A PRIMER ON ELECTROPHYSIOLOGICAL TESTING FOR AUDIOLOGICAL PURPOSES

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AN INDEPENDENT PROJECT WORK SUBMITTED IN PART FULFILMENT FOR FIRST YEAR M.Sc., (SPEECH AND HEARING) TO THE UNIVERSITY OF MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING: MYSORE - 570 006.

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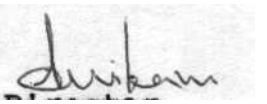
CERTIFICATE

This is to certify that the Independent Project entitled: " A PRIMER ON ELECTROPHYSIOLOGICAL TESTING FOR AUDIOLOGICAL PURPOSES " is the bonafide work, done in part fulfilment for First Year M.Sc., (speech and Hearing) of the student with Register No.M8902.



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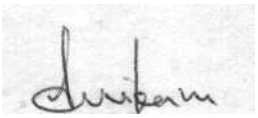
CERTIFICATE

This is to certify that the Independent Project entitled: "A PRIMER ON ELECTROPHYSIOLOGICAL TESTING FOR AUDIOLOGICAL PURPOSES" has been prepared under my supervision and guidance.



GUIDE

DECLARATION

This Independent Project entitled: A PRIMER ON ELECTROPHYSIOLOGICAL TESTING FOR AUDIOLOGICAL PURPOSES is the result of my own study undertaken under the guidance of Dr.(Miss) S.Nikam, Prof. and Head, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore
May, 1965. Register No.M8902

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I am deeply indebted to Dr.(Miss) S.Nikam, Prof. and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore for her invaluable guidance, encouragement and patient listening. But for her suggestions, comments and criticisms, this project would not have been possible.

I also express my gratitude to the Director of the All India Institute of Speech and Hearing, Mysore.

I am very grateful to Srividya, Kiran, Jyothi and Shailashree for their valuable suggestions and criticisms.

Many many thanks to my friends especially Sharmila and Priya for their support and help.

My thanks are also due to my parents who have been a constant source of guidance and encouragement.

Last, but not the least, I am very grateful to Miss Rajalakshmi R Gopal, for her patience in typing out this project neatly.

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INTRODUCTION

Around 50 years ago, Davis (1939) noted that the electrical activity of the brain as indicated by electroencephalographic recordings showed a change when the subject heard a loud sound. This led not only to the usage of the standard EEG technique as a test for hearing acuity, but also to intensive research in this area, which, over the years, has resulted in a number of other electrophysiological measurements like the brain-stem evoked response (BSER), Electrocochleography (ECochG), and others, all of which help in assessing the hearing acuity of the individual under test.

Conventional audiometry, which includes puretone audiometry and speech audiometry, helps in differentiating between conductive and sensorineural hearing impairments whereas tests such as short increment sensitivity index (SISI), alternate binaural loudness balance (ABLB), the tone decay test (TDT) help us to determine if the lesion is cochlear or retrocochlear. Tests are also available for identifying central auditory disorders.

In a majority of the cases hearing loss can be reliably assessed by means of conventional puretone audiometry and speech audiometry. However, this involves the subjective response of the patient, thereby putting a premium on the

patient's cooperation and attention, which cannot be expected prior to 5 or 6 years of age in normal children. In children with brain damage, however, an accurate and critical evaluation of auditory acuity is hardly possible even beyond this age. This is where electrophysiological procedures have a decided advantage over conventional and behavioural audiometry.

The difference between the two techniques lies in the fact that in electrophysiological audiometry, the response to acoustic stimulation manifests itself by a change in the observed electrical properties of the person under test, whereas in behavioral audiometry, the response is an overt bodily reaction. This overt response can be voluntary or involuntary, but the listener has no control over his electrophysiological responses. Hence, the term "objective" is used with reference to electrophysiological audiometry.

Electrophysiologic (or evoked response) audiometry has two main clinical applications:

a) a means of estimating hearing acuity,
b) a method of diagnosis - identifying the cause of a hearing defect or detecting some lesion which is affecting the auditory system.

Not only can evoked response audiometry be used as an independent measure for the above purposes, but it can also be used to cross-check behavioral, conventional and impedance

audiometry test results whenever there is discrepancy between the different results or none of them yield useful information.

Evoked response techniques have become an integral part of audiological and neurological test procedures. Besides having claimed the attention of audiologists and neurologists, it is interest to other professionals such as otorhinolaryago-logists, paediatricians, speech-language pathologists, general physicians, including other allied professionals.

Here, an attempt has been made to cover the available material on ERA with the following aims:

a) To familiarize the reader with the basic concepts and principles related to evoked response audiometry measure-ments,
b) To provide the reader with the information regarding the procedure to be utilized in making the measurements for different types of evoked potentials,
c) To give the reader an idea about the different types of evoked potentials and their respective utility and clinical applications, and
d) To familiarize the reader with the recent advances in the area of evoked potentials as applied in audiological assessment and diagnosis.

The reader may attempt the pre-test prior to reading the chapter, following which he/she can take the post-test. It

is hoped that this manual will be of help to the reader in knowing about the area of evoked potentials and that it will succeed in satisfying the many questions that the reader may have, while simultaneously creating an interest for further acquisition of knowledge in this field.

CHAPTER 2

THE HISTORY AND DEVELOPMENT OF EVOKED RESPONSE AUDIOMETRY

PRE-TEST

1. Fill in the blanks:

1. ..... was the first to detect and record electrical potentials in the animal brain in 1875.
2. A series of auditory evoked cortical potentials were obtained from alert and sleeping humans by ..... and ..... respectively in 1939.
3. The evoked potentials are ..... than the ongoing EEG activity.
4. The discovery and usage of ..... techniques has been responsible for the advancement of the science of electric response audiometry.
5. The principle of averaging or algebraically summing the bioelectric events elicited by time-locked repetition of stimuli was developed by ..... in 1958.
6. ..... responses were the first to be recorded using electronic averaging techniques by Geisler, Frishkopf and Rosenblith in 1958.
7. The ..... refers to the auditory evoked potentials recorded in EEG tracings by Davis, P.A., in 1939 and Davis, H., et al. in 1939.
8. In 1970, ... identified and described the origin of the ABR.
9. The ..... was first identified by Never and Bray in 1936, in the internal auditory meatus.

10. ..... refers to shift in the dc potential characterized by a shift in the baseline of the cochlear microphonic.
11. Attempts to measure the cochlear microphonics, summating potential and the action potential,(in man) using the averaging computer enabled researchers to obtain the ..... in man.
12. The middle-latency AER components occur at a latency of ..... and are also known as ..... cortical responses.
13. The ..... are sustained responses, elicited by each cycle of a low frequency tone burst or continuous signal, which mimic the signal frequency.
14. The FFR was first recorded in man by ....., ... and ..... in 1973.
15. The ..... which was first described by Walter et al. in 1964, requires the subject to be conditioned to expect the stimulus.
16. Both the ..... and ..... are used in threshold-detection audiometry and in the identification of neurological abnormalities.

II. Match the following:

'A'	'B'
1. Walter et al.	(a) Evoked potential in sleeping brain.
2. Never and Bray	(b) FFR
3. Davis, P.A.	(c) Intra-tympanic method of BCochG.
4. Davis, H.	(d) CNV
5. Clark et al.	(e) Cochlear microphonics
6. Jewett	(f) Evoked potential in the waking brain.
7. Worden and Marsh	(g) ABR
8. Portmann	(h) Extra-tympanic method in ECochG.
9. Yoshie et al.	(i) Averaging principle.

THE HISTORY AMD DEVELOPMENT OF EVOKED RESPONSE AUDIOMETRY

The history and development of evoked response audiometry (ERA) may be tabulated as follows:

CATON (1875)	:	noted the presence of electrical potentials in the brain.
BERGER (1929)	:	recorded the first human encephalogram (EEG) from electrodes placed on the scalp.
LOOMIS, HARVER and HOBART (1938)	:	described diphasic or triphasic potentials which occured at the vertex of the head in response to tactile stimulation daring sleep.
DAVIS, P.A. (1939)	:	recorded the evoked response to acoustic stimuli from the alert waking brain.
DAVIS, H. et al. (1939)	:	recorded the evoked potential to acoustic stimuli from the sleeping brain.

In the above electrophysiological measures, the spontaneous EEG voltage exceeds that of the evokd potential. Since these responses were difficult to detect throughout the history of the development of ERA, various techniques have focussed on the means of eliminating unwanted physiological noise from response recordings.

It was the introduction of electronic averaging techniques that entirely revolutionized the science of ERA. This allows the experimenter to accumulate as many responses as she wishes. Hence, the response grows larger as it is a time-locked phenomenon, while the background fluctuations, being random in nature, cancel themselves out.

DAMSON (1951, 1954)	:	used the above additive technique, originally suggested by Hunt, J.D., to detect visual and tactile stimuli.
CLARK (1958) and CLARK et al. (1962)	:	developed an 'average response computer' based on the principle of algebraically summating the bio-electric events elicited by stimulus synchronization.

2.1: <u>The Myogenic 'Sonomotor' Responses:</u>

GEISLER, FRISHKOPF and ROSENBLITH (1956)	:	discovered responses with short latencies of 8-30 m.sec. when electrodes were placed on the scalp. The largest potentials were obtained when the electrodes were placed over the inion.
BICKFORD, GALBRAITH and JACOBSON (1963 a, b)	:	established with utmost certainty that the response elicited was from the muscle.
CODY, JACOBSON and WALKER (1964)	:	demonstrated that these myogenlc responses could be obtained even in

: deaf patients with normal vestibular function, and hence, can lead the clinician to believe that a patient is hearing, when in fact he is totally deaf.

GIBSON (1974) : found that the inion response cannot be reliably used as an objective method of assessing vestibular function, since the presence or size of the inion response correlated poorly with the results obtained by caloric testing.

GOLDSTEIN and RODMAN (1967) : found the parietal responses to be useful in objective audiometry.

KIANG, CRIST, FRENCH and EDWARDS (1963) : reported of the post-auricular response with characteristics similar to the inion response and with its most prominent components occuring between 10 and 20 m.sac.

Changes in the location of the recording electrode resulted in both amplitude and latency variability . However, this response gets abolished by the administration of anesthesia to the post-auricular branch of the VIII cranial nerve.

2.2: Cortical Evoked Response Audiometry (CERA):

For almost two decades between 1963 and 1972, many workers concentrated on the measurement of the slow evoked auditory response which is cortical in nature.

DAVIS, P.A.(1939)	:	first recorded auditory evoked response in EEG recordings.
BANCAUD, BLOCH and PAILLARD (1953)	:	suggested the term 'V potential' to emphasize the anatomical distribution of this response which is centred around the vertex of the head.
DAVIS and TOSHIE (1963)	:	gave a clear account of the shape and latency of the response.
DAVIS, HIRSCH, SHELNUTT and BOWERS (1967)	:	found the CER to be useful in determining the subjective hearing thresholds within a few decibels, given only the passive co-operation of the subject.
BEAGLEY (1971, 1972):		found that even in co-operative children, there is usually a 20 dB gap between the objective and subjective thresholds and this gap is greater in neonates.
BEAGLEY and GIBSON (1974)	:	suggested that contra-indications to using CERA in young children includes brain damage, muscle tics or spasms and epilepsy.

To avoid artifacts which may produce false positive results, sedation of children has been tried. However, under sedation, CERA yields responses which are less reliable than those obtained in the waking state.

Researchers have attempted to discover whether or not the cortical evoked response has any value in revealing the cause or level of hearing dysfunction. However, there are no definite criteria for using CERA data for otoneurological diagnosis.

2.3: The Auditory Brainstem Responses: (ABR)

JEWETT (1970); JEWETT, ROMANO and WILLISTON (1970); and SOHMER and FEINMESSER (1971)	:	described and recorded the brainstem responses, which consist of a series of five or more deflections, by placing the reference electrode on the surface of the scalp at the vertex or the midline of the forehead immediately beneath the hairline.
LEV and SOHMER (1972)	:	compared the experimental results obtained in cats with human recordings and postulated the relation of each wave to important parts of the auditory tract.
JEWETT, ROMANO and WILLISTON (1970)	:	found the fifth wave to be an excellent measure of auditory acuity which may be

: 5 to 15 dB above the subjects absolute hearing threshold.

SOHMER, FEINMESSER and SZABO (1974) : found that in cases with known brainstem lesions, it is possible to determine the point at which the auditory tract is damaged by noting the number of waves which remain intact, and which waves are absent or prolonged in latency.

The ABR has been used as a method of threshold-detection audiometry and in the identification of neurological abnormalities. However, the ABR technique must be handled and interpreted only by knowledgeable and experienced professionals in order to avoid misinterpretation of results.

2.4: Electrocochleography (ECochG):

In ECochG, electrical activity that originates within the cochlea or the auditory nerve is recorded and evaluated. There are three classes of electrical potentials which could be analyzed in ECochG - the compound action potential (AP), of the auditory nerve, the summating potential (SP), and the cochlear potential or microphonic (CM). Of the three potentials, the AP has been found to be the most sensitive indicator of the functional state of the peripheral auditory system.

WEVER and BRAY (1930) : placed an electrode in the auditory nerve of the cat and detected an electric

	:	potential that accurately reproduced the frequency and waveform of the sound stimulus. Subsequent experiments revealed that the same electrical activity could be detected by placing an electrode in the vicinity of the cochlea. This came to be known as 'cochlear microphonics'.
SAUL and DAVIS (1932)	:	were the first to isolate the CM and action potential, which reflects the neural activity in the auditory nerve.
FROMM, NYLEN and ZOTTERMAN (1935)	:	were the first to attempt to record electrical activity from the cochlea of man. However, the initial results were not encouraging since the recordings were contaminated with unwanted noise, and the surgical procedures produced a significant conductive hearing loss. Responses were observed only for high intensities and were dominated by CM activity.
DAVIS, FERNANDEZ and McAULIFFE (1950) and BEKESY (1950)	:	found that, in addition to the CM potential, a d.c. potential may be recorded in response to acoustic stimulation. This was termed as the 'summating potential'.

With the advancement of technology and the employment of electronic averaging techniques by Ronis (1966), there was rapid development of ECochG.

YOSHIE et al (1967) : developed the extratympanic technique of recording wherein the electrode is inserted into the skin of the external auditory meatus (EAM).

PORTMANN et al. (1967) : obtained potentials from a thin needle electrode which pierced the tympanic membrane (TM) to lie on the bony promontory (intra-tympanic technique of recording).

There are two main clinical uses of ECochG. Firstly, it is a reliable and valid test for predicting the hearing status of young children. Secondly, ECochG has great potential in the diagnosis of various conditions that affect the auditory system such as neural lesions, recruitment, etc.

2.5: Middle Latency Response (MLR):

GEISLER, FRISHKOPF and ROSENBLITH (1958) : in one of the earlier studies using the summing computer to study the auditory evoked response (AER), discovered the middle response which they believed to be neurogenic in origin.

BICKFORD et al (1963 a, b) : gave irrefutable evidence that the middle responses described by Geisler et al(1958)

: was myogenic, especially the responses recorded from the post-aural region and the inion.

MAST (1963, 1965) : provided evidence that some of the MLRs (8 - 60 ms) obtained usiag electrodes placed near the parietal region of the scalp are neurogenic.

MENDEL and GOLDSTEIN (1969) : investigated low voltage waves with onset latencies of 25 - 50 ms which are thought to be derived from the medial geniculate and primary cortical projection areas.

MENDEL and HOSICK (1975) : found the MLR to be stable during sleep and under anesthesia.

DAVIS and HIRSH (1973) : investigated 40 retarded children but since the early cortical responses could not always be identified, they concluded that the CERA was more reliable.

2.6: <u>Frequency - Following Response (FFR):</u>

WORDEN and MARSH (1968) : recorded the frequency - following response inanimals. The FFR is a faithful electrical waveform of the sound input.

MOUSHEGIAN, RUPERT and STILLMAN (1973). : were the first to obtain the FFR in man.

MICHELSON and VINCENT (1975) : recorded a sound-evoked sinusoidal response in man with active electrodes placed in the temporal area of the scalp. This response was found to have characteristics similar to the FFR.

These responses have been found to be frequency specific. Measurable responses can be obtained using stimuli 15 - 20 dB above the subject's hearing threshold. However, the utility of the FFR is not clearly understood.

2.7: The Contingent Negative Variation (CNV):

This response requires the subject to be conditioned to expect a stimulus. The subject is asked to perform a task, such as pressing a switch, everytime he hears a sound. An expectancy wave develops as is shown by a shift in the baseline of the EEG tracing.

WALTER (1964) : was the first to describe the CNV.

BURIAN, GESTRING and HAIDER (1969): related the CNV to meaningful words and suggested that it can be used as an objective test for word discrimination.

SKINNER (1972) : found that the CNV lacks stability when recorded from very young children and subjects with learning and emotional problems.

DAVIS, HIRSH and LAUTER (1975). : reported,however, that children as well as adults give reliable CNVs.

The CNV has the unique potential to gain information or test specific cognitive or psychological operations in children as well as adults.

2.8: Conclusions:

The above is a brief account of the development of the different acoustic electrical responses. Prior to the development, of averaging techniques only psycho-galvanic skin response audiometry (PGSRA) and Electro-encephalographic audiometry (EEGA) were used. However, with the introduction of the averager around 30 years ago and the development of technology, several useful methods of assessing auditory thresholds have been made available.

POST-TEST

I. Fill in the blanks:

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9. Yoshie et al.	(i) Averaging principle.

CHAPTER 3

PRINCIPLE OF ERA, CLASSIFICATION OF THE BIO-ELECTRIC POTENTIALS AND APPRATUS FOR ERA

PRE-TEST

I. Choose the correct answer.

(1) The basic principle of ERA is that:

a) When an individual is quiet and relaxed, his brain wave shows a random activity which indicates no change in response to external stimulation.

b) When an individual is active, his brain wave shows a random activity which changes in response to external stimulation.

c) When an individual is resting and relaxed, his brain wave shows a definite pattern which indicates a change in response to external stimulation.

d) When an individual is resting, his brain activity shows a definite pattern which remains so irrespective of any amount of external stimulation.

(2) A change in brain activity consequent to acoustic stimulation is -

a) Comparable to the background activity

b) much larger than the Background activity

c) absent

d) very small compared to the background activity

(3) The principle that has enabled us to bring up the area of evoked potentials to its present level is:

a) magnetism

b) averaging

c) localization

d) none of the above

(4) In carrying out electrophysiological measurements, sufficient number of stimuli must be used

a) to permit accurate measurement of the response

b) to reduce the signal-to-noise ratio

c) both (a) and (b)

d) none of the above.

(5) The compound auditory potential, the cochlear microphonic and the summating potential, all come under the category of

a) Electrocochleography

b) Cortical potentials

C) Endocochlear potentials

d) Brain-stem evoked potentials.

(6) Slow responses include

a) brainstem potentials

b) contingent negative variation wave

c) myogenic responses

d) none of the above

(7) Before installing the equipment, an important consideration is

a) the subject who will be tested

b) the test environment

c) the type of ERA that is to be carried out

d) the type of storage system that is to be followed.

(8) The active electrode is placed on the

a) the mastoid process on the side of the test ear

b) vertex

c) the ear lobe of the non-test ear

d) the promontory.

(9) The final response may be visually displayed on the

a) Oscilloscope

b) Beat frequency analyzer

c) Sound level meter

d) all of the above.

(10) Latency measurements done on the visual display include

a) absolute latency

b) inter-peak latency

c) inter-aural latency

d) one or all of the above depending on the type of ERA measurement done.

II. <u>Fill in the blanks:</u>

1. Fast responses have a latency between .... to ....
2. CNV is a . . . . . response
3. The cochlear microphonic is generated by the . . . . . of the organ of corti.
4. During ECochG, the . . . . . potential is recorded
5. . . . . stimuli are used for obtaining ECochG, BER and some other responses.
6. . . . . are evoked using tonal stimuli.

7. The ..... is placed close to the electrodes to immediately amplify the minute evoked response.
8. The heart of the recording unit is the .....
9. ..... are used to remove the unwanted frequencies from the amplified signal response.
10. Besides displaying the response, the same has to be ..... for future references.

PRINCIPLE OF ERA, CLASSIFICATION OF THE BIO-ELECTRIC POTENTIALS AND APPARATUS FOR ERA

3.1: Principle of ERA:

Evaluation of the auditory system enables us to understand one's language and hence, one's communicative ability. It also enables the professional in making appropriate medical referral and instituting correct treatment procedures. Conventional audiological assessment involves the subjective and motoric response of the subject under test, and hence, has tts limitations in those cases afflicted with mental retardation, motor incoordination, etc. The advantage of ERA lies in the fact that it is technique wherein the subject can exert little control over his responses. Hence, use of electrophysiological techniques enables us to obtain an objective measure of the subject's hearing without need for his co-operation. This, thereby, when used along with other behavioral testing procedures, especially in the case of small children, helps us in making a more accurate diagnosis about the subjects hearing and neuro-otological status.

The basic principle of ERA is that when an individual is quiet and relaxed, his brain wave recorded shows a definite pattern. In the presence of an external stimulus, be it auditory, visual or tactile, there is a change in the brain

wave which is response to the sound. This change is known as the evoked potential, or evoked response, and this change indicates that the subject under test has perceived the acoustic signal.

However, this change in the brain activity is negligible when compared to the background activity. In other words, the background noise obscures the response, since the elicited responses are smaller than the ongoing brain activity.

The adoption of the electronic averaging techniques in recording these small responses helped to overcome this problem. Electronic averaging allows the investigator to accumulate as many responses as desired by presenting many identical stimuli successively. The responses are added together and the response, being time-locked, grows in magnitude, while the background fluctuations, being random in nature, gradually cancel themselves out. Hence, when larger number of stimuli are used, there will be a greater reduction in background EEC activity and there will be a greater summation of the response amplitude. The signal-to-noise ratio should be such that it permits detection of the response. Hence, an adequate number of acoustic stimuli should be used in eliciting a response.

Every ERA procedure uses the above principle of electronic averaging in the summing computer with the aim of determining

the hearing threshold, and if possible, the site of lesion in the auditory system.

3.2: Classification of the Bio-Electric Potentials:

There are various bio-electric potentials of the CNS which may be utilized as neurophysiological indices of auditory function. Starting at the periphery (the cochlea) and progressing along the auditory pathways to the cortex, there are:

a) Endocochlear potentials
b) Brainstem evoked potentials
c) Middle latency responses
d) Cortical evoked potential
e) Very late cortical potentials

a) Endocochlear potentials:

(i) The compound auditory nerve action potential:

This is generated by the fibres of the auditory nerve with a latency of about 2 msec. when the cochlea is stimulated by an acoustic stimulus which is abrupt in onset. Teas et al. (1962) established that this is a diphasic potential with two negative peaks. The typical compound action potential has its main origin in the basal turn of the cochlea, and is recorded during ECochG.

(ii) The cochlear microphonic:

The cochlear microphonic is generated by the hair cells of the Organ of Corti. This gives a reasonably faithful reproduction of the incident sound, eg. a pure tone (an acoustic sine wave) produces a sinusoidal microphonic in the cochlea. The cochlear microphonic which has no perceptible latency, is difficult to quantify, and does not have a physiological threshold which precludes its utility in the assessment of hearing loss.

(iii) The summating potential:

Like the cochlear microphonic the summating potential (SP) has no discernable latency. The SP is a d.c. potential recorded in response to continuous acoustic stimulation. Davis (1958) referred to two types of SP:

(a) Positive SP - These are produced by the outer hair cells.
(b) Negative SP - These are produced by the inner hair cells.

b) <u>Brainstem evoked potentials:</u>

These potentials consist of five or more peaks separated temporally by about 1 msec. each of which arises from different points in the auditory pathway. Even though these potentials have very small amplitudes, i.e. hardly one microvolt, they are of immense value in audiological diagnosis and in neurological investigations.

c) Middle latency responses:

The site of generation of the middle latency responses is believed to be situated in the auditory radiations in the thalamic region, and in the primary auditory cortex in the temporal bone. These are frequency sensitive responses, with a latency of 10 - 50 msec.

d) Cortical evoked potential:

This is the cortical response evoked by an auditory stimulus. This potential is most robust and prominent when recorded from the vertex. Hence, it is also called the V-potential, which is a good index of auditory function.

e) Very late cortical potentials:

This refers to the contingent negative variation which is obtained through operant conditioning of the subject. This results in an expectancy wave, which indicates that the stimulus has been processed in the higher cortical areas.

Besides the above potentials, it is relevant to know about the frequency following response (FFR). This is an alternating current response which reproduces the electrical waveform of the input stimulus and is generated in several nuclei of the brain stem.

The above classification of responses is based on the point of origin of the potential. Responses may also be classified on the basis of their latency characteristics as explained below:

Response		Latency
(1) Fast responses	-	2 - 8 msec.
(2) Middle responses	-	8 - 50 msec.
(3) Slow/late responses	-	50 - 300 msec.
(4) Very late responses	-	250 - 600 msec.
(a) Expectancy wave	-	250 - 360 msec.
(b) CNV	-	300 + msec.

3.3: Apparatus for ERA:

The instrumentation required for ERA is highly complex, sophisticated, and expensive. Basically, the apparatus consists of two parts - one part to record the responses, and the other part to generate the necessary stimuli to evoke the responses. The recording unit includes electrodes, amplifiers, filters, averager, display and permanent recording device. The sound producing unit comprises of an audiometer connected to a loudspeaker, earphone or a bone vibrator. The test environment forms an important aspect of the test situation.

3.3.1: Test environment: The test environment influences the responses recorded from the subject, and thus the reliability

of the results. Several important factors must be borne in mind, when constructing a test room, in order to create the ideal environment for electrophysiological testing. These are:

(a) Ample space must be available for the tester, the subject and the equipment.

(b) The room should be sound treated so as to have valid results and to avoid contamination of the responses from extraneous, unwanted stimuli.

(c) It is preferable to have a two-room situation with a window through which to observe the subject. When only one room is available, a partition is necessary between the subject and the tester and equipment.

3.3.2: The stimulating apparatus: The apparatus which generates the acoustic stimulus may be a separate instrument or it may be built into the averaging computer. If the former, the timing of the onset of the stimulus must be accurately linked to the averager so that each stimulus occurs at a definite time during each analyses period.

The stimulus-generating unit produces, at first, an electrical waveform, which gets amplified, modified, and finally transduced into the acoustic waveform. The accuracy with which the electro-acoustic transduction takes place depends upon the quality of the transducer.

Depending on which response, i.e. the fast response, the middle response, etc., we are interested in, the acoustic stimulus has to satisfy certain requirements. The number of stimuli required and the rate of presentation are determined by the rate of triggering and each presentation has to be accurately synchronized with the sweeps of the averager to facilitate averaging.

3.3.2.1: The stimulus: The output cannot be interpreted when there is uncertainty about the input. Hence, the stimulus parameters are important. An ideal stimulus mast meet three criteria:

(a) It must be exact in timing so that the latency of the response is clear.

(b) It must be frequency - specific.

(c) Its intensity must be known.

The different types of stimuli that are used include:

(i) Click stimuli: This is an electrical and acoustic wave form with a very rapid onset. It stimulates the entire length of the cochlea. This is used in obtaining ECochG (action potential), brainstem evoked response, myogenic responses and the MLR.

(ii) Tonal stimuli: These are frequency-specific stimuli (pure tones) having a gradual rise and fall time to avoid

scattering the acoustic energy. However, the rise time of the stimulus should not be as great as 20 msec. as is seen in pure tone audiometers. This is because the slow rise time would result in a loss of synchrony as individual nerve fibres would fire at different moments during the rise time of the stimulus and this would lead to blurring of the averaged response.

These stimuli can be used to evoke the slow responses such as the cortical responses (CERA and CNV).

(iii) **Filtered clicks** are clicks stimuli obtained by passing the clicks through high-pass and low-pass filters to eliminate all frequencies except those within a limited bandwidth. These have a fast rise time and cannot be produced at frequencies below 2 KHz.

(iv) **Tone pips**:- Here a single sinusoidal wave which starts and stops at zero crossings is passed through high-pass and low-pass filters and the resulting waveform is used as the stimulus.

(v) **Tone bursts**:- Tone bursts have a duration which is very dependent on the frequency of the stimulus. It has a fast rise and fall time and is short in duration.

(vi) **Masking noise:**- A masking noise contains a range of frequencies (the range being wide or narrow) Which is

used to prevent the hearing of a sound or part of it. For eg. in puretone audiometry and speech audiometry, masking noise is presented to the better ear (non-test ear) to prevent it from hearing the sound stimulus presented to the poorer ear (ear under test). In the case of some evoked potentials such as ECochG the need for masking does not arise because one can accurately estimate the cochlear function without the question of the better ear participation arising.

3.3.2.2: The amplifier: This is needed for the amplification of the electrical waveform of the stimulus.

3.3.2.3: The attenuator: In order to present the stimuli at varying intensities, we need the attenuator to attenuate the input and output of the power amplifier.

3.3.3: Calibration: To obtain reliable and valid results, it is important that accurate calibration of the intensity and frequency parameters of the stimulus through the different modalities - air conduction, and bone conduction, is done.

3.3.4: The Recording Apparatus: Once the stimulus is presented, it evokes a bio-electric response which should be collected and recorded. The recording apparatus consists of the electrodes, amplifiers, filters, averager and display, including a print-out to get a permanent record.

(a) The electrodes: Depending on the site of location on the subject, the form of the electrode varies. Electrodes used for ERA may be either the 'surface' or 'specialized' type. The active electrode (usually tagged red) is placed nearest to the source of the potential. This is called the vertex electrode. A reference electrode (usually tagged white) is placed at a neutral point such as the ear lobe or mastoid. The ground electrode(usually tagged black) is placed at a further neutral point such as the earlobe of the non-test ear or the mastoid process.

Surface electrodes are those that are placed on the skin, whereas specialized electrodes are of a type that they may be placed in a particular anatomical area such as on the promotory or the round window of the cochlea.

(**b) The pre-amplifier:** The evoked response is small when compared to the ongoing electrical activity which can easily dampen the evoked response. So, the pre-amplifier is placed close to the electrodes so that the response can be amplified, perhaps a couple of hundred times, so that it becomes larger when compared to any other background electrical activity.

(c) The main amplifier: The final amplification or gain is provided by an amplifier located in the main portion of the recording apparatus.

Both the pre-amplifier and the amplifier accurately amplify all the frequencies in the physiological spectrum without distortion (biological amplification).

(d) Filters: The amplified signal contains a wide range of frequencies, the upper and lower limit of which correspond to that of the amplifier characteristics. Each one of the evoked responses has energy concentrated in a particular frequency range. By using appropriate filters based on prior knowledge of where the energy is concentrated, we can remove the unwanted frequencies, which only contribute to interference.

The 'cut-off' capability of the filter is usually measured in decibels per octave.

(e) The averager: Forming the core of the entire apparatus, the averager adds the separate responses to successive identical stimuli, and the response. being time-locked, becomes larger, while the background activity cancels out owing to its randomness. Thus an account of the averager, the final recording of the response is clear.

(f) Display: Usually the end result of averaging is displayed on an oscilloscope. It is advantageous to see the build-up of the response, since any sudden changes or baseline fluctuations due to artefacts may be noticed. Latency measurements should be done since latency values, be it absolute, inter-peak or inter-aural, have diagnostic value.

3.3.5: Datastorage: Storage may be achieved by making a permanent recording using print-outs, or a tape, or even the memory of a computer, storage of data must be arranged in such a way that previous work is easily accessible so that cases can be easily checked and comparisons with the baseline can be made.

Each set of data must be labelled with the patients name, age, clinic number, address and date of testing.

3.4: Conclusion:

In this chapter the basic instrumentation that is needed for any ERA measurement has been dealt with. Specific details and requirements for specific responses are given in the respective chapters under the heading "Instrumentation".

POST-TEST

I. Choose the correct answer:

(1) The basic principle of ERA is that:

a) When an individual is quiet and relaxed, his brain wave shows a random activity which indicates no change in response to external stimulation.

b) When an individual is active, his brain wave shows a random activity which changes in response to external stimulation.

c) When an individual is resting and relaxed, his brain wave shows a definite pattern which indicates a change in response to external stimulation.

d) When an individual is resting, his brain activity shows a definite pattern which remains so irrespective of any amount of external stimulation.

