BRAIN-STEM EVOKED RESPONSE AUDIOMETRY IN CHILDREN - A REVIEW.

Register No. 8801

An Independent project work submitted as part fulfilment for first year M.Sc. (Speech and Hearing) to the University of Mysore, Mysore.

All India Institute of Speech and Hearing

Mysore - 570 006

MAY 1989

Dedicated to .

"BAB A"

CERTIFICATE

This is to certify thdt the Independent project entitled "Brain-Stem Evoked Response Audiornetry in children - A Review " is the honafide work done in part fulfilment for first year M. Sc (Speech and Hearing) of the Student with Register No - 8801

Dr. N.Rathna
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CERTIFICATE

This is to certify that the Independent project entitled " **Brain - Stem Evoked Response Audiometry in children - A Review** " *has of been prepared under my supervision and guidance.*

Guide

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DECLARATION

I hereby declare that this Independent project entitled " **Brain-Stem Evoked Response Audiometry in children : A Review "** *is the result of my own work undertaken under the guidance of Dr. M.N. Vyasamurthy, lecturer in Audiology, Ail India institute of Speech and Hearing, Mysore - 6, and has not been submitted earlier at any University or institution for any other Diploma or Degree.*

Mysore
Dated- May 1989. **Register No. 8801**

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INTRODUCTION

(BSERA - Its need while testing children)

Need for BSERA IN CHILDREN:- One of the problems encountered by the clinician in testing patients with hearing loss is while testing the pediatric population. Early identification and diagnosis is especially essential in these children as hearing loss can interfere with their language, development. This can also interfere with their social, adaptive and Congnitive development.

In order to test children, many modifications of pure tone and speech testing procedures have been made which makes use of variety of conditioning techniques, to get reliable audiograms. Despite these, problems persist in testing children, especially if they are too young say less than one year, where the clinician has to rely more on behavioral observations. Also, in certain difficult to test patients, or children with multiple handicaps say cerebral palsy or children with emotional problems like autism, usual test procedures do not yield reliable results. With the development of objective testing methods like impedance audiometry, Electrocochleography and Evoked Response audiometry, they found these could be used with greater accuracy in identifying hearing problems in adults. Eg. Acoustic neuroma can be more reliably and objectively identified using BSERA. Hence they decided to try these in testing children also. It was found that using the above instruments accurate estimate of hearing is possible. It was also found that even age-related changes in hearing can be assessed. Apart from normal children, other paediatric population were also tested using these objective measures and these were found to give reliable results.

Now, Auditory 6voked potentials have become an acceptable procedure for assessing auditory functions in newborns, infants, difficult to test children like newborns, infants and multiply handicapped.

Historical Development:- The CNS generates random bio-electric activity in the absence of sensory stimulation. These electrical events can be recorded using scalp electrodes and constitute the Electroencephalogram (EEG). EEG activity was first described by Berger (1929). This EEG activity undergoes change when there is sensory stimulation. It was found that it is possible to record the bioelectric events which are related to sensory stimulation and extract these from the ongoing EEG activity.

Around 1939, the first recordings of AEP's were obtained from alert and sleeping subjects. Principle of algebraic summation of electrical activity following repeated simulation was introduced by Clark (1958 & 1961).

Early interest in AEP's focussed on slow (50-200 msec) latency potentials thought to be of cortical origin.

In the 1970's investigations on the clinical application of ABR, began. These early potentials waveform was first recorded by Sohmer and Feinmesser (1967) and later described definitively by Jewett and Williston (1971).

These auditory evoked potentials can be classified variedly. One common classification is based on the latency "epoch" of response. The various epochs are designated as

first = "0-2" msec,

fast = 2-10 msec.

Middle = 10-50 msec.

Slow = 50-300 msec.

Late = 300 msec.

Among the above possible AEP's Auditory Brain Stem responses is one of the several clinically useful evoked potential and is extensively used than any other response. As the term suggests, the origin of these waves is in the brainstem. These waves are identifiable within 10 msec after stimulus onset. Stimuli which are commonly used for ABR measurements are clicks, brief tonepips or tone bursts. In normals following stimulus presentation; a series of 7 waves have been identified and numbered from I -VII. (Jewett & Williston -1971).

Each of these Jewett Wavelets have a highly predictable post- stimulus latency. At high intensities 5 or 6 major waves beginning at about 1.5 - 2 msec and recurring at about 1 msec intervals can be detected in the first 10 msec post stimulation in the averaged response.

The source of origin of the 7 waves are believed to be as follows.

Wave I - Auditory Nerve

Wave II - Cochlear Nucleus

Wave III - Superior Olivary Complex.

Wave IV - Lateral lenmiscus.

Wave V - Inferior Collicules.

Wave VI - Medical Geniculate body.

Wave VII - Auditory radiation.

Among these, V th wave is the one which is most identifiable and is often used as a criteria for determining threshold.

The parameters which are considered in interpreting BSERA waveforms are

1. Absolute latency of the waves.
2. Wave form Morphology.
3. Interpeak latency values.
4. Intra aural latency differences.
5. Amplitude ratio of V / I Waves.

Based on these, diagnosis of hearing loss and identification of possible site of lesion too is possible.

The following chapters give a brief review of the instrumentation needed for testing children, BSERA findings in normal and in the multiply handicapped. Finally usefulness of BSERA in hearing and selection too will be considered.

CHAPTER II

INSTRUMENTATION

In order to do accurate testing, it is essential that we have the proper equipment/instrument. Also the instrument must be properly calibrated, so that the responses obtained from it are reliable.

The following block diagram gives a summary of the elements of the stimulation and recording systems of an ABR equipment

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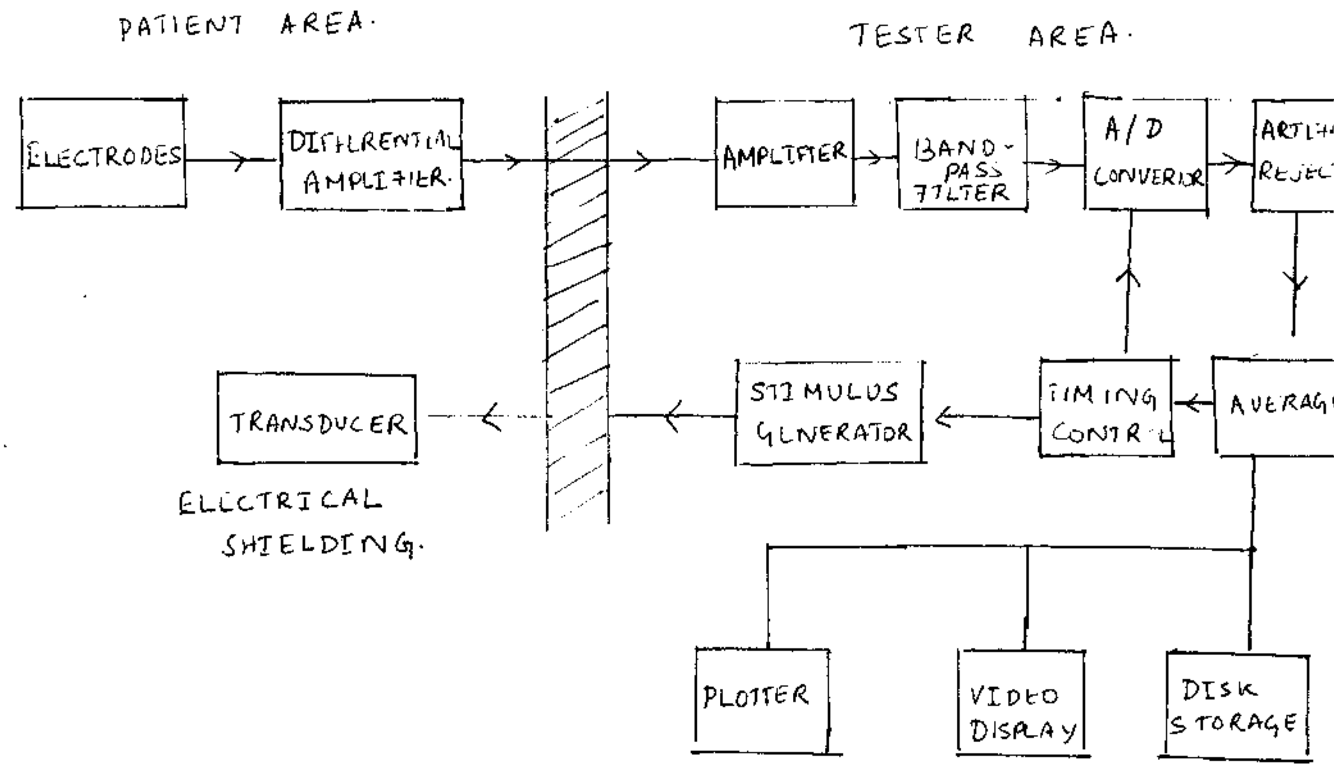


Starting from the stimulus generator (shown in the above diagram), there are many types of acoustic stimuli that can be used. Generally it is necessary to have a stimuli with rapid onset, as this is more efficient in causing neural synchrony in firing. However such a stimuli will lack frequency - specificity. Often used stimuli are clicks, produced by eliciting a headphone with a rectangular voltage pulse, typically of 100 μ sec duration.In efforts to get greater frequency specificity, filtered clicks and tone pips are used. Tonepip is specified in terms of its rise, plateau and fall times. In case of sustained AEP, using stimuli like tone pip, entire duration of the stimulus becomes essential.

Depending on whether the initial stimulus segment causes a positive pressure or negative pressure, the stimulus is called as Condensation or Rarefaction stimuli accordingly, If polarity in successive stimuli are alternated, then it may be efficient in cancelling out stimulus artifacts. However stimuli with alternating polarity may cause slightly different excitation patterns along the basilar membrane.

The stimulus thus generated is routed through the transducers. The transducers generally used are conventional headphones. Loudspeakers and Bone conduction vibrators too can be used.

The stimulus passes through the transducers kept on the ear. The changes in the electrical activity occurring with in the patients Auditory system are picked by electrodes. These are placed on the head and neck. These response picked up by the electrodes are connected to the preamplifier, the main function of which is to increase the size of the electrical signal in order to provide gain.

A single electrode pair will register the auditory evoked potentials and will also register a great deal of unwanted noise. Hence 3 electrodes are used to provide input to the differential pre-amplifiers. One of these is called the "ground" or "common". The other two electrodes are known, as the "non inverting" and "inverting" electrodes respectively. The difference in activity between these 2 electrodes is what which is amplified. Owing to this many of the noise components and other unwanted signals which are common at both electrodes are cancelled out. This rejection of signals common to both electrodes is called Common-Mode Rejection Ratio (CMR). Thus if the auditory evoked potential has opposite polarity at the two differential electrodes it will be enhanced by differential action.

The next step is filtering of the amplified signal to attenuate the noise. Filter is an electronic device which reduces the energy content of an electrical input signal, over some particular range of frequencies. The type of filter used depends on the degree of overlap between the frequency distributions of energy for the AEP and noise. Generally for a click stimulated ABR, band pass filter of 100 - 2000 Hz will be more useful.

Summation and Averaging:- Despite filtering the AEP will be obscured by the background activity and thus has to be enhanced. This is done by summing or averaging the recorded activity following repeated identical stimulus presentation. These operations are best carried out not on continuously varying (analog) voltage output from the filter but on strings of numbers generated by periodically sampling that output. This is called Analog to Digital converter.

Noise and the reliability of Summed or- Averaged Records: –

Unwanted noise (Internal & 6xternal) can affect the reliability of the recordings. Non physiologic Noise sources can be controlled in many ways including electrical shielding of the test enclosure, headphone, cables,electrodes and power lines. Physiological noise sources are more problematic. Procedures for reducing these include careful application/ positioning of electrodes, and manipulation of patients state like sleep, sedation or anesthesia. One way of increasing the reliablity of interpretation of the average record is the "silent" or "no stimulus' run. This run should not produce response like activity.

Once an averaged record has been accumulated the final step is visual inspection of the waveform and measurement of special features such as latencies and amplitudes. A video display of the averaged record, with movable cursor for selection and digital read out of amplitude latency values at selected points is common. Also graphical point out of the records are equally common.

The preceding paragraphs gave a brief overview of the different components of the BSERA equipment and their function. When BSERA testing is done with children, it has been found that several parameters especially stimulus and recording factors, have to be controlled as they can alter the responses obtained.

The factors influencing the ABR response and how they must be controlled are considered below:-

Factors Influencing Normal ABR Responses:—

The ABR response obtained from infants are affected by many factors, chief among which are age and stimulus intensity. Hence an effect of the various factors must be known and controlled if ABR testing is to be completed.

The Factors can be divided into:-

1. Subject factors
2. Stimulus factors.
3. Recording factors.

Subject Factors

a) ABR Maturation with Age:- Much of the normal ABR variability among infants is attributable to Maturation, the significance of this factor being proportional to conceptual age of the child. Variable rates of maturation and imprecise estimate of Gestational Age in preterm infants have brought down the clinical value of test in this population. Yet ABR is being used for providing new information into patterns of human auditory development.

In pre-term period Latency– Age function for wave V has ranged from 0.04 to 0.4 msec/decrease per week. (Schulman - Galambos, & Galambos, 1975 ; 1979 ; Starr et al., 1977), with a general consensus of approximately 0.2ms (Hecox & Burkhard, 1982). For wave I, report of 0.45 ms/week, decrease upto 32 weeks and 0.15 msec/week average to term have been reported (Stockard et al., & Coen,1983).

Maturational changes in the IPL have also been noted. Stockard & WestMore and (1981) have reported considerable variations among subjects between 32 and 34 weeks of CA. The IPL decreased at a rate of 0.45 Msec/week, while at 40 weeks change was less than 0.1 ms/week. Both Absolute latency

& IPL's exhibited decreases in latency from term, (approx , 5.0 msec) to a period between 12&18 mths, when adult values (approx, 4 msec) were reached. (Salamy & Mckean , 1976; Salamy et al; 1982).

b) <u>Temperature</u> :- Hypothermia too can affect ABR response. Central temperature reductions to below 35 °c can produce amplitude reduction and prolonged IPL's . (Stockard, Sharbrough & Tinker 1978 & Stockard & Coen 1983). This problem is particularly acute in low- birth weight Infants, in whom hypothermia is common. Normothermia should prevail during testing.

c) <u>Sex</u> :- Adult female IPL's are comparatively less than those of male's while wave V latencies are approximately 0.2 msec. Shorter (kjaer, 1979 ; Mc. Clelland & Mecrea, 1979). In normal Infant & preadolescent child, no sex differences have been documented. (Jacobson et al.,1982, Stockard et al., - 1983). In case of preterm infants, opinions differ but differences in latency between male & female subjects have been noted. (Cox, Hack & Metz -1981). The differences noted were transient because retesting of the same subjects at 4 mths produced no sex difference.

<u>Stimulus factors affecting ABR</u> : -

1) <u>Stimulus polarity</u> :- Polarity of the stimulus typically used has been either the 6ondensation (c) or Rare faction (R) or alternating. Wave form morphology differences between single and alternating polarity clicks have been recognised (Picton , Stapells & Campbell, 1981; Stockard et al., 1979). Stockard et al. have reported that wave I latency difference between. Condensation and rarefaction clicks averaged. 0.12 msec, for newborns. Also wave I is more affected by phase dependent delays than wave V and hence IPL is affected.

Stockard et al., (1980) have also reported that in,a small percentage of normals, absence of wave or reduction of IV/V : I Amplitude ratio was noted when higher Intensity, rarefaction click stimulation was used and with Condensation stimulus, Amplitude and Morphology normalised in these subjects.

In contrast to this finding, study by Ornitz, Mo, Olson & Waller (1980) have shown that Response to rarefaction clicks were significantly shorter for wave IV than with condensation clicks. Rarefaction clicks induced a significantly earlier wave IV (0.30 msec for 3150 Hz & 0.24 msec for 5kHz) response than condensation clicks.

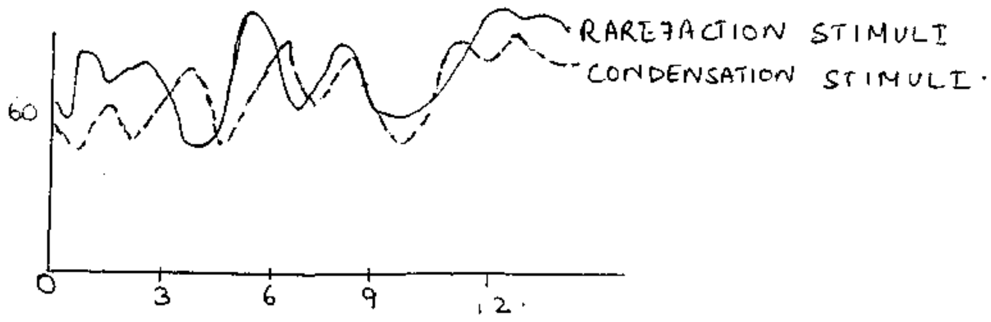


Figure above illustrates the use of alternating stimuli to reduce artifact.

