THE OBJECTIVE ASSESSMENT OF HEARING IN CHILDREN USING THE AUDITORY BRAINSTEM RESPONSES

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SYNOPSIS

The Auditory Brainstem Responses (ABRs) of 208 children presented with suspected hearing loss and/or speech delayed were analyzed. The ABR measurements suggested 54.9% of the ears tested had severe to profound hearing loss and this number increases to 70% with those 'at risk-registered' children. The ABR test is found to provide useful diagnostic information in those 'difficult-to-test' children when compared to conventional behavioural techniques. The advantages and disadvantages of the ABR test are discussed. Useful clinical examples are illustrated.

INTRODUCTION

In our previous study (1) with the hearing-impaired pre-schoolers, we had discussed the importance to diagnose deafness early so that appropriate management including the use of a hearing aid may allow satisfactory development of speech and language. A variety of techniques were used to assess these children who were between 5 to 6 years old and we had reasonable success in obtaining their hearing thresholds. However, with younger children and multi-handicapped children, we often encountered difficulties in firmly establishing their hearing thresholds using the conventional behavioural techniques and even with the objective impedance audiometry.

In recent years, the introduction of commercial electric response audiometry (ERA) equipment have given clinicians new confidence to deal with those 'difficult-to-test' children. Basically, the electric response audiometry consists of a source producing auditory stimuli in the forms of clicks or tone bursts of varying frequencies. The electrical responses produced in the auditory nervous system are recorded from electrodes taped to the mastoids, the vertex or through the tympanic membrane onto the promontory of the middle ear. These auditory responses are passed through a filter to reduce noise and then further amplified. Still the responses are minute and are buried with other 'noises' originating from muscles of the body and other parts of the brain. To suppress the unwanted 'noises' and to enhance the auditory responses, these responses are fed into an averaging computer where the 'time-locked' stimuli will be enhanced and the random noises tend to cancel out in the summating process. Fig. 1 shows the components of a complete Electric Response Audiometry System in block form.

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Currently, three levels of response have found to be clinically useful. They are 1) Electrocochleography (Ecoch G) 2) Brainstem Response (ABR) 3) Cortical Evoked Response Audiometry (CERA). Depending on the clinical needs, the three different types of recording are used at different times. Auditory Brainstem Responses (ABRs) with latencies between 2 and 10 msec were recognised by Jewett (2) and had found a measure of acceptance in the clinic.

The clicks were presented monoaurally and each averaged response represented the sum of number of clicks and such averages were routinely replicated at least once. Recording usually began with stimulus at 115 dB SPL. If a response was obtained at this Intensity level, the stimulus was decreased in 10 dB steps and in some cases, 20 dB. The originally reported wave PV threshold was used as the ABR predictor for positive hearing responses as it is the most prominent