(2) A change in brain activity consequent to acoustic stimulation is -

a) Comparable to the background activity

b) much larger than the background activity

c)absent

d) very small compared to the background activity

(3) The principle that has enabled us to bring up the area of evoked potentials to its present level is:

a) magnetism

b) averaging

c) localization

d) none of the above

(4) In carrying out electrophysiological measurements, sufficient number of stimuli must be used

a) to permit accurate measurement of the response

b) to reduce the signal-to-noise ratio

c) both (a) and (b)

d) none of the above

(5) The compound auditory potential, the cochlear microphonic and the summating potential, all come under the category of

a) Electrocochleography

b) Cortical potentials

c) Endocochlear potentials

d) Brain-stem evoked potentials

(6) Slow responses include

a) brainstem potentials

b) contingent negative variation wave

c) myogenic responses

d) none of the above

(7) Before installing the equipment, an important consideration is

a) the subject who will be tested

b) the test environment

c) the type of ERA that is to be carried out

d) the type of storage system that is to be followed.

(8) The active electrode is placed on the

a) the mastoid process on the side of the test ear

b) vertex

c) the ear lobe of the non-test ear

d) the promontory.

(9) The final response may be visually displayed on the

a) Oscilloscope

b) Beat frequency analyzer

c) Sound level meter

d) all of the above.

(10) Latency measurements done on the visual display include

a) absolute latency

b) inter-peak latency

c) inter-aural latency

d) one or all of the above depending onthe type of ERA measurement done

II. <u>Fill in the blanks:</u>

1. Fast responses have a latency between .... to ....
2. CNV is a . . . . . response
3. The cochlear microphonic is generated by the . . . . . of the organ of corti.
4. During EcochG, the . . . . . potential is recorded
5. . . . . stimuli are used for obtaining ECochG, BER and some other responses.
6. . . . . are evoked using tonal stimuli.

7. The . . . . . is placed close to the electrodes to immediately amplify the minute evoked response.
8. The heart of the recording unit is the . . . . . .
9. . . . . are used to remove the unwanted frequencies from the amplified signal response.
10. Besides displaying the response, the same has to be . . . . . for future reference*.

CHAPTER 4

THE AUDITORY MYOGENIC RESPONSE (AMR)

PRE-TEST

I. Fill in the blanks:

(1) The . . . . . of the body give an involuntary response to auditory stimulation.

(2) Geisler et al (1958), who recorded the auditory myogenic responses, considered them to be . . . . . in origin. However, in 1963, Bickford and his colleagues proved these responses to be .....

(3) The . . . . . response can be obtained in deaf subjects with normal vestibular function.

(4) The parietal response has now come to be known as the . . . . . or the . . . . . response.

(5) Of the 4 responses identified, the ..... has received maximal attention.

(6) While Cody and Bickford (1969) found . . . . . to be in-effective in eliciting responses, Yoshie and Okudaira, in the same year, reported ..... to be effective in eliciting consistent responses.

(7) Douek et al (1973) introduced the term . . . . . to describe the post-aural response.

(8) In general, the myogenic response is elicited by the . . . . . of the stimulus.

(9) ..... muscle tone .... and ..... all diminish the response.

(10) As the stimulus intensity is increased, ... also increases in an exponential manner.

(11) The post-aural responses can be obtained within ..... of the hearing threshold of the individual.

(12) One of the characteristics of the optimum stimulus is that it should have a rapid .....

(13) The CAR can be used as a ..... technique in assessing hearing acuity.

(14) In a unilateral moderate hearing loss case, a 60 dB HL click elicits similar responses from both ears. A possible reason for the normal response in the ear with hearing loss could be .....

(15) Increased latency values have been reported in cases of .....

II. <u>Multiple choice</u> - <u>Choose the correct answer:</u>

1) Bickford et al (1963) demonstrated that the myogenic responses could be elicited from:
   (a) only the scalp muscles
   (b) muscles all over the body
   (c) only the pinna
   (d) the nerves of the body

2) The largest post-auricular responses can be obtained by placing the active electrode:
   (a) on the vertex
   (b) on the ear lobe

(c) on the wrist

(d) immediately behind the pinna

3) To keep the subjects in an alert and unrelaxed state, they should be:

(a) seated on soft cushioned chairs

(b) asked questions once in a while

(c) seated on wooden chairs

(d) both (b) and (c)

4) The post-aural response is:

(a) neurogenic in origin

(b) muscular in origin

(c) both (a) and (b)

(d) none of the above

5) The use of crossed acoustic response for neuro-otological purposes is based on the fact that

(a) we use both ears for hearing

(b) the nerves from the cochlea ultimately end in the brain and hence any pathology can be detected

(c) that nerve fibres cross in the brainstem on one side to both the opposite side and continue on the same side.

(d) the myogenic response is a reflex.

6) The instrumentation for recording the post-aural response includes:

(a) a high quality transducer, a loudspeaker and earphones

(b) a microphone and a digitizer

(c) noise makers and pure tone audiometer

(d) none of the above

7) Jumps in latencies with decreasing stimulus intensity are sometimes observed in:

(a) conductive hearing loss

(b) retrocochlear pathology

(c) brain stem lesions

(d) cochlear pathology

8) It has been found that head position affects the response. The largest response is obtained when:

(a) when the head is lifted upwards

(b) when the neck is flexed

(c) when the head is turned to the side where the recording is being made

(d) when the head is turned away from the site of recording.

9) The 'crossed acoustic method' is

(a) a reliable diagnostic tool

(b) can be used for screening purposes

(c) can be used in combination with other more reliable tests

(d) both (b) and (c)

10) Prolonged latencies have been reported in cases of

(a) multiple sclerosis

(b) chromosomal abnormalities

(c) conductive hearing loss

(d) migraine

AUDITORY MYOGENIC RESPONSES

4.1: All the muscles of the body give an involuntary response to acoustic stimulation. These responses are of two main types:

(a) Responses to loud sounds - These responses form part of the startle response

(b) Responses to quiet sounds - This is a generalized response in all muscles of the body to quiet sounds.

The muscles within the middle ear, especially the stapedius responds (by contraction) consistently to sounds. However, the muscles of the leg and arms react in an inconsistent manner to intense sound stimulation. Some of the muscles around the scalp may be excited by sound stimulation. This is evident in the ability of animals to prick up their ears when they hear a quiet sound (Preyer's reflex). Because the same muscles are vestigeal in man, it was with the use of averaging techniques that the responses could be detected.

Actually, the auditory myogenic responses were the first responses to be recorded using the averaging techniques. Geisler, Frishkopf and Rosenblith (1958) recorded responses to clicks from the scalp in human subjects, but they considered

the responses to be neurogenic. However, Bickford et al. (1963) clearly proved that these scalp recordings were myogenic and demonstrated that similar responses could be obtained from muscles in all parts of the body. Out of the responses from the various muscles four have received more attention: those from-

a) the inion
b) the parietal
c) the jaw
d) the post-auricular region.

4.1.1: The Inion Response: To obtain this response, the active electrode has to be placed on the external occipital protuberance (inion). One cannot be sure of the origin of this response as there are quite a few muscles and neurogenic elements in that general area. It is probably derived from the neck muscles, having a negative peak at 30 msec, latency.

This response can be obtained in deaf individuals with intact vestibular function (Cody et al. 1964) and hence, it is not advisable to use the same to predict hearing acuity.

There are problems with this response in that even visual and tactile stimuli can produce measurable responses even though they may lie at different latencies (Cody and Bickford, 1969). Also vestibular or cochlear stimuli can

give rise to a response. Due to it's non-specific nature, the inion response has not yet been put to clinical use.

4.1.2: The_Parietal_Response: This response is a complex containing both neurogenic and myogenic components* The major component is believed to be neurogenic, but it has not been possible to separate absolutely the myogenic from the neurogenic. The neurogenic elements are believed to arise from the medial geniculate body and the primary auditory cortex.

Interest in this area was aroused in 1967 when Goldstein and Rodman stated that they could use responses from parietally placed electrodes in the middle latency area as a method of objective audiometry. In the present day, these responses are classed under the title of'early cortical' or 'MLR' rather than 'myogenic' and hence, are discussed in Chapter 10 in detail.

4.1.3: The Acoustic_Jaw_Reflex: Meir-Ewert et al. (1974) demonstrated that if the jaw muscles are kept under tension, one can elicit a response to high-intensity sound from the same muscles. However, as it can be elicited only using very loud sound, its application for threshold-detection is doubtful.

4.1.4: **The_Post-auricular_response:** This response is obtained by placing the active electrode over the post-auricular muscles immediately behind the pinna. This was first reported by Kiang et al (1963) who observed the response with a maximum peak latency of 15 msec. It appeared to be myogenic in origin and showed signs of fatigue and habituation.

In 1969, Cody and Bickford studied the response using tone bursts with 1 msec, rise time as stimuli and found that many a time the response was not obtained and when they did get a response, they had to use high intensities of around 90 dB to elicit a response. Later in the same year, Yoshie and Okudaira found that using clicks instead of tone bursts elicited consistent responses and provided a measure of hearing.

4.1.5: **Terminology:** Douek, Gibson and Humphries (1973) introduced the post-auricular myogenic response as a clinical tool. They mitigated the problem of variable muscle tone by recording from both sides simultaneously. Thus, in spite of head movements; at least one side retained enough tension to give an adequate response. This way it was made possible to measure hearing acuity even in a moving child. To avoid the term 'bilateral simultaneously-evoked post-auricular sonomotor responses', they introduced the term 'crossed acoustic response'.

However, this term may lead the reader to think that the response is obtained from the contralateral ear whereas it is a bilateral response. There may be further confusion as Jerger et al (1975) have used the same term in intra-tympanic acoustic reflex measurements.

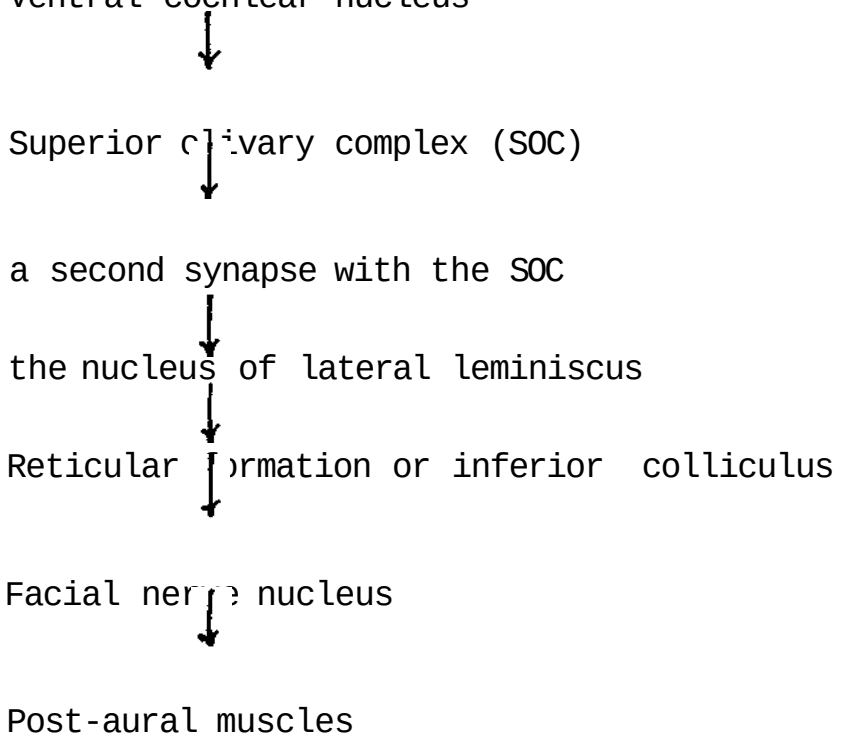
4.2: The Anatomical Pathway:

The sonomotor responses are reflexes. A reflex act is the response resulting from the passage of nerve impulses through a reflex arc. The reflex arc is comprised of a chain of neurones linking the receptor which receives the stimulus (the afferent pathway) to the effector which acts to form the response (the efferent pathway). In the case of sonomotor responses, acoustic stimuli stimulate the receptor placed in the inner ear and the nerve impulses pass through the brainstem to reach a muscle group which affects the response.

One of the characteristics of muscle reflexes is that they fatigue which is true even of the sonomotor responses and is the cause of most of the recording difficulties.

Most evidence available on the post-auricular response suggests that this response is generated by the cochlea and then travels to the cochlear nucleus. The response leaves the brainstem along the facial nerve to reach the postaural muscles.

From the experimental findings in the cat, the speculated central pathway in man is:



It is possible that a somewhat similar central pathway exists for the other sonomotor responses, but there are latency differences due to the differences in the different periphral pathways.

4.3 <u>Characteristics of the Response:</u>

4.3.1: The electrode position: Myogenic responses can be recorded from many parts of the scalp. The largest post-auricular responses are obtained from the active electrode placed immediately behind the pinna with the reference electrode on the ear-lobe. An earth or ground electrode can be placed on the wrist or leg, depending on individual convenience.

4.3.2: The stimulus: Studies have shown that the post-aural response is evoked by a change in the state of the stimulus. So if a pure-tone burst is used, we may get a response both at the onset and the conclusion of the burst. Generally, it is the onset of the stimulus which evokes the sonomotor response. The findings from experimental studies on normal subjects have shown that the rise time is critical. A fast rise time of less than 250 /hsec. is essential in order to obtain post-aural responses using low intensities.

This may explain Cody and Bickford's (1969) failure and Yoshie and Okudaira's (1969) success in recording the responses.

4.3.3: Recovery time and habituation: Recovery time for the post-aural response is quite rapid. Support for this comes from the Kiang et al. (1963) study wherein they found that they could still obtain identifiable responses at presentation rates of over 200 per second. Yoshie and Okudaira (1969) found that after an interstimulus duration of 140 msec, there is full recovery of the response. If the interval is reduced to 100 msec, the response recovers 90 percent of its amplitude. Douek et al.(1973) suggested a click stimulus rate of 10 per second to be satisfactory for clinical purposes.

With regard to habituation, the opinions differ. Some studies report rapid habituation (Davis et al.1963; Kiang

et al. 1963), others negate it. However, practically, fatigue does occur particularly if the subject is tired or bored. The size of the response is dependent on the amount of muscle tone and this varies with the subjects alertness during the test period.

4.3.4: Effect of muscle-tone changes: All sonomotor responses are sensitive to changes in muscle tone. It has been noted that changes in amplitude result from different head positions and that muscle relaxants abolish or diminish the responses.

Clinically, this has been reflected in three problems. Firstly, sleep, tiredness or boredome all of which reduce muscle tone affect the responses. This is especially important in the testing of small babies sleeping after a feed (Fig.4.1).

VARIATION OF AMPLITUDE OF RESPONSE WITH MUSCLE TONE

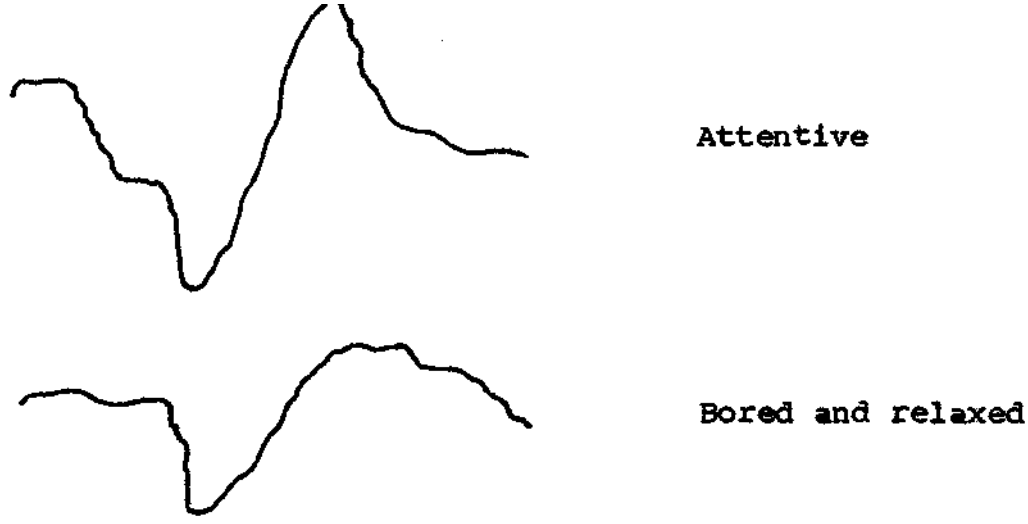


Fig.4.1: Recording from behind one ear in the same patient under different conditions.

Secondly, it is important with respect to head position. The response is largest with the head tilted towards the side where the recording is being made. Voluntary contraction of the post-aural muscle and forced smiling help in increasing the amplitude of the response.

Thirdly, tranquillizers, alcohol, muscle relaxants cause loss of the post-aural response or diminish it.

4.3.5: Stimulus_intensity: The amplitude of the response is exceedingly variable and depends on the intensity of the stimulus. The amplitude of the response is measured as the difference in micro-volts (/uV) between the peak of the main negative deflection at approximately 12 msec, and the peak of the following positive peak. Depending on the stimulus intensity, the amplitude of the response can vary from as little as 2 /uV to nearly 30 /uV. Experimenters have found that amplitude increases with stimulus intensity in an exponential manner (Yoshie and Okudaira, 1969).

Recordings of the latency of the main negative peak with respect to the stimulus onset have indicated that as the stimulus intensity decreases, the latency of the response becomes prolonged.

4.3.6: Configuration and variability_of the_responses: There is considerable variation in the shape, and hence, amplitude and latency of the response, but the following characteristics have been noted.

(i) a small negative peak;

(ii) a negative deflection which is the most sharply defined;

(iii) a second positive peak (Fig.4.1a).

There are wide variations in the size, sharpness and slope of these peaks. However, it is the peak of the negative deflection (ii) which is used as the latency of the 'crossed acoustic response' and it is the difference between the peaks at (ii) and (iii) which is used as a measure of amplitude.

The variability of the responses occurs not only between different subjects but also between responses obtained from the same subject. Most of the changes can be related to muscle tone, but it is possible that the variations could be due to individual variation in the bulk of the muscle available to generate the response. In spite of its variability, Gibson (1974) found it possible to trace small responses down to within 30 dB of the hearing threshold.

4.3.7: Frequency_specificity_of the_responses: Because a stimulus with a fast rise time is needed to evoke consistent responses, it becomes difficult to use stimuli of 1 KHz or lower presented as tone bursts. There are a few subjects in whom low frequency tone burst evoke adequate responses, but their number is limited.

4.3.8: The_test_and_test/retest_reliability: The post-auricular response is not an accurate means of estimating the auditory threshold as the response is too variable. Using the 'crossed acoustic method' and click stimulation, one can identify the response from at least one side of the head at around 30 dB above the subject's hearing threshold and this can be done in 92 percent of subjects (Gibson, 1974). In some cases we may need stimuli of 60 dB SL or above intensity to elicit a response. All this indicates that the post-auricular response can only be used as a crude indicator of hearing status.

The test/retest reliability of the post-auricular response is poor. The amplitude keeps varying in the same individual at different times. This variation may be attributed to loss of muscle tone. Latency, however, is not much affected, although it may be prolonged by one or two milli-seconds when a response diminishes greatly in amplitude.

4.4: Instrumentation:

The basic instrumentation needed for any type of electrophysiological testing has been mentioned in Chapter-3. Here the special requirements and testing procedure related to the recording of the post-aural sonomotor response will be described. Humphries et al (1976) have given a method for recording the 'crossed acoustic response'. This method is a technique of

obtaining the responses from both ears simultaneously so that the side giving the larger response can be selected or because the responses from each side can be compared.

4.4.1: The_test_environment: As clear responses are not obtained from relaxed subjects, the subjects must be seated on a hard wooden chair. The room should be quiet. Adults are usually tested under earphones. For babies and children, where the test is used primarily as a screening technique, a free-field loudspeaker placed close to the child's head, and stimulating both ears simultaneously, should be used.

4.4.2: Stimulus generation: An optimum stimulus is one which is brief with a very rapid rise time. Clicks evoke consistent responses and even pure tone bursts of 8-2 KHz can be used. A useful stimulus repetition rate for clinical purposes is ten per second. A visible response should be obtained within 15 seconds. The stimulus should not be continued for too long as the element of fatigue is introduced after about two minutes.

A high quality transducer is a must to maintain the acoustic wave-form of the click. An electrostatic loudspeaker is preferred for testing children. Also good earphones are necessary if one wants to test each ear separately by employing masking noise.

4.4.3: Recording equipment: Standard EEC silver cup electrodes are used as active and earth electrodes. In using the crossed acoustic method, it is important that we use low noise biological amplifiers having a high input impedance and a high common mode rejection ratio. The main amplifier forms part of the averager while a small pre-amplifier can be attached with a harness to the back of the child, thereby, permitting more freedom to move. Narrow band filters can be used to eliminate background noise.

For threshold determination, a single channel averager will be adequate. A two-channel averager is essential if neuro-otological work is to be performed. The latter provides a control against an artefact being mistaken for a true response (the response from both sides of the head should occur within ±2msec.of each other). However, this is more expensive.

Keeping in mind that the response can get habituated, some manoeuvre must be employed to alert the subject, especially a child, every once in a while.

For permanent recording of results, these are similar to those described in Chapter-2.

4.5: Testing Procedures:

The testing procedure for obtaining the post-auricular sonomotor responses varies according to whether the test is

applied to young children or to adults for estimation of hearing acuity or for neuro-otological diagnosis.

In young children, this technique is mainly need to estimate the hearing status of the difficult-to-test. It is possible to identify responses in normal hearing children within 40 dB of their hearing threshold. If no response can be identified, the child either has a hearing impairment or he is a 'poor responder'. In such cases, the finding has to be compared with findings on behavioral or other electrophysiological testing. Hence, this technique should only be used as an adjunct to clinical methods and not by itself.

Sedation must be avoided since this can abolish the response. In spite of this disadvantage, this method is of special value in the assessment of mentally retarded children who cannot be tested through other means. The crossed acoustic response (CAR) is a good screening test of babies' hearing at birth. There are no false positives obtained.

Co-operative subjects i.e., adults and older children, are seated in a fairly uncomfortable chair without any head support. This is done to maintain muscle tone, which if reduced, results in diminished responses. Hence, the

subject has to be alerted after each response by asking questions or giving instructions and the like.

4.6: Clinical Applications of the Auditory Myoqenic Response(AMR):

The true value of the post-aural response is questionable but a number of observations have been made during experimentation and clinical practice.

4.6.1: As a measure of auditory acuitY: For co-operative subjects* this method does not provide a reliable indication of the hearing acuity, when compared to the other ERA methods available. Its use is limited to providing an approximate determination of hearing level in young alert children or neoaates. This should be used in conjunction with other forms of behavioral and conventional tasting procedures. The response is not consistent, owing to its muscular origin. However, as an initial screening test, it is not time consuming.

4.6.2: As a means of neuro-otological diagnosis: The use of post-aural responses in neuro-otological investigation is based on the concept that fibres cross over the brainstem from the auditory connections on one side to the motor system both on the same side and on the other side. The potential use of this response in this area is questionable owing to its

poor reliability and reproducibility. However, studies conducted on patients who yielded clear responses have revealed the following:

4.6.2.1: Conductive hearing loss: Gibson (1974) reported that the post-aural responses obtained from stimulation of an ear having conductive hearing loss are smaller than those obtained from normal hearing ears even if the same level of stimulus intensity is used.

Children with glue ears give poor and variable results. In many cases the response is broader than the normal case. This may be due to the 'glue' attenuating the rapid onset of the click stimulus and changing it to one with less favorable onset characteristics.

4.6.2.2: Cochlear hearing losses: The post-auricular response has been examined in subjects suffering from recruitment Which is almost diagnostic of cochlear pathology.

It has been found that patients with monaural recruiting ears often give a response from the affected ear having an amplitude similar to that from the normal ear, especially at high intensities (Fig.4.2).

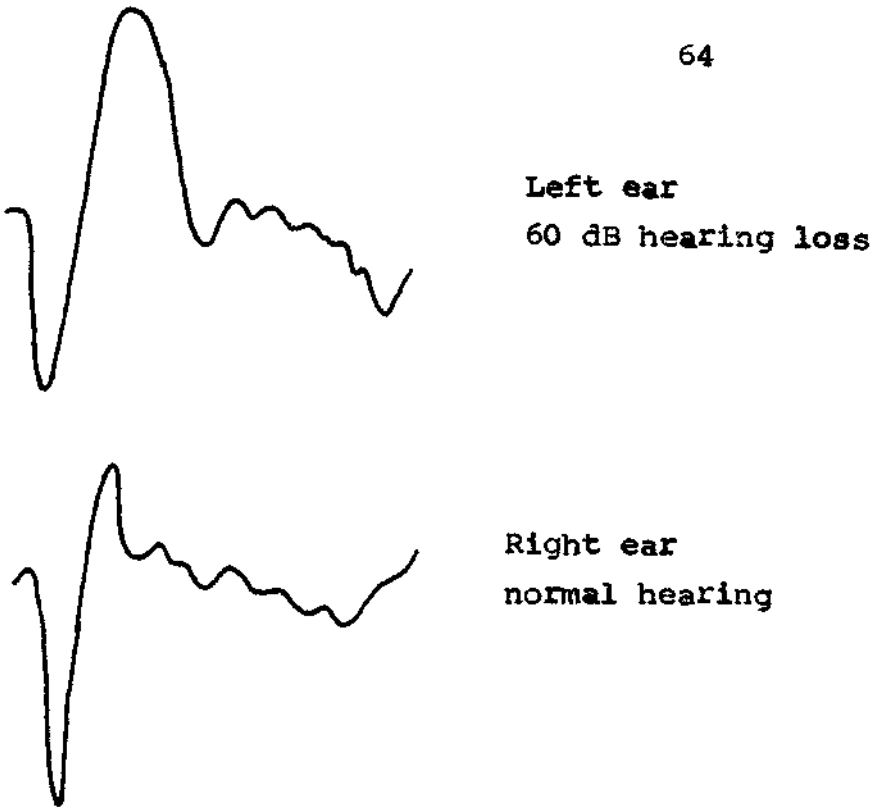


Fig.4.2: The post-auricular responses from a subject with a 'recruiting' hearing loss. Note that the response from the abnormal ear is larger than that from the normal ear.

The above implies that one should not attempt to guess the hearing acuity of a subject after obtaining one response from an ear. Rather, it is essential to trace the responses to the lowest stimulus intensity level possible.

Most patients with recruiting ears give clear responses. in such cases the response amplitude grows rapidly with increasing stimulus intensity. Also, as the stimulus intensity is reduced, the latencies do not gradually increase. Rather, jumps in latency or even shorter latencies occur, when, the contrary, is expected.

4.6.2.3: Retrocochlear hearing losses: Gibson (1974) reported the post-aural responses obtained in three cases of eighth nerve Schwannoma to be very small and that the input-output functions did not indicate recruitment. However, due to the small number, generalization is limited.

4.6.2.4: Brainstem lesions: Douek et al. (1973) noted that a few cases of multiple sclerosis showed a prolonged latency on either one side or the other. Frequently, the interaural difference in latency exceeds 3 msec, in these cases. In 1976, Douek and his colleagues reported 18 cases all of whom showed increased latency.

Clifford-Jones et al (1979) reported that a combination of crossed acoustic response and visual evoked response is a sensitive test for identifying patients with multiple sclerosis. Abnormal latencies for both CAR and visual evoked response (VER) was reported for 90 percent of the cases.

4.7: Conclusion:

Whether the post-aural response can have any clinical value for detection of brainstem lesions is questionable. It requires more study for its full potential to be known and utilized. It has the disadvantages of having poor reliability

and the occurence of false results. However, it is simple to apply and does not inconvenience the subject much. What is clear about its application is that it can only form part of the clinical battery which is used to diagnose a case and it may be used for screening purposes.

POST-TEST

I- Fill in the blanks:

(1) The . . . . . of the body give an involuntary response to auditory stimulation.

(2) Geisler et al (1958), who recorded the auditory myogenic responses, considered them to be . . . . . in origin. However, in 1963, Bickford and his colleagues proved these responses to be .....

(3) The . . . . . response can be obtained in deaf subjects with normal vestibular function.

(4) The parietal response has now come to be known as the ..... or the ..... response*

(5) Of the 4 responses identified, the . . . . . has received maximal attention.

(6) While Cody and Bickford (1969) found . . . . . to be in-effective in eliciting responses, Yoshie and Okudaira* in the same year, reported . . . . . to be effective in eliciting consistent responses.

(7) Douek et al (1973) introduced the term . . . . . to describe the post-aural response.

(8) In general, the myogenic response is elicited by the . . . . . of the stimulus.

(9) ..... muscle tone .... and ..... all diminish the response.

(10) As the stimulus intensity is increased, ... also increases in an exponential manner.

(11) The post-aural responses can be obtained within ..... of the hearing threshold of the individual.

(12) One of the characteristics of the optimum stimulus is that it should have a rapid .....

(13) The CAR can be used as a ..... technique in assessing hearing acuity.

(14) In a unilateral moderate hearing loss case, a 60 dB HL click elicits similar responses from both ears. A possible reason for the normal response in the ear with hearing loss could be .....

(15) Increased latency values have been reported in cases of .....

II. <u>Multiple choice - Choose the correct answer:</u>

1. Bickford et al (1963) demonstrated that the myogenic responses could be elicited from:
   (a) only the scalp muscles
   (b) muscles all over the body
   (c) only the pinna
   (d) the nerves of the body.
2. The largest post-auricular responses can be obtained by placing the active electrodes:
   (a) on the vertex

(b) on the ear lobe

(c) on the wrist

(d) immediately behind the pinna

3. To keep the subjects in an alert sad unrelaxed state, they should be:

(a) seated on soft cushioned chairs

(b) asked questions once in a while

(c) seated on wooden chairs

(d) both (b) and (c).

4. The post-aural response is:

(a) neurogenic in origin

(b) muscular in origin

(c) both (a) and (b)

(d) none of the above.

5. The use of crossed acoustic response for neuro-otological purposes is based on the fact that:

(a) we use both ears for hearing

(b) the nerves from the cochlea ultimately end in the brain and hence any pathology can be detected.

(c) that nerve fibres cross in the brainstem on one side to both the opposite side and continue on the same side.

(d) the myogenic response is a reflex.

6. The instrumentation for recording the post-aural response includes:

(a) a high quality transducer, a loudspeaker and earphones

(b) a microphone and a digitizer

(e) noise makers and pure tone audiometer

(d) none of the above

7. Jumps in latencies with decreasing stimulus intensity are sometimes observed in:

(a) conductive hearing loss

(b) retrocochlear pathology

(c) brainstem lesions

(d) cochlear pathology

8. It has been found that head position affects the response. The largest response is obtained when:

(a) when the head is lifte upwards

(b) when the neck is flexed

(c) when the head is turned to the side where the recording is being made

(d) when the head is turned away from the site of recording.

9. The 'crossed acoustic method' is

(a) a reliable diagnostic tool

(b) can be used for screening purposes

(c) can be used in combination with other more reliable tests

(d) both (b) and (c)

10. Prolonged latencies have been reported in cases of:

(a) multiple sclerosis

(b) chromosomal abnormalities

(c) conductive hearing loss

(d) migraine

CHAPTER 5

CORTICAL EVOKED RESPONSE AUDIOMETEY (CERA)

PRE-TEST

I. Fill in the blanks:

(1) The vertex potential is the ..... response evoked by an auditory stimulus.

(2) The vertex potential occurs between .... to .... milli-seconds.

(3) The energy of the V-potential is concentrated in the frequency range .... to .... Hertz.

(4) When using click stimuli, as the intensity is increased, the latency . . . . . change.

(5) When ..both... ears are stimulated, ... of the response increases.

(6) The V-potential attains adult form by .... years of age.