Stimulus frequency :-

Recording of a well defined, high -amplitude whole nerve action potential and ABR depends on synchronous activation of large number of single fibers connecting to ABR generators- Broad band clicks are the most common stimulus used to elicit ABR. These are generated by exciting a transducer with rectangular voltage pulse. (100 Jus- Rise - fall). Though short duration clicks are ideal, frequency Specificity is sacrificed. However, in hearing impaired patient, habilitation/rehabilitation relies on frequency - specific, informantion and clicks can over estimate hearing sensitivity with precipitous hearing losses above 2-3 KHz.

Frequency Specificity:- Brief tones like tone pips, or filtered clicks produce adequate synchronisation, but their short rise-time results in broader frequency spectrum. (Eggermont & Don, 1980). Hence notched noises presented with tone pips can be used to increase frequency specificity. Brief tone stimuli produce poorer thresholds than clicks and are longer in latency (Suzuki, Harai & Horiuchi, 1977). Wave V latency increases with decreases in frequency-for example/ in term newborns, it averaged 10.65 msec at Ik, 8.44 msec at 4K, & 7.87 msec with broad band stimulation (Stockard & Stockard, Coen 1983)

Stimulus Temporality :- Stimulus duration has limited effects on ABR. latency and amplitude as it is an onset response. (Brinkman & Scherg, 1979). Hecox & Burkhard (1982) have reported on/off effects that are peculiar to neonates, but on a preliminary basis. In adults and infants, increasing the rise time increases response latency, while amplitude remains unaffected (Suzuki & Horiuchi, 1981). In neonates however, incresase in rise time produce smaller increases in latency. Cochlear/ middle ear immaturity have seen suggested as factors.(Hecox & Burkhard, 1982).

Stimulus rate :- Changes in stimulus rate affect the latency and amplitude of virtually all ABR components.

Stockard, Stockard & Coen (1983) have reported that in all age group, effect of stimulus rate was dependent on the acoustic phase of the stimulus. Peak latency of wave I in response to rarefaction clicks were unaltered or decreased by higher rates, but with condensation click stimulus wave I was always prolonged at increased stimulus rate. This large R-C latency difference resulted in complete cancellation of wave I when alternating polarity (R+C) clicks were presented at high rates. However wave V regardless of phase increased with stimulus rate. Magnitude of latency shift being age dependent, the IPL was also influenced by rate due to the above.

Slope of latency - Rate function is about 140-163ms/ decade for term infants. (Hecox & Burk hard 1982;) In case of pre-terms, the slope is more steep 227 ms/ decade. (Lasky , 1983). Within restricted intensities (30-70 dB), the L-R is linear and hence expected functions can be predicted based on subjects age.

Stimulus presentation Mode - As Binaural stimulation causes a 60% increase in amplitude while latency is unaffected,it's use has been suggested. Binaural stimulation with clicks an healthy full-term neonates showed that, Binaural Interaction was apparent during waves IV, V & VI, where there was systematic amplitude increases, peak latencies were not significantly affected. This was shown in a study by (Dunn

H.H, MendelSon .T & Salamy .A, 1981) However with bianural stimulation, unilateral peripherial hearing loss and possibly central auditory disorders can be missed. Hence Binaural presentation is not recommended as standard mode of presentation especially in screening procedures.

Electrode configuration :- Position of the electrode interacts with and affects wave from morphology & latency. (Mcpherson, et al., 1984, Stockard, Stockard & Coen, 1983). According to Stockard & Coen (1983), wave I amplitude was significantly higher with vertex to earlobe recording than vertex - mastoid recording. Also ear lobe to earlobe recordings further enhanced wave I amplitude. On the other hand, maximum wave V amplitude is seen with vertical montage -vertex (C2) or forehead F2 to mastoid / earlobe.

McPherson (1984) in his study found that neonatal subjects had longer latencies and greater variability. In neonates waves In, IIn, IIIn, Vn, seen at Mi was shorter than latencies recorded at Cz. These latency differences are greater in infants than in adults.

Electrode Impedance :- General rule for ABR electrode impedance is that values above 5000* os are unacceptable. This is especially true in the case of neonates. However, Eccard & Weber (1983) in a study of 400 newborns with B.S.E.R -examined for skin contact - electrode impedance effects on screening results. Neither high electrode impedance nor unbalanced impedance between the active electrodes appeared to have a significant effect on the screening results. They recommend impedance of less than 10,000* os before initiating ABR testing.

Number of Samples:- Infant's response amplitudes are lower and morphology is immature, than that of adults. Also noise levels are high in nursery settings, hence sample sizes must exceed 2000 for adequate response wave form. (Stockard, Stockard & Coen, 1983).

Frequency filter setting :- This can affect absolute and relative latencies and also amplitudes. When low frequency filter settings (less than 100 Hz) or high frequency filter settings more than 3 KHz) are used, there was a significant decrease in amplitude, increased threshold and shift in peak latencies (Stockard, Stockard & Coen, 1983). Filter settings normally desired is 150-3000 Hz . which can be used in infant testing.

Ambient Acoustic noise : Background masking is a problem in infant testing. Wave I is unaffected by such noise but wave V shows both relative and absolute latency shifts (Stockard & Westmoreland, 1981). To maintain reliability of established norms, testing must be carried out in similar levels of ambient noise (or preferably in quiet).

Ambient Electrical Noise :- Apart from acoustic noise, a number of other problems can arise due to ambient electrical interference which can contaminate or obscure ABR response. To control for these problems, it is paramount that silent runs and trial replications occur.

Contralateral masking :- At high Intensities a contralateral ABR can be seen with a dead ear (Chiappa et al., -1979). This suggests that at stimulus levels above 60-70 dB HL, contralateral masking may be needed to prevent the non-test ear from producing or contributing to the obtained response.

The above are the factors that can affect the test results, and they must be taken care of and properly controlled, so that the results obtained are reliable.

The following chapter will give an insight on the findings of "Brain-stem Evoked Response Audiometry" in normal infant population.

Normative data

Since when Jewett (1970) recorded a series of 5-7 potentials probably evoked by cochlear processes and by auditory relays, B.S.E.R.A has evoked much interest as an audiometric tool in the early diagnosis of hearing loss in both infants and adults. Unlike adult ABR response which is more or less consistent, infant ABR responses (morphology and latency) vary widely and also the response changes with maturation. Additional variables like premature birth both confounds the problem and dictate specific criteria for ABR testing of the infants. Hence there is a need to have age-related normative data before any accurate assessment of infant ABR is possible.

In testing infants (and adults), the response parameters often considered while evaluating the infant ABR responses are a) Morphology b) Latency [Intre aural latency & Interaural latency] c) Amplitude. These different response parameters achieve adult values at different ages. The following chapter gives a brief review on the different response parameter and the age at which the typical adult values are reached. These age-related norms will aid us while testing infants, in determining the thresholds and also whether the responses obtained are normal or abnormal for that age group.

Most of the research on ABR in infants has centered on the following parameters. The response parameters considered in these different studies are:

a) Morphology

b) Absolute latencies of different waves.

c) Interpeak latency.

d) Amplitude (Absolute & Relative amplitude ratios)

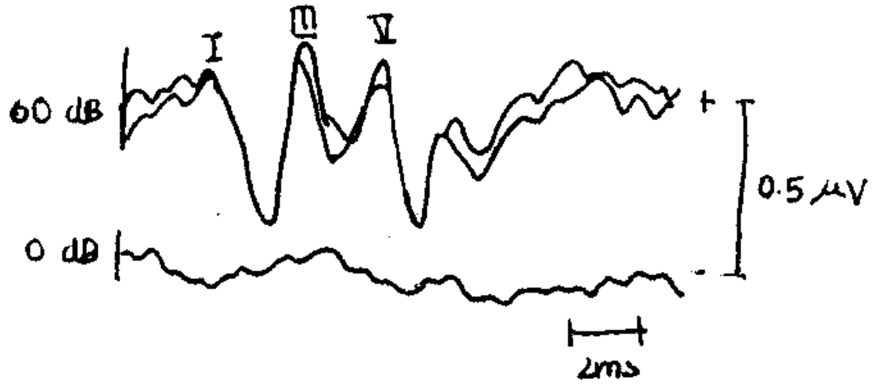
Each of these different response parameters have their own characteristic pattern in infants and adult values /form are reached at different ages. The different parameters have been considered individually in the following paragraphs.

a) Morphology:- The waveform morphology of a typical infant response consists of 3 vertex forehead positive peaks in comparison to 6 or 7 seen in the adult (Jacobson et al; 1981; Salamy & McKean, 1976). These waves correspond to the adult values of I, III,& V given by Jewett Williston designation.

Figure:- I depicts the typical infant ABR response morphology at 60 dB HL.

Paludetti et al., (1981) conducted a study on 59 normal hearing children. They were divided into 4 groups according to age as follows a) 36-41 weeks. b) 1-6 months c) 6-12 months d) 12-36 months. They found that morphology of tracings obtained by delivering the stimuli through head

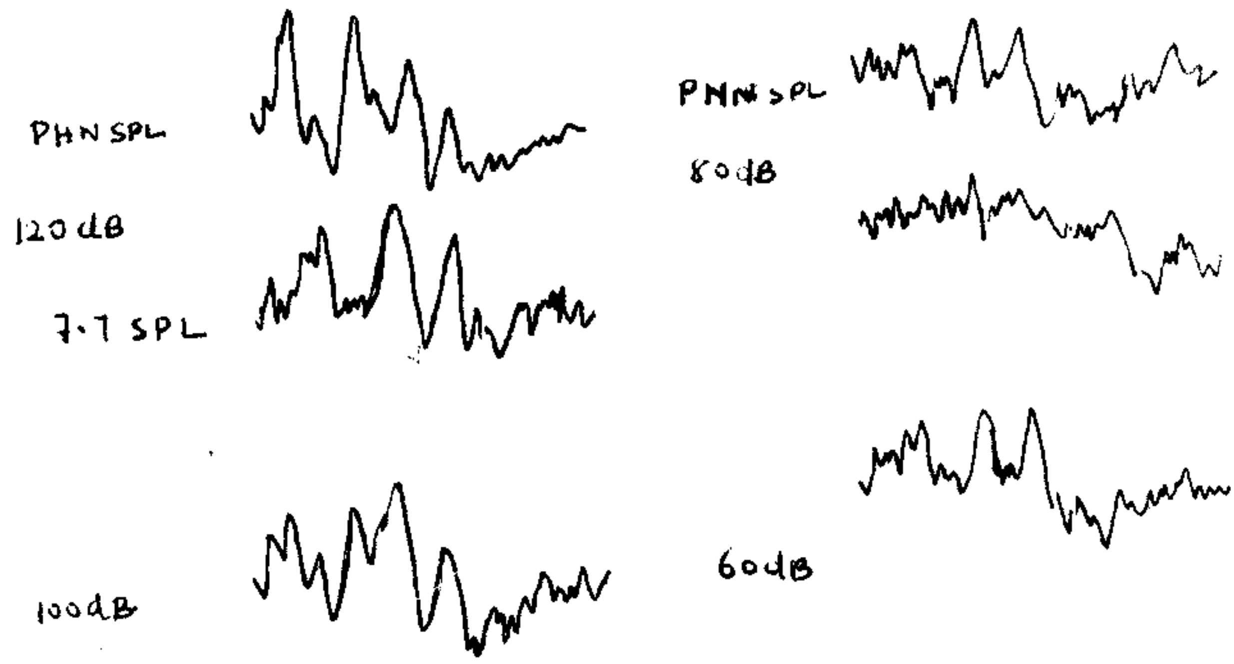
FIGURE I.



TYPICAL INFANT ABR RESPONSE AT 60 dB HL.

PALUDETTI (1981)

FIGURE II.



ABR MORPHOLOGY. AT DIFFERENT STIMULUS INTENSITIES - WITH DECREASING STIMULUS INTENSITIES. ONLY TWO PEAKS ARE ARE DETECTABLE (JII-III, JV) . AT 60 dB ONLY JV APPEARS.

phones became similar to the adult tracings in group 3 and 4. In the first two groups only 3 peaks could be found up to an intensity of 80 dB; near threshold only the 3rd peak remained. This peak is similar to JV seen in adults. The first two intermediate components (JII & JIII) were fused in the first two groups and separate at above 7-8 months of age, thus representing the typical four-peak adult trace. Figure 2 shows the ABR waveform morphology obtained in the four at different stimulus intensities..

Many other studies too have found that infants response morphology consists of only 3 vertex forehead positive peaks. Jacobson & Morehouse (1982) in their study on 124 children with normal hearing whose ages ranging from 40-49 weeks of Gestational &ge found that infant responses consist of 3 forehead positive waves whose latency is a function of stimulus intensity and maturation. He also found that wave II emerged around the 3rd month, and wave V showed signs of wave IV - V separation by the 4th month.

Mjoen (1983) did a study on 212 infants ranging in age from 0-13 years, He recorded the auditory brainstem response of these infants. He too found that in newborns only 3 distinct peaks are identifiable -i.e. the Ist, IIIrd and Vth peak.

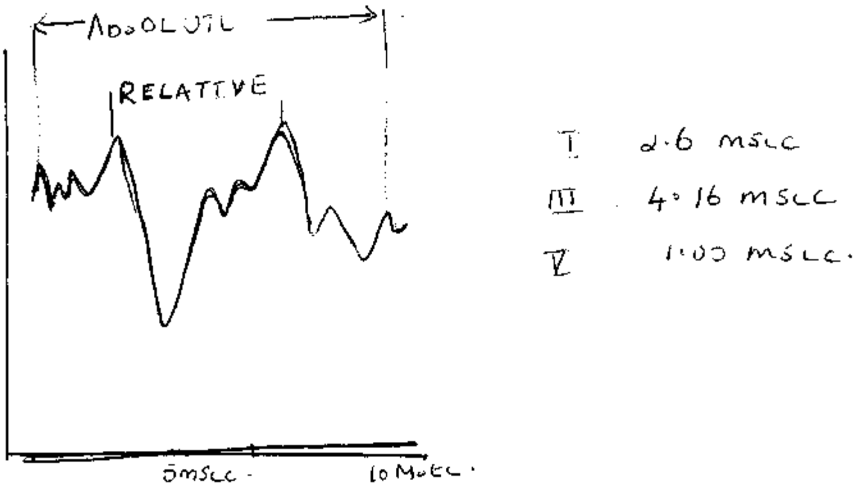
In a study by Rotteveel & Notterman, (1980) ABR recordings were obtained both ipsilateral and contralateral to stimulation. They did the study on 25 healthy newborns, who were about 39-41 weeks of gestational age. ABR's were elicited using 100 usec positive (condensation) clicks presented at a level of 70 dB HL at the rate of 11.1/sec.

They found that, in newborns the wave complex shows a positive-negative composition. Peaks I & II. were fused in the first positivity, peak III emerged from the trough in negativity. Peaks IV & V were fused together and peak VI appeared in subsequent positivity. Wave I was often bifid. In contralateral recordings, peaks II & III were often fused and peak VI became more discernible than in ipsilateral recordings. This is in agreement with the studies of Salamy et al., (1975 & 76); Stockard et al (1981). Peak III is often absent in newborns, but in contralateral recordings, peak III could be got in 21 of the newborns. From 6th week onwards, peak II & III differentiated independently and waveform often changed with age.

Thus many studies have been done to determine the infant ABR waveform morphology. Most of these studies show that infant waveform consists of 3 peaks - Ist, IIIrd and Vth peak. The 3rd peak is similar to the 5th peak seen in adults. Finally, the adult waveform morphology is obtained by about 12 months or 1 year.

Latency:- This is an important response parameter often considered in most of the ABR studies. Latency-refers to the time interval between the presentation of stimulus and the obtained response. Each of the 7 peaks have their own latency value for example - the 5th peak often has a latency of 5 msec in adults. These latency values indicate the speed of transmission of the neural impulses. Depending on which peak shows prolonged / or abnormal latency value, we may be able to detect the site of lesion in the Brain-Stem.

Figure 3 shows how the absolute and relative latencies can be accurately determined. ***



In newborns and young infants, all the ABR wave peaks show prolonged latencies compared to the adult values. With age, the latencies of these different component wave showed a systematic decrease owing to maturation of the central nervous system.