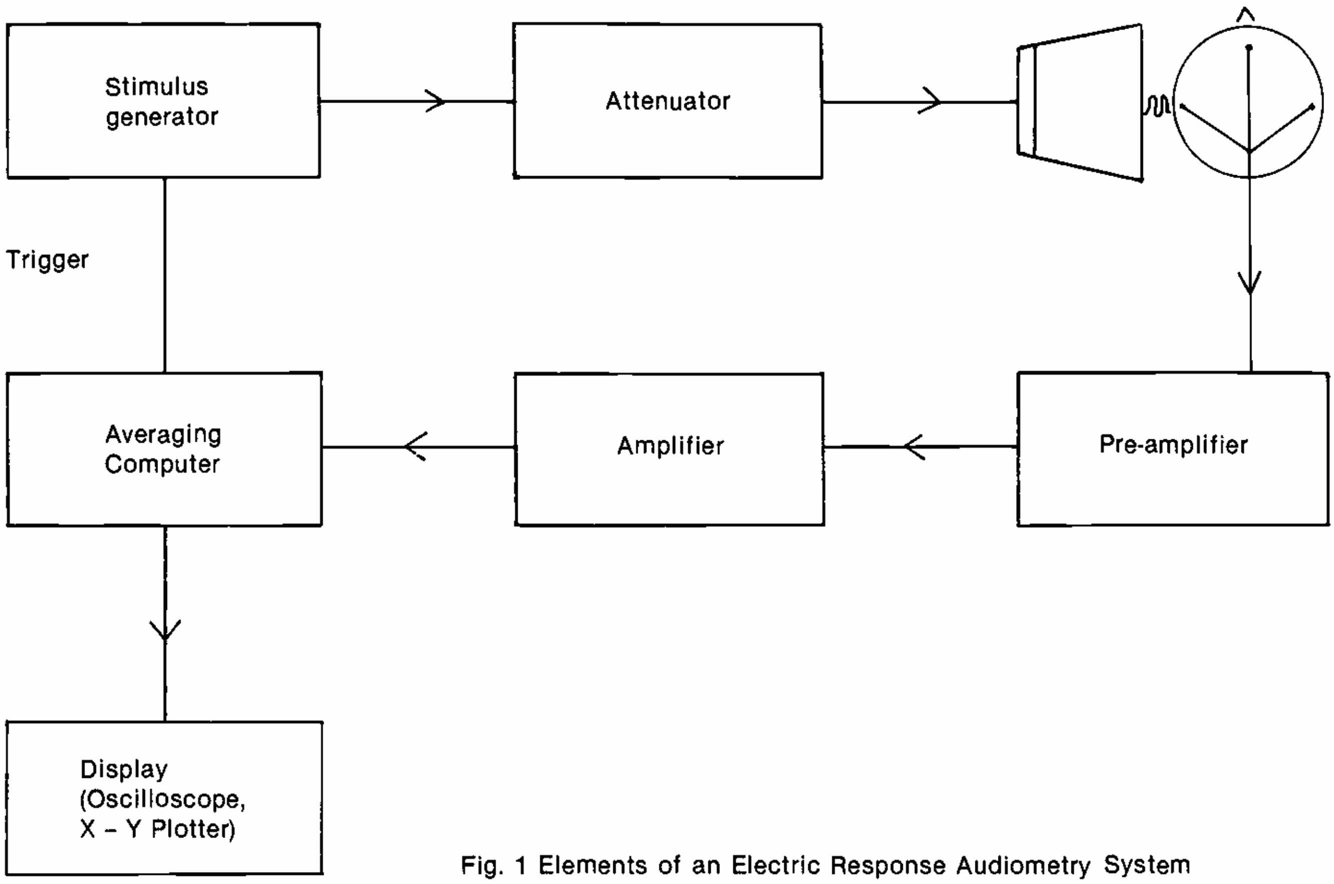


Fig. 1 Elements of an Electric Response Audiometry System

and stable. All the subjects were tested in a sound-treated children's audiometry room.

We classify our ABR results in the following manner. If there was no response to the 120 dB SPL clicks (the maximum stimulus available), the child's hearing loss was said to be profound. A minimum wave PV between 115 - 120 dB SPL was severe, 75 - 110 dB SPL moderately severe hearing loss and 60 - 70 dB SPL or less was considered as mild to normal hearing limits.

In our study here, we report on the 208 infants and children who had received ABR test. Some interesting and useful examples are high-lighted. Distinct advantages and disadvantages in using the ABR audiometry over other ERA measurements and behavioural audiometry are outlined.

METHOD

The study group consisted of 416 ears in 208 subjects, 84 females and 124 males. They ranged in age from 4 weeks through 12 years. They were referred for ABR tests because initial or repeated audiological tests had yielded inconsistent or inconclusive results.

The ABR measurements were obtained using alternating polarity clicks at a rate of 40/sec, a matched pair headset (Telex 1470/10 ohms) and conventional recording techniques. Usually sedative drugs (chloral hydrate and/or paradehyde) had to be used to induce sleep on the subjects. Standard gold-cups EEG electrodes filled with conductive paste were attached to the vertex and both mastoids by surgical tapes. The electrode on the forehead served as ground.

RESULTS

A total of 208 children had ABR test and table 1 shows the sex and the types of residents. The non-residents came mainly from Malaysia and Indonesia. Fig. 2 shows the various age levels of the children.

In most cases, the hearing loss in a particular subject was identified from the medical history. Using the categories of risk-registered as shown in table 2, 84 cases could be linked to one of the groups and the estimated hearing responses of this 'at risk' children from the ABR measurements are shown in table 3.

Fig. 3 shows the distribution of ABRs in the 208 children at different intensity levels in 10 dB steps. A comparison of estimated hearing responses using the subjective and objective audiometry can be seen in table 4.