(7) The latency of the various components of the response varies with ..... and .....

(8) During the testing procedure, the subject should not move his neck, as neck movements may result in ..... potentials.

(9) Cortical evoked response audiometry is contra indicated in children with ..... and .....

(10) If there is a sudden rise in the amplitude of the potential with increase in intensity, ... may be suspected.

II. Indicate whether the following statements are true or false:

(1) Cortical evoked response is a fast response.

(2) The V-poteatial is neurogenic in origin

(3) The slow response shows maximum amplitude when elicited using tactile stimuli.

(4) The active electrode has to be placed on the forehead during testing.

(5) The amplitude of the response decreases at low frequencies.

(6) The slow response takes approximately 10 seconds to recover completely.

(7) Masking is not needed in CERA.

(8) The subjects can be made to stand during the CERA testing.

(9) Subjects having Meniere's Disease exhibit shorter latencies than do normals.

(10) CERA is not useful is diagnosing cerebral disorders.

III. <u>Choose the correct answer:</u>

(1) In neonates, slow cortical responses can be obtained only at intensity levels above

a) 10 dB HL (b) 80 dB HL (c) 60 dB HL (d) 40 dB HL

(2) On retesting, in spite of the variability of the slow response

a) the amplitude is more consistent than the waveform.

b) the waveform is more consistent than the latency.

c) the latency is more consistent than the amplitude.

d) none of the above.

(3) Natural sleep

a) Causes little alteration of the characteristics of the slow cortical response.

b) causes an artefact in the recording.

c) causes the response to be diminished.

d) affects the latency of the waveform.

(4) A low pass filter is needed in order to

a) eliminate artefacts

b) prevent interference from electrical sources

c) eliminate DC disturbances

d) all of the above

(5) In using speech as stimuli, experimenters have found that the response amplitude is larger for

a) only meaning less words

b) only meaningful words

c) both (a) and (b)

d) only for pure tones.

CORTICAL EVOKED RESPONSE AUDIOMETRY (CERA)

5.1: Introduction:

In CERA, we record the slow 'vertex' potential. Until the early seventies, the use of the term ERA was taken to imply this response - the vertex potential or the slow 'cortical response', unless the experimenter or tester stated that some other response was being recorded.

The vertex (or V-) potential is the cortical response evoked by an auditory stimulus. It represents the first serious attempt to develop an objective test of hearing based on the recognition of an evoked potential from the cortex. Hence, it is called 'Cortical ERA.

In recent years, interest in CERA has waned. This is because of the attraction of the faster responses such as ECochG and BER which are easier to interpret, and also due to some problems encountered in the use of CERA with young children. In spite of this, CERA does permit more or less accurate threshold predictions through the entire speech frequency range in adults and older children.

5.1.1: Terminology: The typical adult response has been demonstrated in Fig.5.1.

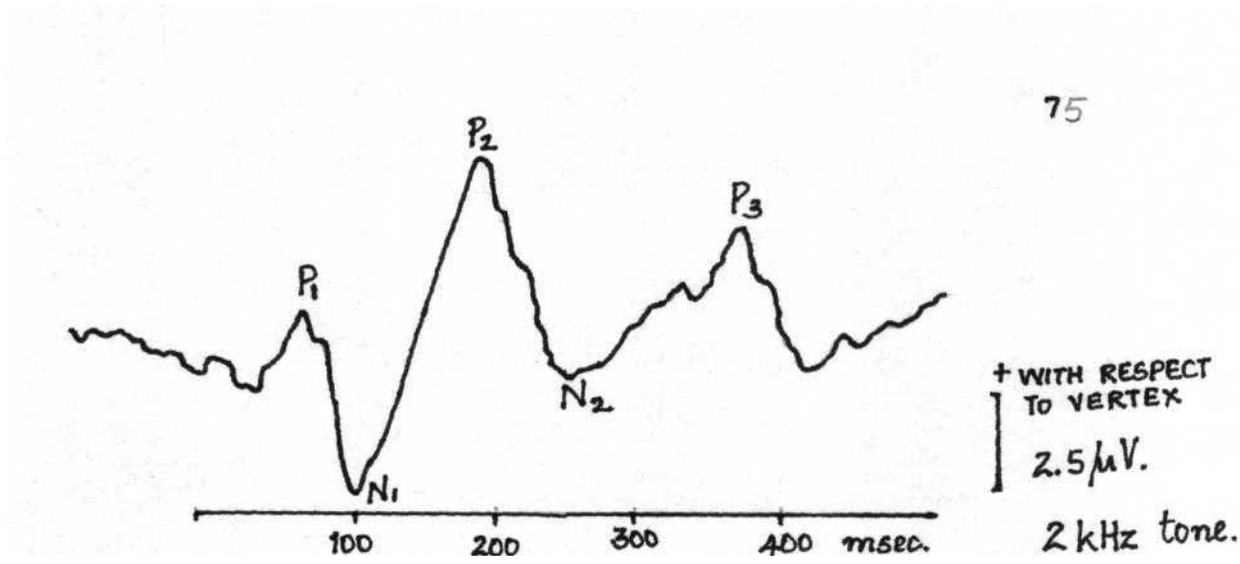


Fig.5.1: A cortical evoked response typical of a normal-hearing adult.

The typical response shows:

(a) a small inconsistent positive peak (P_1) at 50-75 msec.

(b) a large negative peak (N_1) at about 100-150 msec., and

(c) a large positive peak (P_2) at about 175-200 msec.

Usually, this is followed by a low second negative peak (N_2) at 200-250 msec. which is inconsistent in the adult, but prominent in young children. Also, in young children, the latency of this wave may be longer. Following this is a slow positive wave (P_3) at about 300 msec. (Refer page No.241).

This response complex may be referred to in terms of its polarity and latency, as: P_{50}, N_{100}, P_{200}, N_{250}, P_{300}. Initially, the CERA was called electroencephalic response audiomtetry (ERA). However, there was confusion between this and electric response audiometry, which encompasses all the responses. Davis (1971) suggested the term 'slow' response as it occurs between 50-300 msec. Other authors have suggested

the term 'V-potential' (vertex-potential), as the anatomical distribution of the potential is centred around the vertex (Bancaud, et al, 1953). The term 'cortical evoked response audiometry' (CERA) is used for historical reasons.

The neurogenicity of this response is widely accepted. The V-potential is too late (at 50 msec) to originate from the primary cortex. Keeping in mind its duration of about 200 msec., it may be considered as a secondary cortical manifestation. However, Vaughan (1969) provided evidence to suggest that these potentials arose from the primary cortical projection areas of the cortex. He believed that the delay could be either due to reverberating circuits between the medial geniculate body and the cortex, or due to secondary, tertiary or later responses occuring within the primary area. David and Sohmer (1972), by placing electrodes on the exposed cortex of the cat, recorded responses resembling the human cortical potential. This led them to suggest that the response was due to activity passing up the ascending auditory pathway. However, this has not been accepted by all workers.

5.2: Characteristics of the response:

5.2.1: The stimulus modality: The slow response may be elicited using auditory, visual or tactile stimulation, but the response to auditory stimulation generally shows the largest amplitude with the earliest latencies (Walter, 1964).

Just as in conventional audiometry, even in CERA, while testing a deaf subject, the possibility of a tactile modality must be borne in mind, especially when low frequencies are used. A response to a 500 Hz tone, for example, at 110 dB does not essentially mean that the stimulus has been heard, since the vibration produced can be felt.

5.2.2: Electrode placement: The active electrode has to be placed on the vertex, the reference electrode is fixed to the mastoid or earlobe, and the ground electrode to the forehead.

5.2.3: The frequency range of the response: Most of the energy of the V-potential lies in the frequency range of 5-10 Hz. By using band pass filters, we can eliminate, or rather exclude disturbances caused by the AC hum (50 Hz) and some of the muscle artefacts.

5.2.4: Stimulus characteristics:

5.2.4.1: Intensity: While there is a lot of inter- and intra-subject reliability in response amplitude (N_1-P_2), there is a clear, direct relationship between the intensity of the stimulus and the amplitude of the response. It has been found that as the intensity of the stimulus increases, the peak amplitude of each component increases, and the latency becomes shorter.

Considering the relationship between the stimulus intensity and response latency, in the case of tonal stimuli, an inverse relationship exists between the two variables. As the intensity of the stimulus decreases, latency increases. However, the response latency to click stimuli remains constant with intensity change (Rapin et al. 1965).

5.2.4.2: Stimulus frequency: Several studies have reported a significant interaction between the amplitude of the slow response and the frequency of the stimulus (Antinoro et al. 1969; Rothman, 1970). It has been found that as the test frequency exceeds 1000 Hz, the amplitude of the late response decreases. Also, Henderson (1972) reported that late response thresholds at lower frequencies were closer to the behavioral threshold (by about 10 dB) than those obtained at higher frequencies.

5.2.4.3: Stimulus duration: The stimulus duration affects perceived loudness. This phenomenon, known as temporal auditory stimulation, is the physiological process by which the intensity required to obtain the psychophysical threshold for a tone increases as the duration of the tone is decreased.

In using tone bursts, the duration of the tone-burst should be in excess of 30 msec (50-100 msec. is preferable). This is long enough to allow accurate frequency determination without causing a significant decline in amplitude.

5.2.4.4: Stimulus rise time: Increasing the rise time of the stimulus upto 30 msec. and above causes a reduction of the response amplitude. A rise time of 25-30 msec. is considered optimum, as it is gradual enough to avoid click artifacts and abrupt enough to evoke a clear response.

5.2.4.5: Repetition rate: The slow response takes approximately 10 sec. to recover after each stimulus before it can be evoked fully again. In other words, if the inter-stimulus interval is 10 sec. the response will have maximum aplitude. If the inter-stimulus interval is reduced to 1 sec. the amplitude is approximately 75 percent smaller than for the former condition.

The minimum number of responses to be averaged to produce a large potential at low intensities is 32. If the inter-stimulus interval were, 10 sec. the test duration would be prolonged. For clinical purposes, a stimulus repetition rate of 1-2 per sec. for a total of 50-60 stimuli are adequate to give resolution of the response in the minimum time.

Also, if random stimulus repetition rates are used, the amplitude of the response has been found to be larger.

5.2.4.6: Monaural vs. binaural stimulation: The amplitude of the response is enhanced if the stimulus is presented to both

ears simultaneously. This finding supports the psycho-acoustic finding that binaural stimulation results in an apparent increase in loudness.

5.2.4.7: Contralateral masking: By comparing the amplitude of the slow response of the two ears, one cannot determine which ear has been stimulated. This is because the response amplitude to a stimulus presented to the left ear is the same, in spite of whether the recording is made from the right side of the head or the left. Therefore, in order to test each ear separately, the contralateral ear has to be masked. While noise can be used for masking purposes. The masking level should be altered in 10 dB steps until the amplitude of the response does not get altered. The corresponding level of stimulus intensity may he recorded as the threshold.

5.2.4.8: Speech or speech sounds as stimuli: Investigations have been conducted to explore the possibility of using speech or speech sounds as stimuli for CERA. Research findings have shown that the response amplitude is larger for meaningful words than for meaningless words (Sharrard, 1973). However, through this method it is not possible to reliably predict whether the word has been understood.

Spreng (1974) found that there are differences between the amplitudes obtained for tones and that for monitored and

filtered vowels, and that in the latter case there was a significant increase in amplitude. However, the question remains as to whether the subject discriminated between the two stimuli.

5.2.5: Subject effects:

5.2.5.1: Subject variability: There is considerable inter- and intra-subject variability in the response. However, the latencies are more consistent than the amplitudes in the same subject when tested on different occasions.

5.2.5.2: Habituation: Davis and Yoshie (1963) found that the slow responses are larger at the beginning than at the end of the recording session. However, if the interest of the subject can be maintained either by varying the frequency or intensity of the stimuli, habituation would not affect the results of CERA.

5.2.5.3: Effect of attention: The amplitude of the slow response increases when the subject actively listens for the stimulus. Hillyard et al (1973) found that if a subject was instructed to pay close attention to the stimulus presented to one ear and ignore any sounds presented simultaneously to the opposite ear, the N_{100} component was substantially larger for the attended ones. This study shows that it may be possible to objectively evaluate the ability of a subject to select the sound to which he listens.

5.2.5.4: The test and test-retest reliability: The test reliability of CERA, as a means of estimating auditory acuity, varies with the age of the patient and the amount of patient cooperation. In 80-90% of normally-hearing adults, CERA thresholds are with ± 10 dB of their auditory thresholds.

The test reliability for children under seven years of age is worse than in the adult population. Poor reliability in children is related to the difficulty these children have in cooperating with the lengthy test procedure while fully awake. Also, maturation plays a role sothat the late response appears like an adult response only by seven years of age. In neonates thresholds can be obtained only at levels above 40 dB HL.

The test/retest reliability of CERA is fair. Variation between thresholds obtained in two settings is more in the case of children than adults.

5.3. Special considerations of the response during sleep and after sedation:

Often young children have to be tested during sleep, as they are not cooperative when awake. However, the slow responses obtained in sleep differ from those obtained when

the subject is awake. These differences are related to the depth of sleep and to the age of the child. Hence the level of sleep has to be monitored closely. This can be done by obtaining the EEG pattern which can tell us if the subject is in the awake, waking or sleeping states.

It has been observed that as the depth of sleep increases, the latency of the various components of the response also increase. Natural sleep has been reported as causing little alteration of the response characteristics (Skinner and Antinoro, 1969), but this is possible only in young babies who fall asleep after feeding. Some experimental findings have reported the responses to be easily detected in deep sleep. However, in such conditions, some artefacts may lead to false negatives.

Ritvo et al. (l967) have suggested the CERA is best performed at the time of onset of sleep to reduce the number of false results.

To induce sleep in the child sedatives would have to be used. However, CERA under sedation can lead to difficulties in the identification of the 'true' response. Drugs tend to elevate the threshold of the response. However, some studies found the responses clearer when obtained from a sedated child.

There is a lot of conflict in the literature concerning the ideal sedative and the depth of sleep required for CERA in young children. In general, it is found that although the response may have a greater amplitude in sleep, the depth of sleep has to be controlled, and the EEG activity has to be controlled in order to prevent sudden,large fluctuations from being included into the averaged trace, and mistakenly interpreted as a true response.

5.4 Instrumentation:

The instrumentation needed for CERA has been dealt with in Chapter 3. The specific details are mentioned here.

5.4.1: The test environment: Subjects should be tested in a comfortable relaxed position. Adults and older children are seated in a chair with support for the neck so as to reduce neck movements which may result in myogenic potentials. Infants and sedated subjects are made to lie-down on a couch during testing. The room should be sound treated, ideally.

5.4.2: Stimulus generation:

5.4.2.1: Stimulus envelope: Pure tone stimuli are used. The recommended stimulus envelope has a rise and decay time of 25-30 msec. and a plateau of 25-50 msec. Larger amplitudes are obtained for frequencies below 2000 Hz.

5.4.2.2: Stimulus repetition rate: We cannot use fast repetition rates as the response has a slow recovery time. A rate of one stimulus every one or two seconds is used for clinical purposes.

5.4.2.3: Number of stimulus presentations: Around 30-70 stimuli must be presented and the responses averaged. Larger number of responses is necessary as the intensity is reduced to the level of psycho-acoustic threshold.

5.4.2.4: Stimulus transducer: A loudspeaker can be used to deliver the stimuli, but usage of earphones enables monaural information to be obtained. Masking of the non-test ear is essential at high frequencies. The loudspeaker can be used in case of un-cooperative children.

It is advisable to have alternative means of generating stimuli such as a flash of light and a vibration to test for visual or vibrotactile evoked responses respectively. This manoeuvre can be used in cases in whom an auditory evoked potential cannot be elicited. The presence of a response to an alternative stimulus while the absence of it for an auditory stimulus indicates that the auditory evoked potential is indeed absent and that the subject presumably has a marked hearing impairment.

Facilities for stimulus calibration and masking noise should be available.

5.4.2.5: The recording apparatus: The electrode placement has been mentioned earlier. The rest of the instrumentation is similar to what has been described in Chapter 2 in terms of requirement of an amplifier, an averager, an oscilloscope and recording of results. With regard to the filter setting, a low pass filter set at approximately 13.6 Hz is advisable. The high-pass filter should be set to 1.6 Hz. While the low-pass filter prevents interference from electrical sources, the high pass filter eliminates the troublesome DC disturbances. Artefact rejection facilities are required to exclude sudden voltage changes caused by movements or other sources, especially in young children.

5.5: Testing procedures:

Adults are easy to test. They are seated comfortably in a chair with support provided for the neck. They are instructed not to move during the test period. By holding the subjects attention - by asking him to perform some mental task such as arithmetic - the results may be more easily interpreted. Masking of the contralateral ear is done, as the need arises.

In case of children, however, a great deal of skill is needed not only to manage them, but also in interpreting the results.

The stimuli are presented in descending order of intensity. Testing is started well above the presumed threshold. Once a well-defined response has been obtained at high intensities, the intensity is reduced in 20 dB steps, until the response becomes smaller in amplitude and its latency is slightly prolonged. At this point, the intensity is reduced in 10 dB steps until the threshold is crossed as shown by a clear negative trial, that is, the visible slow potential is absent (Fig.5.2 - page No.89). The subject threshold is the value lying half way between that level at which the response was last observed and the level 10 dB less intense at which the response was judged to be absent (Beagley, 1981). Clinically, thresholds are determined at 500 Hz, 1000 Hz and 2000 Hz. The unaveraged EEG on the oscilloscope should be monitored for any sudden changes or fluctuations.

5.6: Clinical use of CERA:

CERA can be used not only to estimate hearing acuity, but also directly compare the results with that of conven tional pure tone audiometry. As a neuro-otological tool, it is not of much use.

5.6.1: As a means of estimating hearing acuity: CERA is a useful technique in adults and older children. It is fairly reliable and is indicated in the following cases:

a) Subjects who are unable to follow the instructions for conventional audiometry.

b) In unreliable subjects Who give varying subjective thresholds Through CERA the threshold can be established accurately.

c) Unduly passive subjects who will not respond reliably during audiometric testing. CERA is easy with such a person.

d) Suspected 'hysterical' or 'non-organic' hearing loss.

e) In medico-legal cases to confirm the subjective audio-metric results and to detect any malingering.

(Gibson, 1978)

Studies have shown that CERA estimates are within 10 dB of the subjective threshold in a majority of the cases. Occasional false positive responses are obtained.

Contraindications to the use of CERA in children are:

(a) Epilepsy

(b) Muscle tics/spasms, eg. athetosis.
These two conditions give rise to numerous electrical artefacts which makes the interpretation of the responses hazardous.

(c) Some forms of brain damage associated with large amplitude slow EEG waves Which tend to be easily confused with the response.

(d) The need for sedation as this affects the response. In such cases some other form of ERA is preferred such as ECochG, BER or MLR.

5.6.2.: As a means of neuro-otological diagnosis: Due to the variability in the slow potential, it is difficult to interpret the changes due to specific pathological conditions in any individual case. However, over the years, experimental studies have given us some conclusive evidence in some conditions.

5.6.2.1: Conductive hearing losses: The slow potentials which are evoked by placing a vibrator on the mastoid area can be recorded. Cody et al (1968) found that the CERA bone conduction thresholds at frequencies of 500, 1000 and 2000 Hz were within 15 dB of the subjective. Bone conduction threshold in normal subjects. This was so in 95 percent of normals.

Hence, if we do not get a response to air conduction stimulation, but a response is elicited by tactile or visual, and bone conduction stimulation, a conductive pathology can be suspected.

5.6.2.2: Cochlear disorders: Ears with cochlear pathology exhibit the characteristic phenomenon of recruitment.

While some studies have found no differences between the amplitude and latency functions of CERA responses to the same loud stimulus presented to ears with normal hearing

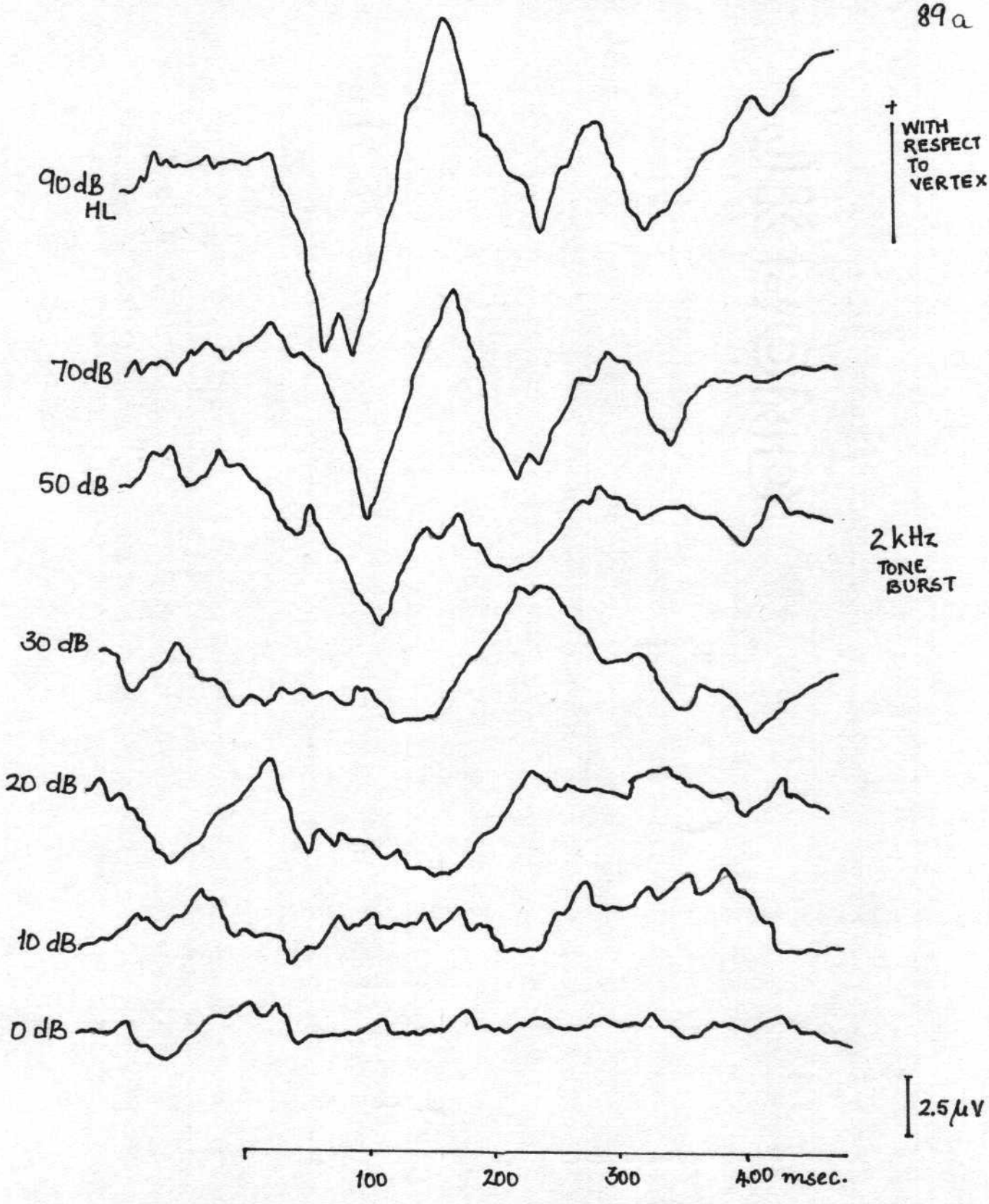


Fig. 5.2. An example of using the slow cortical response to detect threshold.

and suspected cochlear hearing losses (Clayton and Rose, 1970), others have shown that the amplitude/intensity functions of the slow potential rises abnormally steeply in recruiting ears (Knight and Beagley, 1968). However, due to the variability of the response, diagnosis of a cochlear hearing loss in any one case based on this finding is not possible. In spite of this, it can be concluded that if the evoked response is traced down towards its threshold in a subject with mild to moderate hearing loss, and there is a sudden 'collapse' of amplitude as the threshold is approached, recruitment is indeed present.

5.6.2.3: Meniere's disorder: It has been reported that patients having this disorder have, on the average, shorter response latencies than normal hearing subjects (Townsend and Cody,1970).

5.6.2.4: VIII nerve disorder: It was found that the latency of the response increased and the response amplitude diminished in cases of retrocochlear pathology (Shimizu, 1968).

5.6.2.5: Central disorders: With regard to the cortical responses obtained in cases having cerebral disorders, like aphasia, sometimes the CER is different from that obtained in normals.

However, when used in conjunction with other more informative tests such as ECochG, the CERA was found to be useful in terms of helping to confirm the hearing atatus of the individuals.

5.7:concluslon:

Hence, in conclusion it can be said that the slow cortical response has many limitations as a clinical test. The main drawback is the variability of the response which limits its use as a neuro-otological tool. Also problems are encountered with very young uncooperative children. In spite of its dis-advantages, CERA is useful in that it provides an accurate prediction of the pure tone audiogram in adults and older children. Hence, it ean help to objectively assess cases of possible non-organic hearing loss and can also be used in medico legal compensation cases.

POST-TEST

I. Fill in the blanks:

(1) The vertex potential is the ..... response evoked by an auditory stimulus.

(2) The vertex potential occurs between .... to .... milli-seconds.

(3) The energy of the V-potential is concentrated in the frequency range .... to .... Mertz.

(4) When using click stimuli, as the intensity is increased, the latency ..... change.

(5) When both ears are stimulated, ... of the response increases.

(6) The V-potential attains adult form by .... years of age.

(7) The latency of the various components of the response varies with ..... and .....

(8) During the testing procedure, the subject should not move his neck, as neck movements may result in ..... potentials.

(9) Cortical evoked response audiometry is contra indicated in children with ..... and .....

(10) If there is a sudden rise in the amplitude of the potential with increase in intensity, ... may be suspected.

II. Indicate whether the following statements are true or false:

(1) Cortical evoked response is a fast response.

(2) The V-potential is neurogenic in origin

(3) The slow response shows maximum amplitude when elicited using tactile stimuli.

(4) The active electrode has to be placed on the forehead during testing.

(5) The amplitude of the response decrease at low frequencies.

(6) The slow response takes approximately 10 seconds to recover completely.

(7) Masking is not needed in CERA.

(8) The subjects can be made to stand during the CERA testing.

(9) Subjects having Meniere's Disease exhibit shorter latencies than do normals.

(10) CERA is not useful is diagnosing cerebral disorders.

III. Choose the correct answer:

(1) In neonates, slow cortical responses can be obtained only at intensity levels above

(a) 10 dB HL (b) 80 dB HL (c) 60 dB HL (d) 40 dB HL

(2) On retesting, in spite of the variability of the slow response

a) the amplitude is more consistent than the waveform.

b) the waveform is more consistent than the latency.

c) the latency is more consistent than the amplitude.

d) none of the above.

(3) Natural sleep

a) Causes little alteration of the characteristics of the slow cortical response.

b) causes an artefact in the recording.

c) causes the response to be diminished

d) affects the latency of the waveform.

(4) A low pass filter is needed in order to

a) eliminate artefacts

b) prevent interference from electrical sources

c) eliminate DC disturbances

d) all of the above

(5) In using speech as stimuli, experimenters have found that the response amplitude is larger for

a) only meaning less words

b) only meaningful words

c) both (a) and (b)

d) only for pure tones.

PRE-TEST

I. Fill in the blanks:

(1) The contingent negative variation is also called the

(2) The two kinds of stimuli which are used in contingent negative variation audiometry are the ..... stimulus and the ..... stimulus.

(3) Walter (1964) believed the CNV to originate from the

(4) The ..... stimulus is one which requires a mental decision or a motoric action.

(5) The amplitude of the CNV response is maximal in the ..... region

(6) The most common response shape encountered is the ..... response.

(7) We can use .... or ..... as conditional stimuli.

(8) The greater the pressure to be applied to press the button, the ..... the amplitude of the response.

(9) Before placing the electrodes, the tester should see to it that the skin is free of .....

(10) As a method of objective speech audiometry, the CNV technique is called .....

II. True or false.

(1) The CNV response is myogenic in origin.

(2) In CNV audiometry, a conditioning process is established between the conditioning stimulus and the imperative stimulus.

(3) It is not possible to use pictures as imperative stimuli.

(4) Walter et al. (1964) coined the term 'expectancy wave'.

(5) CNV amplitude is maximal when the active electrode is placed on the vertex.

(6) The CNV is a very characteristic finding in psychopathic individuals.

(7) The characteristics of the conditional and imperative stimuli are very critical factors and affect the amplitude of the response to a greater extent.

(8) The latency of the CNV varies between 450-900 msec.

(9) Electric potentials resulting from movements of the eyes can affect the CNV.

(10) The CNV does not have much potential in the evaluation of hearing acuity.

III. <u>Choose the correct answers:</u>

(1) Large CNV amplitudes reflect

(a) the intelligence of the subject

(b) the certainlty with which the subject is expecting the imperative stimulus.

(c) the alertness of the subject

(d) none of the above

(2) There are a number of factors affecting the response amplitude

(a) the inter-stimulus interval

(b) the nature of the operant response

(c) the psychological state of the individual

(d) all of the above.

(3) The 'rebound' effect refers to:

(a) reduction of the CNV for about 0.1 sec. at the onset of the imperative stimulus and its resumption of negative polarity and gradually returning to baseline.

(b) two CNV responses occuring simultaneously

(c) a CNV response with positive polarity

(d) none of the above.

(4) Drifting of the baseline during averaging is generally due to:

(a) brainstem lesions

(b) lack of attention on the part of the subject

(c) poor or loose electrode placement

(d) some error in the equipment.

(5) Burian et al. (1969) found that the aphasic patient, after recovery, developed CNV responses to:

(a) both meaningful and non-meaningful words

(b) only non-meaningful words

(c) only meaningful words

(d) only for pure tones.

CHAPTER 6

THE CONTINGENT NEGATIVE VARIATION(CNV)

THE CONTINGENT NEGATIVE VARIATION (CNV)

6.1: Introduction:

Electrophysiologic methods have been used to investigate the effects of conditioning in both man and animals, and under certain conditions, EEG modifications have been observed. One such modification is the contingent negative variation (CNV) which was first reported by Walter and his colleagues in 1964. The CNV response appears as a slow DC shift in the EEG activity. It can be observed in response to a stimulus only when the stimulus is conditional. This means that the stimulus has to be associated with a second, "imperative" stimulus (one which requires a mental decision or motoric action). The CNV is sometimes referred to as the expectancy wave. Walter (1964) described the CNV as a widespread, negative potential which emanates from the frontal cortex and generally sweeps back from prefrontal to the motor cortex following the response.

Interest in the area of slow cerebral potential shifts started in the late 1950s when Kohler et al. (1952) and Kohler and O'Connell (1957) demonstrated a slow potential shift which accompanied continued auditory and visual stimulation in cats, monkeys and humans. Caspers (1961) reported the same in rats with the shift occuring in the negative

direction in association with locomotion,alerting and exploratory behaviour. Rowland (1961) demonstrated slow potential shifts having a negative polarity after a shirt positive shift. These occured in response to a click which signalled a forthcoming electric shock.

Daring this period, Walter et al (1964) reported and gave their first important description of the CNV response in man (Fig.6.1). They described the basic paradigm for obtaining the CNV. The conditioning stimulus, such as a pure tone is introduced. This is followed by the imperative stimulus, such as a flash of light, to which he has to respond by performing a task, perhaps by pressing a key (the operant response). Repetition of this paradigm, eventually establishes a conditioning process and the subject begins to expect the arrival of the imperative stimulus. It is this expectancy which is related to the slow potential change known as the CNV (Fig.6.2). The response becomes clearer if the average of several trials is taken.