Early researchers while testing newborns found that ABR recordings could be done from premature infants as well. This has led to different studies to determine the exact age of initial appearance of the different waveforms.

Attempts have also been made to devise a set of ABR latencies for different conceptual ages; using which it would possible to predict the latency of any group of children when tested. Weber (1982) did a study on 130 infants and the responses obtained were considered to develop wave V latency forms for different conceptual ages and also wave III latency forms for different conceptual ages. Additional norms were also developed using ABR interwave intervals (I-III & III-V) as indicator of Brain-Stem maturation.

Results of his study suggested that wave III is more appropriate for the measurement of response latency than wave V. They also found that conceptual age is not as satisfactory as inter- wave intervals. ABR inter- wave intervals were found to be a more direct measure of maturation level within the conceptual age pathway. However there is disadvantage in using ABR inter-wave intervals as the basis for latency norms in infants. It masks any neurological disorder which may extend central conduction time. Finally they found that it is difficult to compare the results of one lab with the other.

TABLE : I. (WEBER - 1982)

WAVE V LATENCY NORMS IN MILLISECONDS FOR PREMATURE INFANTS USING CA AS THE MEASURE OF MATURATION

CA at test		INTENSITY LEVEL			
		75 dB nHL	60 dB nHL	45 dB nHL	30 dB nHL
30-33 WEEKS	X̄	8.01	8.46	9.06	9.48
	S.D	0.66	0.54	0.65	0.82
	N	14	12	13	10.
34-35 WEEKS	X̄	7.94	8.36	8.86	9.61
	S.D	0.60	0.54	0.52	0.65
	N.	45.	48	48	42
36-37 WEEKS	X̄	7.69	8.09	8.45	9.01
	S.D	0.48	0.39	0.45	0.36
	N	33	34.	34.	24.
38-39 WEEKS	X̄	7.52	8.00	8.45	9.01
	S.D	0.48	0.39	0.45	0.36
	N	33.0	34.0	34.0	24.
40-41 WEEKS	X̄	7.17	7.54	8.09	8.66
	S.D	0.43	0.44	0.45	0.44
	N	46.	47	46.	42
> 41 WEEKS	X̄	7.16	7.45	7.89	8.50
	S.D	0.48	0.56	0.48	0.56
	N	41	38	39	39.

TABLE-I - WEBER - 1982.

WAVE V LATENCY NORMS IN MILLISECONDS FOR PREMATURE INFANTS USING ABR I-V INTERVAL AS MEASURE OF MATURATION.

I-V INTERVAL (MSEC)		INTENSITY LEVEL 75dB	60dB	45dB	30dB nHL
LESS THAN 5.1	$\bar{X}$	6.96	7.30	7.74	8.35
	S.D	0.38	0.43	0.48	0.58
	N	47	50	48	45.
5.1 - 5.2	$\bar{X}$.	7.31	7.72	8.24	8.90
		0.41	0.40	0.46	0.56
		37	38.0	36.0	36.0
5.3 - 5.4	$\bar{X}$	7.45	7.83	8.31	8.96
	S.D	0.37	0.34	0.43	0.52
	N	37	34.	34.0	27.
5.5 - 5.6	$\bar{X}$.	7.75	8.16	8.61	9.25
	S.D	0.38	0.30	0.44	0.46
	N.	38.	44	43	35.
5.7 - 5.8	$\bar{X}$	7.74	8.26	8.77	9.37
	S.D	0.55	0.27	0.42	0.34
	N.	22	22	22	20.
5.9 - 6.0	$\bar{X}$	7.98	8.50	8.89	9.59
	S.D	0.34	0.29	0.31	0.62
	N	16.	18	16.	12.
> 6.0	$\bar{X}$	8.45	8.91	9.32	10.16
	S.D	0.54	0.35	0.44	0.47
	N	21.	21.	18.	14.0

Table(l).

Table I shows the findings of the above study.

The study done by Stockard & Stockard (1982) has been fairly extensive, and gives a detailed description on the origin and development of different wave components. They did their study on 100 normal full-term newborns (l-3days), 16 normal full-term newborns aged 1-2 months and 62 pre mature infants with no other or minimum perinatal complications at conceptual ages ranging from 28-42 weeks. These premature infants had no detectable hearing impairment when followed up later. Additional ABR was recorded from 324 patients in NICU. ABR recorded was correlated with the type of abnormality at the time of discharge.

Stimuli used were clicks presented at different rates of 5, 10, 30, or 80/sec and levels used were 115dB; 100 & 70 dB pe SPL. If either stimulus failed to elicit a response it was increased in 10 dB steps till ABR threshold was established.

They found that at high intensities and low presentation rates, a small broad wave I first appeared in subjects around 27-30 weeks (CA) and latency was about 0.75 msec longer than new born. Around 32 weeks of CA; wave I averaged around 85 dB SPL. After this age, subjects had recordable wave I with click intensity of 75 dB. Maturational changes with wave I latency was greater when lower stimulus intensity was used (75 VS 115dB pe SPL) and regardless of the stimuli were most pronounced in the early stages of component development. Before 32 weeks of CA, latency-Age function for this component (Wave I). averaged 0.45 msec/week then flattened to average of 0.15 msec/week in the remaining pre-term period. Adult latency values for this wave I was obtained by around 3 months of age.

Along with wave I, around 27-30 weeks, a single slow duration component (79 msec) designated as wave V could be discerned. Wave V lagged behind wave I & wave Va in the manifestation of a well-defined peak. However this peak became more defined and amplitude rose rapidly so that this peak was discernible by 32 weeks. By 32 weeks the IV/IV complex threshold dropped to lower level of 15 dB pe SPL. Wave V latency shortened from the time of first appearance to full-term; more than half the change occurred before 33 weeks of conceptual age. Adult values for this wave (V) are reached by the 1st or 2nd year. Stockard et al., gives the inter lab comparison of normative data of different waves at different conceptual ages. (Table 2)

Study done by Fria. J.J & Doyle (1984) has also traced the course of development of different wave latencies. He did a cross-sectional analyses of component latencies of the Auditory Brainsterm Responses on 466 infants ranging in age

Table 1. Interlaboratory comparison of normative data

CA (weeks)	Reference	Wave I $\bar{X}$	Wave I S.D.	Wave I *N*	Wave V $\bar{X}$	Wave V S.D.	Wave V *N*	I–V IPL $\bar{X}$	I–V IPL S.D.	I–V IPL *N*	Rate	Stimulus Phase	Intensity
32	—[a]	2.31	0.32	8	8.58	0.56	8	6.26	0.39	8	10/sec	R	110 dB pe SPL
	9	2.28	0.43	10	8.04	0.69	7	5.53	0.63	10	10/sec	?	65 dB SL
	3	2.80			8.35						10/sec	?	60 dB HL
33	—[a]	1.93	0.22	14	7.71	0.24	14	5.78	0.21	14			
	9	2.02	0.39	8	7.62	0.47	7	5.34	0.53	7			
	32	2.90			8.20			5.40			10/sec	R + C	65 dB SL
34	—[a]	1.93	0.34	24	7.71	0.36	24	5.81	0.29	24			
	9	1.98	0.29	13	7.51	0.28	8	5.53	0.41	13			
	3	2.55			7.93								
35	—[a]	1.95	0.20	30	7.35	0.31	30	5.39	0.28	30			
	9	1.87	0.23	17	7.52	0.42	6	5.42	0.54	17			
	32	2.60			7.60			5.30					
36–37	—[a]	1.88	0.20	35	7.17	0.27	35	5.26	0.31	35			
	9	1.87	0.27	14	7.28	0.45	11	5.36	0.47	14			
	3	2.50			7.77								
	32	2.00			7.30			5.30					
40	—[a]	1.81	0.22	62	6.72	0.32	62	4.90	0.28	62			
	9	1.64	0.18	30	6.74	0.22	23	5.10		30			
	3	2.28			7.37								
	32	1.80			6.90			5.00					
	29	2.12	0.36	15	7.11	0.28	15	4.99	0.31	15	10/sec	R + C	55 dB HL
40	—[a]	2.15	0.21	30	6.93	0.32	30	4.79	0.20	30	10/sec	R	100 dB pe SPL
	—[a]	2.47	0.22	30	7.23	0.36	30	4.76	0.28	30	10/sec	R	90 dB pe SPL
	—[a]	2.83	0.26	30	7.62	0.42	30	4.79	0.32	30	10/sec	R	80 dB pe SPL
	—[a]	3.45	0.38	30	8.10	0.46	30	4.65	0.30	30	10/sec	R	70 dB pe SPL
	—[a]	1.94	0.25	55	6.71	0.27	49	4.79	0.30	49	10/sec	C	110 dB pe SPL
	—[a]	2.06	0.24	48	7.19	0.32	48	5.14	0.36	48	30/sec	R	110 dB pe SPL

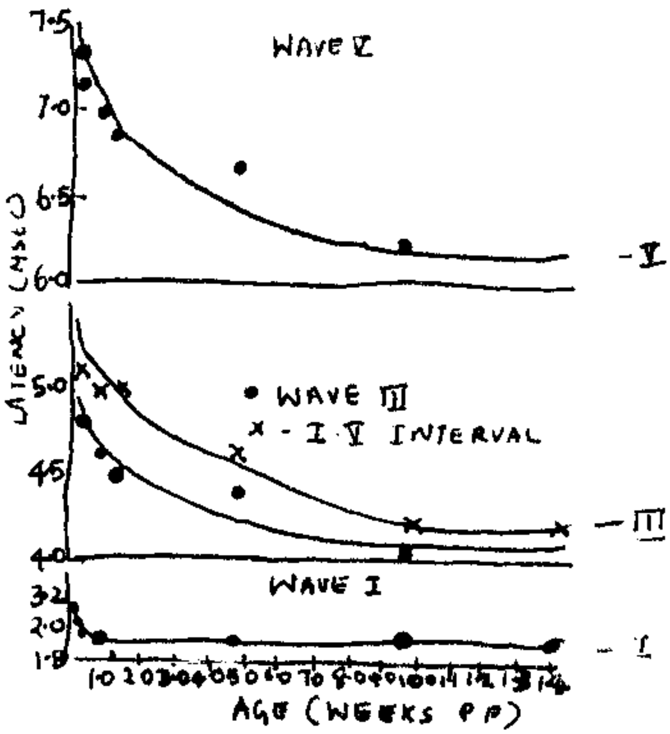
	Average Wave V L-M Function Slope[b] (msec/week) Conceptional age range (weeks)			Average Wave V L-I Function Slope[c] (μsec/dB) Conceptional age range (weeks)				
Reference	31–32	34–40	Reference	32–33	34–35	36–37	Term	Intensity range
—[a]	0.73	0.16	—[a]	41	37	34	34	70–110 dB pe SPL
9	0.73	0.15						
3	0.33	0.09	3	55	48	36	35	30–60 dB HL
31	0.40	0.12						
10		0.11						
19		0.07						

[a] *Present study.*
[b] *L-M = latency-maturation.*
[c] *L-I = latency-intensity.*

(FIGURE: 4

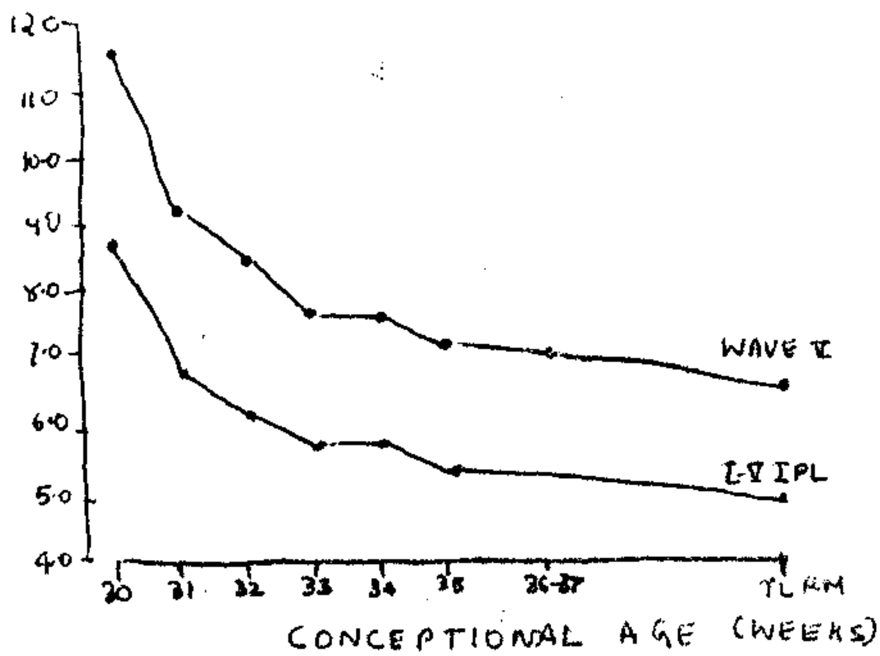
MATURATION OF ABR- DIFFERENT COMPONENT WAVES.

FIGURE: 4



WAVE I STABILISES AT 10WEEKS POSTPARTUM. WAVE III & V LATENCIES CONTINUE TO DECREASE BEYOND THIS AGE.

FIGURE - V



V	$\bar{x}$	11.60	9.31	8.58	7.71	7.32	7.17	6.72
[illegible]	$\bar{x}$	[illegible]	[illegible]	6.26	5.78	5.81	5.39	5.26

from 30 weeks post conception to adulthood. They were divided into 8 age groups; and change in latency of various ABR waves (I,III&V) as a function of age was noted. Their findings too supported the concept of two maturational stages:- an early rapid stage which ended at 8-10 weeks post partum, by when wave I got stabilised and the second more gradual stage which stabilised by the 3rd year of life.

Figure 4 and 5 show the course of change in latency of wave I and wave V at different conceptual ages.

Study by Jacobson & More house (1982) too confirms the findings of the above reported studies. He recorded ABR's from 124 normal ears whose ages ranged from 40-49 weeks of gestational age Unfiltered clicks were used as stimuli.

They found that absolute latencies were prolonged in all the age group studied, and decreased as gestational age increased. However, the only exception was wave I which approximates adult latency by 2 months of age. They recorded mean latency shifts of 0.25, 0.18 & 1.41 msec for waves I, III & V as gestational age increased. The following table gives the change in latency value of different waves at different conceptual ages.

	I		III		V	
Age (Weeks)	60 dB	30 dB	60 dB	30 dB	60 dB	30 dB
40 - 41 (mean)	2.23	3.28	4.84	5.73	7.16	8.20
42 - 43 (mean)	2.24	3.27	4.76	5.74	7.11	8.15
44 - 45 (mean)	2.24	3.27	4.72	5.61	6.93	7.91
46 - 47 (mean)	2.13	3.16	4.71	5.56	6.71	7.85
48 - 49 (mean)	1.98	2.98	4.66	5.63	6.72	7.73

From the above table, we will find that latency decrease for waves I & III are only 0.25 msec 0.18 msec respectively, while wave V shows a latency decrease of 0.44 m sec. Wave I reaches adult latency value by 48 weeks of age, while wave V contained to decrease in the age ranges studied. It reached adult value at 1 year. This finding is in confirmation of the earlier reported study by Fria & Doyle.
Fig (6) illustrates the above findings graphically.

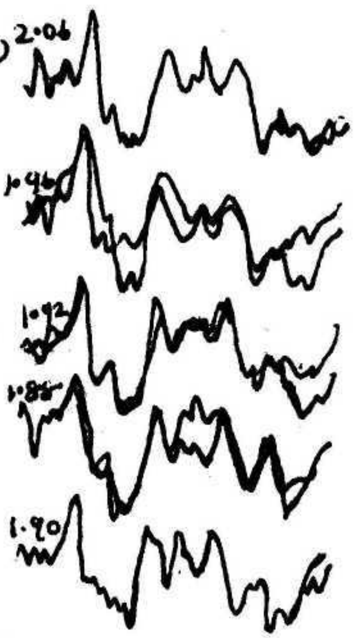
Paludetti et al (1981) did a study on 59 children diagnosed as normal. He wanted to observe the age related variations of the various ABR parameters due to maturational development of the auditory pathways & compare these with normal adult values. He had divided the children into 4 groups according to age as follows a) 36-41 st week : b) - 1-6 months c) 6-12months d) 12-36 months.

They found latency values of JI peak at 100 dB showed a slight progressive decrease with increasing age. However for wave V the decrease in latency value with increasing age was

JACOBSSON & MOREHOUSE (1982).

FIGURE:- 6.

