, but apparently jumped from the early to the late AP component when the high frequency deficit became severe enough to eliminate the early component.

Elberling and Saloman (1976) compared a series of simulated and actual wave forms and input-output curves generated by ears with various audiograms shapes. They suggested that AP latency increased suddenly by abut 1.5 m. sec as 4 to 8 KHz hearing loss was more than 60 dB. This latency jump seemed to be most consistent at high click intensities (95 to 115 dB SPL).

Effects of audiogram shape on Brain stem evoked response

Coats and Martin (1977) found that the AP latency jump at 50 to 60 dB 8 KHz HL was not accompanied by a corresponding peak V latency jump. Thus, at the transitional 4 to 8 KHz hearing level the N_1 to V interval abruptly shortened. They also found that as within the Ap, Brain stem evoked response peak V thresholds were elevated and latencie's were prolonged with increased high frequency hearing losses. However, these brain steme evoked response peak V thresholds were elevated and latencies were prolonged with increased high frequency hearng losses. However, these brain stem evoked response changes tended to correlate best with lower frequency hearing loss than did the corresponding Ap. Changes.

Goldstein and Kiang (1958) observed that, as the rise time of a white-noise burst is increased, the onset Ap response disappears before the corresponding onset cortical-evoked response. Explanation is that, a gross cortical evoked potential requires less single-unit synchrony than does a gross click Ap. This different requirement for synchrony occurs because the cortical single unit response has a longer duration than the auditory nerve single unit response.

Goldstein and Kiang's (1958) explanation of their observations could be invoked to explain the different Ap and BSER – audiogram related changes (1) If the BSER unit responses (at least the one creating peak V) is were longer than the Ap unit response, and (2) both Ap and BSER unit responses became less sunchronised as the total cochlear response shifted apically. Then at the same level of high frequency hearing loss unit desynchrony would cause the first (basal) Ap component to disappear while its BSER remained recordable. At this point the N_1 used to measure Ap latency would jump to the late component thus abruptly shortening the N_1 to V interval.

An alternative explanation of the relative effects of audiogram shape on Ap and BSER is that the auditory units contributing to BSER peak V came from a more extensive basilar membrane area than the units contributing to Ap and that conduction time along the neural pathway from cochlear apex to the peak V generating structure is shorter than the pathway from cochlear base, Tnus as the more apical pathway is "uncovered" by high frequency deficits, N_1 to V interval shortens.

Regardless of their explanation, the different effects of high tone hearing loss on Ap and BSER have been shown to be clinically important. First, the shortened N_1 to V interval with high frequency hearing loss means that, with high frequency hearing loss means that with high frequency hearing loss, the degree of N_1 to V prolongation required to diagnose retrocochlear pathological conditions decreases and the correlation of BSER with lower frequency hearing levels suggests that, at these frequencies, BSER emasuements may serve better than Ap measurements to approximate the pure-tone audiogram.

In 1978, Coats and Martin studied the effect of audiogram shape and location of lesions on brain stem reponse and action potentials to a wider range of intensities. In demonstrated a slight but probably significant, decrease in the normal N_1 - V interval with decreasing click intensity. This study demonstrated that this decreases becomes more precipitous as 4 to 8 KHz hearing loss increases. Lowering the frequency response of the system shortens the N_1 – V interval. In both cases, lowering the systems frequency response tends to broaden the Ap peak.

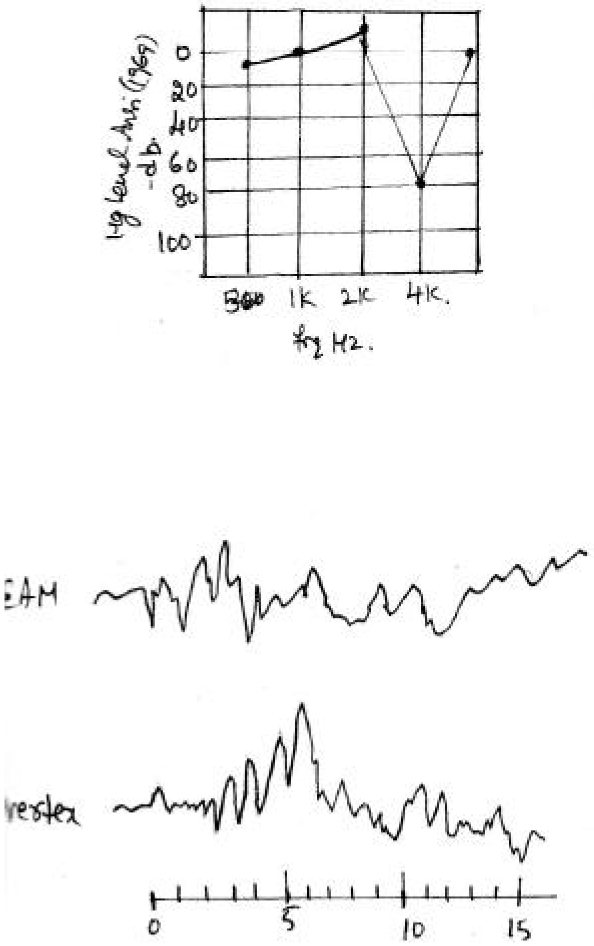
In patients, with Meniere's disease and flat audiograms, Yamada et al reported a brain sten evoked response latency-intensity pattern that closely resembled the Ap and BSER L-I patterns fo high frequency hearing loss ears i.e., a sleeper than normal curve with abnormally long latencies at low intensities but normal or near normal latencies at high intensities.