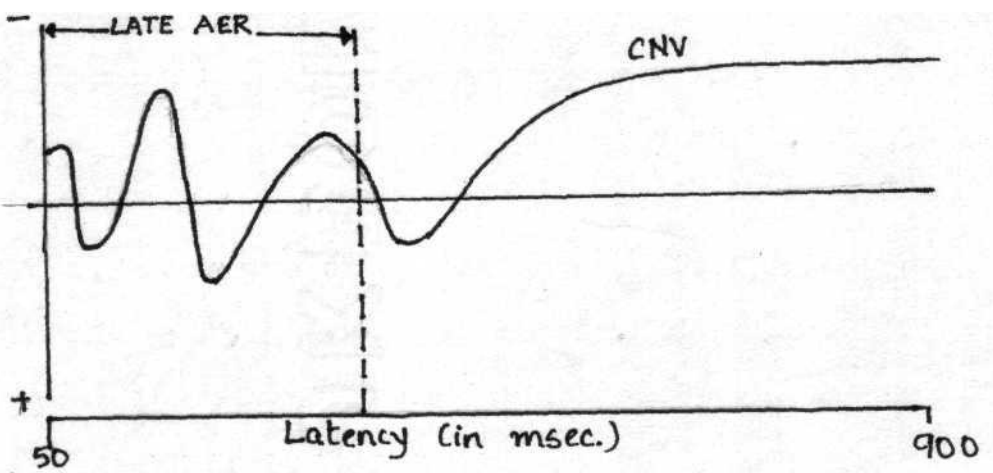


Fig.6.1: Schematic representation of the CNV in relation to the late auditory evoked responses.

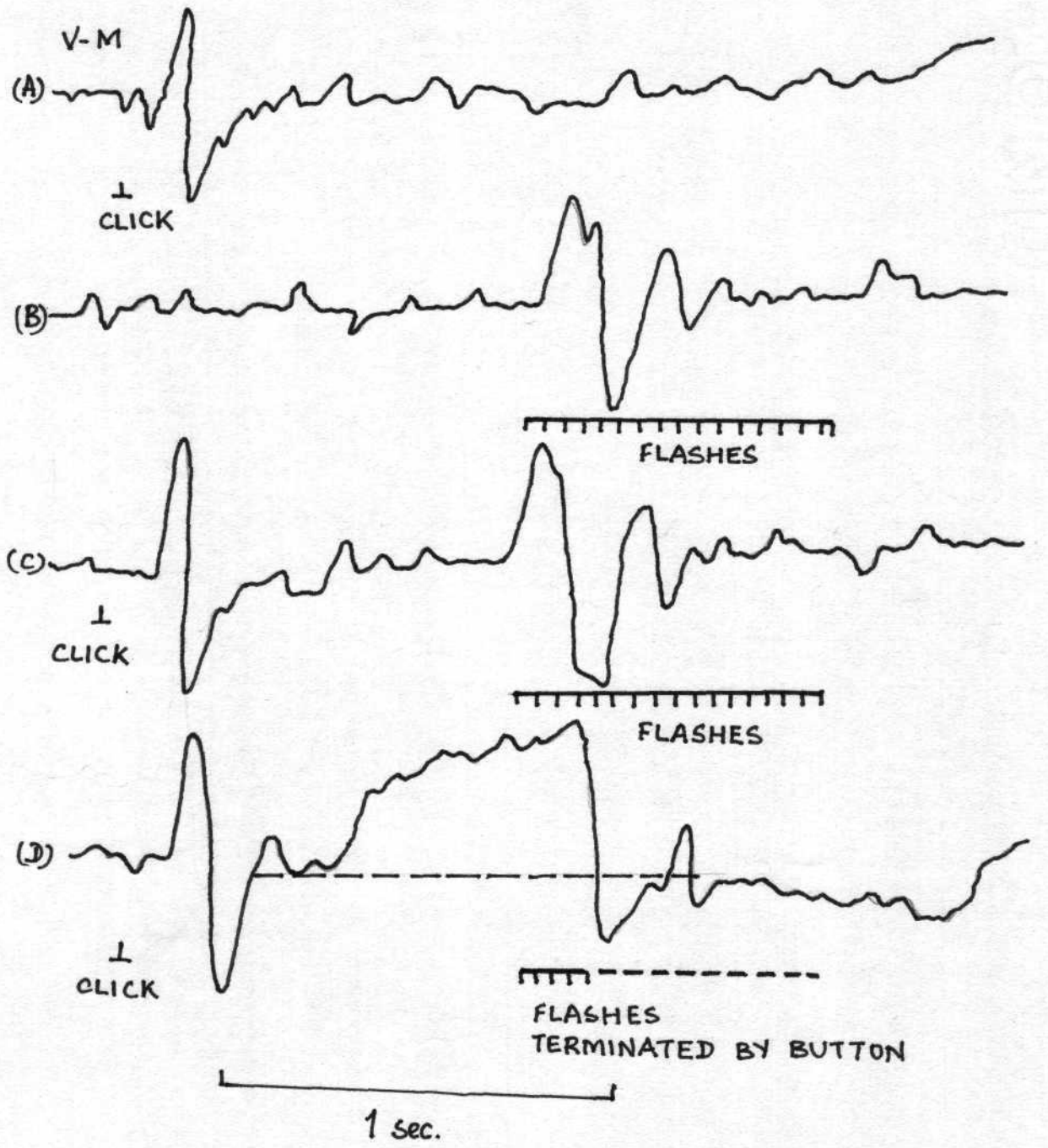


Fig. 6.2: The development of the contingent negative variation (CNV) as a conditioned response.

Following the discovery of the CNV, many investigations were carried out. Cohen and Walter (1966) reported that instead of using a physical operant response such as pressing a button, one can use pictures to be visualized as the imperative stimulus. Some authors have recorded CNV by asking the subject to 'think now' as the operant response. When the operant response was to press a button, a number of authors noted that the amplitude of the CNV was greater when it was necessary to exert more effort to press the button/bar. Often, large amplitudes reflect the degree of certainity with which the subject expects the oncoming imperative stimulus.

The term, CNV, was first coined by Walter et al (1964) on account of the fact that the response was contingent upon the occurrence of an imperative stimulus. Low et al (1966 a) suggested the term 'expectancy wave' since they demonstrated that an imperative stimulus was not entirely essential for the development of the response. However, the term CNV is more commonly used, and hence, accepted.

6.2: Characteristics of the Response:

6.2.1: The distribution of the resgonse: Walter et al (1964) proposed that the CNV mainly originated from the frontal areas of the brain. Later studies, however, showed the CNV was centred near the vertex. Vanghan et al. (1968) found

that the CNV is actually derived from the region of the motor cortex.

Studies have revealed that maximal CNV amplitude is obtained when the active electrode is placed near the vertex and the reference electrode is over the mastoid process. The amplitude of the response reduces from the frontal region backwards to the occipital positions.

6.2.2: The morphology of the response: The shape of the CNV response variesfrom individual to individual. Also, the shape varies depending on the experimental conditions. In the course of research, some common shapes have arisen among adults. These are as depicted in Fig.6.3.

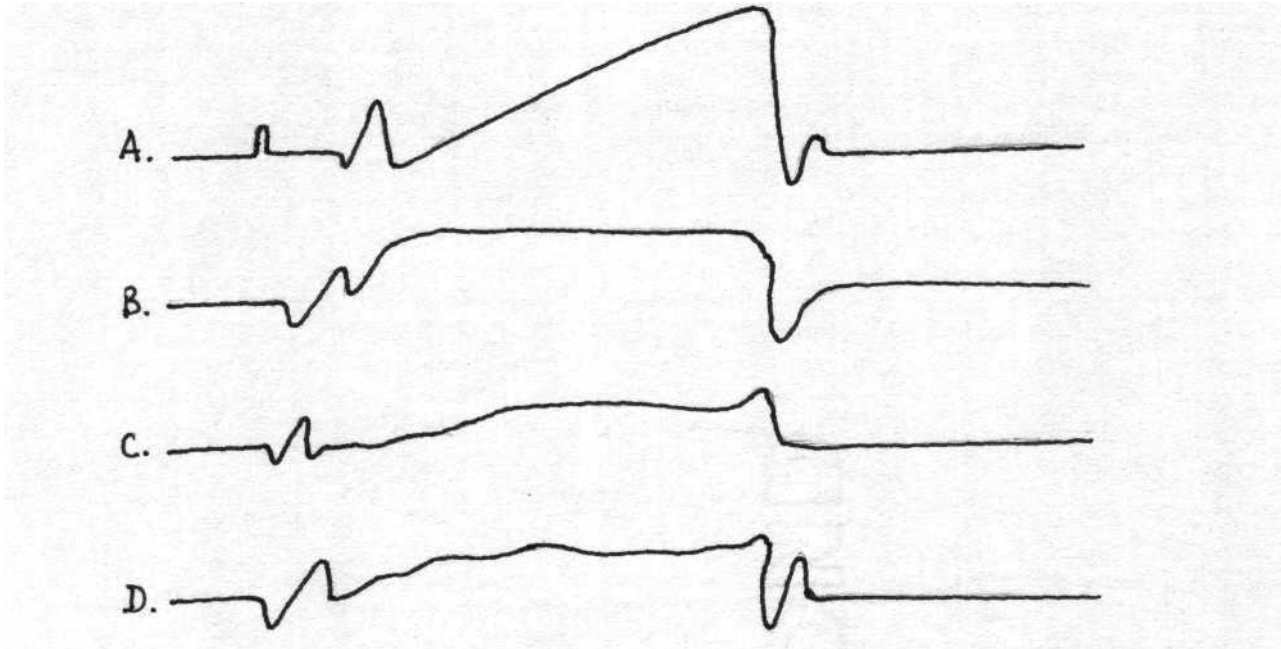


Fig.6.3: Some of the common CNV patterns.

Around 40 percent of the responses are ramp-shaped (Fig.6.3A), 33 percent are rectangular (Fig.6.3B) and the remaining 27 percent are atypically shaped (Fig.6.3C and Fig.6.3D) sometimes the CNV may remain for a short period after the imperative stimulus, or it may reduce briefly for about 0.1 sec. at the time of the imperative stimulus, then resume negative polarity and gradually return to the baseline after 1-2 sec. (Fig.6.3D). The phenomenon was termed as 'rebound' by Bostem, et al.(1967).

McAdam et al (1969) related the morphology of the CNV to the subject's certainlty. They suggested that the ramp-shaped CNV was obtained when the subject was sure that the imperative stimulus would be presented, but if the subject was uncertain, then a rectangular response was more often obtained.

6.2.3: The amplitude of the response: The average amplitude of the CNV response in adults is approximately 20 /uV (Walter, 1964). Cohen (1969) reported that in spite of the variation from one subject to another, those subjects who gave CERA responses of large amplitude also gave large amplitude CNV responses. Low et al (1966a) found that some children give responses with amplitudes as high as 50 /uV.

The CNV is characteristically absent in psychopaths. The psychological state of the subject is an important factor

affecting the amplitude of the response. Some test factors which influence the amplitude are:

6.2.3.1: Stimulus factors: A fundamental difference between CNV audiometry and other forms of ERA is the need of two stimuli - the conditioning stimulus and the imperative stimulus.

For CNV audiometry, the conditioning stimulus generally used is a pure tone burst. A 300 msec, tone burst with gradual rise and decay is adequate. Even clicks or words may be used as conditional stimuli.

The characteristics of the imperative stimulus is not critical provided it can be perceived by the subject. We can use visual stimuli such as a flash of light. However, in the case of blind subjects, one can use audible clicks.

However, the operant task to be executed following the imperative stimulus may affect the CNV amplitude. The CNV amplitude is increased when the subject has to perform a motor task. Also the greater the effort the subject has to put in, the larger the CNV response.

6.2.3.2: The inter-stimulus interval: McAdam, et al.(1969) found that the time that lapsed between the conditioning stimulus and the imperative stimulus is critical. Larger CNV amplitudes were obtained if this interval was between 0.8 and 1.6 sec.

6.2.3.3: Amplitude during the testing period: During the testing period the amplitude of the CNV is related to the probability of occurence of the imperative stimuli-

The CNV response can be maintained if the subjects' attention can be retained throughout the testing period. The CNV disappears progressively if the imperative stimulus is omitted for about 30 trials consecutively. If the subject is told that the imperative stimulus will not be presented, the CNV was extinguished immediately.

6.2.4: The Iatency of the CNV response: The latency of the CNV potential is variable and it is difficult to measure as it develops amongst the late responses. Generally, the latency of the maximum amplitude of the response lies Within 450-900 msec.

6.3: Exclusion of possible contaminating potentials:

6.3.1: Eye artefact potentials: Movements of the eyes can produce electrical potentials. The potential may be scalp during CNV measurement, and hence affect the response. Hillyard and Galambos (1970) found that this is more so if the subjects move their eyes downwards. Hence, it is has been recommended that CNV recordings be obtained with the eyes open and optically-fixated.

6.3.2: The test and test/retest reliability: Both the test reliability and the test/retest reliability of CNV is fair. The response does not diminish as the subject gets accustomed. However, at times, one may encounter a non-responsive subject, especially in the case of chilnren, psychopaths and anxious or neurotic subjects.

Also, subjects who give clear CNV responses at one time continue to do so even in later sessions, and vice-versa(in a majority of the cases).

6.4 Instrumentation:

The apparatus generally used for CNV audiometry is depicted in Fig.6.4.

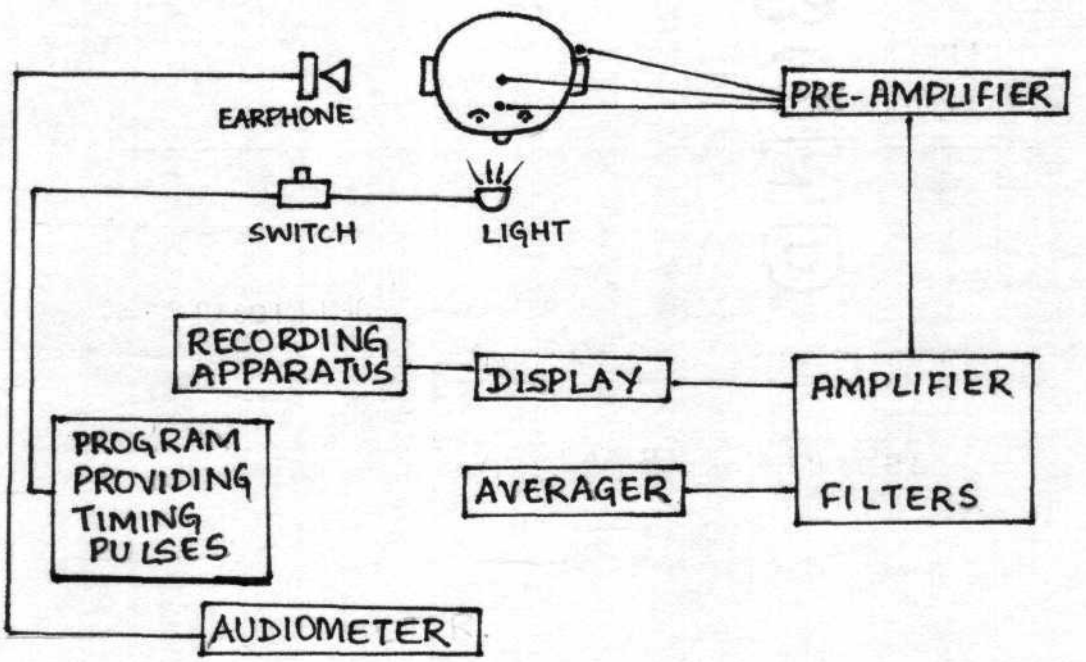


Fig.6.4: A block diagram of the typical apparatus for CNV audiometry.

The special requirements for CNV audiometry are:

6.4.1: Thetestenvironment: The subject should be tested in a sound proof chamber. He should be seated comfortably. The chamber contains the preamplifiers into which the electrode leads are inserted, the earphones or loudspeaker, a switch for the operant response and a light bulb is kept directly in front of the subject (the imperative stimulus).

6.4.2: The stimulus generation: Two separate stimuli - the conditioning and the imperative stimulus should be provided and each must receive a triggering pulse.

The characteristics of the stimuli have been discussed in section 6.2 under 'factors affecting the response amplitude.'

The conditioning stimulus may be of any frequency and the intensity can be varied in 5 or 10 dB steps.

6.4.3: The recording aggaratus: standard silver/silver chloride EEG dome-shaped electrodes may be used. They should be non-polarising. The amplifiers should satisfy low noise biological specifications. Bandpass filters can be used to eliminate some of the unwanted electrical noise.

An averager is needed to visualize the response clearly. Only a few responses need to be averaged. Because of this, a careful watch should be made of the on-going electrical activity so that any sudden changes can be noted.

CNV testing is time consuming. Many find it advantageous to record all the data on a frequency modulation (FN) magnetic tape recorder and analyse it later on.

6.5: Testing procedures:

The subject must be awake and alert. He must be seated comfortably with the neck supported to limit head and neck movements. To eliminated interference of eye movement potentials, the subject has to be instructed to keep his gaze directed at the light bulb which provides the imperative stimulus.

The skin should be clear of grease and a secure contact should be made between the skin and the electrode. This is necessary in order to prevent the baseline from drifting during averaging. One may face this problem with nearly applied electrodes. Hence,it is recommended that testing be initiated 10-15 minutes after applying the electrodes.

Baseline drifting is generally due to poorly applied electrode. This has to be identified and replaced.

The basic electrode positions are: active electrode on the vertex, reference electrode over either mastoid process and earth electrode on the forehead.

The subject should be properly instructed as to when he has to make the operant response. He is told that he will hear a faint pure tone signal which will warn him that a light is about to flash on. He is told to extinguish the light as quickly as possible by pressing a button. The instructions will vary depending on the particular test being performed

6.6: Clinical use of CNV:

The CNV can be used for estimating auditory thresholds and perhaps for neuro-otological diagnosis.

6.6.1: As a method of hearing threshold detection: The most important advantage of the use of the CNV as an audiometric test is that it is an objective method to determine the threshold of subjective perception of an auditory stimulus. The CNV shows that the stimulus has actually been perceived. Another advantage of the CNV is that an compared to other electrophysiological methods, its amplitude does not decrease when the intensity of the stimulus is decreased to the threshold level. This may be due to an inccrease in concentration of the subject to hear the tone.

However, the CNV does have disadvantages in that it is difficult to be used with very young children whose passive cooperation may not be easily obtained. Prevec et al (1977)

suggested use of cartoons as the imperative stimulus for young children.

With respect to puretone audiometry, the CNV is a fairly reliable test to estimate hearing threshold of adults.

Burian et al (l969, 1972) used the CNV as a method of objective speech audiometry and called it 'language electric response audiometry'. They tested two adult aphasics. Shortly after the onset of aphasia, one of the patients could not discriminate between meaningful and non-meaningful words, and this was reflected in the lack of differences between the CNV responses for meaningful and non-meaningful words. However, several months later, when he had recovered, he developed a CNV response only for meaningful words.

This shows that the CNV has the potential to be used as a test for verbal discrimination and verbal comprehension, and canbe used in language disordered adults,and may be even children.

6.6.2: As a means of neuro-otological diagnosis: The CNV can be used by professionals concerned with higher cortical functions. Studies have revealed that psychopaths do not give a CNV response. Anxious subjects have been reported to give CNV responses with smaller amplitudes.

6.7:Conclusion:

The CNV has many advantages and also some disadvantages, as mentioned above. In most centres this is not used as part of the evaluation battery. However, it does have a potential application as a means of assessing higher cortical functions. The use of CNV to find out whether or not the subject has understood a particular word has interesting applications for research, and this has to be probed into further.

POST-TEST

I. Fill in the blanks:

(1) The contingent negative variation is also called the

(2) The two kinds of stimuli which are used in contingent negative variation audiometry are the . . . . . stimulus and the . . . . . stimulus.

(3) Walter (1964) believed the CNV to originate from the .....

(4) The ..... stimulus is one which requires a mental decision or a motoric action.

(5) The amplitude of the CNV response is maximal in the ..... region

(6) The most common response shape encountered is the ..... response.

(7) We can use ....., ... or ..... as conditional stimuli.

(8) The greater the pressure to be applied to press the button, the . . . . . the amplitude of the response.

(9) Before placing the electrodes, the tester should see to it that the skin is free of .....

(10) As a method of objective speech audiometry, the CNV technique is called .....

II. True or false:

(1) The CNV response is myogenic in origin

(2) In CNV audiometry, a conditioning process is established between the conditioning stimulus and the imperative stimulus.

(3) It is not possible to use pictures as imperative stimuli.

(4) Walter et al. (1964) coined the term 'expectancy wave'.

(5) CNV amplitude is maximal when the active electrode is placed on the vertex.

(6) The CNV is a very characteristic finding in psychopathic individuals.

(7) The characteristics of the conditional and imperative stimuli are very critical factors and affect the amplitude of the response to a greater extent.

(8) The latency of the CNV varies between 450-900 msec.

(9) Electric potentials resulting from movements of the eyes can affect the CNV.

(10) The CNV does not have much potential in the evaluation of hearing acuity.

III. <u>Choose the correct answers:</u>

(1) Large CNV amplitudes reflect

(a) the intelligence of the subject

(b) the certainity with which the subject is expecting the imperative stimulus

(c) the alertness of the subject

(d) none of the above

(2) There are a number of factors affecting the response amplitude

(a) the inter-stimulus interval

(b) the nature of the operant response

(c) the psychological state of the individual

(d) all of the above.

(3) The 'rebound' effect refers to:

(a) reduction of the CNV for about 0.1 sec. at the onset of the imperative stimulus and its resumption of negative polarity and gradually returning to baseline.

(b) two CNV responses occuring simultaneously.

(c) a CNV response with positive polarity

(d) none of the above.

(4) Drifting of the baseline during averaging is generally due to:

(a) brainstem lesions

(b) lack of attention on the part of the subject

(c) poor or loose electrode placement

(d) some error in the equipment

(5) Burian et al. (1969) found that the aphasic patient, after recovery, developed CNV responses to:

(a) both meaningful and non-meaningful words

(b) only non-meaningful words

(c) only meaningful words

(d) only for pure tones.

CHAPTER 7

ELECTROCOCHLEOGRAPHY (ECochG)

PRE-TEST

I. Fill In the blanks:

(1) The three potentials that are analyzed ia ECochG are the ....., the ..... and the .....

(2) The ..... can be used to assess the integrity of the hair cells.

(3) Clear responses can be elicited by ..... frequency

(4) ..... and ..... do not affect the response, the latter is true if the electrodes are placed correctly.

(5) ECochG may be conducted in two ways - the ..... and .....

(6) Of the three potentials, the ..... is often employed as an index of hearing.

(7) Best thresholds are obtained when the active electrode is placed on the .....

(8) Besides obtaining a normal waveform in normal ears, we get a normal waveform in cases of .....

(9) The most common clinical finding in cases of acoustic neuroma is a ..... Action Potential.

(10) In order to cancel the ..... potential, a reversal in the polarity of the stimulus is brought about alternately.

II. Choose the correct answer:

(1) The potential which reflects the neural activity in the auditory nerve is the

(a) summating potential

(b) action potential

(c) cochlear potential

(d)-(b) and (c)

(2) An important factor which influences the response to a great extent is:

(a) recording site

(b) stimulus intensity

(c) type of stimulus

(d) filter characteristics

(3) A patient with a low frequency hearing loss may give

(a) a distorted ECochG response

(b) a normal ECochG response

(c) a broadened action potential waveform

(d) a very small action potential

(4) A normal but delayed action potential waveform is very characteristic of:

(a) conductive hearing loss

(b) sensorineural hearing loss

(c) retrocochlear pathology

(d) high frequency hearing loss

(5) A clear cochlear microphonic with an absent action potential would favor the diagnosis of . . . . . in a patient in whom the other tests like speech discrimination, tone decay test, and others also favor the same.

(a) cochlear pathology

(b) acoustic neuroma

(c) Meniere's Disease

(d) none of the above

III. **Indicate whether the following statements are true or false:**

(1) The transtympanic method is a non-invasive technique.

(2) The summating potential has a waveform which is similar to that of the acoustic stimulus.

(3) Low frequency tone bursts are not effective in producing clear responses.

(4) In testing the child, anesthesia is not required.

(5) In conductive hearing loss, the cochlear microphonic is reduced in amplitude.

(6) Masking is not needed in ECochG measurements.

(7) The action potential and the cochlear microphonic have to be separated for the action potential to be clearly visualized.

(8) ECochG has very poor test/retest reliability

(9) The summating potential does not affect the action potential in any way.

(10) The summating potential can be used as a measure of hearing sensitivity.

ELECTROCOCHLEOGRAPHY

7.1: Introduction:

Electrocochleography (ECochG) is an electrophysiologic approach to the study of hearing. This is a method of recording the electrical activity originating in the cochlea and the first order, eighth nerve fibres in response to acoustic stimulation. All three endocochlear potentials can be analyzed in the ECochG, that is the compound auditory nerve action potential (AP) as well as the cochlear microphonic (CM) and the summating potential (SP).

From among the three potentials, and AP is most often employed as the index of hearing. The CM also occupies some importance in this respect, but the SP is usually not used as a measure of hearing sensitivity. The action potential is used for threshold-estimation, while a combination of CM and AP are used for differential diagnosis.

7.2: The Cochlear Microphonic:

The cochlear potential or the cochlear microphonic (CM) are the potentials which are evoked immediately after stimulus presentation. The waveform of the CM reflects the acoustic stimulus over a considerable frequency and intensity range. In this manner, it is very much like the output of a

microphone. The CM is the earliest of the three potentials, and hence has the shortest latency. It disappears or gets diminished when there is damage to the Organ of Corti, especially the hair cells, or when there is diffuse damage secondary to metabolic changes or aging (Dalles, 1973). The CM, in normal ears, can be obtained at a level of around 60 dB SL.

The CM has been used extensively as a monitor of cochlear integrity and function in experimental animals. However, as early as the early fifties, it was reported that the CM recordings are related only to a limited area of the basilar membrane close to the round window (Tasaki et al. 1952; Simmons and Beatty, 1962). Hence, from such recordings one cannot draw conclusions about the function of hair cells outside the basal turn. In man, the basal turn is responsible for the perception of frequencies greater than 10 KHz. So, even by using low frequency stimuli, the CM recorded from outside the cochlea is a poor indicator of cochlear function in the upper apical regions. In order to measure the CM relevant to low frequencies, it is necessary to place the electrodes within the cochlea (Dallos, 1973). The value of the CM in threshold detection is not much as it lacks an absolute threshold.

7.3: The Summating Potential (SP):

The SP, a complex potential, is essentially a DC (direct current) shift which occurs during the presentation of a stimulus. It represents a reaction to the envelope of the waveform of the acoustic stimulus. The magnitude and polarity of the shift are dependent on the recording site, stimulus frequency and stimulus intensity (Dallos, 1973). The SP is very small relative to the other potentials and it is not used as an index of normal cochlear function in humans. It contributes to the broadening of the AP waveform.

7.4: The Action Potential (AP):

Another sound-dependent potential is the compound action potential which reflects the neural activity in the auditory nerve. It may be recorded both in the cochlea and its vicinity and from the auditory nerve. It reflects not only the excitation, but also the degree of dys-synchronization of the activity of the auditory nerve fibres. The exact electrical location of its origin is unknown. The auditory nerve AP is the useful electrical response in cochleography. It has two pronounced negative peaks which are named N_1 and N_2 (Fig.7.1). The latency of N_1 is, around 1.2-2 msec.

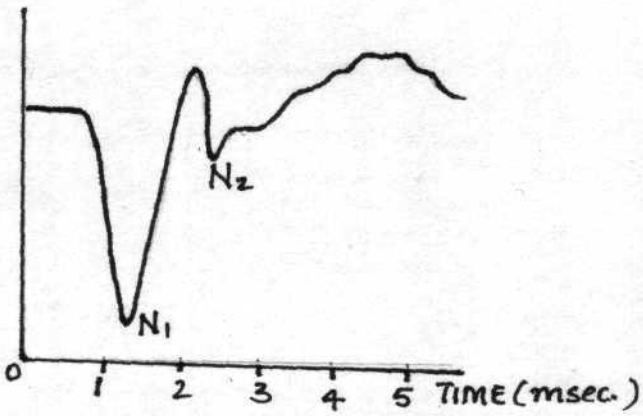


Fig.7.1: Compound action potential (AP) of the auditory nerve.

The AP recorded during ECochG is the sum of many individual AP elicited along a length of the basilar membrane. The greater the number of individual nerve fibres firing in synchrony, the larger and more readily identifiable is the action potential. Clicks, abrupt tone bursts, or bursts of noise are effective if their rise time is sufficiently short.

The principal characteristics of the AP waveform are latency, amplitude and shape. The latency of the AP waveform is considered to be a clue to the frequency region of the cochlea contributing to the response. The amplitude is considered as a reflection of the number of active elements contributing to it and the synchrony of their discharge. The shape of the waveform is considered to be the result of a compromise between the electrical field of neurons which have discharged and the neurons which are discharging at the given moment.

Because the action potential is of clinical interest, is the imperative that the recordings are not influenced by other electrical potentials, especially the cochlear microphonic. The method used for the separation of the CM from the AP is based on the fundamental differences between the two potentials. The AP is invariant in its general shape and polarity whereas the CM follows the shape and polarity of the acoustic stimulus. Thus the CM can be nullified by the averager if the polarity of the waveform is alternately reversed - the AP is unaffected by this as it is produced essentially by the onset of the tone burst or click, and it always has the same polarity. Therefore, we can obtain the AP which is free of CM. Such a method preserves the AP while the CM is lost.

However, in most modern commercial ECochG systems a modification, or rather a refinement in the instrumentation permits either the AP or the CM to be recorded, as required. Here, the averager has a split memory, each half of which is designated A or B. By use of an electronic switch, all the responses from acoustic stimuli of one polarity are directed to enter memory A, where they are recorded, and all the responses to stimuli of the opposite polarity go to memory B. Following this, if memories A and B are added, the action potentials being alike, add together, but the CM

being of opposite polarity, get snullified. Thus A plus B gives AP only. On the other hand, if memory B is subtracted from memory A then the AP gets cancelled, while the CMs get doubled in amplitude. Thus A minus B gives CM only (Fig.7.2).

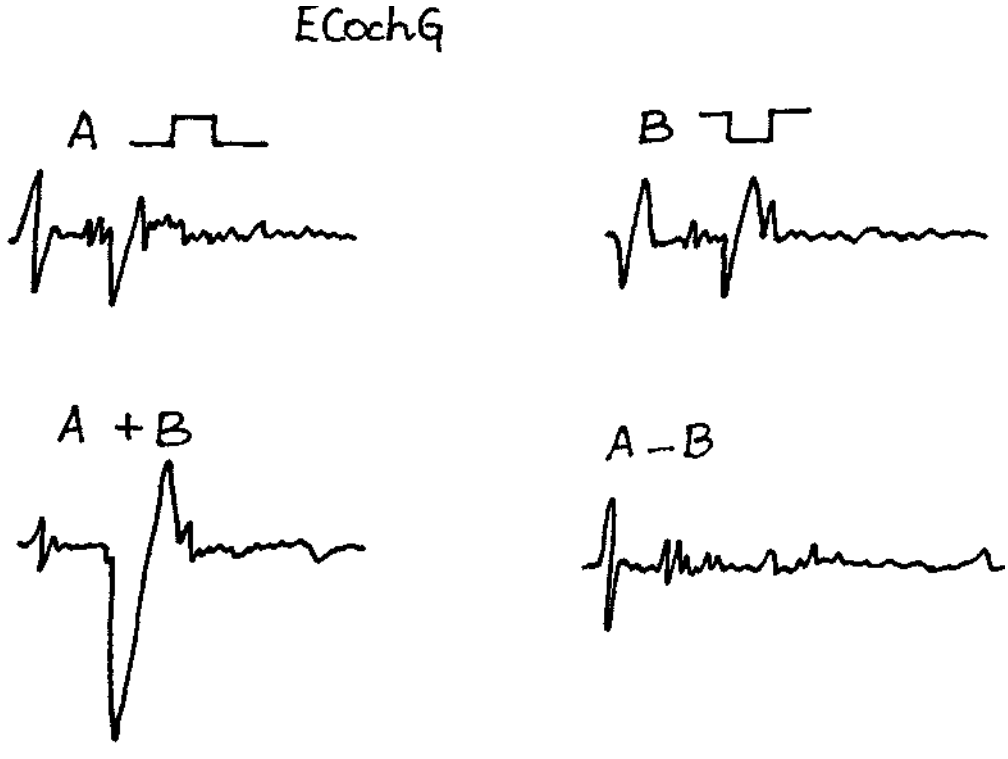


Fig.7.2: In systems with split memory, one can record the AP or CM, as needed.