EFFECTS OF MATURATION ON INFANT ABR TRACINGS RECORDED OVER A 2-MONTH PERIOD. LATENCY DECREASES WERE OBSERVED, AS AGE INCREASED, THOUGH TO A LESSER DEGREE FOR WAVE I.



GESTATIONAL AGE (WEEKS)	LATENCY (MSEC) WAVE V	I-V
40	6.52	4.70
41	6.68	4.72
42	6.62	4.70
43	6.56	4.68
47	6.48	4.58

far more greater, and there was significant decrease in latency between groups. Group I had a latency of 7.3 7 msec; Group 2- 6.63 msec, group 3-6.46 msec; & group IV-6.08 m sec.

Thus this study also supports the findings of earlier reported studies by Jacobson & Morehouse (1982); and Stockard, Stockard & Coen (1983).

Thus many studies have been done on prematures to trace the origin and development of the different waves. In many of the studies, wave V-has been often considered as this response is not susceptible to fatigue or sleep, & it may be useful in evaluating auditory function in high risk newborn infants.

Some of the findings of the different studies on wave V latencies are as follows. Schulman-Galaambos & galambos found that Wave V changed in latency from 8.5 msec at 34-35 weeks of gestation to 7.30 msec at 40-42 weeks of gestation. Starr et al (1975) reported that wave V changed in latency from 9.9 msec at 26 weeks of gestation to 6.9 msec at 40 weeks of gestation. Similarly, Cox et al (1981) reported that wave V changes in latency from 7.9. m sec at 33-34 GA to 7.65 at 39-40 weeks of geStational age.

Often the studies have been done on prematures. There has been a controversy whether BSERA responses obtained from premature babies are different from full term newborns. . Some studies indicate increased latency values on the prematures compared to term newborns while few other studies have failed to demonstrate any significant difference between the two groups.

Morgon & Salle (1980) did a study on 15 prematures to study the influence of gestational age and weight. Age range of the prematures were found to vary from 30-42 weeks of GA and weight from 1100-2050 gms. They found that irrespective of GA or Birth weight, Jewett Vth wave could be identified provided high intensity recordings could be done, and when the baby is calm, JV could be traced till 30 dB. Three intensities of 80, 60 & 50 dB SPL were selected for the study of latencies. As hearing matured, it was found that latency of JV and JV-1 interwave value diminished. Thus gestational age was found to be an important factor, but the influence of weight was not known. They also found that premature babies do not have the same latencies at full-term as the newborn baby.

However, few similar studies done have failed to support the above quoted finding. In a study by Kaga .K, Hashira.S, & Roger. M.R ; 25 pre-terms with post conceptual age of 40 weeks were studied. 12 of them were of appropriate weight for gestational age and 13 were of small weight for gestational age. (SWD). They were matched with 84 full term normal newborn babies of post-conceptual age- 40 weeks. Latencies of 1st, Vth peak and also I-V interval were measured. Contrary to the earlier study, this study failed to show prolonged peak latencies or central conduction time. In other words latencies were not more prolonged with the earlier gestational age at birth. This study did not find any difference between ABR maturation inside & outside the uterus as long as ABRs of full-term and pre-term babies are compared at around 40 weeks of post-conceptual age. Thus if, ABR is found to be prolonged, compared to age matched controls, it is indicative of physiological sign of unusual brain development or Brain-stem or Cochlear.

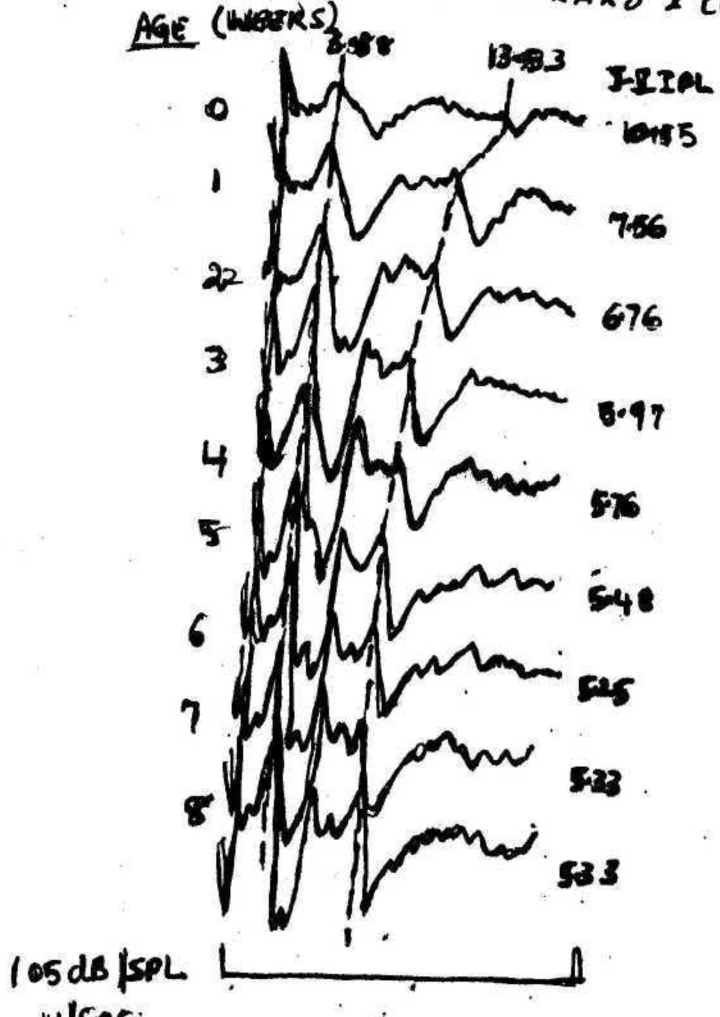
Conclusions:–

1. Different waves have origin at different time intervals. These waves can be identified even in pre term/premature infants. Wave I could be identify around 27-30 weeks of conceptual age, while wave V made its first appearance at about 32 weeks of conceptual age.

2. Latencies of the different wave components decrease as age increases. Wave I reaches adult value by about 3 months of post-partum age, while wave V reaches adult latency value by 2-3 years of age.

FIGURE:- 7.

IPL MEASUREMENTS - NORMATIVE DATA.
(STOCKARD, STOCKARD & COEN - 1983)



Serial ABR in a premature control Infant.
Showing maturation of I-V IPL.
Maturation curve flattens at 33 weeks CA

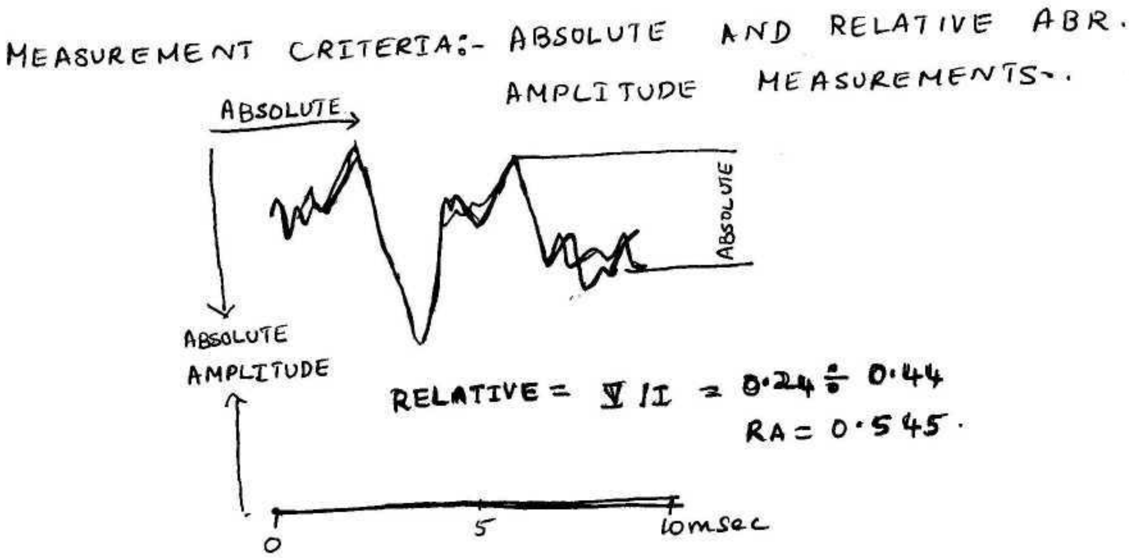
The following fig:7 shows the changes in Inter peak latency value with age.

Summary:- 1) IPL decreases with age.

2) Adult values are obtained around 12-18 months.

Amplitude:- An important parameter often studied is the amplitude. Generally largest amplitudes are seen in infants and smallest in resonates; and those of adults fall in between.

****(Fig: 8)



When absolute amplitude values are studied, infants have wave-V which is considerably smaller than the adult wave V at comparable intensities; but infant Wave I may be twice that of adult amplitude. In infants, the amplitude variability is greater due to a large number of factors. Amplitude ratios too have been determined similar to adults. It has been found that the amplitude ratio is smaller in infants (<1). Adult values are reached around the 1st year of life.

When different waves are separately considered, amplitude of Wave I doubles during the first two weeks after which it reaches a steady value.

Salamy et al (1979) have reported that wave I amplitude reaches a plateau at approximately 3 months of age and decreases through adulthood. In contrast, wave V develops more slowly and peak amplitude of this wave is not reached till 12 months. Wave III develops similar to Wave I, but Hecox & Burkhardt (1982) report that Wave III parallels Wave V in development.

In a study by Jacobson, J.T, Morehouse, C.R. and Madeline, J.J (1982), ABR's were obtained from 124 normal ears who ranged from 40-49 weeks of GA. Both mean absolute amplitude and relative amplitudes were found.

The following table gives the value of absolute and relative amplitudes obtained at different gestational ages.

3. In the initial pre-term period, slope of the latency-Age function tends to be steep, but as age increases slope decreases or rate of decrease reduces.

4. Latencies of the premature babies and normal full-term infants do not differ much, as long as they are compared at identical Post Conceptual Ages.

Interpeak Latency Differences:— (IPL)

With maturation of the auditory pathway, the component latencies decrease and it has been found that 1-V interval too decreases and progressively reaches adult values. Schulman-Galambos and Galambos (1975) have shown that central conduction time (CCT) in the auditory pathways decreased with maturation from 7.2 msec at 26 weeks to 5.2 msec at 40 weeks. Cox et al (1981) have reported that C.C.T decreased from 4.55 m sec at 33-34 weeks to 4.70 m sec at 40 weeks. Other studies too have confirmed the finding that C.C.T decreases as age increases and adult values for this are obtained around 12-18 months of age.

Paludetti (1981) did a study on a group of 59 children diagnosed as normals. They were divided into 4 groups according to age. 36-41 weeks, 1-6 months, 6-12 & 12-36 months.

The I-V interval values obtained for the different groups are shown in the table below :-

	120 dB SPL	100 dB SPL
Group 1 PHN	5.30 ± 0.55	5.40 ±0.57
77	5.79 ± 0.61	5.32 ±0.67
Group IIPHN	4.47 ± 0.29	4.90 ± 0.14
77	4.96 ± 0.72	4.98 ±. 0.57
Group III PHN	4.50 ± 0.18	4.72 ± 0.15
77	4.58 ± 0.27	4.59 ± 0.22
Group IV PHN	4.24 ± 0.35	4.29 ± 0.37
77	4.35 ± 0.48	4.16 ± 0.60

They found that group I differs significantly from all the other 3 groups in the values, while there was a minor but yet significant difference between Group 2 and Group 3 & 4. No significant difference could be obtained between groups 3 & 4 and normal adult values.

JV-JI interval has been considered as an important index of maturational process by Salamy. et al (1975) and this is confirmed by the results of this study which showed a statistically significant increase in Group I children when compared to those belonging to groups 2, 3 and 4.

Rotteveel, Notterman and Stoelinga et al (1981) did a study on 25 healthy newborns in the age range of 0-3 months. They tried to determine at which structural level changes occur more. For this they studied different inter-peak intervals - I-II; II-III, II-V, I-V

They found that IPL of I-II & III-V did not alter much in the age group studied but II-III, II-V & I-V did. Thus there may be greatest change from 0-3 months at the level of cochlear nuclei and superior Olivary complex - both major generators of II & III peaks. In this study, contralateral recordings too were done and they found that IPLD IIc-vc is almost equal to IPLD II-V both at term and at 3 months.

Findings of many studies concerning change in interpeak latencies with age are similar . Most of the studies show that change or decrease in IPL values with age is entremely rapid in the initial few weeks but soon becomes less rapid, so that adult values are reached around 12-18 months of age. For Example:- Jacobson & Morehouse (1982) found that with the exception of I-III interval; all the other inter wave intervals - I-V & III-V showed decrease in latency with age. Mean I-V interweave interval decreased a total of 0.22 msec from 4.94 to 4.72 msec, at 60 dB & 0.16 msec at 30 dB.

Stockard, Stockard & Coen (1983) in their study also found that in infants of 30-31 weeks of conceptual age, I-V IPL varied widely but averaged around 7.3 msec with 110 dB pe SPL. More than half of the IPL shortenings were in the last 10 weeks and occurred before 33 weeks of conceptual age.

	I		III		V		Amplitude ratio: V II	
40-41	0.60	30	60	30	60	30	60 dB	30 dB
Weeks	0.30	0.21	0.07	0.06	0.22	0.18	0.75	0.74
42-43 Weeks	0.29	0.19	0.08	0.07	0.22	0.18	0.76	0.92
44-45 Weeks	0.27	0.16	0.06	0.06	0.23	0.18	0.87	1.11
46-47 Weeks	0.25	0.17	0.06	0.06	0.23	0.19	0.92	1.12

In general absolute amplitudes increased at higher presentation levels. While amplitude of Wave III & V increased, Wave I exhibited an orderly decrease as age increased.

Comparison of Adult and Infant Wave amplitudes produced large discrepancies between comparable waves. Infant Wave V amplitudes are approximately 1/2 half that of adult wave at equal intensity levels. However, in case of Wave I amplitude, full-term newborns have amplitude twice as those of adult Wave I response. Increased amplitude may; be due to smaller head circumference. Wave I amplitude decreased as a function of maturation. The infant V/I Relative Amplitude Ratio in the present study increased as age increased at both presentation levels. The effect continued but fell short of adult values in the age-range studies.

Study was done by Rotteveal, C.J. & others (1986) - on 25 healthy newborns who ranged from 39-41 weeks of GA. He found that amplitudes at term date was 0.12 ± 0.06 mv for peak II & 0.22 ± 0.08 mv for (V) and at 3 months, peak II was 0.13 ±. 0.07 mv and 0.23 ±. 0.09 for peak V. The amplitude ratios (V/1) and absolute amplitude values at birth (Mean & S.D) and at 3 months did not differ significantly in the age range studied except for peak VC. This is in contrast to the earlier studies reported by Salamy et al and Jacobson (1982) which showed changes in amplitude value as age increased till it finally reached a plateau.

Threshold:- It is the lowest intensity level at which a reliable Vth peak can be detected. This is one of the most important parameter and it is used in determining the presence of hearing loss. Galambos & Galambos (1979) have found that J V wave occurs at stimulus intensities which are slightly higher - 10-15 dB more than normal adults. JV occurs at about 45-55 dB SPL in newborns while absence of response in a newborn to a 60-70 dB stimulus must arouse a strong suspicion of hearing loss (Mokotoff, 1977).

Study by Morgon & Salle (1980) has also shown that in their testing of 15 prematures, whose ages ranged from 30-42 weeks of GA, the pattern clearly showed Jewett 5 Waves, provided high intensity recordings of 90 or 80 dB were used. When the baby is calm, it was found that JV wave could be followed as far as 30 dB without any risk of error and in favorable conditions as far as even 20 dB.