Inappropriate Ap presentation

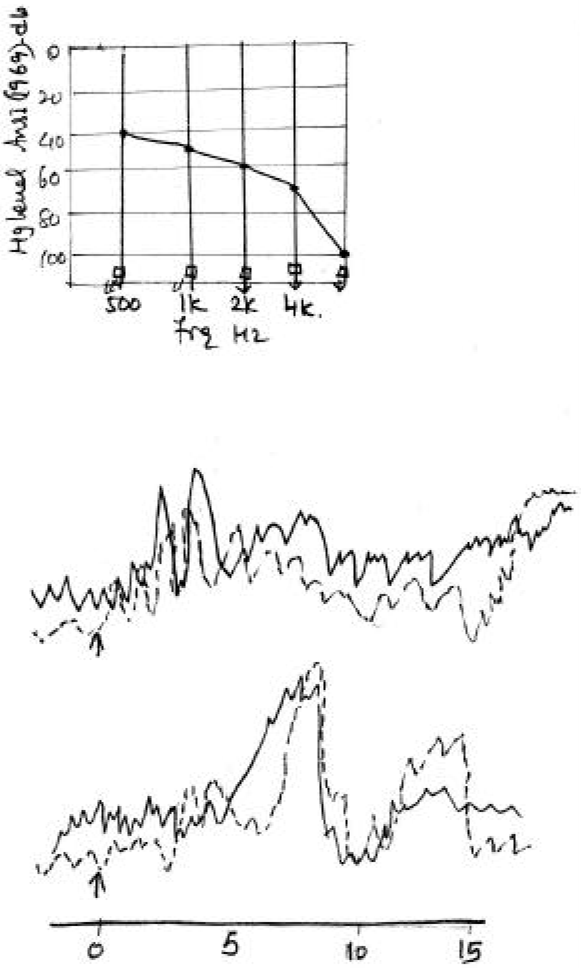
Starr, Thornton and Hawkes (1976) and Sohmer et al (1974) have reported relative presentation of brain stemevoked response component I and depression of the later brain stem peaks in recordings from patients with brain stem pathologic conditions. Coats and Martin (1977) supported this observation and divided the ears with preserved Aps into two sub groups (1) Those with normal high frequency thresholds and (2) those with grossly elevated thresholds particularly at 8 KHz. The second group was designated as “inappropriate Ap preservation”. The explanation of inappropriate Ap preservation is that the brain stem pathological condition spare the primary nerve fibres that generate N_1 and that brain stem neuronal dysfunction creates the subjective pure-tone deficit.

Prolongation of V latency and of N_1 to V interval

Starr, and Thornton and Hawkes (1976) have reported prolongation of both the far-field recorded peak V latency and the I to V interval in patients with brain stem pathologic conditions. Starr notes that the I to V interval seems to be a particularly sensitive indicator of brain stem pathological conditions. Coats and Martin (1977) suggested that accounting for brain stem evoked response audiogram correlations in cochlear deficits increase both the sensitivity and accuracy with which the brain stem evoked response measurements detect vetrocochlear apthological conditions.



These above figures represents the square Wave click APs recorded at the EAM & BSEPs recorded at the vertex from subjects with high fog hg loss response from ear shows e-R phase reversals in Ap and BSER peaks II to IV.Both response show prolonged first AP peak (N1) & BSER peak ,latencies & reduced N1to V Interval .



This fig represents the Audiometric results APs , BSEPs waveform in care of acoustic neurama. Action potential waves are appropriate for degree of hg loss at 4Hz , but Ap is inappropite presented for amount of hearing loss at 8KHz ,N1to V interval & V latency are both abnormally lang

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