TABLE 1
SEX AND TYPES OF RESIDENTS WHO HAD ABR TEST

Sex	Male	Female	Total
Residents	107	50	157
Non-Residents	23	28	51
	130	78	208

Fig. 2 The various age levels of the Children

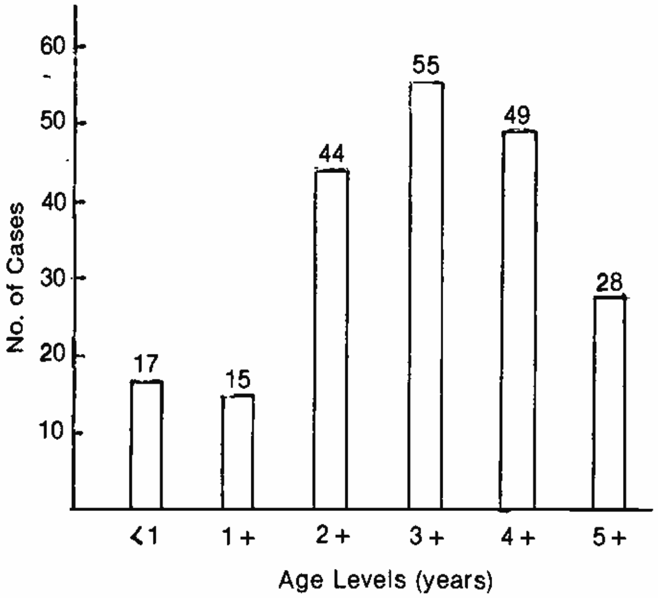


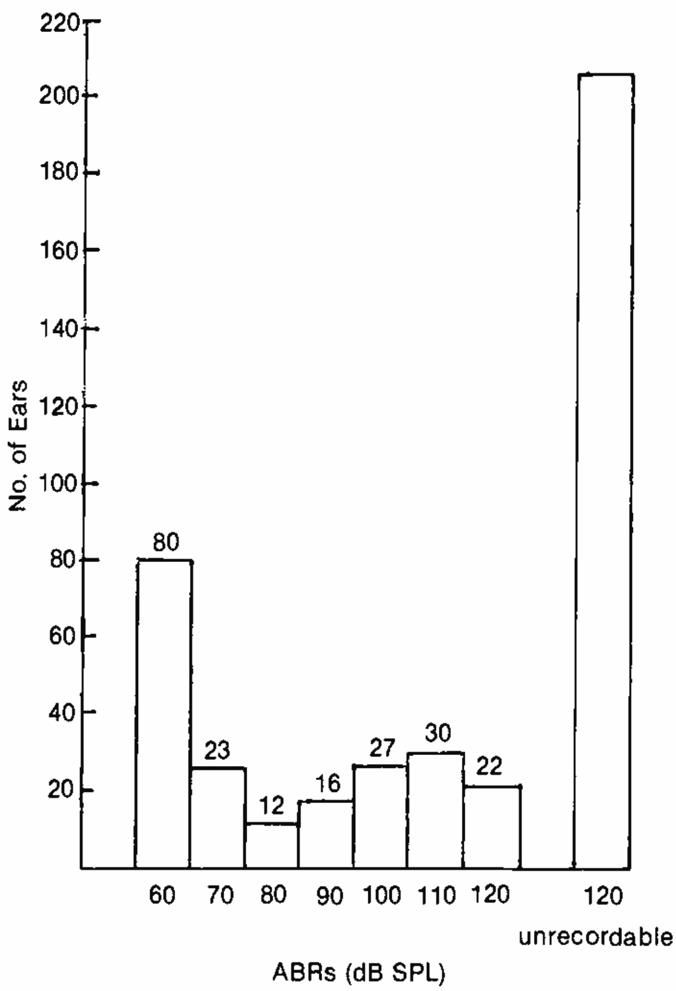
TABLE 2
THE PROBABLE CAUSES FOR DEAFNESS IN THE RISK-REGISTERED CHILDREN

Probable causes For Deafness	No. of Cases	%
Hereditary	5	6.0
Rubella & other Viral exanthems	29	34.5
Defects of ear, nose & throat	2	2.0
Low birth wt/ Premature	13	15.5
Neonatal Jaundice	24	29.0
Meningitis	11	13.5
T O T A L	84	100

TABLE 3
THE ESTIMATED HEARING RESPONSES OF THESE 'RISK-REGISTERED' CHILDREN USING ABRs

Estimated Hearing Responses	Number of risk-registered children	%
Normal - mild	10	12
Moderate - moderately severe	15	18
Severe - profound	59	70
T O T A L	84	100

Fig. 3 Distribution of ABRs in the Children



DISCUSSION

A variety of objective techniques are available to assess hearing in children. In Impedance audiometry, the stapedius reflex threshold estimation will only exclude a profound hearing loss but being unreliable in recruiting ears. The use of Electrocochleography (Ecochg) requires general anaesthesia and is an invasive technique. Cortical evoked response audiometry may be used for threshold testing (3) but their intrinsic variability limits its usefulness for this purpose.