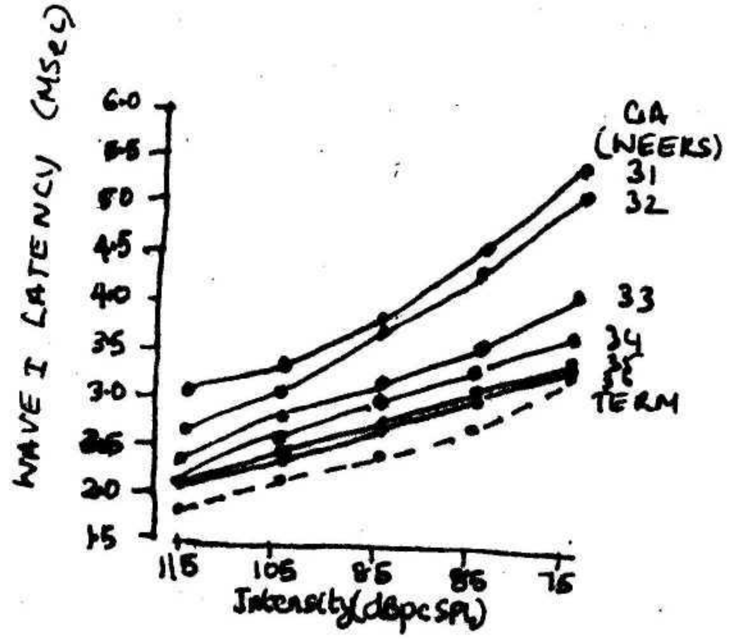
Mjoen.S. (1981) did a study on 212 infants on whom he did ABR recordings. They were divided into different diagnostic category. They found that 20 % did not reveal ABR at 60 dB HL. In 15 % threshold level was between 40 - 60 dB HL. Remaining 60% were judged to have normal functioning peripheral auditory system with ABR threshold equal to or better than 30 dB HL.

The NICU group, in this study revealed a high incidence of non responding ABRs. 10 at risk neonates revealed elevated ABR threshold between 40-60 dB HL and in 11 no ABR appeared to 60 dB clicks in either ear.

In conclusion most of these studies have shown that full-term healthy & normal newborns yield ABR to click intensity of 20-30 dB HL. This is estimated to be about 15-25 dB above the ABR threshold for adults. Also the ABR threshold found within the first day of life were within the range of 10-20 dB HL . However, in prematures and small for dates, ABR thresholds are found to be higher.

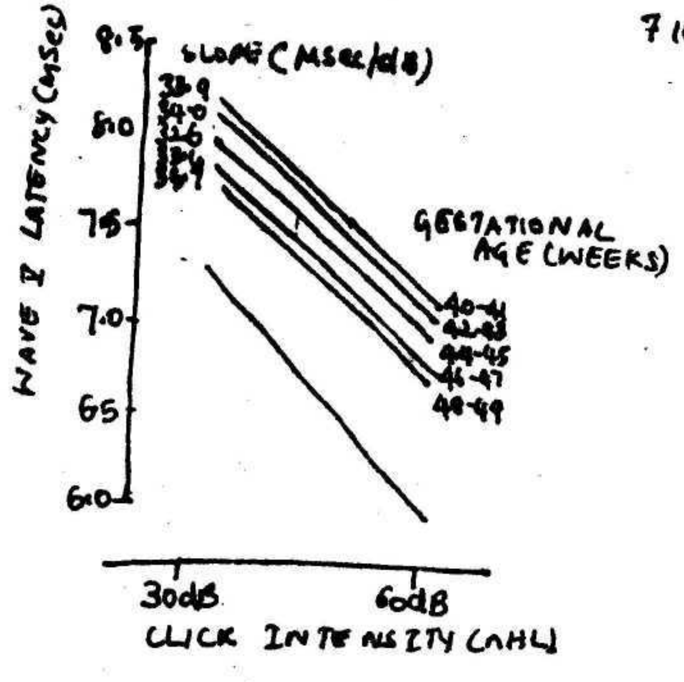
STOCKARD, STOCKARD & COEN (198

FIGURE: 8



WAVE I LATENCY PLOTTED AGAINST STIMULUS INTENSITY IN PREMATURE SUBJECTS STUDIED SERIALLY.

FIGURE: 9



WAVE V LATENCY - INTENSITY CURVE FUNCTIONS PLOTTED FOR FIVE 2-WEEK GESTATIONAL AGE PERIODS.

Latency- Intensity Functions:- Slope of the infants wave V latency-intensity function has been the subject of considerable attention and disagreement. In adults, L-1 function has been reported to be about 0.28 & 0.40 m sec/10dB respectively, while Stockard, Stockard & Coen (1983) have reported a case of 0.14 msec/dB. In infants slope has been demonstrated as being approximately 0.007 msec / dB slower than in adults. They have also reported the slope in pre-term infants to be steeper than in term newborns. Lee and Cox (1982) however found that pre term latency-intensity functions were identical to those of 1-2 months old infants.

Fig-8 and Fig-9 show the changes in the latency - Intensity function at different Gestational Ages.

Findings of the latency-Intensity functions by Stockard Stockard are in accordance with those of Schulman-Galambos & Galambos (1975). They found that newborns showed an average shift in the 40 dB range of 36 u sec/ dB as compared to 28 u sec/dB in adults. Findings of this study are in contrast to that of Hecox (1975) who found a more shallow Wave V slope in newborns (28 msec/dB) than adults (44 msec/dB).

Early detection of hearing loss is a must as without adequate auditory input, the infant cannot receive and hence process those fragments of speech and language which form the conceptual foundation for growth of communication. In order to detect the presence of hearing loss as early as possible, it is necessary for screening newborns for congenital hearing loss. During the 1970s after the 'Novascotia' and Saskatoon* conference on Newborn screening, ABR was considered to be a viable test for newborn hearing population.

Schulman-Galambos & Galambos (1979) have given reports on ABR neonatal hearing screening programme. They screened 220 normal term infants and 75 newborn infants previously confirmed to the Intensive-Care nursery. Stimulus used was a series of 100 msec clicks presented at intensity levels of 60 dB & 30 dB respectively to each ear. They could get response in 368 ears. 85% of all responses were judged to be fair or better. Of the total 75 in intensive care nursery, 21 were "at risk for hearing loss", Out of this total tested,4 were found to be severely hearing impaired in whom later tests revealed irreversible SN hearing loss. Their study also showed that at about 40 weeks of Gestational age, BSERA to clicks can be recorded at about 20 dB. Infant threshold is about 10 dB more than the adult. Response at 30 dB indicates normal cochlear function. If response is got at 40 dB and not at 30 dB, the child can be thought to have mild conductive problem.

In most of the BSERA studies, presence or absence of the Vth peak in one or both ears at a given stimulus intensity is looked for. Generally, all screening procedures use only a pass / fail criteria; and one or two cut off points are used. For instance most of the screening ABR is done at 40 or 30 dB n HL; only one study used a level of 25 dB n HL. (Shanno, Goldstein et al, 1984).

There have been different views regarding the population who should be screened using BSERA. Galambos (78) has suggested that every newborn suspected to have hearing impairment must be screened . However there is general view that children who fall under this category of 1) graduates of NICV, 2) those who appear on High-risk register 3) Those who fail behavioral screening. 4) Suspected for hearing loss due to some other reason must all be screened.

Also most of these studies use two cut off-points a) Lower cut off around 30 dB 40 dB nHL; b) Higher cut off intensity of 60 or 70 dB nHL. Few may pass the screening at higher value of 70 dB nHL but fail in the screening procedure when lower cut off value of 40 dB nHL is used. Such children may be those who have mild hearing problem or problem which may be a transient one. The following table illustrates the different screening studies that have been done using ABR.

Study		N	pass	fail	%	Cutoff
Schulman-Galambor, & Galambor,	1979	75	71	4	5.33	30
Jacobson-Seitz, Mencher & Parrott	1981	96	84	12	12.50	30
Galambos, Hicks & Welson	1982	890	749	141	15.84	30
Myotn-Langset-Tangs-ed & Sundby	1982	60	50	10	16.67	40
Roberts Davis, Phon. petal	1982	75	31	44	58.67	40
Alberti, Hyde Coel.-metal (1983)	1983	234	204	30	12.82	40 dB
DurleKP&K-Smith, Edwards,Hyde	1983	1564	1270	294	18.80	30 dB
Stein, ozdamar, Kraus & Paton	1983	100	89	11	11.00	40 dB
Dennis, Sheldon, Toubas & Mecaffee	1984	200	177	23	11.50	30 dB
Shannon, -Felix., Keumholi etal	1984	168	147	21	12.50	25
Fria, Kurmin, Ashoff & Senclarr Griffith	1984	500	434	66	13.20	30
Jacobson & Moreh-ouse	1984	176	141	5	19.88	30

It has been well established that B.S.E R.A can be used effectively as a screening tool. Bradford, Boudin & Conway et al (1985), did a study on 117 Mewborn infants of less than 33 weeks of Gestational Age. Potentials were found to be absent in 10 of the 117. Out of the 10, 9 were found to have SN hearing loss and I had severe otitis media. On rechecking, none of the 107 had hearing loss. On the basis of their findings they concluded that BSERA is an accurate method of identifying SN hearing loss in very pre term infants.

Levi, Tell & Feinir Esser (1983) did a study in which they have used BSERA along with behavioral audiometry for early detection of hearing loss in infants and young children. They compared 65 hearing impaired children for whom both the behavioral audiometry and BSERA were available. They found correlation between the two in 61 of children; and in a second comparison of 27 infants, 23 were found to be at risk for hearing loss. Hence the authors recommend the use of BSERA as early as possible especially in infants classified as at risk for hearing loss.

Despite the above reported findings, not all studies have shown the BSERA to be an indispensable screening tool. Abramovich, Hyde & Alberti et al (1987) did pre-discharge screening on infants using click stimuli presented at 30 and 40 dB nHL. At 3-4 months follow-up detailed BSERA was done to assess the stability of predischaege findings. In this threshold for clicks, tonepip of 500 Hz & 1 KHz. were determined. When these findings were compared with the pre-dischange findings, they found that at both intensities the failure rates halved in the latter group. They suggested that environmental effects, such as ambient noise might have contributed to considerable failure rates in the initial screening. Hence, they recommend that screening must not be done in newborns as it has substantial inherent inaccuracy. Instead of this, detailed audiometric evaluation can be done straight at 4 months and subsequent habilitation can be initiated if needed.

Summary: l) On the whole most of the studies show that ABR can be effectively used for screening procedure.

2) Screening level recommended is 30 or 40 dB HL. Testing is done at single frequency-either 4 KHz or 500Hz is chosen.

3) ABR can be used along with High Risk Register in a pediatric set-up. however, its usefulness or specility depends on repeated testing and follow up.

ABR using Bone—conducted stimuli:- While doing testing with BSERA, we often find discrepancy between initial ABR screening & follow up testing. This may be possibly due to

1) Middle ear infections found in the ICU.

2) Infant BSERA is difficult to identify & separate as the infants auditory system is not mature at birth.

Under such conditions, Bone-conduction BSERA have been found to be useful. Apart front this, Bone-conduction BSERA helps in identifying any conductive component present in the hearing loss.

However there are certain pitfalls in using B.C stimulil-
1) When bone vibrator is driven at high intensities, there may be generation of huge stimulus artifacts which may obscure the 1-2 msec of ABR .

2) There is also subject variability in transmission of vibratory stimuli mainly due to individual difference in skull impedance.

3) Interpretation of B.C ABR is difficult as the skull and auditory system are undergoing changes during the early stages of life.

Hence knowledge of the developmental aspects of Bone Conduction ABR is needed. Research has been done to evaluate the effects of various vibrator placement on BC ABR and to estimate the interaural attentuation of B.C. stimuli during early period of life.

A study has been done by Edward Y. Y., Allen, R.I and others (1987) using B. C. stimuli. Subject groups included were newborns, 1 year old and adults. Different placement sites for vibrator was used which included frontal, occipital & temporal bones. In the latter vibrator was placed ipsilateral to reference electrode.

In neonates temporal bone yielded shortest Wave V,while frontal yielded the longest. Wave V latency from AC ABR was longer than from bone stimulation.

In 1 year old & adults, temporal placement showed the shortest latency. Wave V latency for air conduction was shorter than from bone conduction at click levels of 35 dB nHL.

Studies have also been done using B.C stimuli on prematures. In a study by Hooks & Weber (1984) 40 premature infants were tested with both air & bone conducted stimuli. Bone-conducted stimuli resulted in a more identifiable. ABR and greater number of subjects passed the hearing screening. B.C audiometry is feasible technique with premature infants. Due to lower frequency composition of the bone conducted click, it may be more effective than AC stimuli when an immature cochlea is being evaluated. BC ABR was observed even at 30 dB HL. & the mean latencies were actually shorter than A.C. ABR.

These studies show that Bone conduction ABR can be used especially while testing neonates & prematures, as they show better responses with Bone-conduction than A.C stimuli. Also, the presence of conductive hearing loss can be effectively ruled out.

Summary: Above chapter gave a brief review on the findings of BSERA in children with normal hearing. Following chapter will give a review of the different ABR findings in other infant populations namely those with hearing loss and the multiply handicapped.

CHAPTER IV

ABR IN THE MULTIPLY HANDICAPPED POPULATION

The major audiometric application of the auditory brain-stem response (ABR) is with the difficult to-test patient ie., The infant at risk for hearing impairment or the child too impaired physically or mentally to cooperate for behavioral testings. Though the clinical value of ABR with both the infant and multiply handicapped was recognised early (Hecox & Galambos, 1974; Schulman, Galambos-& Galambos, 1975) the potential of ABR with the multiply handicapped is only now beginning to be fully realised.

ABR is both a test of audiological and neurological function. Thus it offers a means to identify hearing loss, and in addition, it provides information on the neuroanatomic. or neurophysio Logical nature of the pervasive brain dysfunction suggested by the sensory, cognitive and motor deficits found among the developmentally disabled. Finally, it may also reveal forms of auditory processing deficits unique to sub- populations of the retarded, or children with language learning disorders.

The following chapter gives a brief review on the ABR findings in children with hearing problems of different types. ABR findings in children on the following areas have been considered in detail.

BSERA findings on:-

1) Children with conductive hearing loss.

2) Children with SN. loss (Cochlear & Retrocochlear pathology).

3) Other special populations.

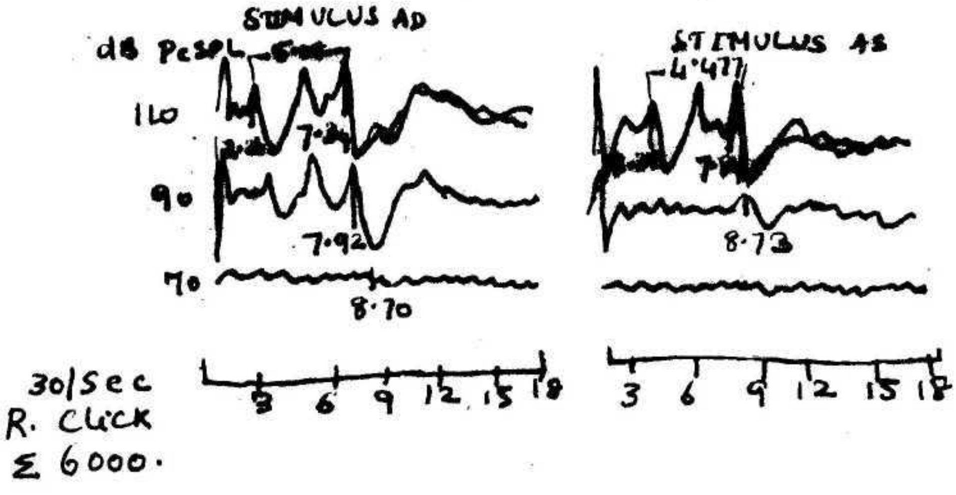
- Autism.
- Deaf-blind.
- Downs Syndrome.
- Mentally retarded.
- Leaning disability.

4) Hearing loss resulting from diseases or infections like Meningitis; certain Syndromes in which there may be brain-stem lesion have also been considered.

STOCKARD, STOCKARD & COEN (1983)

FIGURE: a.

FINDINGS IN A 5 MONTH OLD CHILD WITH SEVERE OTITIS MEDIA

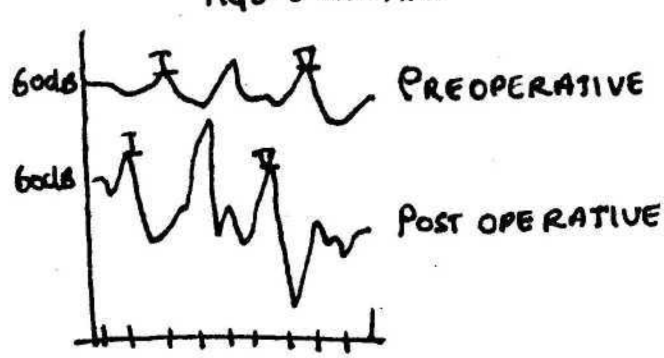


WAVE I LATENCY PROLONGATION WITH AS STIMULATION AND INTERAURAL ASYMMETRY OF WAVE I LATENCY was seen. WAVE I AMPLITUDE WAS NORMAL & LATENCY - INTENSITY FUNCTION WAS WITHIN NORMAL LIMITS.

FRIA-SABO (1984)

Figure (b)

AGE-6 MONTHS.