7.5: Factors affecting the response:

7.5.1: The electrode placement: The most important factor influencing the response is the recording site. The AP may be recorded from various sites around the head (promontory, tympanic membrane, ear canal, earlobe, scalp, hard palate.

nasopharynx, etc.). However, the closer the active electrode is placed to the round window, the larger the potentials recorded. The best and clear responses are obtained from the promontory recordings. Eggermont and Odenthal (1974 c) have given the thresholds at which the responses are identifiable at different recording sites:

Site	Threshold
Round window	0 dB HL
Promontory	5 dB HL
Annulus tympanicus	10 dB HL
External ear	30 dB HL

The above table shows the variations in thresholds that occurs with different recording sites. The external ear shows the poorest response, or rather, it gives an identifiable response at a higher intensity level when compared to other recording sites. However, going in for a promontory recording may be traumatic for the subject. It is always better to do a promontory recording, but if this is not possible then an earlobe recording can be opted for provided one takes into consideration the difference in threshold when judging the response.

7.5.2: Type of stimulus: The frequency and the temporal parameters of the stimuli is found to influence the AP waveform. Clear responses can be elicited by high frequency stimuli of around 2-8 KHz. Pure tone bursts of short duration may be used to elicit the AP. However, high frequency tone bursts

(above 2000 Hz) evoke an excellent AP as their onset is abrupt and they stimulate the relevant areas of the basilar membrane with reasonable synchrony. Low frequency tone bursts (500-l000Hz) do evoke a frequency specific AP but this AP becomes progressively smaller, broader and more prolonged as the frequency is lowered. At frequencies of 250 Hz or less, the AP is practically unidentifiable (Gibson, 1978).

Therefore, ECochG can be claimed to be mainly a high frequency measure. This has to be borne in mind when interpreting ECochG responses in that an individual with a low frequency hearing loss may give a normal ECochG response.

7.5.3: <u>Stimulus Intensity</u>: As the intensity of the stimulus is increased, the latency of the response decreases upto a certain point and maintains a plateau beyond the critical point. Also, with an increase in stimulus intensity, the amplitude of the response grows, and the response is more clear.

7.5.4: Prolonged or repeated stimulation: The amplitude, latency and waveform of the AP is constant despite prolonged or repeated stimulation. Provided that the electrodes are placed accurately, these functions have been found to be unchanged in spite of repeated or prolonged testing (Gibson, 1978).

7.5.5: Stimulus presentation rates: Eggermont and Spoor (1973 a) found that increasing the stimulus presentation rate results in the reduction of the amplitude and increase in the latency of the N_1 component of the AP. Generally a stimulus repetition rate of 10/sec. is convenient for testing purposes.

7.**5.6: Sedation:** Sedatives, including general anesthetic agents do not have much effect on the cochlear responses. This property of ECochG is of great value when it comes to testing un-cooperative children.

7.5.7: Masking: No AP can be recorded from the promontory or ear canal ef the deaf ear of a subject with a unilateral hearing loss. Hence, the need for masking does not arise since an accurate estimation of the cochlear function can be made without the question of the better ear participation arising.

7.5.8: The test/retest reliability: The reliability of the ECochG is better than any of the other variants of ERA. The agreement between the AP threshold and the subjective thresholds is close. At high frequencies above 2 KHz, the difference between the AP threshold and the pure tone average (PTA) threshold is usually less than 10 dB (Aran et al. 1971; Gibson, 1978). However, the same is not true of the lower frequencies.

Hence, the ECochG provides a reliable indication of the PTA only in the higher audiometric frequencies.

The test/retest reliability of the ECochG is excellent. The waveform of the AP is more or less constant even when recorded after intervals of several weeks. The amplitude of the AP may vary due to changes in electrode position or electrode impedance. The excellent test/retest reliability of the AP makes it a useful tool for assessing the changes that may occur within the cochlea after medical or surgical treatment.

7.6:Instrumentation:

The apparatus required for BCochG is essentially what has been described in Chapter-2. Just as with the other ERA measurements, the special requirements are as follows:-

7.6.1: The test environment: It is best if the subjects are made to lie-down on a couch. For un-cooperative children a suction apparatus for the administration of anesthetic drugs, or general inhalation anesthetic agents should be at hand. The room should be sound proof, especially for threshold estimation purposes. Ideally, the room should be anechoic.

7.6.2: The stimulus generation: Use of very brief stimuli with relatively sharp onset characteristics is recommended, Tone bursts have been found to be effective in eliciting the AP

A stimulus repetition rate of 10/sec. is convenient for testing purposes. It is preferable to use an earphone for delivering the stimuli. A loudspeaker may be used provided the chamber is anechoic.

Masking facilities are not essential for clinical purposes, but may be useful for research purposes.

7.6.3: The recording equipment: An important consideration here is the type of electrode used. This varies with the method used for recording the ECochG. In the extratympanic method, a wire electrode is used, or a hypodermic syringe needle is used to insert a silver wire into the meatal lining in the postero-inferior rim of the meatus. The reference electrode is placed on the ipsilateral mastoid or earlobe and the ground electrode is placed on the forehead.

In the transtympanic method, a wire electrode is used. This is a thin steel wire of approximately 0.3 mm diameter, insulated throughout except for the tip and the other end at which point it is connected to the electrode holder. The electrode is pierced through the tympanic membrane and the tip of the electrode tones in contact with the promontory. Adults may be tested with local anesthesia, while children are tested under general anesthesia.

Low biological amplifiers are essential. Even though most of the energy of the AP lies between 600 and 1200 Hz, there are contributions from outside this frequency range. Hence, the filter settings used vary from 2-10 Hz to 3-5 KHz (Gibson, 1978).

An averaging system with a split memory will be of advantage to the tester. A monitor oscilloscope, artefact rejection facilities and facilities for permanent recording are also needed.

7.7:Testing procedures:

For the transtympanic method, children are tested under general anesthesia while adults may be tested using local anesthesia. Even for the extratympanic method, local anesthesia may be needed when the electrode is to be inserted in the meatal wall. Placement of surface electrodes does not need anesthetization of the subject.

Once the electrodes have been properly placed, testing is started with the selected stimulus presented at a high intensity level, well above the subject's threshold. The CM and AP are recorded and this is repeated at successively lower levels until the threshold of the AP is determined. In case of normally hearing subjects, this is in the region of 20 dB HL, and is correspondingly higher, if hearing is impaired.

7.8:Clinical Applications:

7.8.1: As a means of threshold estimation: It must be remembered that the EochG only measures the threshold of the auditory mechanism at the level of the first order cochlear neurones. Therefore, more higher or central lesions can affect hearing without affecting the ECochG.

The ECochG provides a completely reliable measure of the individual's hearing sensitivity. Difficult-to-test children may be tested by ECochG if conventional testing is impractical./ It can be carried out at any age of the subject i.e., from a few months old until puberty, fit is often required for very hyperactive and un-cooperative children, multiple-handicapped cases, and/or children with athetosis, etc. It can be used in autistic children to confirm if the child has an associated hearing loss.

If the ECochG reveals reduced cochlear function, the child must be having some hearing loss. In some cases having a history of kernicterus, the AP waveform is distorted and widened and monophasic in its configuration.

In addition to threshold estimation, ECochG offers a means of determining the nature of the disorder, and this can be done by a careful analysis of the data obtained. For

example, the slope of the amplitude/intensity function of the AP provides a good indication of recruitment, and a sharp rise in these functions suggests that a child may not tolerate a powerful hearing aid.

It can also be used in those cases with functional hearing loss, in which cases a normal AP waveform is obtained.

7.8.2: As a means of neuro-0tological diagnosis: The ECochG aids not only in neuro-otological diagnosis, but also in differential diagnosis, and this is achieved by a combined use of the CM and the AP.

7.8.2.1: <u>Conductive hearing losses</u>: The shape of the waveform of the AP resembles that of the normal, in that the cochleograms are identical in configuration, except that in conductive hearing losses, the threshold is shifted to a higher level, the increase corresponding to the degree of loss. Also the amplitude of the N_1 peak is reduced and there will be an increase in the latency.

The CM in conductive pathologies is generally of small amplitude in spite of the hair cells being intact. Similarly, the SP is usually reduced in amplitude. This is because the conductive pathology reduces the amount of energy reaching the cochlea.

7.8.2.2: 'Dead ears': A patient with total loss in one ear is often misdiagnosed during conventional testing due to the participation of the better ear. ECochG does not provide an AP waveform in an ear with no residual cochlear function, without applying masking. ECochG provides the only test of cochlear function in which no masking of the contralateral ear is required and provides a definite indication of residual cochlear activity.

7.8.2.3: Cochlear hearing loss: The most common AP response configuration in cochlear hearing losses is the recruiting cochleogram (Portmann, et al. 1973). There is a sudden increase in the amplitude of the response waveform beyond a certain intensity level (Fig.7.3).

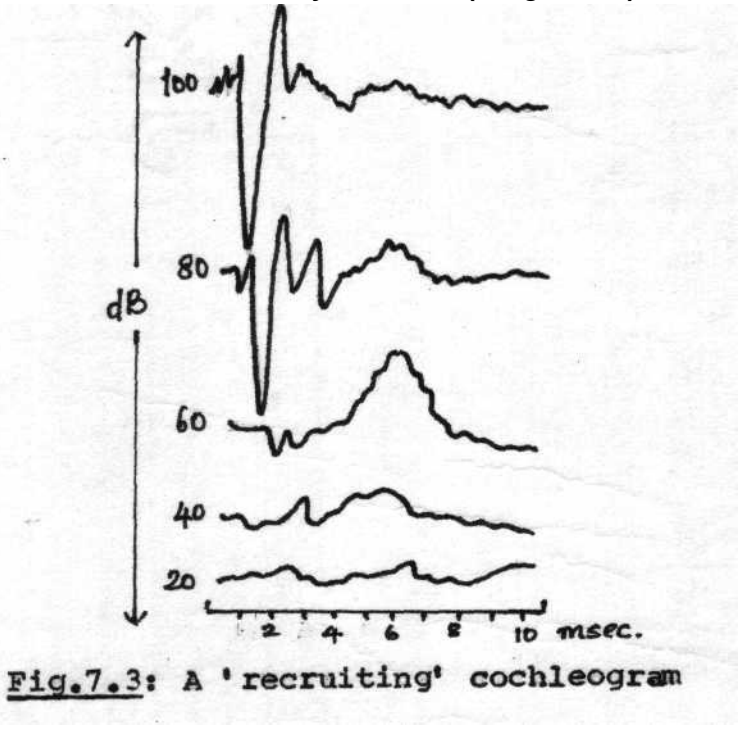


Fig.7.3: A 'recruiting' cochleogram

The amplitude/intensity functions are much steeper than in normal ears. Sometimes a diphasic pattern is obtained at all levels of the stimulus. Also the threshold is elevated.

The CM varies in amplitude but is generally smaller than normal. The SP is also small.

In case of high frequency hearing loss, the AP waveform is characteristically delayed. This is because the AP from the basal coil is reduced in amplitude, while the AP derived from the middle turn of the cochlea is normal. The summated effect is the delayed waveform. The CM is of minute amplitude and the SP is small (Gibson, 1978).

With respect to ototoxic cochlear damage, Aran et al (1975) noted that there are specific changes in the AP in guinea pigs following the administration of kanamycin. Ramsden et al (1977) reported similar effects in man. It has been suggested that ECochG may be of use in assessing the early effects of a drug in the individual patient.

ECochG is valuable in the diagnosia and management of Meniere's disease as it provides direct evidence of disturbed cochlear physiology. The commonest BCochG finding is a broadening of the AP waveform due to relative enhancement of the negative SP component (Gibson, 1978). The amplitude/

intensity function is twice as steep as in the normal case, thus indicating recruitment. The CM in Meniere's disease tends to be small and distorted. The presence of a broad/ SP/AP waveform and a small CM provides objective confirmation of the clinical diagnosis of Meniere's Disease. One may use these responses as the baseline to monitor the immediate effects of drugs.

Gibson (1978) reports that in cases of tinnitus, ECochG reveals a massive CM in the affected ear which is superimposed upon the AP in spite of the use of stimulus polarity alteration.

7.8.2.4: <u>Retrocochlear hearing losses</u>: Very often ECochG is used to diagnose the presence of acoustic neuroma in adults with unexplained, progressive sensorineural hearing loss, generally unilateral and sometimes of rapid onset. Various ECochG changes can be seen in the affected ear in cases of acoustic neuroma.

(i) Widend, distorted, monophasic AP (Fig.7.4)

(ii) AP threshold better than subjective threshold suggesting a neural block which prevents the nerve impulses reaching the higher centres normally or not at all, in some cases (Fig.7.4).

(iii) A well marked CM with an absent or largely suppressed AP suggesting a neural rather than a cochlear lesion, which would favor the diagnosis of acoustic neuroma (Fig.7.5).

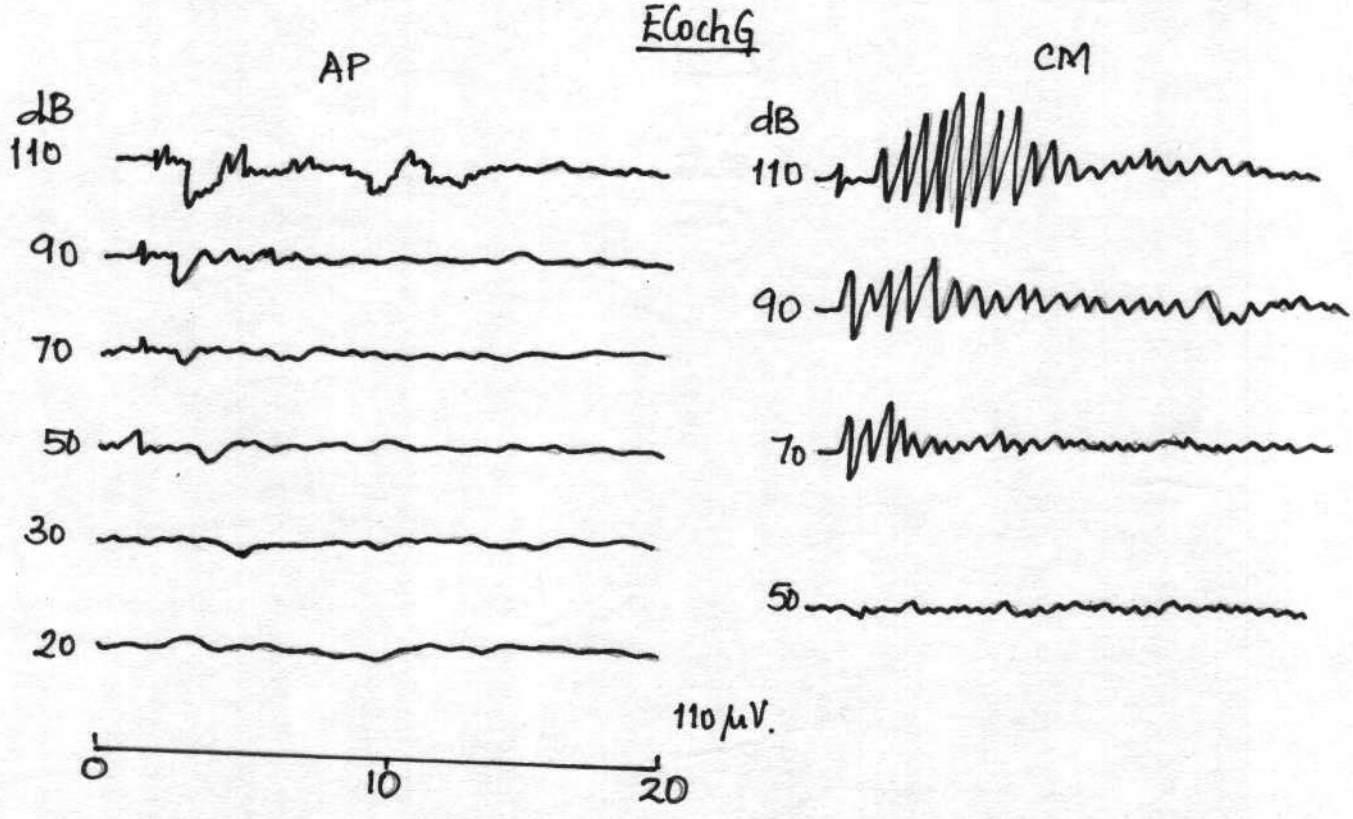


FIG. 7.4: This shows the widened monophasic AP from a patient with an acoustic neuroma. The Pure Tone Audiogram showed a hearing loss of 70 dB. Yet the AP in this case could be traced down to at least 30 dB. Both findings are typical of acoustic neuroma.

ECochG.

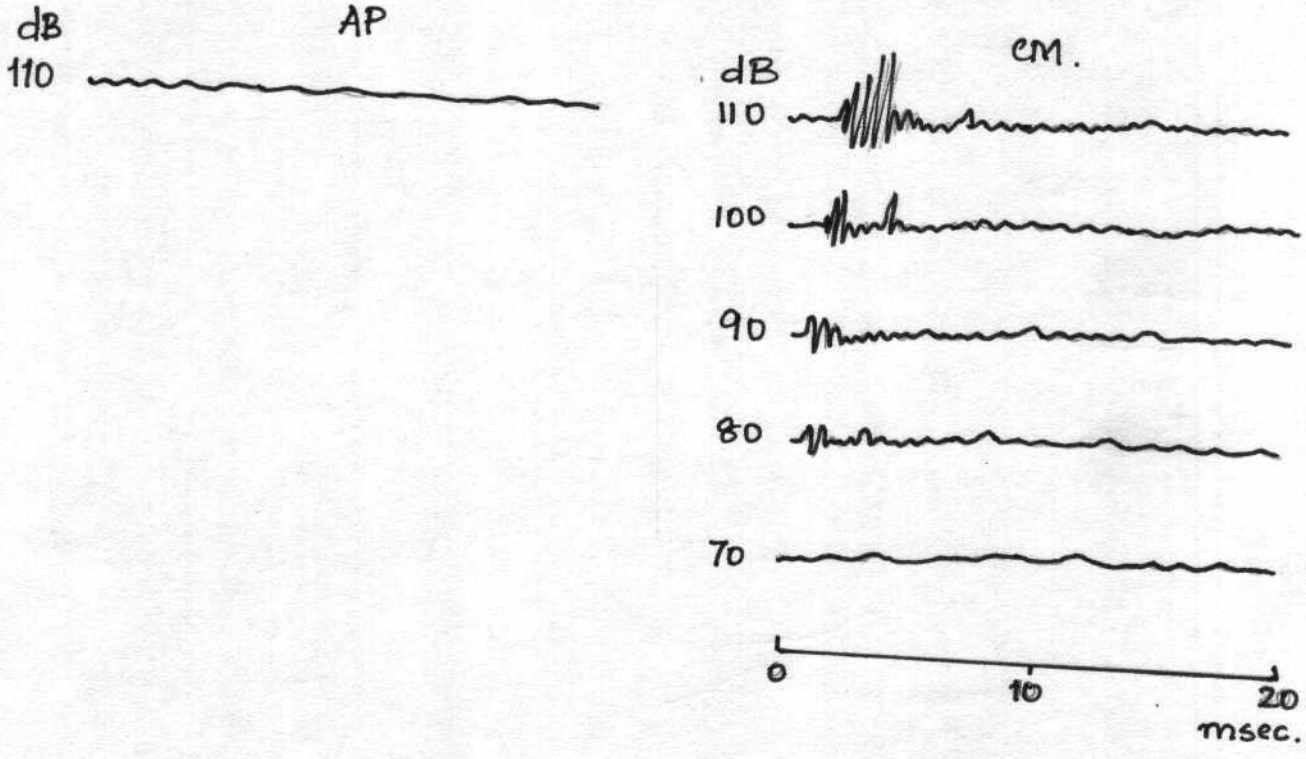


FIG. 7.5: This patient had a right acoustic neuroma with total hearing loss on the affected side. There is no AP but a well-marked CM at different levels of stimulation indicating that some cochlear hair cells are functioning but that the auditory nerve is not functioning. It confirms a neural loss of hearing and was the factor which indicated the presence of a acoustic neuroma.

(iv) Very rarely, the AP is normal especially in some medially placed acoustic neuromas. In these cases, pressure of the tumor on the brainstem can lead to delayed brainstem conduction time, which may be detected using BSERA.

(Beagley, 1981).

In testing cases of suspected acoustic neuroma, it is advisable to test the normal ear first and use the same as a baseline for comparison with the traces obtained from the affected ear.

In general, any lesion affecting the eighth nerve, affects ECochG in the same way as the acoustic neuroma. Other space occupying lesions in the posterior fossa may show electro-cochleographic changes similar to those caused by acoustic neuroma, eg., meningioma, congenital cholesteatoma, angioma, ecstasia of basilar artery and secondary tumors (Beagley and Gibson, 1976). Disseminated sclerosis in the form of an isolated plaque on the cochlear nerve can also mimic acoustic neuroma.

Thus the AP response of the ECochG seems to be a valuable clinical tool not only in the determination of thresholds, but also in the area of neuro-otological diagnosis. In combination

with the CM, it also helps in differential diagnosis. By comparing the CM and AP responses, a differentiation between the sensory and neural disorders can be made.

7.9: Conclusion:

ECochG is an extremely sensitive indicator of cochlear and auditory nerve integrity. However, most of the clinical findings mentioned in this chapter have been arrived at on the basis of the transtympanic method. In spite of the invasive nature of this technique, it does provide reliable and valid results. ECochG has many advantages over some of the other ERA measurements. At the same time it also has its own limitations in that it provides information only in the high frequency regions, it is an invasive technique (the transtympanic approach), and just as with the other measurements, it cannot be used in isolation, but in combination with the others. This will enable us to be more acceurate in our diagnosis.

Therefore, ECochG,while having a promising future in the diagnosis, understanding and treatment of zensorineural hearing loss, should be used as a supplement to behavioural and other conventional measures but not as a substitute for the same in the evaluation of subjects with hearing loss.

POST-TEST

I. Fill in the blanks:

(1) The three potentials that are analyzed in ECochG are the ....., the ..... and the .....

(2) The ..... can be used to assess the integrity of the hair cells.

(3) Clear responses can be elicited by ..... frequency

(4) ..... and ..... do not affect the response, the latter is true if the electrodes are placed correctly.

(5) ECochG may be conducted in two ways - the ..... and .....

(6) Of the three potentials, the ..... is often employed as an index of hearing.

(7) Best thresholds are obtained when the active electrode is placed on the .....

(8) Besides obtaining a normal waveform in normal ears, we get a normal waveform in cases of .....

(9) The most common clinical finding in cases of acoustic neuroma is a ..... Action Potential.

(10) In order to cancel the ..... potential, a reversal in the polarity of the stimulus is brought about alternately.

II. Choose the correct answer:

(1) The potential which reflects the neural activity in the auditory nerve is the

(a) summating potential

(b) action potential

(c) cochlear potential

(d) - (b) and (c)

(2) An important factor which influences the response to a great extent is:

(a) recording site

(b) stimulus intensity

(c) type of stimulus

(d) filter characteristics

(3) A patient with a low frequency hearing loss may give

(a) a distorted ECochG response

(b) a normal ECochG response

(c) a broadened action potential waveform

(d) a very small action potential.

(4) A normal but delayed action potential waveform is very characteristics of:

(a) conductive hearing loss

(b) sensorineural hearing loss

(c) retrocochlear pathology

(d) high frequency hearing loss

(5) A clear cochlear microphonic with an absent action potential would favor the diagnosis of ..... in patient in whom the other tests like speech discrimination, tone decay test, and others also favor the same.

(a) cochlear pathology

(b) acoustic neuroma

(c) Meniere's Disease

(d) none of the above

III. Indicate whether the following statements are true of false:

(1) The transtympanic method is a non-invasive technique.

(2) The summating potential has a waveform which is similar to that of the acoustic stimulus.

(3) Low frequency tone bursts are not effective in producing clear responses.

(4) In testing the child, anesthesia is not required.

(5) In conductive hearing loss, the cochlear microphonic is reduced in amplitude.

(6) Masking is not needed in ECochG measurements.

(7) The action potential and the cochlear microphonic have to be separated for the action potential to be clearly visualized.

(8) ECochG has very poor test/retest reliability

(9) The summating potential does not affect the action potential in any way.

(10) The summating potential can be used as a measure of hearing sensitivity.

CHAPTER 8

THE AUDITORY BRAINSTEM RESPONSE (ABR)

PRE-TEST

I. Fill in the blanks:

(1) The component waves of the auditory brainstem response (ABR) are also called as the .....

(2) The wave V which is the most prominent wave originates from the .....

(3) The fusion of the waves IV and V is called the ..... and a total of .... variant forms have been identified in adults.

(4) For evaluation purposes the ..... latency, the ..... latency and the ..... latency are considered.

(5) Females present ..... latencies and larger ..... than men.

(6) Based on the ..... we can have some idea as to the type of hearing loss the subject is having.

(7) The V/I amplitude ratio is greater than 1 in ..... and smaller than 1 in ..... and ..... subjects.

(8) ..... should be done whenever the interaural latency difference of the wave V exceeds 1-5 msec.

(9) It is the ..... of the stimulus which elicits the ABR.

(10) Filter characteristics affect the ..... of the ABR component waves.

II. Indicate whether the following statements are true or false.

(1) The ABR is a far-field potential

(2) Waves I, III and V are absent in children.

(3) Increasing the stimulus repetition rate enhances the morphology and amplitude of the ABR.

(4) It is not necessary to have separate normative values for men and women.

(5) The ABR can be used to assess the maturity of the infant.

(6) The absolute latency of the component waves of the ABR is prolonged in cases of retrocochlear pathology.

(7) The ABR cannot be used with children having psychiatric disorders.

(8) The results of the use of ABR with neurologic conditions has been discouraging.

(9) With an increase in age in infancy, the latencies of the component waves of the ABR decrease.

(10) All the waves can be clearly seen at stimulus intensities close to the subject's threshold.

III. Choose the correct answer:

(1) The wave III originates from the

(a) superior olivary complex

(b) cochlea

(c) cochlear nuclei

(d) none of the above

(2) A patient is found to have mild sensorineural hearing loss in the right ear. The ABR results indicate a prolonged wave V latency and the V/I amplitude ratio is less than 1. You would suspect.

(a) cochlear pathology

(b) retrocochlear pathology

(c) conductive pathology

(d) multiple sclerosis

(3) The ABR is unaffected by

(a) sleep

(b) sedatives

(c) repeated stimulation

(d) - (a), (b) and (c)

(4) The ABR may be used as a prognostic indicator of recovery in

(a) comatose patients

(b) multiple sclerosis

(c) infectious conditions

(d) psychiatric disorders

(5) In children the absolute response amplitude was found to be

(a) similar to that in adults

(b) larger than that in adults

(c) smaller than that in adults

(d) varying in individual cases.

THE AUDITORY BRAIN-STEM RESPONSE (ABR)

8.1: Introduction:

When an acoustic stimulus is presented, certain potentials are generated which can be recorded from the vertex. Those potentials Which are evoked within the first 10 msec. following stimulation are known as the "Brainstem evoked potentials". These potentials represent the bioelectrical responses of the VIII nerve and the brainstem nuclei.

The history of the ABR began in 1967 when sohmer and Feinmesser, in their attempts to devise a non-invasive alternative to transtympanic electrocochleography, recorded multiple waveforms from the vertex to repetitive firings of the auditory nerve. While confirming the validity of the responses, Jewett and his colleagues (1970, 1971, 1972) introduced the concept of "far-field" recordings to describe the situation where electrodes on the surface of the scalp recorded the activity of distant neural generators.

Jewett and Williston (1971) reported that the normal human ABR consisted of five to seven vertex positive waves occuring in the first nine milliseconds following a click stimulus (Fig.8.1).

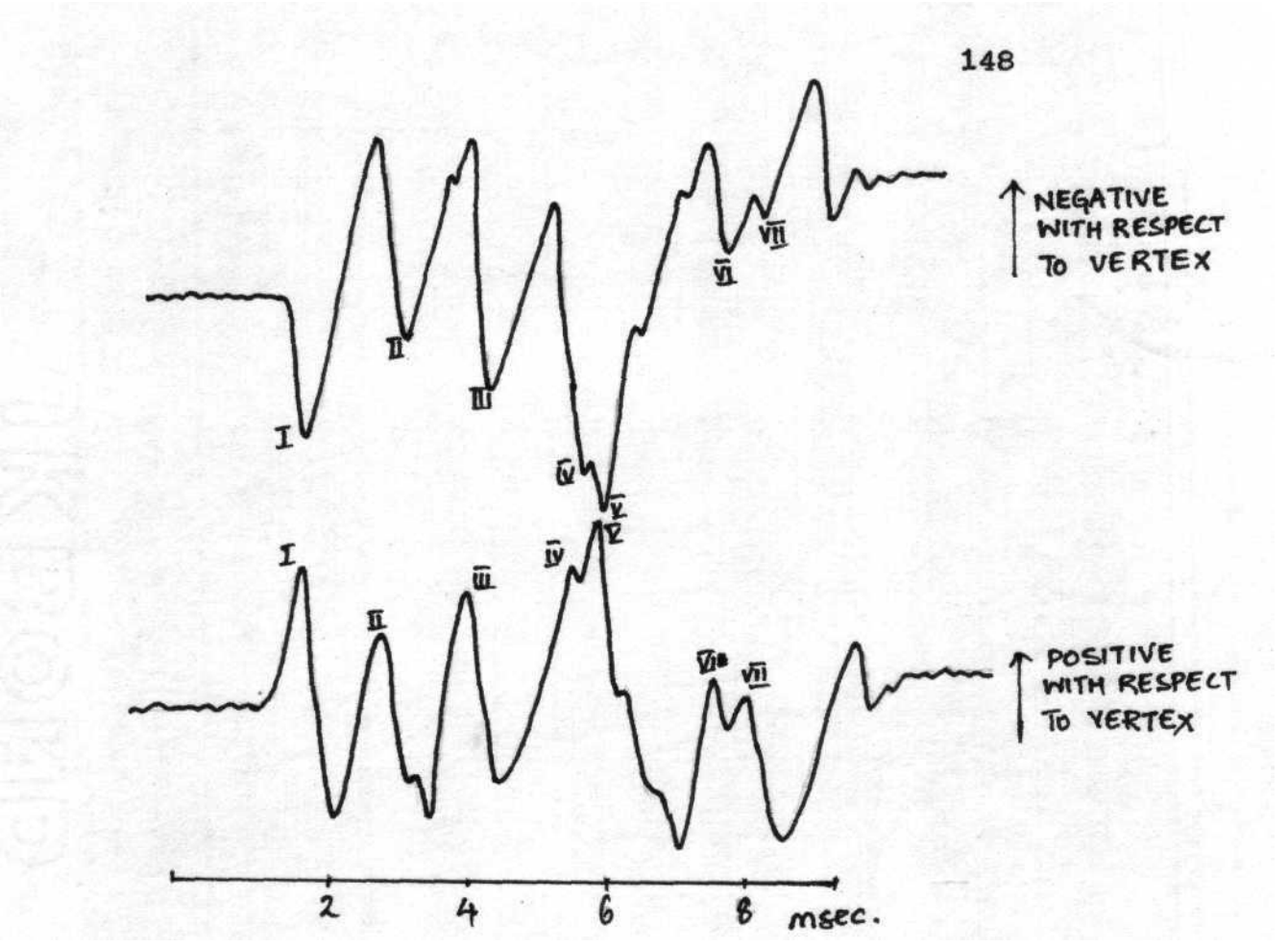


Fig.8.1: A typical young adult BER waveform showing the labelling of the peaks according to Jewett's classification. The upper trace shows the response with vertex negative waves as an upwards deflection. The lower trace is in the opposite polarity.