TABLE 4
COMPARISON OF ESTIMATED HEARING RESPONSES USING THE SUBJECTIVE AND OBJECTIVE AUDIOMETRY

	Types of Audiometry	
Estimated Hearing Responses	Subjective (Conventional)	Objective (ABR)
Normal - mild	17.3%	24.8%
Moderate - Moderately severe	14.9%	20.4%
Severe - profound	44.2%	54.8%
Inconclusive - Not Done	23.6%	
TOTAL	100%	100%

The ABR audiometry provides a reliable method for estimating threshold sensitivity in children and appears to be gaining wide acceptance. The technique is non-invasive and generally requires no sedation if testing is performed immediately after a feeding when the infant is sleeping. Even in the case of sedation, induced sleep has no apparent effect on the patterns of the ABR or its relation to stimulus magnitude. The ABRs can be obtained practically from the first day of life and they measure the responses from the peripheral section of the auditory pathway up to the inferior colliculus. Other clinical attributes of ABR were summarised by Davis (4) to include waveform consistency, easy record-ability and optimal latency.

More than 200 children had undergone ABR measurements in our ENT Clinic. This group of children is referred by ENT Surgeons, paediatricians, general practitioners who suspect a hearing loss or have delayed speech. In our ABR study of these 208 children, 54.8 per cent shows severe to profound hearing loss, 20.4 per cent with moderate loss and 24.8 per cent with normal to mild hearing responses. However, in our 'risk-registered' categories, the number of cases with severe to profound hearing loss increases to 70 per cent. The study done in the County of Lancashire (5) have demonstrated that the incidence of deafness is 12.75 times higher in the 'at risk' groups than in the rest of the infant groups. We would, therefore, strongly advocate these 'at risk' groups to have their hearing tests done as early as possible and their degree of hearing loss determined for immediate habilitative programme.

A comparison of estimated hearing responses using where possible free-field tests or conventional pure-tone audiometry and ABR test suggests that the ABR measurements are more sensitive. Where the cases are considered 'difficult-to-test' by conventional audiometry, the ABR measurements provide us with additional diagnostic information. Mokotoff et al (5) on comparing ABR with impedance thresholds in 81 infants and children found that ABR was a highly reliable tool in those who were 'difficult-to-test' by behavioural means. Brackmann et al (7) also had reported that the ABR results in a group of 90 children correlated well with clinical tests and felt that extensive time and expenses of a general anaesthesia on electrocochleography were not justified. Jerger and Hayes (8) recommended that ABR testing as a useful cross-check in determing hearing levels of young, difficult-to-test subjects.

A recent study by Smith and Simon (9) compared the ABR estimated hearing levels with hearing levels obtained by pure-tone audiogram for 42 children. The ABR accurately predicted the pure-tone average in 76% and was in error by no more than about ± 10 - 12 dB in another 19%. With our groups of children who had ABR measurements, a long-term follow-up will be most interesting and useful to do. By using pure-tone audiometry when feasible, the results will confirm the general predictions of hearing status made by ABR measurements. However, it will be most difficult to obtain the results from those non-resident cases (24.5%).

Typical cases of patients considered 'difficult-to-test' by our audiologist and had ABR measurements to provide us with additional diagnostic information are illustrated in the following examples.

Case 1
This infant was 28 weeks gestational age at birth and was hospitalized for 3 months. He was referred by the paediatrician at the age of 8 months old on his hearing. Preliminary hearing assessment using the distraction test on the infant was judged to have hearing within normal limits. Brainstem responses were elicited at 50 dB SPL bilaterally and the results confirmed the audiologist's impression that the peripheral auditory system was normal. His ABR results in intensity series for the right ear are shown in fig. 4.

Case 2
A 3 year old boy was referred because of no speech. He was a hyperactive child and said to be mildly retarded. His other developmental milestones are within normal limits. Using the behavioural hearing test, it was observed that his left ear could not respond so well. It was then recommended that he be tested objectively with the ABR test to confirm our diagnosis. Wave Vs were obtained bilaterally at 60 dB SPL. Because of demonstrated intact function at least to the level of the brainstem, it was concluded that amplification was contraindicated.