POSTOPERATIVE LATENCIES OF WAVE I & V HAD DECREASED CONSIDERABLY

Let us consider each one in detail.

1) <u>Conductive hearing loss:-</u> Any abnormality in the external or middle ear will result in a delay in transmission of sound into the internal ear. As a result, a pure conductive loss gives rise to prolongation of the absolute latencies of all the waves; with essentially normal latency intensity function slope. Threshold elevation and amplitude diminution are often minimal. As there is a high incidence of middle ear effusions in infants, ABR abnormalities are very common in these patients. Wave I latencies generally tend to be more prolonged than wave V resulting in a slightly shortened 1-V I PL values. In cases of pure conductive type deficits Wave I & Wave V thresholds are below 95 dB SPL. The above findings have been reported by Stockard, Stockard & Coen (1983). Fig: a - shows the findings of ABR in a child with otitis media.

Fria, T.J, Sabo, (1984) did an ABR study on 14 infants and 12 school-age children with history of recurrent acute otitis media with effusion. Stimulus used were clicks with alternating polarity presented at the rate of 23/sec. Preoperative results showed that Wave I was either not discernible or it showed prolongation in about 14 of the 17 ears found to have otitis media with effusion. Wave V latency too tended to be prolonged in all the 20 ears containing fluid; however the correlation between Wave I latencies and conductive hearing loss was greater compared to wave V. Post operative measurements showed that the latencies of wave I & V had decreased considerably, (Figure 8)

The following table gives the latency values obtained preoperatively and postoperatively.

ABR Measurement (msec)	ABR OME	Wave NO OME	I OME	Wave V NO OME
	n=16	n=4	n=16	n=4
PremyMingotomy	2.2	1.4	6.9	6.2
Post myxingotomy	1.6	1.4	6.2	6.2

OME - Otitis Media with effusion

Similar findings had been reported in an earlier study by Mendelson, Salamy, Lenoir & McKean (1975). 63 children from 2-12 years of age were studied by Brain-Stem 5voked audiometry and otoscopic evaluation in a preliminary assessment of the sensitivity of BEP latency measures to middle ear abnormality. Wave I proved to be most sensitive component 81.25 % of subjects with ASOM and 62.5% of subjects with secretory otitis media demonstrated latencies prolonged by more than 1SD beyond the values seen in normals. In the same subjects, Wave I latencies came with in normal limits on retesting after otitis had resolved.

Many studies on animal literature have shown that reduction of auditory input can affect the brain-stem a higher structures. Folsom et al., (1983) did study on 15 children with histories of recurrent middle ear effusion to determine the effects of reduced auditory input on the brain-stem function. Comparisons were made with a control group of children with no h/o of middle ear disease.

Results of the above study showed that ABR latency of III & Vth peaks, I-V interval, L-I function for Wave V all showed a significant difference between the two groups. This indicates that nuclei in the brain stem are susceptible to deterioration and or physiological modification as a result of reduced input. Fluctuating hearing loss seen in young children due to recurrent otitis media will create conditions of decreased auditory stimulation, and results suggest that there may be long-term central effects created which may persist even after the middle ear disease has been cleared.

The most striking finding in patients with Sensory hearing deficits are marked amplitude diminution and threshold elevation. Peak latencies are not necessarily prolonged white latency-Intensity function slope may be shallow, steep or normal.

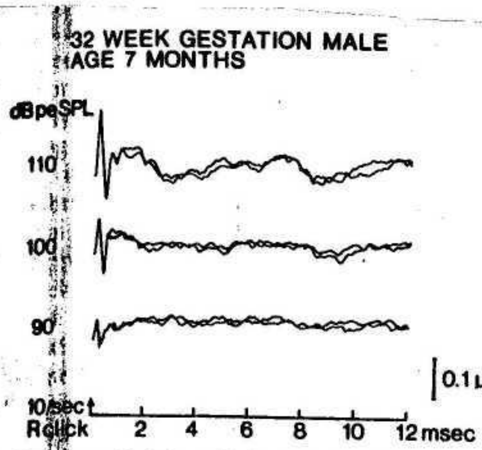
Stockard et al (1983) found that in their series of tests done on infants with confirmed Sensory hearing loss showed absence of response, ie absence of Wave I or a high threshold (1.110 dB pe SPL), low amplitude of Wave I. They also found that in 2 infants with abnormally steeply sloping audiograms, Wave V threshold was within normal units. Older infants with sensory deficits occasionally had normal response at moderate to high intensities but with decreasing stimulus intensities, response amplitudes dropped rapidly indicating possibility of Recruitment and peak latencies shifted dramatically yielding an abnormally steep latency-Intensity function slope. Preterm infants and infants with clinically apparent brain-stem disease, but with normal or near, Normal hearing, occasionally showed ABR patterns similar to those associated with severe SN hearing impairment.

Fig:c Shows the responses of the ear to a click stimulation in a premature infant with a history of birth asphyxia & severe hyperbilurubinemia.

At times even in SN hearing loss, thought to be of cochlear origin; there may be changes which have occurred in the higher pathways namely the brainstem or higher levels and early detection of such irreversible Brain stem lesion is a must.

For instance in a study by Blegvad, B; Svane Knudson, & Borre-s (1984)- ABR was recorded in 14 young patients with mild-moderate to severe congenital/ acquired SN hearingloss and abnormal stapeduis reflex threshold. Speech problems were more pronounced than which would be explained from

FIGURE : C : SENSORINEURAL HEARING IMPAIRMENT



gure 3. Responses to left ear (AS) click stimulation in a premature fant with a history of birth asphyxia and severe hyperbilirubinemia econdary to liver disease. At age 1 yr, results of standard audiometric udies were consistent with severe sensorineural hearing impairment, nd the infant is now aided. Note high threshold, low amplitude (quesonable) wave I and elevated wave V threshold.

FIGURE : D :- BRAIN-STEM PATHOLOGY.

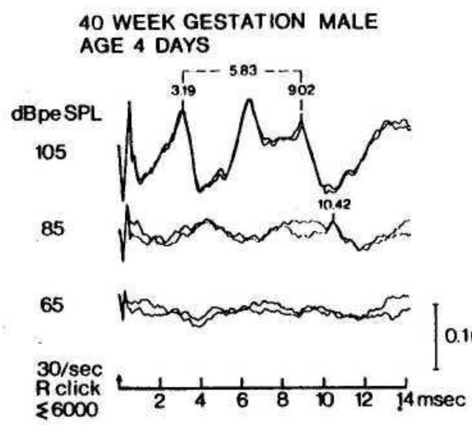


Figure 4. Interpeak latency prolongation in an infant with Antley-Bixter syndrome. The child died at age 2 mos. In the presence of the wave I latency prolongation and steep L-I function slope, a normal I–V IPL would have been unintérpretable.

hearing loss by pure-tone average. All of them gave abnormal ABR indicating dysfunction of the auditory brainstem pathway or in a few cases cochlear part of the auditory nerve was involved. The ascertainment using ABR response clearly proved that the hearing loss was not merely due to hair-cell degeneration.

In summary, infants with Cochlear hearing loss tend to show elevated ABR threshold , poor wave form morphology. The different peaks may be diminished in amplitude or absent. Along with the above results, latency-intensity function tends to be abnormal.

c) Findings in Brain stem pathology:-

The difference between the latencies of the Vth peak and 1st peak is known as the inter-peak latency difference. Prolongation of IPL in adults correlate well with brain stem dysfunction and pathology. Similar findings have been found in older infants with clinically apparent brain-stem lesions Fig (d). Shows the interpeak latency prolongation seen in infants with Antley-Bixter syndrome. Brain-stem is the main site of lesion.

Yet another useful index of Brain-Stem pathology is determining the amplitude ratio of Wave IV/V to that of I (IV/V / I). Hecox & Cone found a perfect correlation between this ratio which tends to be reduced in severe and irreversible neurological disability.

Stockard et al (1983) have reported that ABR in severely asphyxiated newborns and newborns with major malformations involving the posterior fossa.a or having severe brain-stem dysfunction, often showed either absence of later wave components (Waves, III, IV, & V) or reduction of the V/I amplitude ratio.

Studies have been done to determine the enact site of lesion in several pathological condition like Brain-Stem gliomas. ABR findings have been correlated with that of CAT scan findings to increase the validity. The criteria used for assessment are:-
1) Peak-latency 2) Intra peak latency 3) Inter-peak latencies 4) Response stability 5) Amplitude 6) Wave Shape (Morphology 7) Peak presence.

The often frequent findings in cases of Brain-Stem Glioma was a) Prolongation of absolute latency b) Increased central conduction time, c) Becreased amplitude and d) Poor waveform morphology. This has been given in a study by Lenhardt (1981).

ABR studies have also been done on infants with perinatal changes to evaluate the hearing level and also the changes that have occurred at higher levels. Kileny, Connely & Robertson- recorded ABR from 14 asphyxiated newborns with clinical evidence of CNS suppression. They were matched with a control group of normal healthy neonates. In general longer ABR latency values and abnormal IOPL values were found in children with perinatal Asphyxia.

IV ABR findings In other Special Population

1) Down's Syndrome:- This syndrome can be easily identified by the characteristic physical and behavioral signs. There has been well established reports of anatomic abnormalities in the cochlear and neural structure like shortened cochlear spirals, disorders of the vestibular system; reduced weight of the cerebellum, suggesting lack of development of these structures in children with Down's syndrome. Incomplete myelination and cellular agenesis have also been reported. Squires, Aine, Buchwald, Norman, (Sal-Braith (1980) compared the ABR's of 10 Down's Syndrome retarded male adults and 15 male adults of unknown etiology with 15 non-retarded control as a function of stimulus intensity and repetition rate, Two characteristic findings were demonstrated in the Down's syndrome group.

a) They showed shorter inter wave intervals (IWI) and an overall decrease of central conduction time as reflected by a shortened Wave I-V interval. This abnormal transmission was due to a selective shortening of the I-II and III-IV intervals.

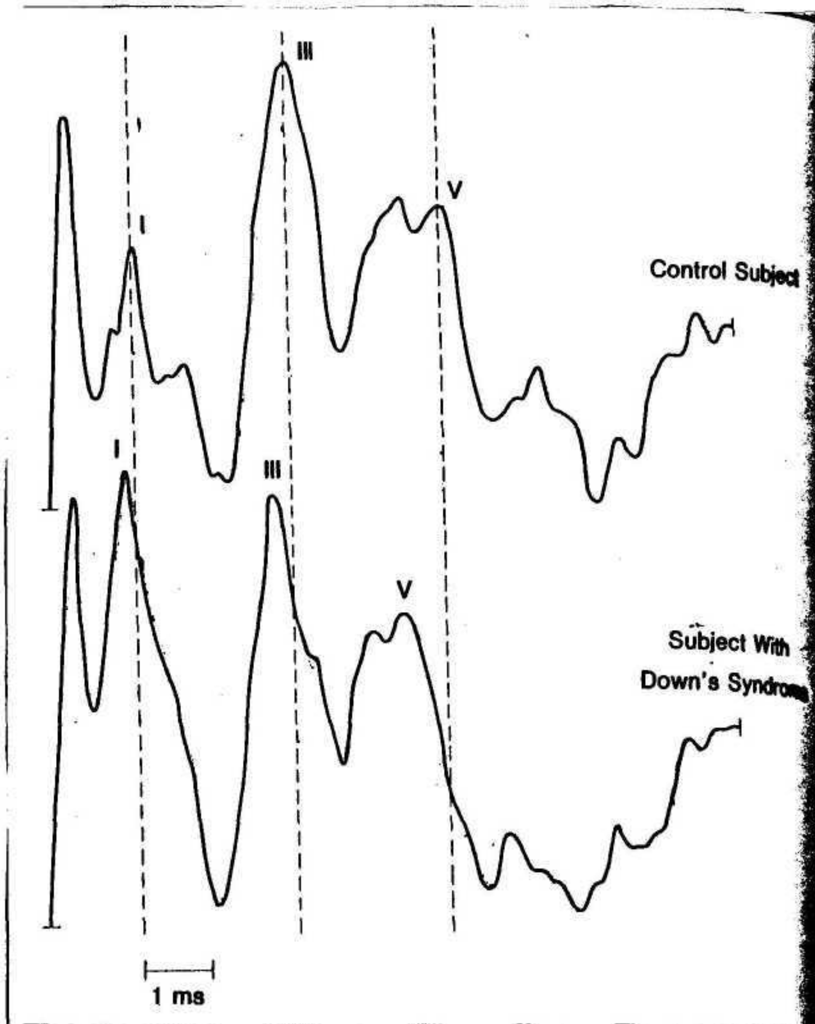


Fig 1.—Auditory brain-stem response results from two selected subjects in each group. La
values for these subjects approximate respective group means. Vertical dotted lines re
position of waves I, III, and V in control group. Intensity, 60 dBnHL; rate, 13.3/s; and
sweeps.

b) Downs syndrome group also showed significantly less change in Wave V latency with increased rate of Stimulation.

Consistent with the above findings are those of Folsom, Widen & Wilson (1983). They did a study on 38 subjects with Downs syndrome at ages of 3 weeks, 6 weeks 12 months. They were compared with 35 normally developing infants at the same age-level.An attempt was made to delienate age dependant and intensity-dependant latency changes in this population. They could not find any difference between groups for wave I or for Wave I-V values at any age but at 12 months, Down's Syndrome group showed shorter wave V latencies and steeper latency-Intensity functions at 40 and 60 dB nHL than the controls.

Fig E Shows the findings obtained in children with Downs syndrome.

Further evidences of differences in the ABR patterns of individuals with Downs syndrome was found by Gal braith, Aine, Squares & Buchwald (1983). They took 35 male retarded as subjects-14 were with Downs syndrome and 21 were those with retardation of unknown etiology. Down's syndrome children were found to have significantly smaller amplitude of waves II & III, shorter latencies for Waves III and V and shorter interwave conduction times (I-III and I-V) compared with the unknown etiology retarded group.

When binaural interaction measures were used, they did not find any difference between the Downs syndrome group and the other retarded or normal group. Hence they proposed that significantly smaller overall amplitudes of the ABR waves seen in Downs syndrome, may be due to the brain-stem pool generating ABR being abnormally small as avariable.

Thus majority of the ABR studies on children with Downs syndrome report significantly shorter latencies, smaller amplitudes, and reduction on the interwave intervals. Also Wave V latency does not show any change when the repetition rate is altered.

Infantile Autism:- There has been diverse opinions regarding this condition. Despite these, there has been general agreement that brain stem dysfunction may result in altered auditory input, severe enough to account for the failure of autistic children to develop specific skills in these area.

One of the earliest studies on these autistic children has been by Sohmer & Student (1977). 3 groups of children C13 with autism ,16 with MBD and 10 with Psychomotor Retardation) were tested. ABR was absent in 4 children suggesting cochlear hearing loss in addition to autistic traits. Other children had ABR at normal threshold values, but the latency of each response wave was significantly longer than normal. These findings seems to support the hypothesis that the abnormal behavior seen in these children may be due to an organic lesion.

Rosenblum et al., (1980) in their study of 6 autistic children well matched for age and sex with 6 normal children found significantly longer ABR latencies and central conduction time in the autistic group. Also, the autistic children showed significantly more variability than did the normal control group.

Tanguay & Edwards (1982) after their own study accepted the possibility that some autistic children may have abnormalities in auditory reception due to abnormal brain-stem processing of auditory input. They used 16 autistic and 16 matched control subjects. They found two types of ABR abnormalities in the autistic group:-

1) Belay in Wave I latency primarily in response to right ear stimulation.

2) Increased interwave latencies for Waves I-III, III-V or I-V. Based on these findings , they advanced an interpretation that brain-stem dysfunction leading to a distortion to auditory EP to the forebrain may have been present during the critical phase of early post-natal development.

(In the whole, these studies have shown that ABR shows abnormalities in the autistic children namely prolongation of the various waves and increase in the central conduction time.

Findings in Deaf-Blind: In these children, doing routine audiometry is often difficult and will not yield accurate results. Hence BSERA is a more useful method as it is objective method. Few studies have been done using BSERA on this population.

Stein, Ozdamar and Schnabel (1981) have reported ABR findings with 79 severely developmentally delayed infants and children suspected of being both blind & deaf. Of the 79 children, 34 demonstrated click threshold in the 0-30 dBHL range, 16 in the 40-70 dB HL range 3 in the 80-90 dB HL range. and 26 had no response to 90 dB stimuli. These 26 children were later judged to be severely hearing impaired or deaf.

However they also reasoned that absent ABR or elevated Wave V threshold believed to reflect hearing loss may be due to concomitant brain-stem involvement which may have compromised the ABR, their by leading to an overstimation of the actual severity of hearing loss.