They found that the wave series was consistent across and within subjects, and of the waves, wave V was found to be the most prominent component. It was mentioned in their report that high frequency tone pips elicited a more distinct wave-form. Waves I to IV were found to be particularly sensitive to increases in stimulus repetition that, in that at high repetition rates the resolution of the waves was markedly reduced. In this respect wave V was the most resistant.

The position of the electrode at and around the vertex did not affect the responses, thereby confirming its neural origin. The component waves were labelled with Roman numerals I through VII.

Lev and Sohmer (l972) reached the same conclusion from their work on cats. They concentrated on the negative waves.

Buchwald and Huang (1975), from their work on cats, associated the seven waves to different anatomical sites. They gave the neural loci for all the waves as follows:

WAVE	NEURAL LOCUS
I	Neural activity in the cochlea
II	Cochlear nucleus
III	Superior olivary nucleus
IV	Lateral leminiscus nuclei
V	Inferior colliculus
VI	Medial geniculate body
VII	Auditory radiations

However, Jacobson (1985) reported that this is not true of human beings. Rather the neural loci of each of the peaks in man is as follows:

WAVE	NEURAL LOCUS
I	Cochlea
II	Between the cochlea and cochlear nuclei
III	The cochlear nuclei
IV	Superior olivary complex
V	Lateral leminiscus
VI	Inferior colliculus
VII	Medial geniculate body

The ABR has great neurological significance as they demonstrate the course of the auditory response through the important brainstem areas and hence, may reveal the site of any pathology which disrupts this passage.

8.2:Terminology:

While Sohmer and Feinmesser (1967) named the response 'Electrocochleaography'(ECochG) since they were concerned only with the first wave (AP). Later Jewett and Williston (1971) termed it as 'auditory evoked far fields' to differentiate the response from the near field techniques. However, Hecox and Galambos (1974) used the term 'Brainstem auditory evoked responses' as the components of the wave series, they believed, were derived from the brainstem. Gibson (1978) preferred the term 'acoustic brainstem electrical response' because the response could be obtained even from

decerebrate animals. In recent parlance, however, the most common abbreviations are 'Brainstem Evoked Response' (BER) and 'Auditory Brainstem Response'(ABR).

8.3:Some characteristics of the response:

8.3.1: Response Morphology: This refers to the visual appearance of the waveform. It is a subjective parameter when compared to latency and amplitude as morphology cannot be quantified.

Some investigators display positive waves at the vertex as upward deflections, others display the same waves as downward deflections. This has to be borne in mind when comparing waveforms published by different investigators.

Several researchers have observed that the waves IV and V often are fused together into what is called the IV-V complex. Chiappa, et al. (1979) described six variant froms in normal young adults (Fig.8.2 - page No.152). The variants were labelled A-F and consisted of:

A) a single peak with no separation of waves IV and V.
B) separate IV and V waves with wave IV lower than wave V.
C) separate waves with wave IV higher than wave V.
D) wave V riding on wave IV
E) wave IV riding of wave V
   The riding wave looks more like a 'shoulder' than a peak.
F) Separate waves of the same height.

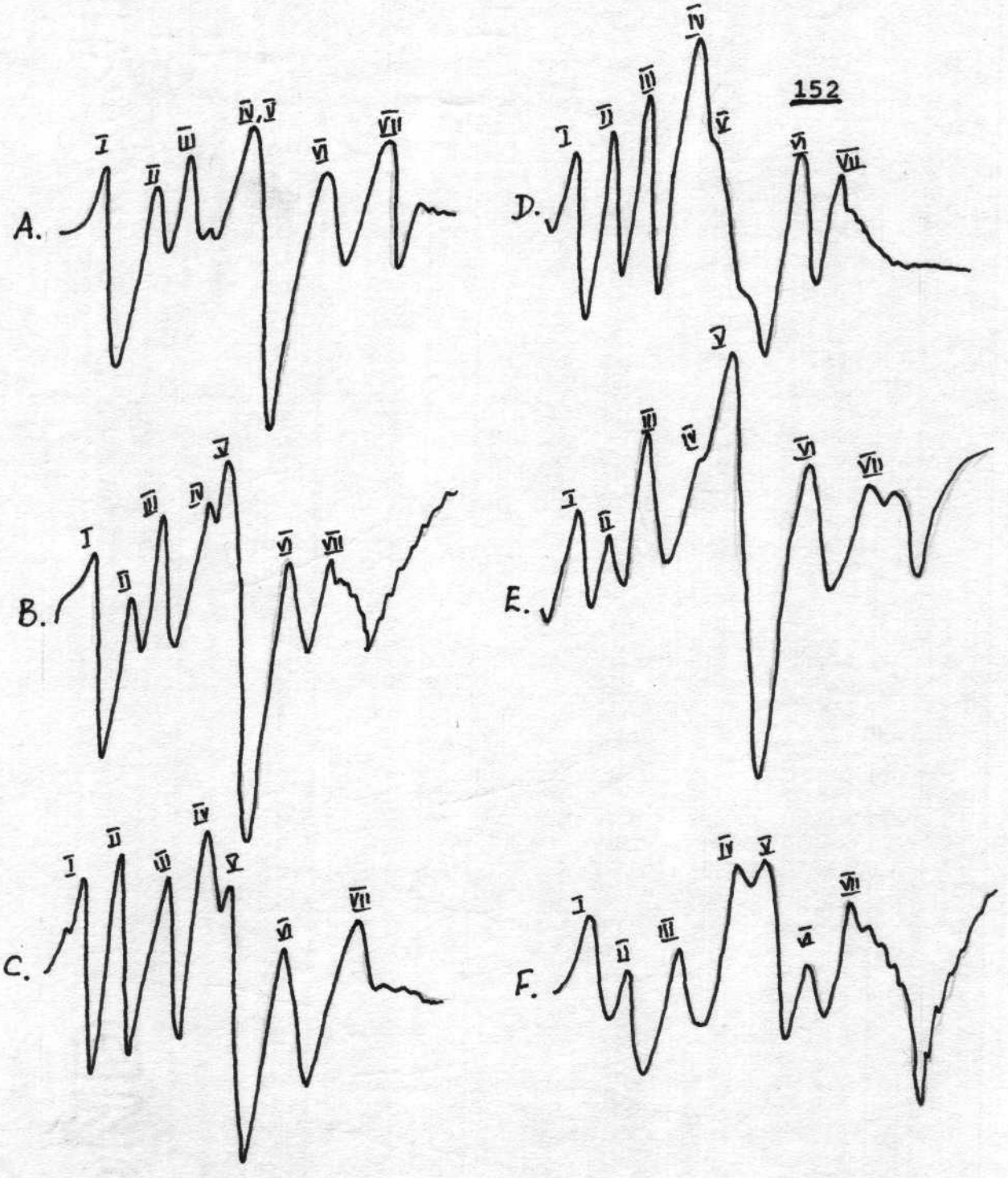


Fig.8.2: Possible variations in the morphology of the 'IV-V complex' for normal adult subjects (Chiappa, et al.(1979).

Rowe (1978) reported that in normal adult subjects wave V was the most frequently observed component of the ABR in response to high intensity clicks, while waves II and IV occurred with least frequency. Fria (1980) found the wave III to be a prominent feature of the normal human ABR.

8.3.2: Response Latency: The latency of each of the ABR peaks for similar stimuli is more or less constant amongst adult speakers. Both absolute latency and interwave latency are considered. The former refers to the time lapse between the presentation of the stimulus and the onset of the response. The latter, how-ever, refers to the time difference between two component waves, e.g., the I-V interwave latency.

Beagley and Sheldrake (1978) observed an interesting coincidence. The absolute latency of the ABR component waves, in response to high intensity clicks, is approximated by the Roman numeral designating the wave; e.g., wave I latency falls between 1.0 and 2.0 msec, wave II between 2.0 and 3.0 msec, and so on. The wave V almost invariably follows wave I after 4 msec exactly. The waves occur at approximately 1.0 msec. intervals from roughly 1.7 to 5.7 msec. in response to high intensity clicks.

Selters and Brackman (1977) reported that the wave V latency difference between ears (interaural latency difference) of the same normal adult was less than 0.2 msec. Rowe (1978) found that normal interaural latency differences were within 0.4 msec. for waves I through V in majority of the normal individuals.

Normal interwave latency values have been reported for several combinations of ABR component waves (Stockard and Rossiter, 1977), especially the I-III, III-V and I-V inter-wave latencies. The I-III value estimates transmission time through the ponto-medullary junction and lower pons, and the III-V values estimates transmission time from caudal pons to caudal midbrain levels. The I-V latency estimates the time needed for impulses to travel the entire system, and is called the "central" or "brain stem" transmission time. These values prove valuable for clinical purposes. The 1-V interwave latency approximates 4.0 msec (Chiappa, et al.1979? Stockard and Rossiter, 1977), and the 1-111 interwave latency is slightly more than half of this time, that is somewhere around 2.1 msec.

The latencies of the ABR peaks are prolonged in neonates and in premature babies (Hecox, 1975).

8.3.3: Response Amplitude: The ABRs are minutes and the peak-to-peak amplitude of the individual waves rarely exceeds 1 /uV.

The first wave I is not usually identifiable using stimulus intensities of less than 25 dB SL (Thornton, 1975 a). The second wave II has the smallest amplitude of all the ABR waves and can rarely be identified at low stimulus intensity levels. Wave V is the largest in amplitude and this is the wave that can be most easily visualized at stimulus intensities close to the subject's subjective threshold.

8.4: Factors affecting the response:

8.4.1: Stimulus intensity: Although all ABR component waves usually are observed in response to high intensity stimuli, the likelihood of observing all waves is reduced with each intensity decrement as the threshold is approached. Waves I and III are seen more frequently than II and IV at intensities below 40 dB nHL, and wave V often is the only remaining wave in response to stimulus intensities that approximate threshold levels (Rowe, 1978). When wave V is fused into a "IV-V" complex, its resolution is improved at lower stimulus intensities (Rowe, 1978).

With decrease in stimulus intensity, there is an increase in component wave latencies. However, the I-V interwave latency is resistant to stimulus intensity changes (Fria, 1980).

The effect of change in intensity on latency for a given ABR wave is often displayed on a grph, with the abscissa and ordinate representing intensity and latency, respectively. The

curve depicting this relationship is called a "latency-intensity function". The slope function is measured in milli-seconds or microseconds. The adult slope function is about 0.04msec/dB with a range of 0.03 to 0.06 msec/dB (Galambos and Hecox, 1978). This may also be used in determining the site of lesion.

With a decrease in stimulus intensity, the amplitude of the ABR also decreases. Since wave I is more affected by a decrease in stimulus intensity, the V/I amplitude ratio increases with decreasing stimulus intensity (stockard, et al. 1978b).

8.4.2: Stimulus repetition rate: With increase in stimulus repetition rates, there was a reduction in the definition of waves I through IV. The waveform degradation was very noticeable at rates of 20/sec. or higher rates. The wave V was found to be the most resistant to rate effects (Jewett and Williston, 1971; Chiappa, et al. 1979). Stockard, et al. (1978 b) found that at very high stimulus repetition rates, the ABR may be uninterpretable.

In general, an increase in the absolute latency of all ABR component waves is associated with an increase in stimulus repetition rate. It has been found that increased stimulus rate results in greater latency increases for wave V than for

wave I. Consequently, the wave I-V interwave latency increases with an increase in stimulus repetition rate (Chiappa, et al. 1979l; Stockard, et al. 1978 b, 1979).

8.4.3: Stimulus enveloge: The ABR is elicited using tone pips which are actually filtered clicks. Hecox, et al. (1976) examined the influence of stimulus envelope on wave V latency and amplitude, and noted that stimulus rise time had the greatest effect (of increasing latency) on wave V latency, while the stimulus duration and stimulus off-time were found to have minimal influence. They concluded that the ABR was an "onset" response, i.e., its properties were largely dependent on stimulus onset characteristics.

Studies have shown that at a particular stimulus intensity, the wave V latency is inversely related to the frequency of the stimulus (Hecox, et al. 1976; Picton, et al. 1979). This could be due to an increase in the rise time as frequency is lowered. Hence, the wave V latency is increased in response to low frequency tone pips (Suzuki, et al. 1977; Picton, et al.1979).

Response morphology and amplitude are also influenced by stimulus envelope characteristics. Responses to low frequency tone pips are significantly smaller and less clearly

defined than responses to unfiltered clicks. This is because the increased rise time associated with these stimuli is less effective in producing a synchronous firing of neuronal groups necessary for clear response definition. Also, synchronous firing would increase the likelihood of out-of-phase responses which would be cancelled in the averaging process, thereby reducing the response amplitude.

8.4.4: Monaural vs. binaural stimulation: In individuals with normal hearing in both ears, binaural stimulation results in binaural summation, and hence, results in increased amplitude of the response (Blegvad, 1975; Jewett and Williston, 1971; Stockard, et al. 1978 b). The binaural advantage has been observed in response to stimulus intensities of 10 to 90 dB above the hearing threshold of the individual (10 to 90 dB SL). On the average, the binaural amplitude corresponded to the monaural amplitude associated with about a 20 dB increase in stimulus intensity. Stockard,et al.(1978 b) found that binaural stimulation increases the amplitude of wave III to V, but not the amplitude of waves I and II.

8.4.5: Prolonged or repeated stimulation: The amplitude and latency functions of the ABR are remarkably constant on repeated or prolonged stimulation (Thornton, 1974; Thornton and Coleman, 1975).

8.4.6: Electrode placement: Best results are obtained if the active electrode is placed on the vertex of the skull or around the ear, and the reference electrode is placed on the ipsilateral earlobe or mastoid. The ground electrode is fixed to the contralateral earlobe or mastoid process. Problems arise from increased myogenic interference, or inferior signal-to-noise conditions (Chiappa, et al. 1979).

8.4.7: Bandwidthfilters: Bandwidth filters are used to reduce noise interference by eliminating the high and low frequency information. Fourier analysis of the ABR shows that most of their energy lies in his range of 800 to 1200 Hz (Gibson, 1978).

Stockard, et al.(1978 b) found that increasing the low frequency cut-off point from 1 Hz to 300 Hz resulted in a smaller wave V relative to wave IV. At the same time decreasing the high frequency cut-off point from 3000 Hz to 300 Hz resulted in poor resolution of all component waves. Clinically, the filters used vary between 100-500 Hz to 3-5 KHz. The effectiveness of the filters depends, greatly, on the sharpness of their cut-off frequencies (Gibson, 1978).

In conclusion, before comparing the waveforms obtained by different investigators one should know the stimulus presentation rate, the polarity of the recordings, mode of presentation and the filter bandwidths together with the slope of the filters.

8.4.8: Sedation: The ABR does not appear to be affected by sleep or sedatives (Goff, et al. 1977; Sanders, et al. 1979), which is a considerable advantage in testing children.

8.4.9: Age: There is a difference between adult and infant responses in all measurement parameters. The wave I is the most prominent and the wave V is small in amplitude. Hence the V/I amplitude will be less than 1. This is in contrast to the normal value.

The ABR matures with age in that with increase in there is a gradual decrease in the component wave latencies (Fabiani, et al. 1979; Rubinstein and Sohmer, 1982). These authors have suggested that the response matures in at least two stages. The first is characterized by a fairly rapid decrease in component wave latency and is completed by about two months post partum. The second involves a slower reduction in the latency of later components (particularly wave V which is not completed until approximately two years of age. Even the I-V interwave latency difference decreases with maturation (Starr, et al. 1979; Salamy and McKean, 1976). The clinical application of ABR tests for paediatric populations must be guided by the age related changes in the absolute and interwave latency of the response (Fria, 1980);.

Studies of newborn and infant responses have also revealed age-related changes in morphology and amplitude (Salamy, et al.

1978). In infants only three waves are seen prominently- I, III and V. The wave I is the most prominent and the wave V is small in amplitude. Hence the V/I amplitude ratio will be less than 1. Starr, et al. (1977) reported that wave V amplitude increased with maturation, thereby approximating the V/I amplitude ratio to the adult value with increase in age. Stockard, et al. (1978 b) reported that the absolute response amplitude was greater in children perhaps due to a smaller head circumference, and less distance between the recording electrodes and the response generators.

8.4.10: Sex: Generally, females present with shorter response latencies and larger amplitudes than males (Beagley and Sheldrake, 1978; Goldman, et al. (1981). This may be due to a smaller head circumference in combination with a fore-shortening of the brainstem pathway between the auditory nerve and midbrain. Hence normative latency and amplitude values must be generated for both sex groups.

8.5: Instrumentation:

Basically the apparatus is similar to that used in obtaining other BRA responses and this has been described in Chapter 3. The special requirements are as follows:

8.5.1: The test environment: The subject must be tested in a relaxed position in order to minimize any myogenic activity. The subject can be made to relax on a couch with a pillow

placed under the neck to allow the neck muscles to relax. Children should be sedated. For free-field testing a sound proof chamber is needed.

8.5.2: The stimulus generation: The ABR can be satisfactorily obtained by using a very brief stimulus with a sharp rise time. Clicks, filtered clicks and tone bursts may be used.

As the voltages involved are very minutes, many individual ABR epochs have to be summed and averaged before the responses can be clearly identified from the background activity. Ordinarily, 2048 stimuli are presented and the individual responses are summed, averaged and displayed on the oscilloscope.

A good quality transducer should be used which is not affected much by magnetic fields. The stimuli may be presented under earphones or through loudspeakers. In the latter case, testing should be done in an anechoic chamber (Thornton, 1975 a).

Facilities for masking should be available if monaural information is sought. Masking should be done whenever the interaural latency differences of corresponding wave components exceeds 1.5 msec.

8.5.3: The recording equipment: Just as with the other ERA measurements, we need high quality EEG electrodes, low noise biological amplifiers, filters, an averager, a monitor oscilloscope, artefact rejection facilities and facilities for recording the results such as print-outs.

8.6: Testing procedures:

Testing cooperative subjects is not a problem. Un-cooperative children and babies would have to be sedated. After proper electrode placement, testing should be started at a level above the suspected threshold and the stimulus intensity should be decreased down to that level below which the wave V cannot be identified. The ABR component wave can be easily identified at a stimulus repetition rate of 10/sec. That minimum stimulus level at which the wave V can be identified is considered as the subject's threshold.

8.7: Clinical applications of the ABR:

8.7.1: Formeasuring auditoru acuity: The ABR is a valid and reliable test of measuring threshold in a vast majority of cases. The wave V can be identified at 10 dB SL or even less using click stimuli or tone bursts of 2-8 KHz (Davis, 1976 b). The ABR is recordable almost without exception from adults and children as young as 33 weeks gestational age (Galambos, 1977).

Using the latency-intensity function one can detect conductive hearing loss as well as sensorineural hearing loss. Deviations of greater than 0.06 msec/dB are indicative of sensorineural pathology, whereas slope functions of 0.03 msec/dB or less suggest primarily high frequency hearing loss (Galambos

and Hecox, 1978). For slope functions that are parallel but are prolonged in latency, conductive pathology is suspected (Jacobson, 1985).

The ABR has good test/retest reliability. The ABR wave-form does not show any change on repeated or prolonged testing.

8.7.2: As a means of neuro-otological diagnosis:

8.7.2.1: <u>The maturation of the auditory pathway in premature infants and neonates:</u> The ABR may be used to reliably screen neonates and infants having normal hearing or having some hearing loss. It may also be used to assess the maturity of the infant.

In recent years, the ABR has been widely applied for the investigation of neurologic integrity in paediatric populations such as:

(a) infectious diseases including bacterial meningitis, cytomegalovirus, herpes, rubella, and others.

(b) tumors of the cerebellopontine angle (CPA), intrinsic brainstem, suprapineal region and cerebellum. Also acoustic neuroma and brainstem glioma have been investigated. Although very few cases have been evaluated, most of them had abnormal ABRs.

(c) asphyxia. Hypoxia can produce brainstem auditory dysfunction. The presence of central auditory dysfunction in the ABR increases the risk of long-term neurologic deficit,

especially when the response abnormality is a decrease of wave V amplitude relative to waves I and III (Finitzo-Heiber, et al. 1979).

(d) toxic metabolic disorders leading to coma.

(e) neurodegenerative disorders

(f) trauma. In such closed head injury cases, reversals of abnormal amplitude ratios, abnormal interwave intervals and rate dependent abnormalities have been reported.

(g) chromosomal disorders. For example - in Down's syndrome cases, abnormal latencies of waves III and V was observed. There was reduced interpeak latency.

(h) psychiatric disorders such as autism in whom prolonged latencies and brainstem transmission times have been reported.

(Jacobson, 1985).

In all the above cases, the recorded ABR was abnormal in one or other of its parameters. The ABR has wide application in the area of paediatric disorders.

8.7.2.2: <u>Eighth Nerve and low brainstem lesions</u>: In retro-cochlear lesions, the absolute latency and the interaural latency difference increases. Absolute latencies have been shown to be of value in detecting eighth nerve, CPA and vertebrobasilar lesions in a number of studies, but are seldom used as the "only" latency measure (Clemis and McGee, 1979;

Bauch, et al. 1982; Glasscock, et al. 1979). The interaural latency difference must be cautiously interpreted since the degree of loss and auditory configuration between the ears as well as the intensity presentation levels may significantly affect interaural latency difference (ILD) results.

In a majority of the cases, there is abnormal waveform morphology. In most of the eases of acoustic neuromas, there is an absence of all waves or unreadable waveforms (Jacobson, 1985). Total absence of ABR waves is likely to occur in an eighth nerve or low brain stem lesions if there is hearing loss. If the hearing is normal, only wave I may be noted (House and Brackmann, 1979; Selters and Brackmann, 1977). Partial absence of the waveform is noted in cases of high brainstem lesions, and in some cases of CPA lesions (Harris and Almquist, 1981; Rosenhall, et al. 1981).

Another characteristic of retrocochlear lesions is the amplitude ratio (V/I) which is reduced and is less than 1 (Museik, et al. 1984).

Paludetti, et al. (1983) and Yagi and Kaga (1979) reported that use of high repetition rates in cages of eighth nerve or low brainstem lesions results in significant wave latency shifts or degradation of wave V morphology. This has to be investigated further.

Some differential ABR trends can be noted in comparing the results from high and low brainstem lesions as noted below:

LOW BRAINSTEM	HIGH BRAINSTEM
Earlier waves or entire waveform may be absent	Earlier waves are present; Later waves may be absent.
Most common interwave latency prolongation is between I-III	Most common interwave latency prolongation is between III-V
Ipsilateral abnormalities are commonly observed (unless the lesion is large)	Bilateral, ipsilateral and contralateral abnormalities may be present.

Although the ABR is a powerful clinical procedure in the detection of eighth nerve and low brainstem lesions, it is not infallible. Hence, employment of various other audiologlc site-of-lesion tests is necessary and clinically prudent.

8.7.2.3: Multiple sclerosis: There is a considerable variability in ABR abnormalities observed in patients with multiple sclerosis. These include abnormality of symmetry, delay in latency, fragmented response, decreased amplitude or absence of peaks, poor response variability,abnormal responses to changes in rate and abnormal latency-intensity function.

Chiappa, et al. (1979) reported that the I-V separation is increased and that there are wave V abnormalities in patients having multiple sclerosis. The most common inter-wave interval latency abnormality occurs in the III-V separation (Chiappa, 1980; Lynn, et al. 1980).

A wide variety of ABR results is possible in multiple sclerosis. In spite of these being inconclusive data, with respect to the wave I,consistent results have been obtained indicating that it is unaffected and this indicates that multiple sclerosis does not usually affect the peripheral portion of the auditory nerve where the myelin sheath is formed by Schwann cells rather than glial cells (Hausler and Levine, 1980).

Chiappa and Ropper (1982) reported that 20-50 percent of multiple sclerosis patients without brainstem symptoms could be expected to have abnormal ABRs. Since even small multiple sclerosis plaques produce marked ABR abnormality, the test has substantial clinical utility not only in diagnosis but also in checking the effectiveness of therapeutic measures.

8.7.2.4: Comatose patients: The ABR may be used in patients who are in a state of coma provided there is no fracture of the temporal bone. Starr and Anchor (1975) found that the

latency was unaffected in coma cases with etiologies including drag overdoses, hypoxia, diabetic coma, hepatic failure aad status epilepticus. The ABR may be used as a prognostic indicator in comatose patients. A normal ABR may indicate good neurologic/cognitive outcome.

8.7.2.5: Brain death: Starr and Anchor (1975) found that typically only the first wave (wave I) was obtainable in cases of brain death. It can be effectively used to determine brain death. (Starr, 1976).

8.8:Conclusions:

The ABR is one of the recent additions to the field of clinical ERA and is a valuable tool for the assessment of audiologic and neurologic impairment.

The main advantages of the ABR is that it is a non-invasive technique and that it is unaffected by sedatives. It is less time-consuming and can be obtained at near threshold levels at frequencies above 2KHz, but not in the low frequency domain.

The ABR has a lot of clinical utility in the area of neuro-otological disorders. However, as with all other audiological procedures it identifies the site and not the type of lesion. It merely indicates an abnormality in the system.

Hence, the ABR cannot test "hearing" in the perceptual sense, nor can it identify a specific neurologic lesion at a given location (Fria, 1980). Hence, the results must be interpreted in the light of other clinical data. The "cross-check" principle (Jerger and Hayes, 1978) is essential to the clinical application of the ABR.

POST-TEST

I. Fill in the blanks:

(1) The component waves of the auditory brainstem response (ABR) are also called as the .....

(2) The wave V which is the most prominent wave originates from the .....

(3) The fusion of the waves IV and V is called the ..... and a total of ..... variant forms have been identified in adults.

(4) For evaluation purposes the ..... latency, the ..... latency and the ..... latency are considered.

(5) Females present ..... latencies and larger ..... than men.

(6) Based on the ..... we can have some idea as to the type of hearing loss the subject is having.

(7) The V/I amplitude ratio is greater than 1 in ..... and smaller than 1 in ..... and ..... subjects.

(8) ..... should be done whenever the interaural latency difference of the wave V exceeds 1-5 msec.

(9) It is the ..... of the stimulus which elicits the ABR.

(10) Filter characteristics affect the ..... the ABR component waves.

II- Indicate whether the following statements are true or false.

(1) The ABR is a far-field potential

(2) Waves I, III and V are absent in children

(3) Increasing the stimulus repetition rate enhances the morphology and amplitude of the ABR.

(4) It is not necessary to have separate normative values for men and women.

(5) The ABR can be used to assess the maturity of the infant.

(6) The absolute latency of the component waves of the ABR is prolonged in cases of retrocochlear pathology.

(7) The ABR cannot be used with children having psychiatric disorders.

(8) The results of the use of ABR with neurologic conditions has been discouraging.

(9) With an increase in age in infancy, the latencies of the component waves of the ABR decrease.

(10) All the waves can be clearly seen at stimulus intensities close to the subject's threshold.

III. <u>Choose the correct answer:</u>

(1) The wave III originates from the

(a) superior olivary complex

(b) cochlea

(c) cochlear nuclei

(d) none of the above

(2) A patient is found to have mild sensorineural hearing loss in the right ear. The ABR results indicate a prolonged wave V latency and the V/I amplitude ratio is less than 1. You would suspect.

(a) cochlear pathology

(b) retrocochlear pathology

(c) conductive pathology

(d) multiple sclerosis

(3) The ABR is unaffected by

(a) sleep

(b) sedatives

(c) repeated stimulation

(d) - (a), (b) and (c)

(4) The ABR may be used as a prognostic indicator of recovery in

(a) comatose patients

(b) multiple sclerosis

(c) infectious conditions

(d) psychiatric disorders

(5) In children the absolute response amplitude was found to be

(a) similar to that in adults

(b) larger than that in adults

(c) smaller than that in adults

(d) varying in individual cases.

CHAPTER 9
THE FREQUENCY FOLLOWING RESPONSE (FFR)

PRE-TEST

I. Fill in the blanks:

(1) ..... and ..... in 1968 recorded the frequency following response in cats.

(2) In FFR, the waveform of the response resembles that of the .....

(3) The FFR is easily seen in ..... frequencies below .....

(4) The FFR can be obtained at and below the level of the .....

(5) The FFR can be obtained within ..... of the hearing threshold.

(6) The ..... and ..... of the FFR vary with the stimulus frequency used.

(7) We have to set a ..... frequency limit on the pre-amplifier while recording the FFR.

(8) For clinical purposes, the ground electrode is placed on the ..... and for research purposes, it is placed on the .....

(9) The FFR can provide us information in the low frequency regions where the ..... and ..... are at a dis-advantage.

(10) Some cases of ..... exhibit aberrant FFRs.

II. Indicate whether the following statements are true or false:

(1) The FFR is not confined to the auditory pathway. It can be recorded from any part on the scalp.

(2) Only a few sweeps need to be averaged for the response to be seen clearly.

(3) If the FFR is recorded and played back to the subject through earphones, he will hear the original acoustic stimulus.

(4) The FFR is different from the cochlear microphonic.

(5) The FFR provides information in the high frequenty region.

III. <u>Choose the correct answer:</u>

(1) The FFR is not observable in

(a) low frequency region

(b) high frequency region

(c) throughout the frequency range

(d) normal subjects.

(2) The source of the FFR is believed to be

(a) the cochlea

(b) the auditory cortex

(c) the inferior colliculus

(d) none of the above.

(3) The electrode placement for research purposes is

(a) target electrode on the earlobe
reference electrode on the vertex
ground electrode on the leg.

(b) target electrode on the vertex
reference electrode on the test earlobe
ground electrode on the opposite earlobe.

(c) target electrode on the leg.
reference electrode on one of the earlobes
ground electrode on the vertex.

(d) target electrode on the vertex
reference electrode on both the earlobes
ground electrode on the leg.

(4) The FFR was criticized by Davis (1976) on the grounds that it does not

(a) diagnose the problem accurately

(b) provide any more information than ECochG or BSERA

(c) have good reliability

(d) discriminate between normals and learning disabled.

(5) The FFR may provide added information on

(a) the middle ear status

(b) the facial nerve

(c) the integrity of the brainstem

(d) none of the above.

FREQUENCY FOLLOWING RESPONSE (FFR)

9.1: Introduction:

From the preceding chapters it is understood that several forms of electrical activity are observable in recordings from the central nervous system. The FFR is one such electrical activity which was first reported by Worden and Marsh in 1968. The most striking feature of this evoked response, noticed by them, was that its pattern resembles that of the waveform of the acoustic stimulus, reproducing almost exactly the sine wave and frequency of that stimulus. The resemblance of the FFR is so close to the original stimulus, that if this response is recorded on a frequency modulation (FM) tape and played back to an observer through earphones, he will hear essentially the original acoustic stimulus with remarkably little distortion (Worden and Marsh, 1968).

The FFR is recordable from electrodes placed the central auditory pathway and it appears to be confined to the afferent auditory pathway. Worden and Marsh (1968) found that the FFR could not be recorded from the auditory cortex or non-auditory brain structures.

9.2: Characteristics of the response:

Fig. 9.1 shows the response obtained from a normal individual's vertex.

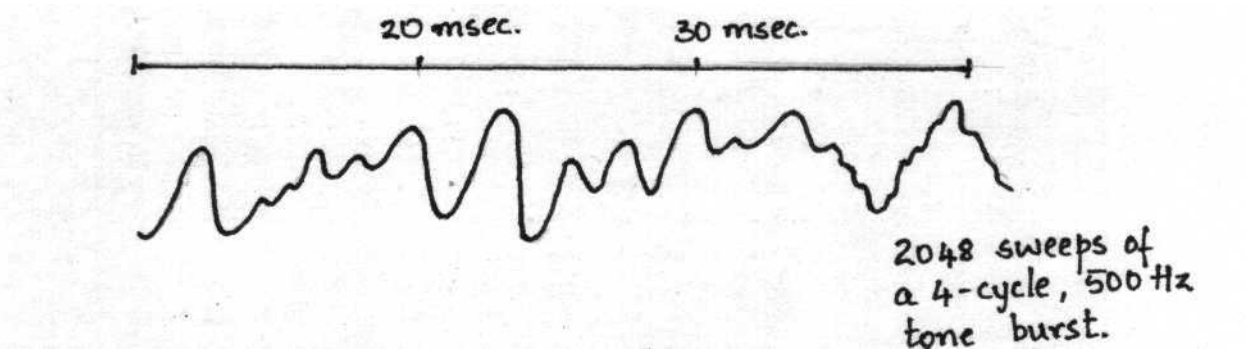


Fig.9.1: Sample FFR to 500 Hz tone burst

It is believed that the response is due to the frequency-locked synchronous discharge of many fibers in the auditory pathway to low frequencies. For example,if a stimulus of 250 Hz is presented to the cochlea, initially at the level of the cochlea two things can happen. First, the neural elements will start discharging at their characteristic frequency, andalso multiples of the stimulating frequency. Secondly, in addition to this, there are many fibers that will discharge at the reciprocal of their most sensitive frequency (Kiang, et al. 1965).