The principle conclusion was high percentage of multiply handicapped children who appear to be deaf may not be hearing impaired.

These findings were confirmed by the study done by Sohoel, Ma et al., (1979); and Harris, Mollerstorm & Broms (1981). In 12 of 22 children earlier regarded as having some degree of hearing loss, Sohoel et al., (1979) reported ABR thresholds consistent with normal hearing sensitivity was revealed on later follow-up.

ABR findings on the learning disabled:-

Earlier literature suggests that some learning disabled children demonstrate neurological dysfunction thought to be due to minor defects in brain-stem level auditory functioning. Ayres (1972) has stated that the soft signs of Brain-stem involvement are evident in many children with learning disabilities. Also these children have been found to show poorer scores on tests which evaluate the brain-stem integrity like the Masking-level Difference, and the Binaural fusion tasks. Sohmer and Student (1978) obtained click-evoked ABR's on children exhibiting various neuropathologies. They found longer response latencies in about 16 of the children having minimal brain dysfunction.

However the findings of abnormal ABR are not equivocal. Several other studies done in the recent years have failed to demonstrate abnormal ABR in this population.

Roush, J and Tait, C.A, (1983) did a study on 20 boys aged 9-14 years all classified as learning disabled. The results were compared with a control group consisting of 10 normal public school boys aged 10-14 yrs. Results showed that none the absolute latencies for waves-I, III, III-V & I-V, showed any significant difference between the two groups. (means.) Further more, none of the learning disabled subjects exhibited interwave latencies > 2 S.D. from the controls.

Roush & Tait (1984) in yet another study of 18 learning disabled children again failed to show any significant difference between this group and normals. They did binaural fusion task for diotically and dichotically presented passbands of filtered speech, masking level difference and ABR recordings for both the groups. They found normal MLD values & normal ABR on both the groups. Also both the groups exhibited superiority of diotic over dichotic listening performance. Hence brain-stem may not be the site of dysfunction in such children.

In the earlier studies the children studied have been an heterogenous population, but in one study by Grontved, A; Walter, B & Gronbors, A; (1988) they have taken only severely constitutionally dyslexic children. ABR were performed prospectively in 24 such children. The results were compared with a corresponding group of normal children. The response latencies of the two groups were almost identical. Hence they conclude that dysfunction of the brain-stem auditory pathways should not be expected in constitutionally dyslexic children.

On the whole, the finding are contradictory with few studies reporting normal ABR and few other studies showing ABR abnormalities in Dyslexic children.

ABR finding on the Mentally Retarded (MR) :- It may be difficult to ascertain the exact thresholds in certain mentally retarded using behavioral audiometry as they may be unable to comprehend the instructions. In such cases. BSERA may be a more objective measure. If there is no hearing loss complicating mental retardation, then the ABR findings are not significantly different form that of normals.

Harnes, Broms & {Kollerstorm (1981) did a study on 13 children with M.R, on whom hearing loss was suspected and hearing aids too were tried. Out of the 13, there was agreement with earlier estimation in about 20%. In 5 cases the ABR findings indicated a normal peripheral auditory function which meant that hearing aids could be discarded. This study agrees with Sohmer & Student (1978) & Sohoel et al (1979) on the usefulness of ABR this group of patient.

ABR Findings In other diseases

1) Infantile Spasms :- This includes motor abnormalities, abnormal EEG and mental retardation. These infants are frequently suspected of having an associated hearing impairment as they tend to be behaviorally in responsive to sound. Kaga, Marsh & Fukuyama (1982) compared ABR and behavioral audiometric findings in 30 infants. They found ABR thresholds were elevated in early 27%. They also reported ABR evidence for brain-stem dysfunction in 30 % of the patients with infantile spasms.

b) Hydrocephalus:- In this condition, there is an enlargement of the ventricular system as a result of an imbalance between production and absorption of CSF. ABR was measured in 40 patients with confirmed hydrocephalus by kraus, Ozdamar et al (1984). Responses indicative of brain-stem dysfunction seen include prolonged I-IV inter Wave latency, reduced V/I amplitude ratio and abnormal morphology of waves III & V.

Bactarial Maningitis:- This condition can result in hearing loss as a complication. Early assessment of such hearing loss is possible using ABR. Ozdamar, Kraus & Laszlostein (1988) did a study on 60 patients recovering from Bacterial meningitis. ABR results were consistent with unilateral or Bilateral hearing loss in 35% of the cases tested. Of these 15% were found to have conductive hearing loss 12% were found to have SN hearing loss, remaining 8% had elevated ABR thresholds. Totally, 120 ears were tested and the results were classified as follows-normal, border-line, normal, conductive, senorineural and neurologic.

All patients in normal category had ABR thresholds < than or equal to 20 dB HL. Their inter wave latencies and latency.- Intensity functions were within 2 S.D's of the norms for the appropriate age group. Patients with normal interwave latencies but abnormal latency-intensity functions and elevated thresholds were classified as having hearing loss. Conductive loss group consisted of those who had latency-Intensity functions shifted along the intensity axis, while SN loss group had no ABR response at 90 dB and below, or L-I-F which were outside the normal range. As meningitis typically affects young children who are difficult to test with conventional audiometry, they concluded that ABR might provide an effective means of testing hearing in this population.

D) There have been few ABR studies in children showing peculiar behavioral/ and neurological manifestations. For instance Xaga. K-Yokochi. K et al (1986) have reported a syndrome in 5 male patients all of whom showed 1) Absence of all components of ABR except Waves I&II.

2) Congenital pendular Nystagmus

3) General hypotonia of head & limbs in early infants.

On the basis of the above findings congenital brainstem abnormalities were strongly suspected. When ABR was repeated, it showed neither improvement nor deterioration. Thus it was concluded that the lesion involved the low brain stem primarily and it was a non progressive one.

ABR has also been tried out in children with Friedrich's ataxia. Jabbari, Shwartz, Macneil. Coker (1984) did a study on 5 children with classic Friedrich/s ataxia. An audiological test battery was administered and the results showed that brainstem may be the primary site of dysfunction.

Conclusion:- The above chapter gave a brief review on the findings of ABR in infants population with hearing loss. Also ABR findings in certain disorders like Autism, Downs Syndrome where the structures involved in generating ABR, may be involved have also been considered. The following chapter will give an insight into the application of BSERA in the rehabitation aspects namely its usefulness in hearing aid selection procedure.

Auditory Brain stem response : Hearing Aid Applications :—

The preceding chapters gave a detailed description of the electrophysjcological basis of the response, methods utilized in generation and recording, its clinical application to early identification, differential diagnosis and neurological function. This chapter will further exemplify the versatility of ABR in the field of auditory habilitation.

Need for ABR in hearing aid Evaluation :-

In hearing impaired patients, it is essential that they be fitted with the most appropriate hearing aid, as early as possible. Hearing aid selection is one of the difficult tasks and most of the present procedures can be considered tobe in developmental stages. The basic problem in fitting infants with hearing aids is that the clinician is faced with making clinical determinations on difficult to obtain and often questionable nonverbal data. In such populations, an objective method for determining the usefulness of amplification is needed. Early attempts in using such an objective method - namely ABR was tried out by Hecox, Breuninger and Krebs (1975) & Mokotoff & Krebs (1976) who were among the first to generate ABR responses under amplification from normal and hearing - impaired adults. These studies were optimistic that a valid ABR -HAE would eventually be realised fore infants, young children and difficult to test populations. Due to the complex nature of the subject, a variety of different methodologies were proposed including an aided ABR wave V latency paradigm, wave V Amplitude -intensity (A-I) growth and a combination of ABR latency and amplitude determinations. These efforts are reviewed in this chapter.

Instrumentation:- Any ABR equipment used for diagnostic purposes can be used for hearing aid evaluation also. However one prerequisite is that the ambient room noise must be kept low or else poor aided wave form morphology will result.

The stimulus may be presented at a specified distance from the hearing aid microphone. Though both loudspeakers and earphones have been used as transducers, many favor the latter as it maintains the a acoustic qualities of conventional ABR stimuli. The infants are usually tested when they are fast asleep.

However there are certain factors which must be taken care of in doing hearing aid evaluation using ABR.

1) Transducer distance:- The obvious effect of moving a transducer from the ear and stimulating at a distance will be an increase in the waveform latency.

Mahoney, T. A. (1985) recommends a distance of 8cm from the hearing aid microphone, a distance which significantly reduces radiation artifact and yet allows for adequate stimulus intensity. This distance amounts to an approximate 0.25 msec distance correction factor.

2) Radiation Artifact :- Whenever a sound is generated by a conversion of electrical to acoustical energy, a certain amount of energy is lost in the form of radiant electrical waves. These are referred to as electrostatic or electro-magnetic artifacts. This can arise when earphone is activated by high intensities. The energy thus radiated can be picked by the surface electrodes which are in close proximity. Also in aided condition, the addition of an amplifier close to the recording electrodes can also cause artifact contamination. Hence these artifacts should be kept to a minimum as they can contaminate the average response obtained.

3) Signal procesing:- Auditory clicks are the commonly used ABR stimulus as its abrupt rise time elicits maximal response from primary auditory neurons in the acoustic nerve and brain - stem.

Another aspect to be considered is the effect of amplification on the ABR stimulus. In transducing the signal the amplifying device may alter frequency and temporal parameters. Although hearing aids have recently undergone drastic electronic improvements harmonic, transient and inter modulation distortion remains all off which may impose changes in ABR stimulus.

The above factors must be considered in interpreting the aided and unaided results using ABR for hearing aid evaluations.

Applications :- Various ABR hearing aid evaluation procedures have recently emerged. There has been an attempts to synthesize, information into several major evaluation strategies, discussing possible advantages and disadvantages whenever applicable.

The various proposed hearing aid evaluation procedures can be categorised into those utilising a)wave V threshold, b)latency and c) Amplitude.

ABM Threshold Methods :- In this, difference in threshold between the unaided and aided conditions are used to interpret the usefulness of amplification. For determining this, wave V peak is used and the lowest intensity at which the V peak is elicited is taken as the threshold. In presenting case reports from young and difficult to test patients, Kileny (1982) also suggested that aided ABR threshold can be used to predict the feasibility of amplification and in selecting the ear to be amplified.

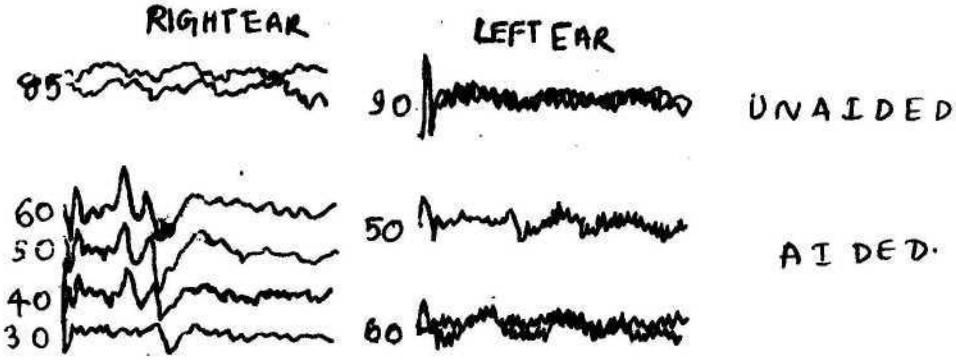
In a study by Kileny,(1982) they have tried to use Auditory Brain Stem Response as indicators of effective amplification. In their study, brain stem responses were recorded by a vertex to Ipsilateral earlobe-surface electrodes configuration. Contralateral earlobe served as ground. Clicks were obtained by delivering 100 us duration rectangular pulses alternated in polarity and presented at a rate of 17/sec.

Initially unaided ABR thresholds were obtained. Then a hearing aid was placed on the patients ear. Click stimulus was delivered to the aided ear by TDH - 39 earphone kept at a distance of 5cm, from the microphone of the hearing aid. Depending on the necessity to mask, contralateral ear was left open or covered.

In their case reported, there were no unaided responses obtained bilaterally. Using an aid,well defined typical Brain - stem responses were evident down to 30 dBHL in the right ear In the left ear, aided responses were poorly defined and the aided threshold was around 50 dB. Based on this, right ear was aided. Thus in this study, threshold has been used as a criteria in assessing aided & unaided performance. Figure shows the aided and unaided response.

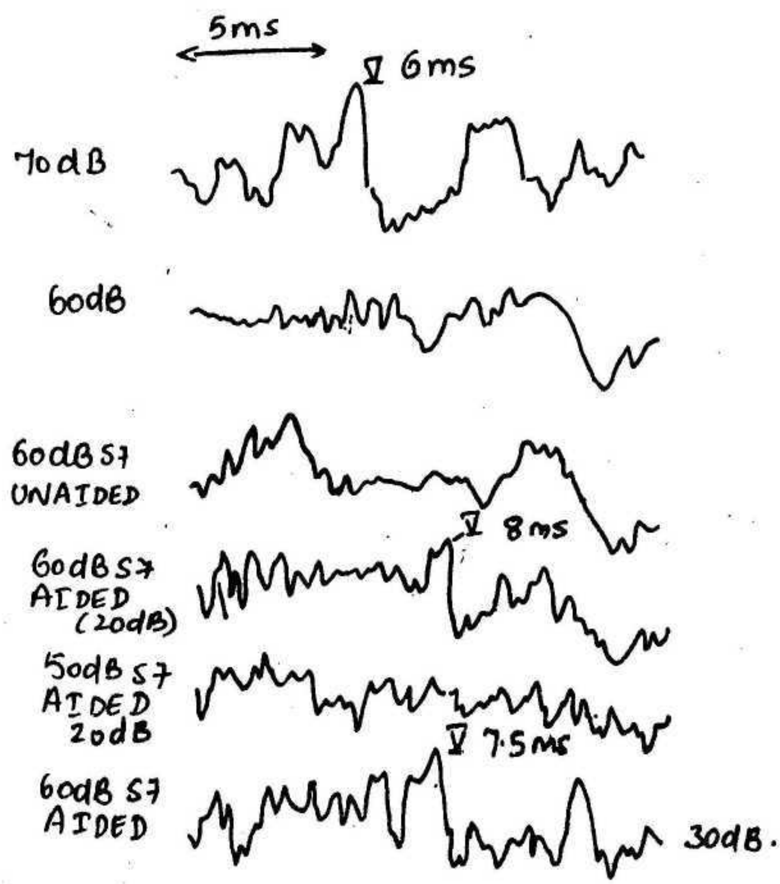
ABR THRESHOLD METHODS.

KILENY (1982): ABR as indicators of Hearing-Aid Performance.



UNAIDED AND AIDED BRAINSTEM RESPONSES (CLICKS) HAVE BEEN SHOWN IN THE FIGURE ABOVE.

ABR LATENCY METHODS. (MAHONEY ET AL)



Although aided ABR thresholds provide necessary gain and out put measures, they do not provide the more valuable information concerning the dynamic hearing aid function. Hence wave V latency and amplitude have undergone serious investigation in ABR Hearing aid evaluation.

ABR Latency Methods :-

Cox & Metz, (1980) ; Hecox (1983) have all suggested the use of ABR wave V absolute latency or latency - Intensity slope to predict appropriate hearing aid specifications. The basic assumptions are that normal. L-I slope suggests normal dynamic loudness function and normal wave V latencies require an intact auditory system upto the neural generator. It follows that if a hearing aid can be adjusted in gain out put and compression characteristics to generate as normal an ABR as possible in a pathological ear, this procedure has merit as a tool for evaluation of amplification.

Cox & Metz (1980) presented data from 8 hearing aid users, who were given standard behavioral tests, aided speech discrimination tests in quiet and in noise, unaided versus aided click and tone - pip elicited ABR's. At a sound field level corresponding to the recommended 50 dB HTL for speech audiometers, a variable hearing aid was adjusted to 3 different settings. L-I function were obtained at 10dB above and below comfort, and ABR threshold,latency - data were rank ordered into 3 hearing loss categories. ABR ranking was determined by hearing aid setting that produced the shortest wave V latencies and lowest wave V thresholds. Speech discrimination scores too were ranked according to best combined scores for quiet & noise. On the whole they found that hearing aid setting which produced the best speech discrimination scores produced shortest wave V latencies.

Another ABR latency based study was presented by Hecox (1983) who asserted that the main contribution of ABR was in characterising the dynamic range of the impaired listener.

In this study, adult subjects aged 18-56 years were used who had considerable variation in degree and pattern of audiometric impairment. The dependant variables considered in the unaided and aided condition were the absolute latency of Wave V and slope of the latency and intensity function. Patients were first tested without hearing aids & later with the hearing aids in place at the patients preferred hearing-aid setting. A comparison of responses was made with and without the amplification device to determine the degree of improvement in both the absolute latencies and latency intensity functions.

The results obtained were classified as

a) Satisfactory Response:- Responses considered were satisfactory if there is a marked improvement in wave V latency and decrease in signal intensity required to elicit

FIGURE: 1. (SATISFACTORY PERFORMANCE WITH AN AID

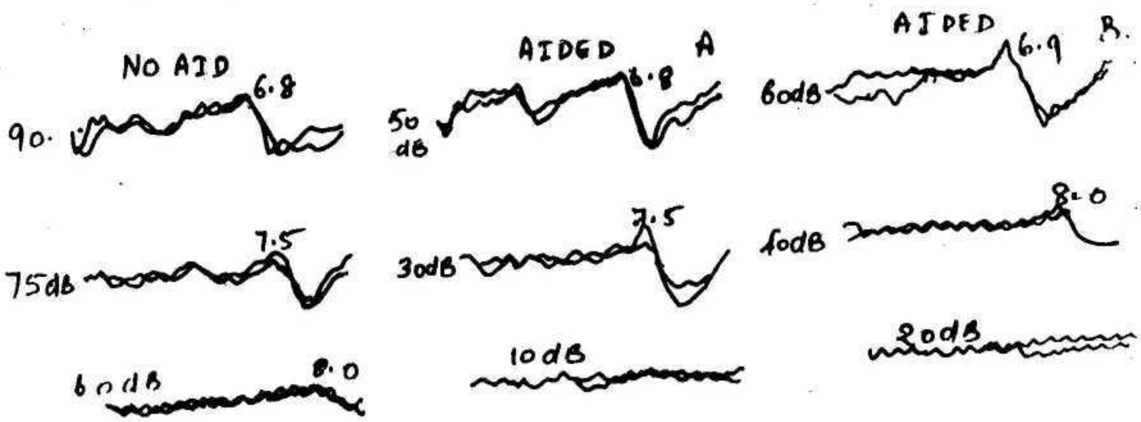
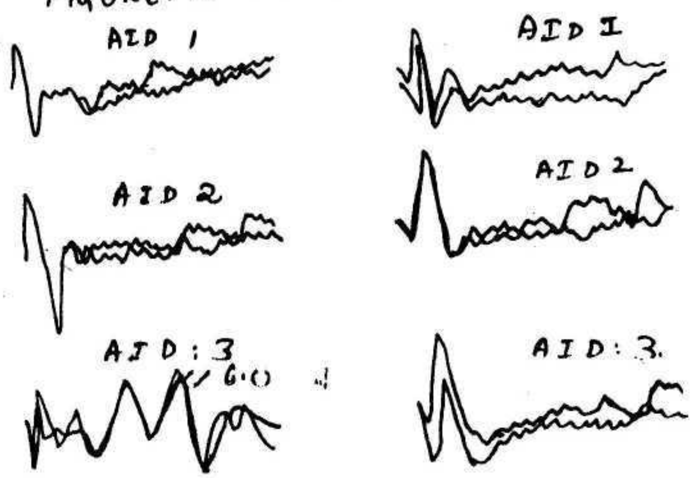
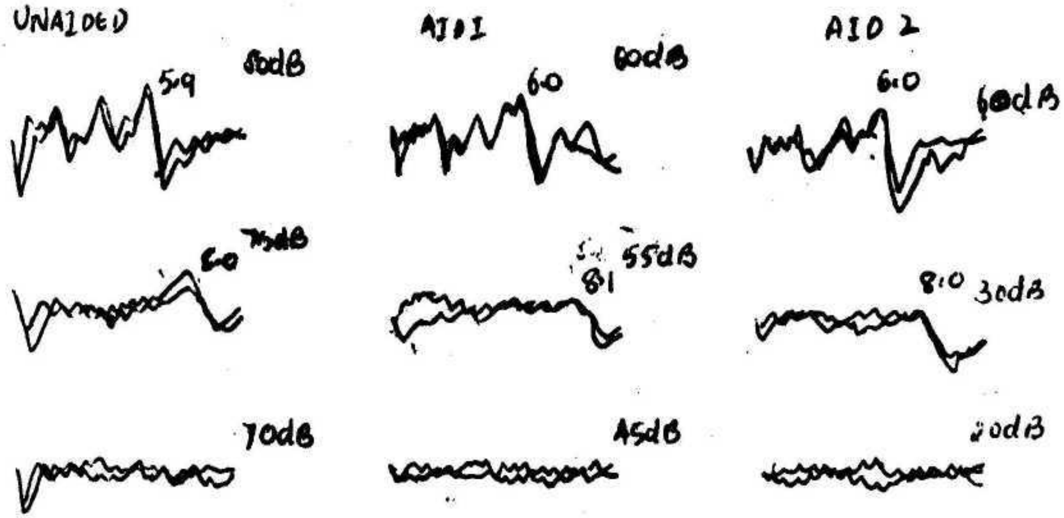


FIGURE: 2 : UNSATISFACTORY PERFORMANCE WITH AN AID



RESPONSES WERE ABSENT EVEN WITH AIDS OF INCREASING GAIN FROM AID 1 to 3. RESPONSE WAS PRESENT IN PATIENT 'C' AT 90dB HL WITH AID-3.

FIGURE 3: ILLUSTRATES THE EFFECT OF COMPRESSION AMPLIFICATION VS LINEAR AMPLIFICATION IN A PATIENT SHOWING RECRUITMENT.



UNAIDED CONDITION SHOWS THE RECRUITMENT PATTERN

<u>AIDED CONDITION</u> – SLOPE OF THE LATENCY - INTENSITY FUNCTION IS STEEP WITH LINEAR AID 1. (420µsec/dB

WITH NON-LINEAR AID, MORE NEARLY NORMAL SLOPE WAS OBTAINED [67µsec/dB].

an equivalent wave V latency in the aided condition. This is shown in fig 1.

b) **Unsatisfactory Response:-** When there was no improvement in threshold seen in aided condition. This is shown in fig 2., Where the results show no change in the aided condition.

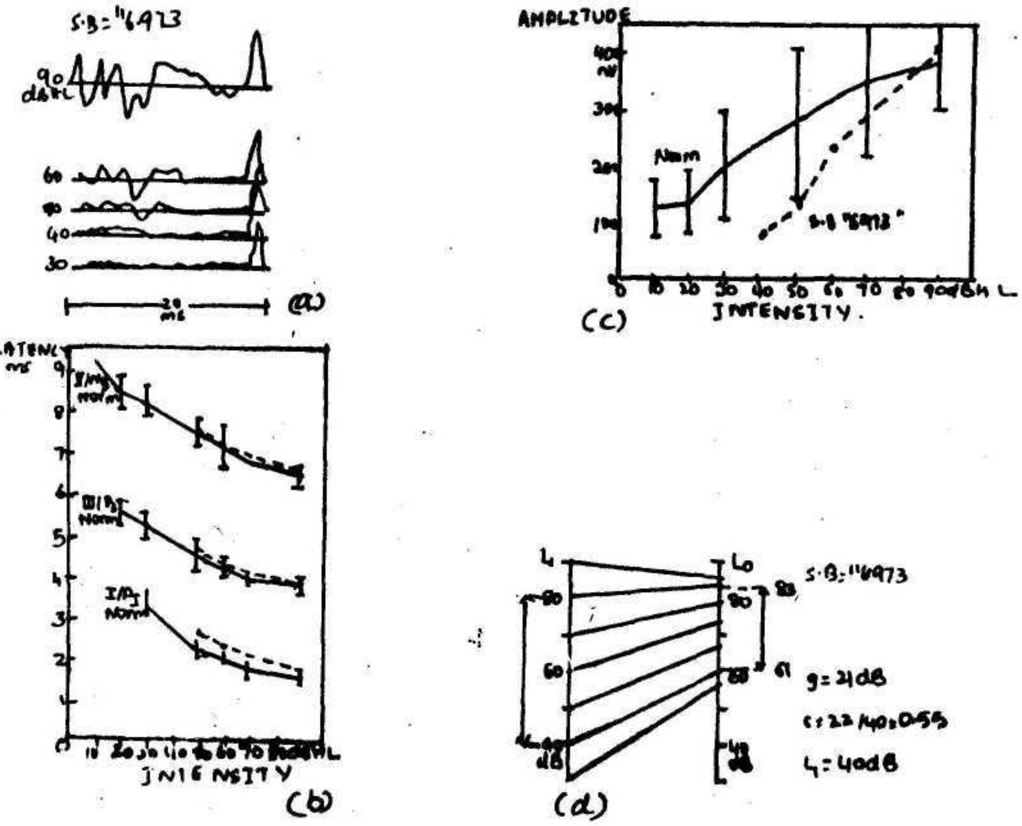
c) **Recruiting pattern:-** Fig 3 illustrate the phenomenon of electrophysiological R. The figure shows that in the unaided condition, the slope was greater than 400 msec/ dB. However with the introduction of an compression amplification system, slope normalised to 67 msec/dB , so that effective dynamic range increased.

d) **Central Auditory dysfunction:-** IM, such a patient, ABR responses were normal but he did not benefit from amplification.

ABR Amplitude methods:- Amplitude measures have been investigated considerably in ABR hearing aid evaluation. Relative intrasubject ABR Wave V amplitude growth has been proposed as a direct index of cochlear loudness function, offering a valid electrophysiological index of preferred amplification characteristics. Keissling (1982) used an unaided ABR projection system, based on normal and pathological amplitude growth, to prescribe appropriate hearing-aid gain compression ratio and compression onset.

ABR AMPLITUDE METHODS.

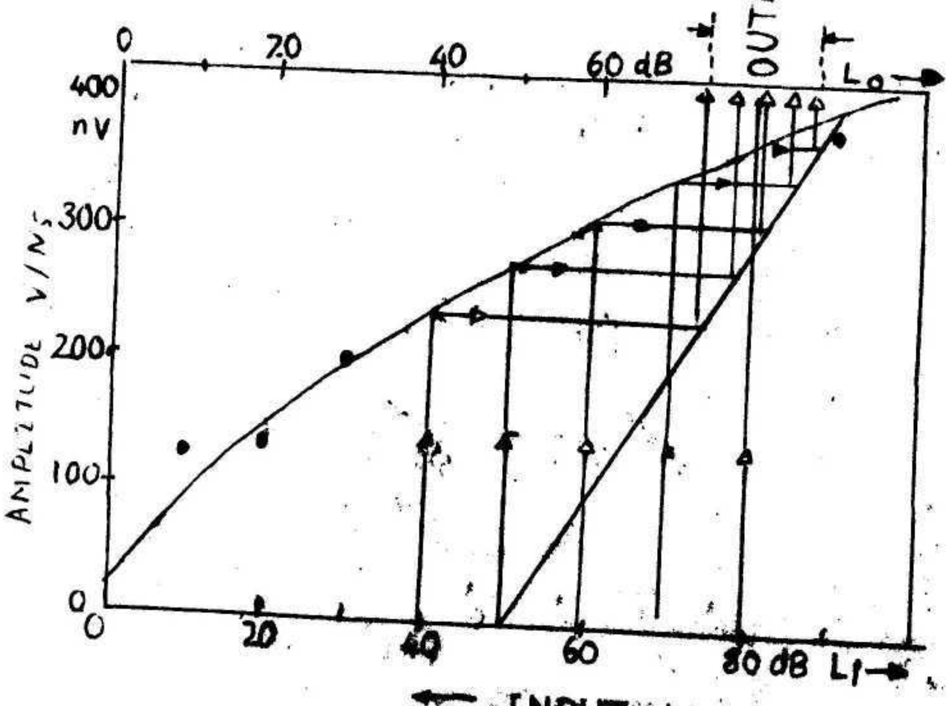
KIESSLING (1982): ABR V/N5 VALUES (a) FOLLOWED BY LATENCY-INTENSITY FUNCTIONS OF WAVE I, III and V/N5 PLOTTED AGAINST NORMAL SOLID LINES. b) INTENSITY-AMPLITUDE FUNCTION OF V/N5 PLOTTED AGAINST NORMAL (SOLID LINES)



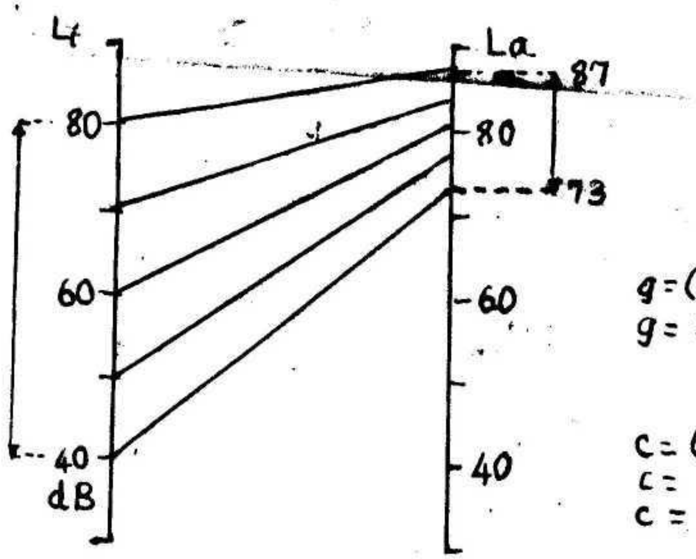
C- RESULTING PROJECTION DIAGRAM INDICATING HEARING AID CHARACTERISTICS.

D- FROM KEISSLING (1982)

Determining the dynamic range of a pathological ear by the amplitude-Intensity method.



Projection diagram derived from the amplitude Intensity shown in the above figure.



$g = (73-40)$ dB
$g = 33$ dB

$c = (87-73)/(80-40)$
$c = 14/40$
$c = 0.35$

Asserting that ABR amplitudes correlate with actual loudness perception, Keissling suggested that hearing aid settings, can be adjusted in accordance with amplitude normalisation.

The work of Keissling (1982) too has indicated that Wave V amplitude may be more sensitive than Wave V latency as an index of pathological loudness in SN hearing impairment and the amplitude intensity function may be more useful in determining gain, dynamic range, compression type compression factor & compression onset level.

Thus there are variety of hearing aid evaluation procedures possible with the ABR. Few investigators like Stecker (1982) reported on the use of a combination of threshold, latency and amplitude measurements in ABR hearing aid evaluations.

Limitations:- Many investigators who have had experience in the ABR hearing aid applications outline various limitations of the procedure. Most controversial is the notion that hearing aids with compression circuits cannot be evaluated because their circuits cannot allow the very fast stimulus rise time needed to elicit an ABR.

2) A more universally accepted limitation is the high frequency emphasis of the ABR hearing aid evaluation procedure. This is in concurrence with its & Martin (1977)

and Holier & Blegvad (1976), who show that click-generated ABR reflects primarily the frequency range of 1000-4000 Hz. Thus limitation is not overly concerning as frequencies above 1 KHz are important for intelligibility.

3) ABR cannot be used for amplification in severe and profound hearing losses.

Summary- Despite these limitations, future directions in ABR hearing aid evaluations present inciting possibilities.

There are many diverse approaches to hearing aid evaluations, and they provide a dynamic assessment of suprathreshold & threshold auditory functions. In reviewing the favorable results of several emerging hearing aid evaluation strategies, one can conclude that this procedure is probably forthcoming in the near future.

CHAPTER -VI

Summary:

In this project an attempt has been made to provide a concise report of the usefulness of BSERA in children.BSERA findingsseen in normal pediatric population, in children with hearing loss of different types and other retrocochlear pathologies have been reviewed. Finally, usefulness of BSERA in hearing aid selection has been considered.

In the chapter titled Instrumentation', the equipment needed for testing, and functions of the several components have been considered. Along with this, several factors which can affect the test procedure and the results obtained have also been considered.

In the next chapter titled Normative data' BSERA findings in children with normal hearing starting from pre term babies (age at which different waves make their first appearance) till the age - level when different waves are stabilised have been reviewed. Different response parameters like latency, amplitude and thresholds have been considered and the ages at which these different parameters attain adult values are given. Apart from response parameters, signal parameters have also been taken into accounts. BSERA finding in children on bone -conducted click stimulation, Rree -field stimulation have also been considered. Finally, the applicability of ABR a screening tool has been discussed.

In the next chapter entitled " BSERA findings in the multiple handicapped " BSERA findings in children with hearing losses of different types and other retrocochlear disorders have been considered.

The final chapter " ABR in hearing aid utilisation " discusses the recent advance in BSERA - namely its usefulness in hearing aid selection procedures.

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