Thus, a 250 Hz stimulus can elicit a group of synchronous firings from units at the cochlear level every 4 msec. (4 msec being the period of a 250 Hz signal)

If the stimulus had a frequency of 500 Hz, then the units would tend to discharge every 2 msec. Similarly, for a stimulus frequency of 1000 Hz, the units would discharge every 1 msec, and so on. This sosrt of frequency following begins to taper off drastically between 1000 Hz to 2000 Hz but it can be seen easily at low frequencies. Thereafter, it is believed that the other auditory nuclei may perform similarly, discharging in phase with cochlear stimulation.

This indicates that there are frequency limits beyond which FFR is not observable. For a stimulus intensity of 80 dB SPL, the frequency range at the cochlear nucleus is 500 Hz-5000 Hz. The range is narrower for less intense stimuli and may be wider for more intense stimuli (Worden and Marsh, 1968).

The source of the responseis not clealy known. However, in contrast to the auditory evoked potential, which can be recorded widely in the brain, the FFR is recordable within, or close to the auditory pathway. Worden and Marsh (1968) obtained it only at and below the level of the inferior colliculus. This indicates that the FFR may have a close relationship to the fifth wave (wave V) in the BSER complex.

From the figure (Fig.9.1) it can be seen that the response seems to ride on a pedestal, which helps make

the identification of the responses more precise. The actual frequency-following 'bumps' in the response occurs at around 40 dB above the hearing threshold (40 dB SL). The pedestal on which the responses seem to be mounted occurs somewhere within 20 dB of the patient's threshold.

The waveform and amplitude of the FFR vary with stimulus frequency used. The response is most easily obtained to tones of 500 Hz and below, and can be elicited by a tone whose rise time is around 4-5 msec.

To visualize a response after averaging, we need around 999-3000 sweeps, 6 to 16 msec in duration each. The stimulus presentation rate can range from 1 per second to 15 per second.

9.3: Instrumentation:

The basic instrumentation is similar to the one described in Chapter 3. As in ECochG and BSERA,a high-gain and high frequency response pre-amplifier is necessary. However, a lower-frequency limit has to be set on the pre-amplifier to allow for passage of the low-frequency synchronous discharges.

9.4: Procedure for testing:

Subjects are made to sit on comfortable chairs. The target electrode is usually fixed at the vertex. Experimenters,

who wanted to compare monaural to binaural stimulation and acquire data about voltage differences between the vertex and the two ears, fixed indifferent electrodes to each earlobe and a ground electrode to the leg (Moushegian, et al. 1973, Gerken, et al. 1975; Daly, et al. 1976). However, for clinical applications, Stillman, et al (1976) used a vertex target electrode, a reference electrode on the right earlobe and a ground electrode placed on the opposite earlobe.

9.5: Clinical use of the FFR:

On ECochG and BSERA clicks and tone bursts are essential for testing, as a result of which the assessment has limited audiometric value for low frequencies, especially those below 1000 - 2000 Hz. However, it is possible that the FFR, because of its low frequency responsibility, can provide us with information on the frequency range where ECochG and BSERA have limitations.

In 1976, Davis suggested that the response arises from the basal-turn elements of the cochlea, and therefore, does not provide any added information to the ECochG or BSERA results. There are other criticisms suggesting that the responses could be "artifactual", that is, it would be a "microphonic", an induction artefact, or a volume conduction artefact.

Worden and Marsh (1968) found that the FFR differs from the cochlear microphonic in that it is less resistant to anoxia or deprivation of oxygen, than the cochlear microphonic, and it disappears before the CM is seriously affected.

An induction artefact occurs when the electrical activity of the stimulating transducer cuts across the electrodes and electromagnetically induces a current in the target electrode and can be mistaken for a response. Volume-unit conduction artefacts refer to the generation of electrical currents by the jelly used which can be confused for neural events.

In spite of criticisms, Stillman,et al. (1976), on testing normal and learning disabled children, found that in the case of learning disabled children the FFR peaks were not seen, even at levels of 70 dB SL. However, not all learning disordered children showed such responses. But the aberrant responses suggest that these subjects had dys-synchrony of neural firing in their brainstems. Hence, the FFR may reveal disorganization of some of the brainstem structures in early conductive losses (Clopton and Silverman; 1976).

Thus in addition to the physiological assessment of auditory sensation, especially in the low frequency, the FFR may also provide information about the integrity of the brainstem for synchronous firing to low frequency stimuli. This could be important to understanding children's "disorders of learning" that may have auditory perceptual bases.

9.6: Conclusion:

In conclusion, we can say that the FFR may be related to the brainstem evoked response (BSER) in ways we do not understand, but the FFR can complement the ECochG and the BSERA as it is responsive to low frequency tones.

POST-TEST

I. Fill in the blanks:

(1) ..... and ..... in 1968 recorded the frequency following response in cats.

(2) In FFR, the waveform of the response resembles that of the .....

(3) The FFR is easily seen in ..... frequencies below .....

(4) The FFR can be obtained at and below the level of the .....

(5) The FFR canbe obtained within ..... of the hearing threshold.

(6) The ..... and ..... of the FFR vary with the stimulus frequency used.

(7) We have to set a ..... frequency limit on the pre-amplifier while recording the FFR.

(8) For clinical purposes, the ground electrode is placed on the ..... and for research purposes, it is placed on the .....

(9) The FFR can provide us information in the low frequency regions where the ..... and ..... are at a dis-advantage.

(10) Some cases of ..... exhibit aberrant FFRs.

II. Indicate whether the following statements are true or false:

(1) The FFR is not confined to the auditory pathway. It can be recorded from any part on the scalp.

(2) Only a few sweeps need to be averaged for the response to be seen clearly.

(3) If the FFR is recorded and played back to the subject through earphones, he will hear the original acoustic stimulus.

(4) The FFR is different from the cochlear microphonic.

(5) The FFR provides information in the high frequency region.

III. Choose the correct answe:

(1) The FFR is not observable in

(a) low frequency region

(b) high frequency region

(c) throughout the frequency range

(d) normal subjects.

(2) The source of the FFR is believed to be

(a) the cochlea

(b) the auditory cortex

(c) the inferior colliculus

(d) none of the above.

(3) The electrode placement for research purposes is

(a) target electrode on the earlobe
reference electrode on the vertex
ground electrode on the leg.

(b) target electrode on the vertex
reference electrode on the test earlobe
ground electrode on the opposite earlobe

(c) target electrode on the leg
reference electrode on one of the earlobes
ground electrode on the vertex.

(d) target electrode on the vertex
reference electrode on both the earlobes
ground electrode on the leg.

(4) The FFR was criticized by Davis (1976) on the grounds that it does not

(a) diagnose the problem accurately

(b) provide any more information than ECochG or BSERA

(c) have good reliability

(d) discriminate between normals and learning disabled

(5) The FFR may provide added information on

(a) the middle ear status

(b) the facial nerve

(c) the integrity of the brainstem

(d) none of the above.

CHAPTER 10

THE MIDDLE LATENCY RESPONSE(MLR)

PRE-TEST

I. Fill in the blanks:

(1) The middle latency responses that are recorded by placing the electrodes near the parietal region are ..... in origin.

(2) The MLR is also called the ..... response.

(3) Recording the MLR directly from the cortex increases the ..... of the response.

(4) The MLR is not affected by .....

(5) The middle latency response may be obscured by ..... and ..... activity.

(6) Depending on the bandwidth of the recording system, the ..... and ..... of the response peaks vary.

(7) ..... or ..... may be used to clicit the response.

(8) The MLR has been used in the diagnosis of .... and .....

(9) One of the issues in current research on MLR is the ..... characteristics which provide easily identifiable responses.

(10) In cerebral lesions the MLR may be ....., ..., ... or unaffected.

II. Choose the correct answer:

(1) The MLRs are produced by:

(a) the onset of the stimulus

(b) the offset/cessation of the stimulus

(c) the plateau portion of the stimulus

(d) both (a) and (c)

(2) Use of filters in recording the MLR introduces:

(a) amplitude distortion

(b) phase distortion

(c) both (a) and (b)

(d) neither (a) nor (b)

(3) In the area of neuro-otological diagnosis, the MLR may have some predictive value as to:

(a) the duration of existence of the tumor

(b) the size of the tumor

(c) site of the tumor

(d) none of the above

(4) In order to identify the response, most commonly a combination of the:

(a) P_o and N_a is used

(b) P_a and N_b is used

(c) N_a and P_a is used

(d) P_o and p_b is used.

(5) Fast stimulus repetition rates result in

(a) reduction of response amplitude

(b) increase of response amplitude

(c) no change in the amplitude

(d) latency prolongation.

III. Indicate whether the following statements are true or false:

(1) Puretones are effective in eliciting the MLR

(2) The detection of the MLR is made easier by some amount of amplitude distortion.

(3) prolonged stimulation does not result in fatigue or habituation of the response.

(4) The MLR is unaffected by sleep

(5) There is no difference between the MLRs that are obtained under different filter settings.

MIDDLE LATENCY RESPONSE (MLR)

10.1: Introduction:

In Chapter 5, it has been mentioned that electrical responses with onset latencies varying from 8 msec to 30 msec can be recorded by placing the active electrode on the inion process or the parietal region of the scalp or the post-auricular region (auditory myogenic response). Experimental evidence indicates that some of the middle latency responses (8-60 msec) obtained using electrodes placed near the parietal region of the scalp are neurogenic (Mast, 1963; Goldstein, 1965; Vaughan and Ritter, 1970). Ruhm, et al. (1967) compared the scalp recordings with recordings taken from the surface of the brain during surgery. This was done in two subjects. The response components were similar in latency under both conditions, but the amplitude of the responses was three times greater when the recordings were made directly from the cortex. This study provided convincing evidence in support of the neurogenic origin of the middle latency or early cortical responses.

It has been suggested that the MLRs are derived from the auditory areas of the thalamus and the primary auditory cortex. However, Picton, et al. (1974) found that the

neurogenic components were easily obscured by myogenic activity. Support to this was provided by Davis (1976), who also added that the distinction between neurogenic and myogenic components is not complete. Gibson (1978) observed that at low sensation levels, the myogenic components may sometimes be out-of-phase with the neurogenic components and hence, cancel the latter.

10.2: Terminology:

Mast (1963) termed the evoked potentials having onset latencies of 8-60 msec. as the 'short latency responses.' With the discovery of the ECochG and the BSERA (the fast responses), these potentials came to be known as the 'middle latency responses', or the 'early cortical responses' - the latter was introduced to stress the neurogenic origin of this response.

Going by Davis'(1971) method of describing a response by the polarity and latency of each of the constituent peaks, the configuration of the MLR is as follows (Fig.10.1)

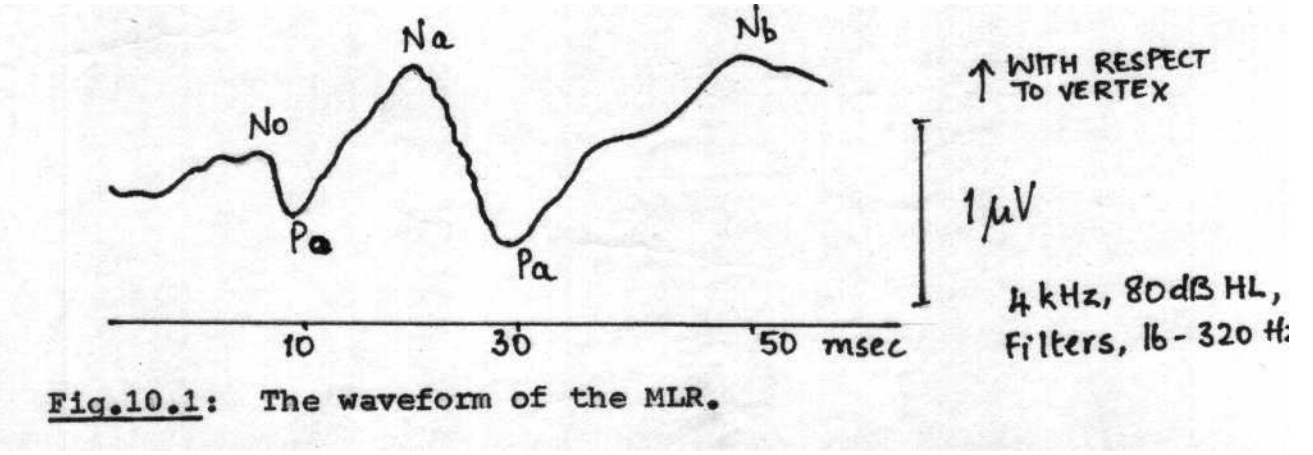


Fig.10.1: The waveform of the MLR.

10.2.1: Response configuration:

The waveform of the MLR varies with the filter set at different cut-off frequencies. However, the waveform of the response may be described as consisting of two major positive peaks and three major negative peaks - N , P_o , N_a , P_a , and N_b. (Goldstein and Rodman, 1967). Sometimes, one may be able to identify a sixth peak, P_b. The peak latencies of the responses occur within the following limits:

N_o - 8-10 msec.

P_o - 10-13 msec.

N_a - 16-30 msec.

P_a — 30-45 msec.

N_b - 40-60 msec.

P_b - 55-80 msec.

However, the lowering of frequency of the low pass filter results in the prolongation of the peak latencies.

In the same subject, the latency of the responses is quite consistent. Peak P_a is the most stable of the five peaks. A combination of N_a and P_a has been found to provide the best means of identifying the responses. This is because N_o is not identifiable and it is identical to the V peak of the BSER. Peaks N_b and P_b may foam part of the slow cortical response and hence should not be considered.

10.3: Some characteristics of the response:

10.3.1: Electrode position: Clearest responses are obtained when electrodes are placed on or around the parietal region of the scalp. The MLRs are usually recorded from the vertex, referred either to a mastoid or an earlobe with the earth electrode placed on the forehead.

Direct recording from the cortex increase the response amplitude. It has been found that binaural stimulation resulted in larger responses than monaural stimulation (Sem-Jacobson, et al. 1956).

10.3.2: Changes in muscle tone: Studies have shown that the parietal MLR is not altered by head movements (Mast, 1965), by the administration of paralytic drugs (Harker, et al. 1977) or sedatives. All this supports the neural origin of the MLR.

10.3.3: Subject state: There are diverse views regarding the subject state which is most conducive for obtaining identifiable responses. Mendel and Goldstein (1969) found the MLR remained essentially unchanged with attention to the stimulus, ignoring the stimulus (such as reading a book), or sitting with eyes closed/open. In 1971, the same researchers found that the various stages of natural sleep or sleep deprivation have little effect on the MLR. However, in 1977, the work of

Goff, et al. showed that in deep sleep a complete anesthesia the MLR gets eliminated. Brown (1982) indicated that the amplitude of the MLR decreases due to sleep. The deeper the stage of sleep, the greater the effect, especially on the later MLR waves.

However, the MLR has stability even when recorded during sleep and this has an important implication especially in the assessment of hearing status in the paediatric population.

10.3.4: Stimulus conditions:

10.3.4.1: Stimulus duration: Changes in stimulus duration from 1.5 to 4.0 msec have not been found to produce consistent changes in the response (Skinner and Antinoro, 1971; Kupperman (1970).

10.3.4.2: Stimulus rise and decay time: Experimental evidence indicates that more consistent and clear responses can be obtained using faster rise times. Skinner and Antinoro (1971) found that rise times greater than 25 msec. did not produce identifiable responses.

The amplitude of the response has been found to increase when it is elicited by clicks rather than by pure tone stimuli.

The decay time of the stimulus is not of much importance in eliciting the response. The MLRs are on-responses in that

they are produced by the onset of the stimulus only.

Hence, clicks or frequency specific tone pips may be employed to elicit the MLR.

10.3.5: Effect of repeated stimulation: The MLRs show no evidence of fatigue or habituation on repeated or prolonged stimulation. This has been found to be true of both alert and sleeping subjects (Mendel and Goldstein, 1971).

10.3.6: Effect of stimulus repetition rate and stimulus frequency: The MLRs can be elicited even when using fast stimulus repetition rates, unlike the slow cortical responses. A stimulus repetition rate of 6-10 per second is recommended (Mendel, 1974). Higher rates produce amplitude decline.

With respect to stimulus frequency, it has been demonstrated that the waveform of the MLRs is more dependent upon the stimulus rise time than the frequency of the stimulus (Kupperman, 1970).

10.3.7: Effect of altering the stimulus intensity:

10.3.7.1: <u>Amplitude intensity function</u>: Madell and Goldstein (1972) noted that the relationship between stimulus intensity and response amplitude was not consistent in all subjects. They found that with increase in intensity, the response amplitude increased. However, this was not observed in all the subjects.

10.3.7.2: <u>Latency intensity functions</u>: As the stimulus intensity was decreased, the latency of the response was found to increase.

10.3.8: Effect of altering the bandwidth: Altering the bandwidth of the recording system used for MLR results in alteration of both the amplitudes and latencies of the peaks. This can be seen in the figure given below (Fig.10.2).

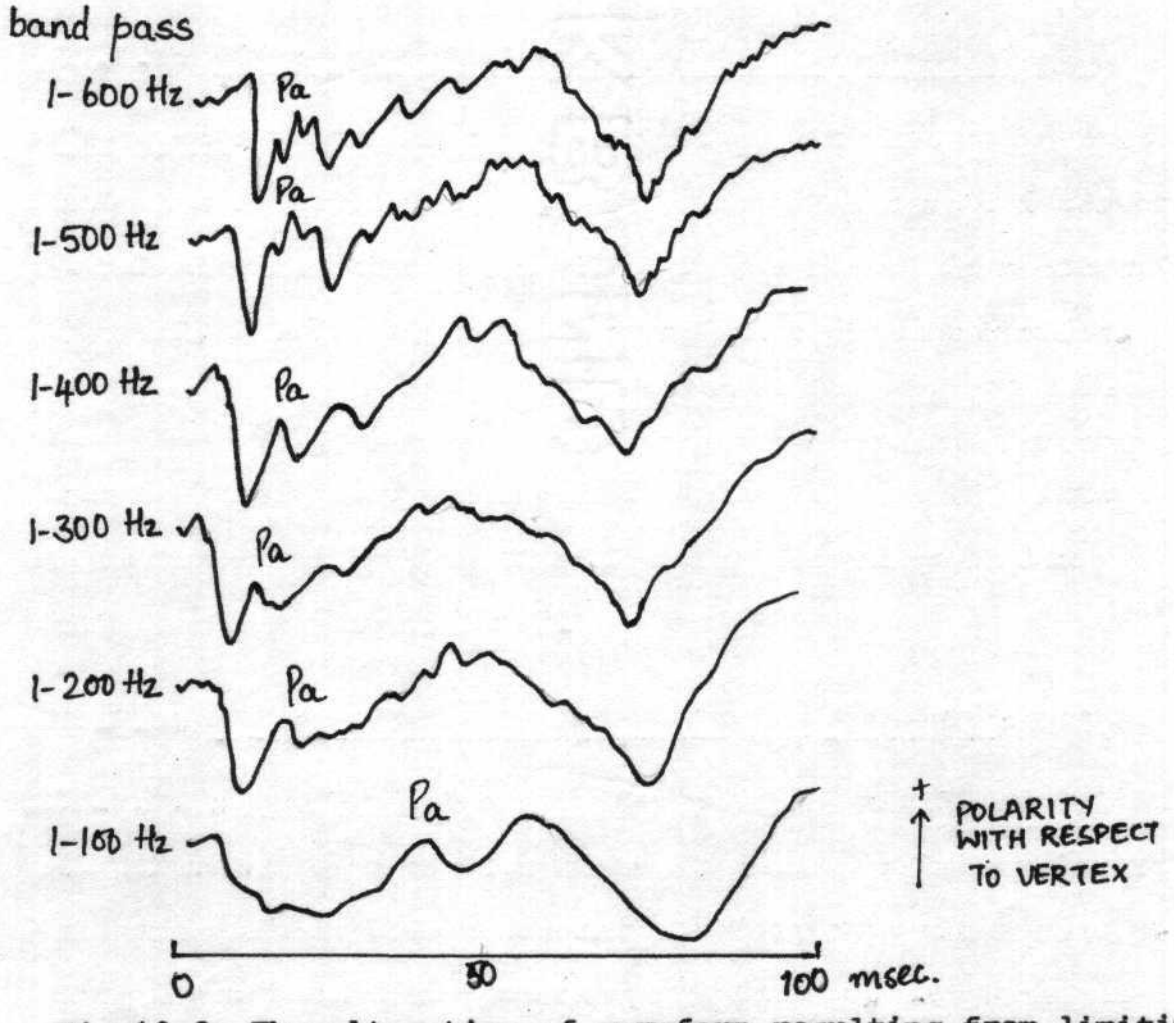


Fig.10.2: The alteration of waveform resulting from limiting the bandpass of the recording system.

While the amplitude distortion enables the detection of absence or presence of a response easier, phase distortion causes marked shifts in the latencies of the peaks in the waveform.

10.3.9: The test/retest reliability: The view that MLRs are stable, easy to elicit to within a few decibels of the auditory threshold is not shared by all as the responses are of small amplitude and may be obscured by the ongoing EEG activity and random myogenic activity. The MLR has fair reliability in that in some subjects it is not very reliable. With respect to test/retest reliability, this is also fair in that there are exceptions to the general population in whom the MLR can be elicited on re-testing.

10.4: Instrumentation:

The apparatus and other facilities required for the MLR is similar to that needed for the other methods of ERA. The specific requirements are as follows:

10.4.1: The testing environment: Testing should be done in a room which is electrically shielded to protect the response from getting obscured. The subjects,who should be relaxed, should be tested in a sound-treated test chamber. Otherwise, the response may be obscured by myogenic activity. Young children have to be usually sedated.

10.4.2: Stimulus specifications: The optimum stimulus is a click with a sharp rise time (10 to 100 /µsec). Tone bursts with sharp onsets may also be used.

A good quality transducer is needed to transmit an acoustic waveform free of click artefacts. Earphones are used with adults and sleeping children.

10.4.3: Recording equipment: The electrodes used are similar to that used in CERA, that is silver chloride dome-shaped electrodes may be used.

Low biological amplifiers are needed. Filtering introduces amplitude and phase distortion, but the same is needed in6rder to easily identify the responses. Hence a compromise has to be made. Musiek, et al. (1984) theorize that the difference in the findings, as to whether the MLR is present or absent in normally-hearing infants, is due to the difference in the filtering parameters used by different labs. Recent research has taken the direction of trying to find out what type of filter characteristics will enable the experimenter to identify the responses easily (Kavanagh and Domico, 1986, 1987).

Besides the above, we need an averager and an oscilloscope to monitor the background electrical activity, and hence avoid false interpretations. An FM tape recorder will enable us to have recordings of the response for later analysis.

The averaged response can be permanently traced on to paper or photographed.

10.5: Testing procedures:

Adults and older children can be tested lying on a couch or they can be seated with neck support. Young uncooperative children have to be tested under sedation since movement of any kind will produce myogenic electrical artefacts. Infants can be tested during natural sleep or when sedated. Light sleep has been suggested to be the best for recording responses.

The active electrode is placed on the scalp while the reference electrode is placed on the mastoid process of the contralateral ear. The ground electrode is situated on the forehead. The stimuli are presented via earphones. The test period extends to around two to three hours for the determination of threshold at several frequencies. We have to use the same stimulus at near-threshold intensity levels for several trials. This enables the judgement of whether the responses are present 50 percent of the time.

10.6: Clinical application:

10.6.1: As a measure of hearing acuity: The MLR is an excellent frequency-specific tool for measuring hearing sensitivity.

Goldstein and Rodman (1967) found a close correlation between the auditory threshold and the threshold of the response. Mendel, et al. (1977) obtained identifiable responses within 15 to 30 dB HL in most of his infant subjects. With the exception of a few reports (Engel, 1971; Davis and Hirsh, 1973), most of the early studies (Wolf and Goldstein, 1980; McRandle, et al. 1974) on various normal paediatric populations indicated the MLR to be a valid and viable tool for the estimation of hearing acuity.

The MLR helps in the identification of functional hearing loss because of its stability, sensitivity and frequency-specificity (Musiek, et al. 1984).

10.6.2: As a means of neuro-otological diagnosis: The MLR contributes significantly in this area.

10.6.2.1: **Acoustic neuroma:** Harker and Backoff (1981) reported that acoustic neuromas generally result in increased latency of the MLR waves. In comparing ABR with MLR, they found that MLR is not as sensitive as ABR for acoustic tumor detection. However, they found that there was significant interaural MLR latency differences between a group of subject with small tumors and a group of subjects with large tumors. The larger tumor group showed greater latencies for both click and tone stimuli. This led them to suggest that MLR may be of some Predictive value as to the size of the tumor.

The MLR has another advantage in evaluating acoustic neuromas in that because of its frequency-specificity, a variety of frequencies can be tested for better comparison to the other ear or for setting up normative data, especially in unilateral acoustic tumor cases.

10.6.2.2: Cerebral lesions: One of the current clinical research interest in the use of MLR is in the detection of legions in the higher auditory system. A prerequisite to MLR evaluation of cortical lesions is obtaining basic audiological datam, as well as normal ABRs bilaterally. Auditory periphery or brainstem dysfunction can contaminate MLR results and hence this possibility must be considered. Most cases of cortical hemispheric lesions have yielded essentially flat or highly distorted bilateral MLRs. However, more research is needed to establish norms (Musiek, et al. 1984).

Some reports have shown bilaterally absent MLRs in patients with well-defined lesions of the auditory cortex (Graham, et al. 1980; Ozdamar, et al. 1982; Kraus, et al. 1982; Musiek, et al. 1983). Kraus, et al. (1982) found that half of his subjects with cerebral lesions had normal MLRs, but the other half had abnormal MLRs (in terms of amplitude or latency of the P_a wave) with normal ABR results.

Further investigation is needed on the use of MLR in cortical lesions. The reports, so far, indicate that it has great potential in the evaluation of central auditory disorders.

10.7: Conclusion:

The clinical research conducted on MLR has clarified many questions, but raised an equal number of them. The MLR has a much potential for clinical application. The current research trends are aimed at finding filtering effects on the response, and their relationship to the assessment of infants and children. Also the effects of cortical lesion on MLR has to be probed into deeply. The combined use of MLR with other evoked potentials such as the ABR, EBochG and late cortical potentials would allow analysis of various parts of the auditory system with minimal time involvement.

POST-TEST

I. Fill in the blanks:

(1) The middle latency responses that are recorded by placing the electrodes near the parietal region are ..... in origin.

(2) The MLR is also called the ..... response.

(3) Recording the MLR directly from the cortex increases the ..... of the response

(4) The MLR is not affected by .....

(5) The middle latency response may be obscured by ..... and ..... activity.

(6) Depending on the bandwidth of the recording system, the ..... and ..... of the response peaks vary.

(7) ..... or ..... may be used to elicit the response.

(8) The MLR has been used in the diagnosis of .... and .....

(9) One of the issues in current research on MLR is the ..... characteristics which provide easily identifiable responses.

(10) In cerebral lesions the MLR may be ....., ..., ... or unaffected.

II. Choose the correct answer:

(1) The MLRs are produced by:

(a) the onset of the stimulus

(b) the offset/cessation of the stimulus

(c) the plateau portion of the stimulus

(d) both (a) and (c)

(2) Use of filters in recording the MLR introduces:

(a) amplitude distortion

(b) phase distortion

(c) both (a) and (b)

(d) neither (a) nor (b)

(3) In the area of neuro-otological diagnosis, the MLR may have some predictive value as to:

(a) the duration of existence of the tumor

(b) the size of the tumor

(c) site of the tumor

(d) none of the above

(4) In order to identify the response, most commonly a combination of the:

(a) Po and N_a is used

(b) P_a and N_b is used

(c) N_a and P_a is used

(d) P_o and P_b is used

(5) Fast stimulus repetition rates result in

(a) reduction of response amplitude

(b) increase of response amplitude

(c) no change in the amplitude

(d) latency prolongation

III. Indicate whether the following statements are true or false:

(1) Puretones are effective in eliciting the MLR

(2) The detection of the MLR is made easier by some amount of amplitude distortion

(3) Prolonged stimulation does not result in fatigue or habituation of the response.

(4) The MLR is unaffected by sleep

(5) There is no difference between the MLRs that are obtained under different filter settings.

CHAPTER 11

THE 40 Hz EVOKED POTENTIAL

PRE-TEST

I. Fill in the blanks:

(1) The 40 Hz evoked potential was first described by ....., ... and ..... in 1981.

(2) The 40 Hz evoked potential waves to be categorized as a ..... potential.

(3) The slow negative waves, identified by Davis and Hirsh (1976, 1979), as responses to low frequency sounds were termed as .....

(4) ..... are used as stimuli in eliciting the 40 Hz response.

(5) Most of the energy of the 40 Hz response is at .....

(6) Both ..... and ..... can be used to record and analyze the signals.

(7) The 40 Hz response can be obtained with .... decibels of the behavioral threshold.

(8) One of the other modalities in which the 40 Hz response can be recorded is the ..... modality.

(9) As the frequency of the stimulus is increased, both ..... and ..... of the response decrease.

(10) The effect of ..... on the 40 Hz response is controversial.

II. Choose the correct answer:

(1) To elicit the 40 Hz response the stimuli should have a presentation rate of

(a) 31/sec. (b) 21/sec. (c) 40/sec. (d) 46/sec.

(2) The 40 Hz response waveform is a

(a) triangular wave

(b) square wave

(c) irregular wave

(d) sinusoidal wave

(3) The 40 Hz evoked potential can be elicited by

(a) pure tones

(b) tone bursts

(c) warble tone

(d) noise.

(4) Galambus, et al. (1981) suggested that the site of origin of the 40 Hz response may be

(a) the cochlea

(b) the cortex

(c) the cochlear nuclei

(d) the brainstem and thalamus.

(5) In recording the 40 Hz response, use of analog high-pass filters causes

(a) phase-distortion

(b) amplitude reduction

(c) increase in latency

(d) no problems whatsoever

III. Indicate whether the following statements are true or false:

(1) Sleep does not affect the 40 Hz E.P.

(2) The 40 Hz response is not a transient response

(3) A sound proof chamber is necessary for making the measurements.

(4) The 40 Hz response technique need not be modified for use with children.

(5) The 40 Hz potential cannot be elicited in the visual modality.

THE 40 Hz EVOKED POTENTIAL

11.1: Introduction:

An important clinical application of evoked potentials is the estimation of hearing acuity in un-cooperative individuals or those who are unable to provide behavioral threshold information. So far, we have seen that many different auditory responses can be recorded from the human scalp and each may provide important information about auditory function. Some of them such as the ABR have the limitation in that it does not provide frequency-specific information, and hence it is difficult to use ABR to estimate low frequency sensitivity.

Attempts have been made to obtain frequency-specific information. Davis and Hirsh (1976, 1979) identified a slow negative-going wave having a latency of 10 msec. and termed it as SN-10. However, the SN-10 response has not been easy to elicit from young children (Hawes and Greenberg, 1981}, and has been demonstrated to be a relatively poor predictor of low-frequency behavioral thresholds (Hayes and Jerger, 1981).

Galambos, et al. (1981) described a low-frequency technique which is beginning to gain clinical acceptance. This is the 40 Hz evoked potential. The 40 Hz response can be

categorized as a steady state evoked potential (SSEP). A SEEP is elicited by presenting stimuli at such a high rate that there is an overlapping of responses to successive stimuli. This results in a periodic response which has a constant phase relationship to the repeating stimulus. It was with the work of Galambos, et al. (1981) that interest in the SSEP was aroused. Prior to this, SSEP in humans were mainly studied in the visual modality (Regan, 1977, 1981).

11.2: Characteristics of the response:

The 40 Hz potential is basically elicited by tone bursts delivered at a rate of 40/sec. The resultant recording appears as a sinusoidal waveform which is composed of energy from both the ABR and the MLR, but more so of the latter (Fig.11.1 - page No.211). Since the response waveform approximates a 40 Hz sinusoid, it is probably enhanced by the 40/sec. stimulus rate.

In their initial report, Galambos, et al. (1981) showed that when the stimuli are presented at a rate of 40/sec, the MLRs have an amplitude about two to three times greater than when the stimuli are presented at the conventional 10/sec.rate. Actually, the 40 Hz potential is the MLR conducted at a repetition rate of 40 tone pips per second. At this high rate, a tone pip is presented every 25 msec. Since the three

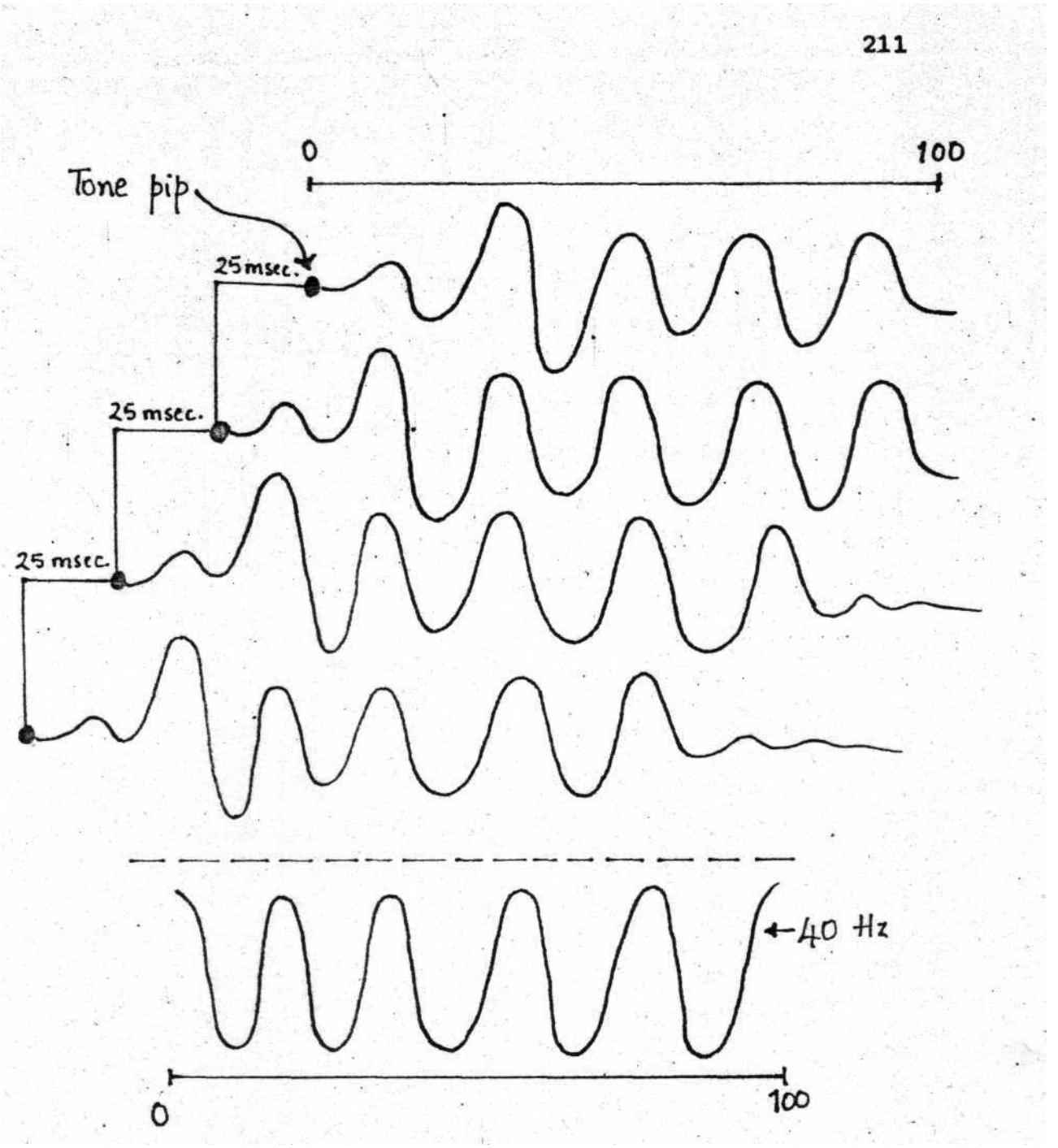


Fig.11.1: The derivation of the 40 Hz waveform. Each tone pip presented every 25 msec. generates its own waveform. The MLR waves which occur approximately every 25 msec. overlap to yield compositely large waves every 25 msec. in a 100 msec. time window.

major peaks (P_a , P_b , P_c) of the MLR occur at approximately 25 msec. intervals, there is an overlapping effect in time of these waves which enhances their amplitude. This amplitude enhancement aids the detection of the waves, thereby making it a powerful threshold-detection test. The 40 Hz auditory potential can be recorded to tones of low (250 and 500 Hz) as well as high (5000 Hz) frequencies. However, as the stimulus frequency increases, the amplitude and latency of the 40 Hz response decreases. Also, with decrease in intensity, the amplitude decreases and the latency increases.

The potentials are recorded by placing the active electrode on the forehead and the reference electrode on the ipsilateral earlobe. The contralateral earlobe carries the ground electrode. The responses can be reliably recorded from all subjects, and neither gender nor age have any clear effect on the response (Stapells, et al. 1984).

11.3: <u>Factors affecting the response:</u>

11.3.1: Stimulus rate: When the stimuli are presented at a rate of 40/sec, the amplitude of the response is twice the magnitude of that produced at the conventional rate of 10/sec. (Galambos, et al. 1981; Stapells, et al. 1984). This was true of adults. However, Suzuki, et al. (1983) found that the

responses from infants were enhanced with a stimulus rate of 20/sec. rather than 40/sec. Hence, the 40 Hz evoked potential (EP) may have to be modified for use with infants and young children. The effect of rate is similar across the different tonal frequencies.

11.3.2: Stimulus required: Researchers who have conducted experiments on this response have used tone bursts as stimuli. The rise and decay time of the stimuli have varied between 2 to 6 msec. and while some have used plateau duration (Lynn, et al. 1984; Stapells, et al. 1984), others have not (Suzuki, et al. 1983).

11.3.3: Stimulus frequency: The 40 Hz response can be evoked by both high and low frequencies. However, as the tonal frequency increases, the amplitude and latency of the 40 Hz response decreases.

11.3.4: Stimulus intensity: As the intensity of the stimulus is decreased, the amplitude decreases and the latency increases.

1.3.5: Effect of sleep: She amplitude of the 40 Hz EP has been found to decrease to half its original size when recorded in a sleeping subject (stapells, et al. 1984). However, Lynn, et al (1984) suggested that since the 40 Hz EP is critically dependent on MLR latencies and since MLR is only slightly

affected by natural sleep, the 40 Hz EP can be obtained from individuals under conditions other than that of being awake.

11.3.6: Filters used: The 40 Hz response has its main energy centred at 40 Hz. The use of analog high-pass filtration on the 40 Hz response was found to result in very little frequency elimination but this created phase-shift distortion and reduction in amplitude. However, high-pass digital filtration of the 40 Hz response did not significantly change the response amplitude. Hence, minimal high-pass analog filtering of the 40 Hz response should be performed (Kavanagh, and Domico, 1986).

11.4: Instrumentation:

Just as with the other ERA measurements, the basic instrumentation needed for the detection of the 40 Hz response is mentioned in Chapter 2. The specific requirements are as follows:

11.4.1: The test environment: The subjects are made to lie down comfortably in a sound-treated room. The subjects are to remain awake during testing. The sound stimuli are presented through earphones in case of both adults and children.

11.4.2: The stimulus generation: We need a pulse generator which is set to trigger tone bursts at a rate of 40/sec.

The rise and fall time of the tone bursts will vary depending on the experimenter's need. Good quality transducers are needed to deliver the stimuli without introducing any distortion and/or artefacts.

11.4.3:The recording equipment: Standard EEG silver cup electrodes may be used. The electrode placement has been discussed in Section 11.2. A clinical averager which is externally triggered by the stimulus pulse generator may be used, or one may opt for Fourier Analysis. Both provide nearly identical amplitude-rate, amplitude-intensity and latency-intensity functions. Not only is Fourier Analysis economical - both in terms of time and money - but it also provides objective measures of amplitude and phase. However, its reliability needs to be substantiated (Stapells,et al. 1984). Besides this, low biological amplifiers and monitoring oscilloscopes are also needed. The data can be stored using print-outs or FM tape recorders.

11.5: Testing procedures:

Adults and cooperative children can be made to lie down on a couch in a comfortable position. If seated, the neck should be supported so as to avoid any movement causing artefacts. While Suzuki, et al (1983) report of no change in

responses when recorded from sleeping or sedated children, Stapells, et al.(1984) reported that the sleeping state reduced the amplitude of the 40 Hz responses.

The stimuli are presented through earphones after the electrodes are properly placed. Evoked potential threshold is the lowest signal level at which a response can be obtained.

11.6: Clinical applications:

In the beginning it was mentioned that the ABR dovs not provide information regarding hearing sensitivity in the low frequencies. However, the 40 Hz evoked potential is a low-frequency technique which has been found to be a good indicator of auditory sensitivity in the low frequencies. Since the 40 Hz response is larger at lower tonal frequencies, it may be complimentary to the ABR which is more easily recorded in the higher tonal frequencies. The 40 Hz potential can be recorded to within a few decibels of the behavioral threshold with an amplitude which decreases linearly down to threshold. The predictive error is around 15 dB. It can be used with both normals and hearing-impaired individuals (Stapells, et al. 1984). Lynn, et al. (1984) found that the EP seems to underpredict behavioral thresholds by about 10 dB at 500 Hz. This phenomenon has to be investigated further.

11.7 Conclusion:

In conclusion, the 40 Hz evoked potential canbe elicited by both high andlow frequencies at high and low intensities. It may be considered as a reasonable predictor of low frequency behavioural thresholds. There are many questions about this response that are yet to be answered such as the relationship between the auditory 40 Hz response to similar responses in other modalities and to other 40 Hz phenomena that can be recorded from the human scalp (Stapells, et al. 1984), the effect of sedation on the response, and so on. Also little is known about its cerebral origin. Galambos, et al.tl981) speculated that it may arise from the polysensory extraleminiscal areas such as the brainstem and/or the thalamic reticular formation. Further investigation is needed. Nevertheless, the 40 Hz EP has a promising future in the area of objective audiometry.

POST-TEST

1. Fill In the blanks:

(1) The 40 Hz evoked potential was first described by ....., ... and ..... in 1981.

(2) The 40 Hz evoked potential waves to be categorized as a ..... potential.

(3) The slow negative waves, identified by Davis and Hirsh (1976, 1979), as responses to low frequency sounds were termed as .....

(4) ..... are used as stimuli in eliciting the 40 Hz response.

(5) Most of the energy of the 40 Hz response is at .....

(6) Both ..... and ..... can be used to record and analyze the signals.

(7) The 40 Hz response can be obtained with .... decibels of the behavioral threshold.

(8) One of the other modalities in which the 40 Hz response can be recorded is the ..... modality.

(9) As the frequency of the stimulus is increased, both ..... and ..... of the response decrease.

(10) The effect of ..... on the 40 Hz response is controversial.

II. Choose the correct answer:

(1) To elicit the 40 Hz response the stimuli should have a presentation rate of

(a) 31/sec. (b) 21/sec. (c) 40/sec. (d) 46/sec.

(2) The 40 Hz response waveform is a

(a)triangular wave

(b) square wave

(c) irregular wave

(d) sinusoidal wave

(3) The 40 Hz evoked potential can be elicited by

(a) pure tones

(b) tone bursts

(c) warble tone

(d) noise

(4) Galambus, et al. (1981) suggested that the site of origin of the 40 Hz response may be

(a) the cochlea

(b) the cortex

(c) the cochlear nuclei

(d) the brainstem and thalamus

(5) In recording the 40 Hz response, use of analog high-pass filters causes

(a) phase-distortion

(b) amplitude reduction

(c) increase in latency

(d) no problems whatsoever

III. Indicate whether the following statements are true or false:

(1) Sleep does not affect the 40 Hz. EP.

(2) The 40 Hz. response is not a transient response

(3) A sound proof chamber is necessary for making the measurements.

(4) The 40 Hz. response technique need not be modified for use with children.

(5) The 40 Hz potential cannot be elicited in the visual modality.

SUMMARY

Evoked response audiometry has become part and parcel of the audiological evaluation procedures. Over the years of research, starting from the late twenties, we have come a long way in our attempts to answer the many questions that ERA has raised. At the same time the studies have resulted in quite a number of questions which are yet to be answered.

Chapter 2 covers the history and development of the different types of ERA by considering the important landmarks made by the investigators over the initial decades of research.

Chapter 3 deals with the principle underlying the recording of the evoked potentials, how these potentials are classified, and the basic apparatus needed for making the evoked response measurements.

Chapter 4, titled, 'Auditory Myogenic Response'(AMR), is about potentials recorded from the muscles, which can be from the inion, the parietal region, the post-auricular region and the jaw. Of these, the potentials from the post-auricular region from the auditory myogenic response.

The auditory evoked cortical potential covered in Chapter 5, was the first potential. It is believed to originate from the auditory cortex and the adjacent cortical areas.

Chapter 6, the contingent negative variation is concerned with the very late cortical potential, which is believed to originate from the frontal cortex. The CNV is based on conditioning principles and has been found to have value in both diagnosis and assessment of the efficacy of treatment.

Chapter 7, is concerned with electrocochleography which involves the study of potentials reflecting the activity in the cochlea and auditory nerve. This is an area which has aroused a lot of interest in recent years.

Chapter 8 deals with the auditory brainstem response which is a far-field potential in that the recording electrode is not close to the site of generation of the potential. The ABR consists of several peaks each of which is obtained from different points along the auditory pathway. This is one of the most widely used evoked potentials.

It is possible to have responses which resemble the acoustic stimulus in terms of the waveform. Such responses are called frequency following response and this has been dealt with in Chapter 9.

In Chapter l0, the MLR assumes importance. These are also called the early cortical responses and the site of generation of these responses is believed to be in the auditory radiations in the thalamic region and in the primary auditory cortex in the temporal lobe.

Finally Chapter 11 covers an evoked potential which has a promising future in the field of diagnostic audiology. The 40 Hz EP is similar to the MLR. The only difference lies in how the evoked potential is elicited, that is, in the stimulus generation.

Each of the different types of ERA measurements covered in the preceding chapters has its own advantages and disadvantages, its own individual characteristics, and instrumentation and stimulus requirements. While the initial interest aroused by cortical evoked response audiometry(CERA), auditory myogenic response (AMR), contingent negative variations (CNV) and the frequency following response (FFR) has gradually waned, the electrocochleography and the ABR continue to dominate in clinical settings, and a greater interest has been directed in the direction of the p_{300} wave, the middle latency response (MLR) and the 40 Hz potential.

While this primer has covered most of the available material on ERA, there is more to ERA than what is given here. Interested readers may refer to the respective references cited in the Bibliography.

CONCLUSION

In the preceding chapters we have seen how the different types of evoked potentials can be elicited, how they appear morphologically, what factors affect them, what instrumentation is needed to record the same, the modification in testing procedures, and last, but not the least, in what way they have been used clinically and the characteristic clinical findings obtained for different conditions. Each type of measurement has its own advantages and disadvantages, and each, on its own, cannot be used as a substitute for the entire audiological evaluation because each provides some information in a limited way. If we compare the audiological assessment to a jigsaw puzzle, each type of ERA measurement forms only a part of it. The rest is comprised of the conventional methods of testing like pure tone and speech audiometry, impedance testing, special tests and so on. So, ERA can complement the information from the other conventional methods of testing and help solve the puzzle that the subject is presenting.

So when used as part of the entire audiological procedure, we can be more accurate in our diagnosis and effective in implementing an appropriate remediation program, than if we were to use only the results of ERA alone.

SELF-EVALUATION TEST

I. Guess the correct evoked potential.

(1) This response is not as resistant to anoxia or deprivation of oxygen as the cochlear microphonic.

(2) This late response is contra-indicated in cases having epilepsy, athetosis or brain damage.

(3) To elicit this response, one may also use pictures as stimuli.

(4) The results obtained using this response are inconsistent owing to its muscular origin.

(5) The absolute latency, the interpeak and the interaural latency differences of this response are used for the purpose of diagnosis.

(6) A stimulus repetition rate of 40/sec. is needed to elicited this response.

(7) Like the auditory brainstem response, this response also provides information in the frequency region at and above 2 KHz.

(8) Initially, this response, when recorded from the parietal region, was thought to be muscular, but research has shown this response to be predominantly neurogenic.

(9) This response may be used to assess the maturation of the child.

(10) The speech discrimination ability of an individual can be assessed using this response.

II. Names of various contributors and a number of responses (in abbreviated form) have been arranged vertically, horizontally, forwards, backwards, diagonally. Try to locate and match the evoked potential with the respective contributor.

C J X M H U D F N P
E E K T L H P F C W
R G S A C R L R E V
A A L N W F S J R S
M Y W O R D E N X I
R E T L A W A B R V
J M A R E H C W S A
S I K T I E A N D D
Q C T O R M Z I V A
O S M W E V E R Q P

III. Indicate whether the following statements are true or false.

(1) The compound action potential originates from the cochlea.

(2) The middle latency response has a latency that lies between that of the auditory brainstem potentials and the cortical potentials.

(3) The diagnostic peak in auditory brainstem response (ABR) is wave V, and this arises from the lateral lemniscus.

(4) Sedation affects auditory brainstem response (ABR) and ECochG, but not the cortical evoked response (CER).

(5) The frequency following response (FFR) is observable in the high frequency region.

(6) The contingent negative variation (CNV) is not affected by the psychological state of the individual.

(7) Masking is necessary in the use of cortical evoked response and auditory brainstem response.

(8) The parietal response is a myogenic response.

(9) The 40 Hz response may be classed as a steady state evoked potential.

IV. Choose the correct answer.

(1) A "rapid-rise" time stimulus is needed for evoking the potentials in

(a) MLR and ECochG

(b) ABR and myogenic responses

(c) MLR, ABR and ECochG

(d) both (a) and (b)

(2) Reversing the polarity of the acoustic stimulus alternatively

(a) cancels the AP, but preserves the CM.

(b) cancels the CM, and preserves the AP.

(c) cancels the CM and SP, and preserves the AP.

(d) cancels the AP and SM, and preserves the OM.

(3) The ABR findings in the case of eighth nerve tumors generally include:

(a) loss of the later ABR waveform following wave I.

(b) interaural latency difference is prolonged.

(c) prolongation of both absolute latency and interpeak latency difference

(d) either (a) and/or (c).

(4) A case comes with a complaint of fluctuating hearing loss and tinnitus. Conventional audiometry reveals a mild to moderate sensorineural hearing loss. Special tests like ABLB point to presence of recruitment. ECochG finding is a broadening of the SP/AP waveform, a small and distorted CM and a large SP component. All these findings coupled with the patients history favor the diagnosis of:

(a) Acoustic neuroma

(b) Syphilitic hearing loss

(c) Meniere's Disease

(d) Round window membrane rupture.

(5) The CNV is not obtained in cases of

(a) psychopaths

(b) brainstem lesions

(c) retrocochlear pathology

(d) none of the above.

V. Fill in the blanks:

(1) The two types of approaches to ECochG are the ..... and .....

(2) The MLR may be used in the diagnosis of ..... and

(3) The neurological maturation is reflected not only in the ABR, but also in the .....

(4) The crossed acoustic response refers to the.....

(5) The amplitude of the cortical response increases with ..... stimulation.

(6) In a case having loss of hair cells of the cochlear, the characteristic cochleogram is called ..... cochleogram.

(7) In Language Evoked Response Audiometry, ...are used as stimuli.

(8) The FFR is believed to originate from the .....

(9) ..... and ..... are commonly used as stimuli in ERA.

(10) The 40 Hz potential and the MLR differ mainly in the ..... that is used to elicit both the potentials.

ANSWERS

CHAPTER 2:

I. Fill in the blanks:

1. Caton
2. P.A.Davis; H.Davis
3. Smaller
4. averaging
5. Clark, et al.
6. Myogenic
7. V-potential
8. Jewett
9. cochlear microphonic
10. summating potential
11. Electrocochleography
12. 25-50 msec; early
13. Frequency-following response
14. Moushegian, Rupert and stillman
15. Contingent negative variation
16. auditory brainstem response and electrocochleography.

II. Match the following:

1. d; 2. e; 3. f; 4. a; 5. i; 6. g; 7. b;
8. c; 9. h.

CHAPTER 3

I. Choose the correct answer.

1. c; 2. d; 3. b; 4. c; 5. c; 6. e; 7. b; 8. b; 9. a; 10. d.

II. Fill in the blanks:

1) 2-8 msec.
2) very late
3) hair cells
4) compound action
5) click
6) cortical responses
7) pre-amplifier
8) averager
9) filters
10) stored.

CHAPTER 4:

I. Fill in the blanks:

1. muscles
2. neurogenic
3. inion
4. early corticaly middle latency
5. post-auricular response
6. tone burstsy; clicks
7. crossed acoustic response (CAR)

8. onset
9. reduced; sleep; tiredness; drugs.
10. amplitude
11. 30 dB
12. rise time
13. screening
14. recruitment
15. multiple sclerosis

II. Choose the correct answer:

1. b; 2. d; 3. d; 4. c; 5. c; 6. a; 7. d; 8. c; 9. d; 10. a.

CHAPTER 5:

I. Fill in the blanks:

1. cortical
2. 50; 300
3. 5; 10
4. does not
5. amplitude
6. seven (7)
7. sedation; sleep
8. myogenic
9. epilepsy; athetosis
10. cochlear pathology.

II. Indicate whether the following statements are true or false.

1. False; 2. True; 3. False; 4. False; 5. False;
6. True; 7. False; 8. False; 9. True; 10. True.

III. Choose the correct answer:

1. d; 2. c; 3. a; 4. b; 5. b.

CHAPTER 6:

I. Fill in the blanks

1. expectancy wave
2. conditions; imperative
3. frontal cortex
4. imperative
5. frontal
6. ramp-shaped
7. pure tone bursts; clicks; words
8. larger
9. grease
10. language electric response audiometry (LERA).

II. Indicate whether the following statements are true or false.

1. False; 2. True; 3. False; 4. False; 5. True;
6. False; 7. False; 8. True; 9. True; 10. False

III. Choose the correct answer:

1. b; 2. d; 3. a; 4. c; 4. c.

CHAPTER 7:

I. Fill in the blanks:

1. cochlear microphonic; summating potential; action potential.
2. cochlear microphonic
3. high; tone bursts.
4. sedation; repeated stimulation
5. trans-tympanic; extra-tympanic
6. action potential
7. round window
8. malingering/functional hearing loss
9. widened
10 cochlear.

II. Choose the correct answer:

1. b; 2. a; 3. b; 4. e; 5. c.

.III. Indicate whether the following statements are tru or false

1. False; 2. False; 3. True; 4. False; 5. False;
6. True; 7. True; 8.False; 9. False; 10. False.

CHAPTER 8:

I. Fill in the blanks:

1. Jewett bumps
2. lateral lemniscus
3. IV-V complex; six (6)

4. absolute; interwave/interpeak; interaural
5. shorter; amplitudes
6. latency-intensity (L-I) function
7. normals; children; retrocochlear pathology
8. masking
9. rise time
10. morphology

II. Indicate whether the following statements are true or false:

1. True; 2. False; 3. False; 4. False; 5. True
6. True; 7. False; 8. False; 9. True; 10. False.

III. Choose the correct answer:

1. c; 2. b; 3. a; 4. a; 5. b;

CHARTER-9

I. Fill in the blanks:

1. Worden and Marsh
2. acoustic stimulus
3. low; 1000 Hz.
4. inferior colliculus
5. 40 dB
6. waveform; amplitude
7. lower
8. earlobe, leg
9. ABR; and BCochG
10. learning disability.

II. Indicate whether the following statements are true or false:

1. False; 2. False; 3. True; 4. True; 5. False.

III. Choose the correct answer:

1. b; 2. c; 3. d; 4. b; 5.c.

CHAPTER-10:

I. Fill in the blanks:

1. neurogenic
2. early cortical
3. amplitude
4. sedatives
5. on-going EEG; random myogenic
6. amplitude, latency
7. clicks; tone bursts
8. pseudohypacusis; acoustic neuroma
9. filter
10. absent; flat; distorted; abnormal

II. Choose the correct answer:

1. a; 2. c; 3. b; 4. c; 5. a.

III. Indicate whether the following statements are true or false:

1. False; 2. True; 3. True; 4. False; 5. False.

CHAPTER 11

I. Fill in the blanks:

1. Galambos, Making, Talmachoff.
2. Steady state evoked potential
3. SN-10
4. tone bursts
5. 40 Hz.
6. signal averager; Fourier analysis
7. 15 (fifteen)
8. visual
9. amplitude; latency
10. sleep.

II. Choose the correct answer:

1. e; 2. d; 3. b; 4. d; 5. a.

III. indicate whether the following statements are true or false:

1. False; 2. True; 3. True; 4. False; 5. False.

ANSWER TO THE SELF EVALUATION TEST

I. Guess the correct evoked potential:

(1) Frequency following response

(2) Cortical evoked response

(3) Contingent negative variation

(4) Auditory myogenic response

(5) Auditory brainstem response

(6) 40 Hz evoked potential

(7) Action potential (ECochG)

(8) Middle latency response

(9) Auditory brainstem response

(10) Contingent negative variation

II. Naming and matching of the evoked potential with the respective contributor.

C J X M H U D F N P

E E K T L H P F C W

R G S A C R L R E V

A A L N W F S J R S

M Y W O R D E N X I

R E T L A W A B R V

J M A R E H C W S A

S I K T I E A N D D

Q C T O R M Z I V A

O S M W E V E R Q P

Contributor	Evoked potential
1. Worden	FFR
2. Mast	MLR
3. Walter	CNV
4. Wever	CM
5. P.A.Davis	CERA
6. Jewett	ABR

III. Indicate whether the following statements are true or false:

1. False; 2. True; 3. True; 4. False; 5. False; 6. False; 7. True; 8. False; 9. True.

IV. Choose the correct answer:

1. d; 2. b; 3. d; 4. c; 5. a

V. Fill in the blanks:

1) extratympanic; transtympanic

2) VIII nerve lesions; cerebral lesions

3) cortical evoked response

4)auditory myogenic response

5) binaural

6) recruiting

7) words

8) inferior colliculus

9) tone bursts, clicks

10) stimulus repetition rate.

APPENDIX

The P_{300} component of the cortical evoked response is a positive wave. (Fig.A.1)

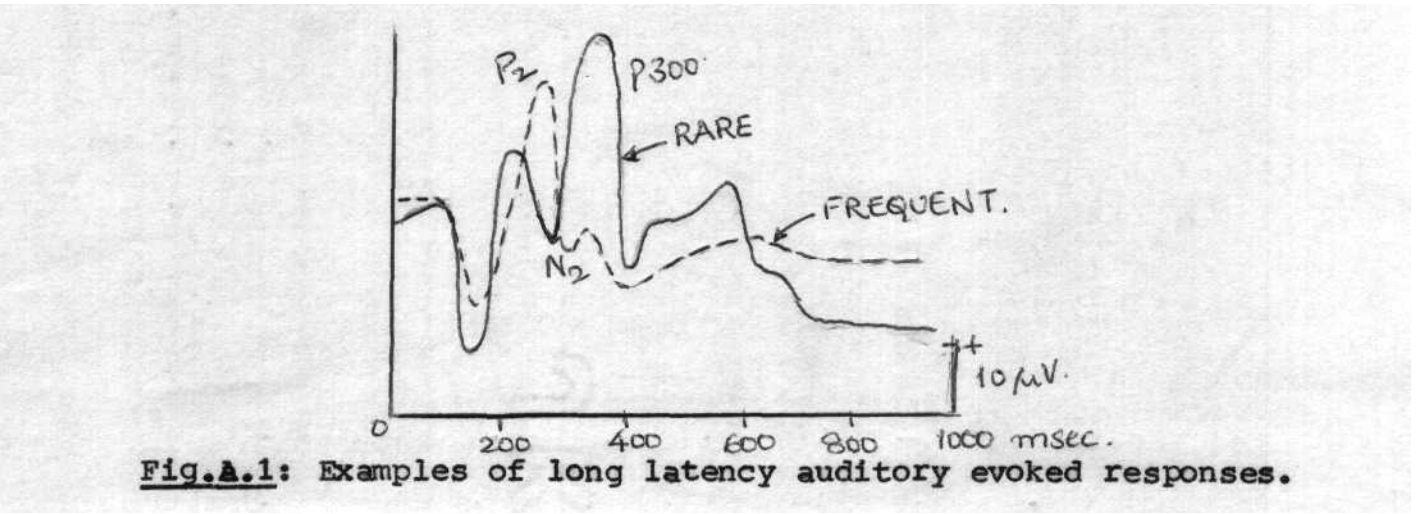


Fig.A.1: Examples of long latency auditory evoked responses.

This positive wave is similar in form for visual and somatosensory stimuli. This component can be obtained with a number of stimulus presentation conditions in which the subject processes task-relevant information. Often he has to count rare occurences of a target tone embeded in a series of more frequently occuring standard tones. While the target tone is physically different from the standard tone, it is not the physical difference which produces this component, but the information supplied to the subject with the occurence of the relevant target tone (sutton, et al. 1967). Donchin, et al (1978) suggests that P_{300} wave is associated with the detection of a task relevant stimulus event and a memory updating process involved with the decision that a novel event has been perceived.

The P_{300} wave is believed to originate from the subcortical brain structures, such as the hippocampal formation and amygdala (Hagren, et al 1980). It may be utilized in investigation of:

(a) cognition in various forms of psychopathology (Roth, et al. 1979).

(b) attentional or memory abilities in the aged (Smith, et al. 1980)

(c) a variety of problems in human information processing (Donchin, 1979).

(d) in audiometric evaluations

Also the P_{300} component has the potential in investigating how the brain processes information.

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ACRONYMS

ABR - Auditory Brainstem Response

AER - Auditory evoked Response

AMR - Auditory Myogenic Response

AP - Action Potential

BAER -Arainstem Auditory Evoked Response

BER - Brainstem Evoked Response

BERA - Brainstem Evoked Response Audiometry

BSER - Brainstem Evoked Response

BSERA - Brainstem Evoked Response Audiometry

CAR - Crossed Acoustic Response

CER - Cortical Evoked Response

CERA - Cortical Evoked Response Audiometry

CM -Cochlear Microphonic

CNV - Contingent Negative Variation.

ECochG - Electrocochleography.

EDA - Electrodertmal Audiometry

EEG - Electroencephalography

EP - Evoked Potential

ERA - Evoked Response Audiometry

Electric Response Audiometry

Electroencephalic Response Audiometry

EDR - Electro-dermal Response

FFR - Frequency Following Response.

ILD - Interaural Latency Difference

IPL - Interpeak Latency

ISI - Inter-Stimulus Interval

LBRA - Language Electric Response Audiometry

MLR - Middle Latency Response

PGSR - Psycho-Galvanic Skin Response

PGSRA - Psycho-Galvanic Skin Response Audiometry

SP - Summating Potential.