Case 3
A 4 year old girl had a history of severe neonatal jaundice and had poor speech development. Her medical doctor diagnosed her as severely deaf and had advised her to attend the school for the deaf. However, her parents were certain that she could hear with shouted speech-stimuli. In our audiology clinic, she was not cooperative for localization to sound field. The ABR results suggested moderate abnormality because Wave Vs could be elicited only at 100 dB SPL bilaterally and the left ear responses are shown in fig. 5. With intensive speech therapy and proper amplification by a hearing aid, she may enter into a normal hearing school. Recommendation was made for periodic otological and audiological evaluations.

Case 4

This is the all-too-common story of a 5 year old who had several audiological evaluations with inconclusive results. Professional opinions regard his diagnosis ranging from profound hearing loss to mental retardation. Fig. 6 shows positive ABRs for his right ear using high intensity levels (above 90 dB SPL) with clicks. Several months later, he was able to co-operate sufficiently for behaviour audiometry and his pure-tone thresholds showed mild sensorineural loss through 1000Hz and moderate to severe about 1000Hz. His audiometric results are shown in fig. 7

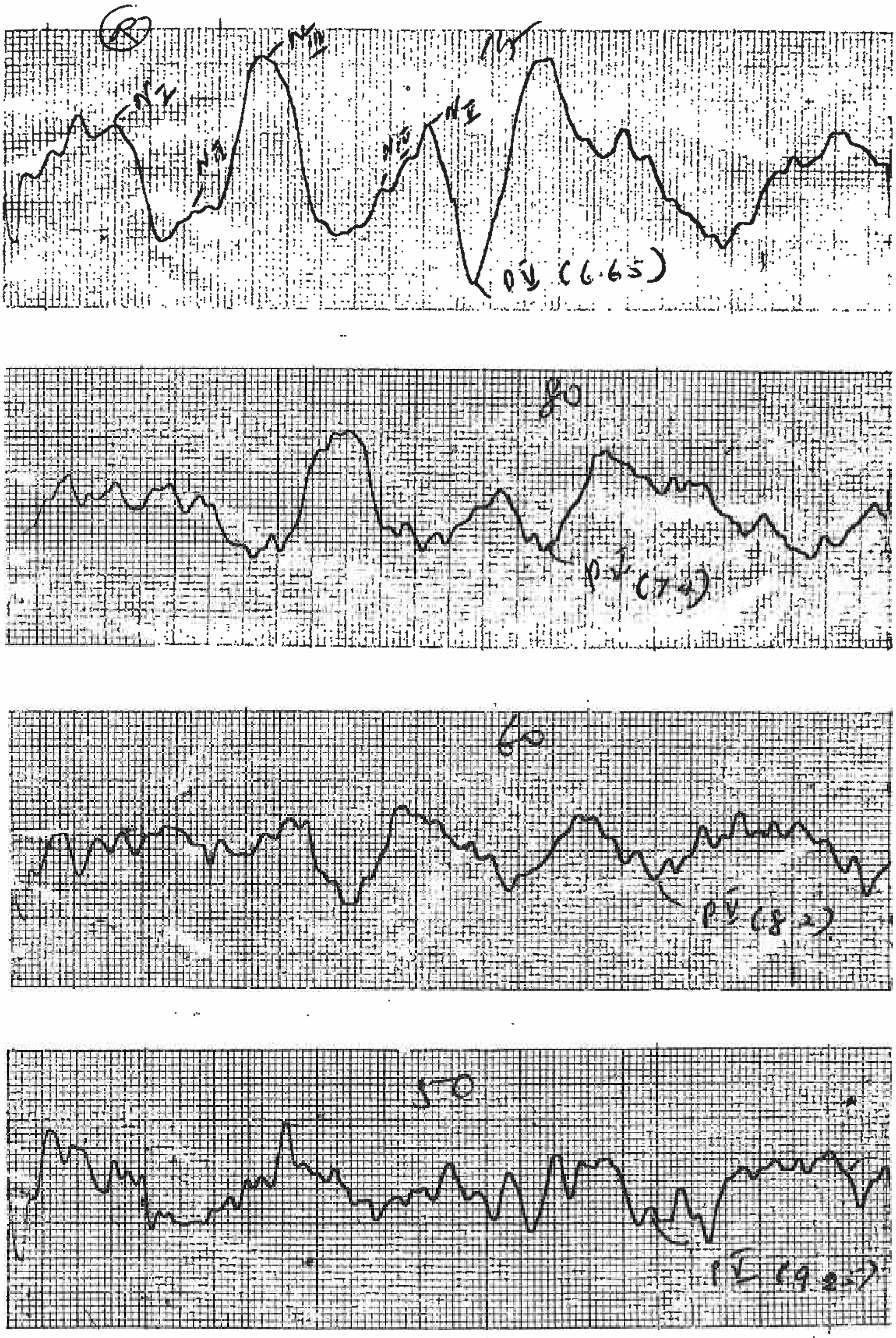


Fig. 4 ABR results in intensity series for a premature baby

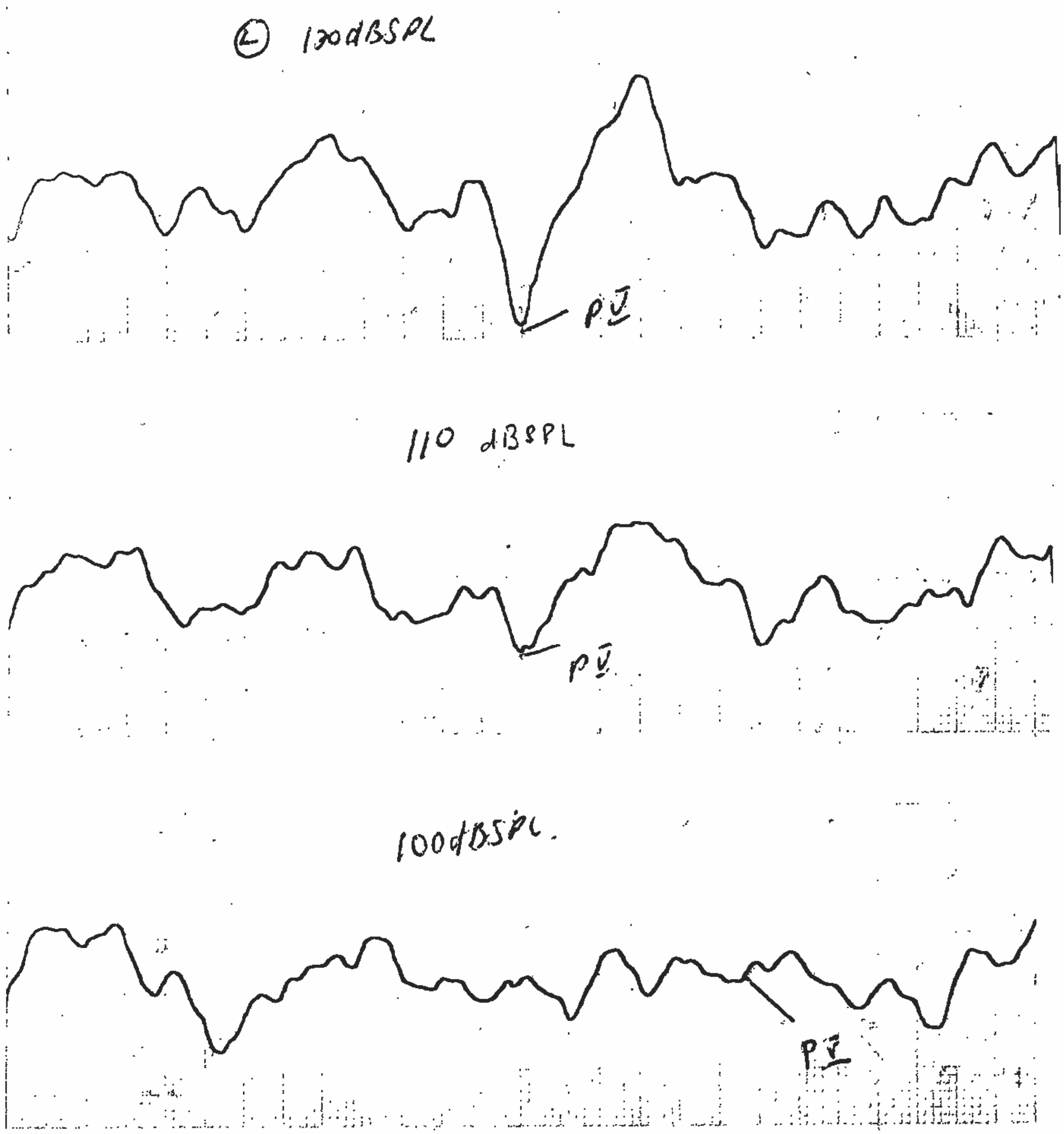


Fig. 5 The ABR results of a 4-year old girl who had neonatal jaundice

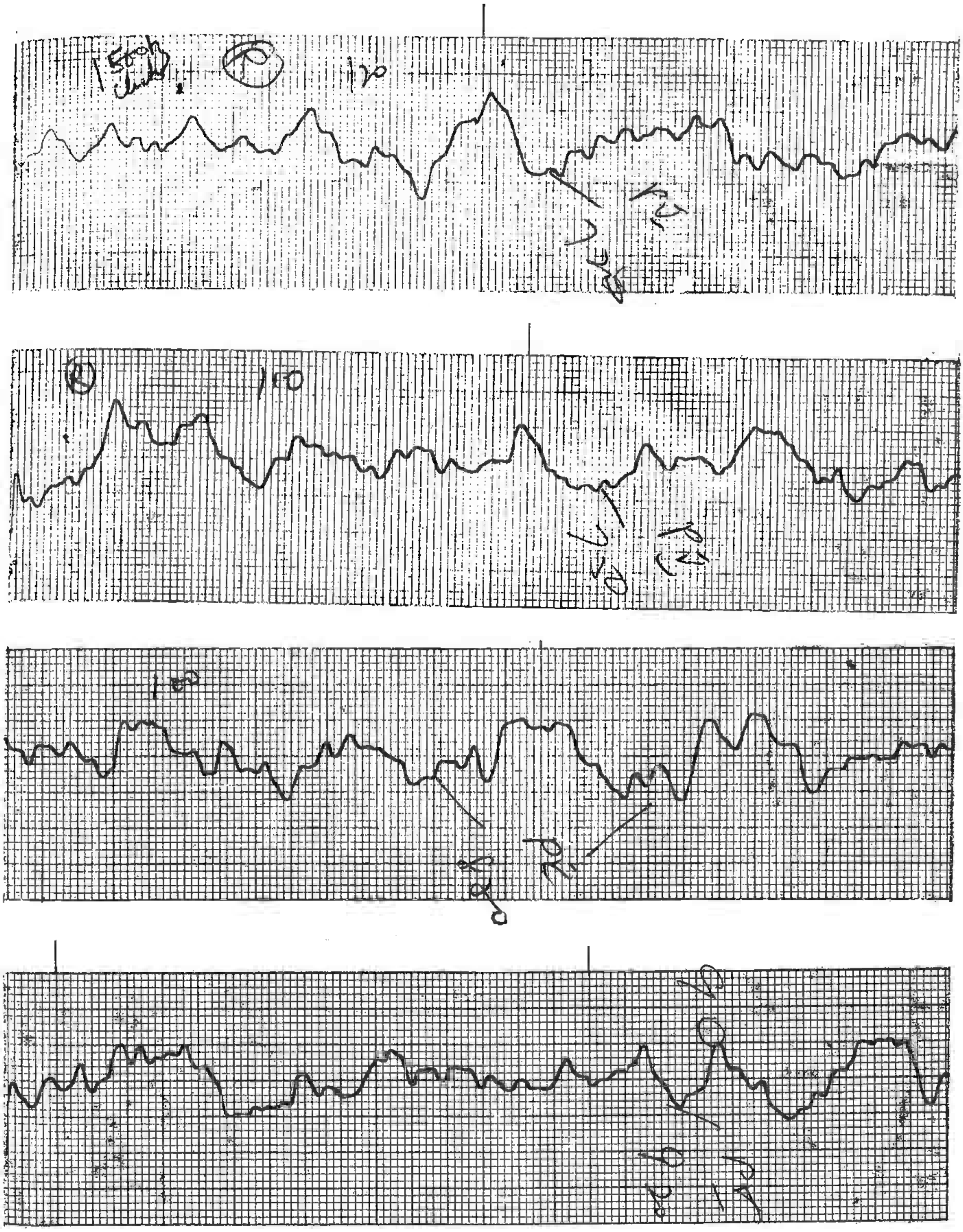


Fig. 6 The ABR results of a 5-year old boy who had several audiological tests but were inconclusive

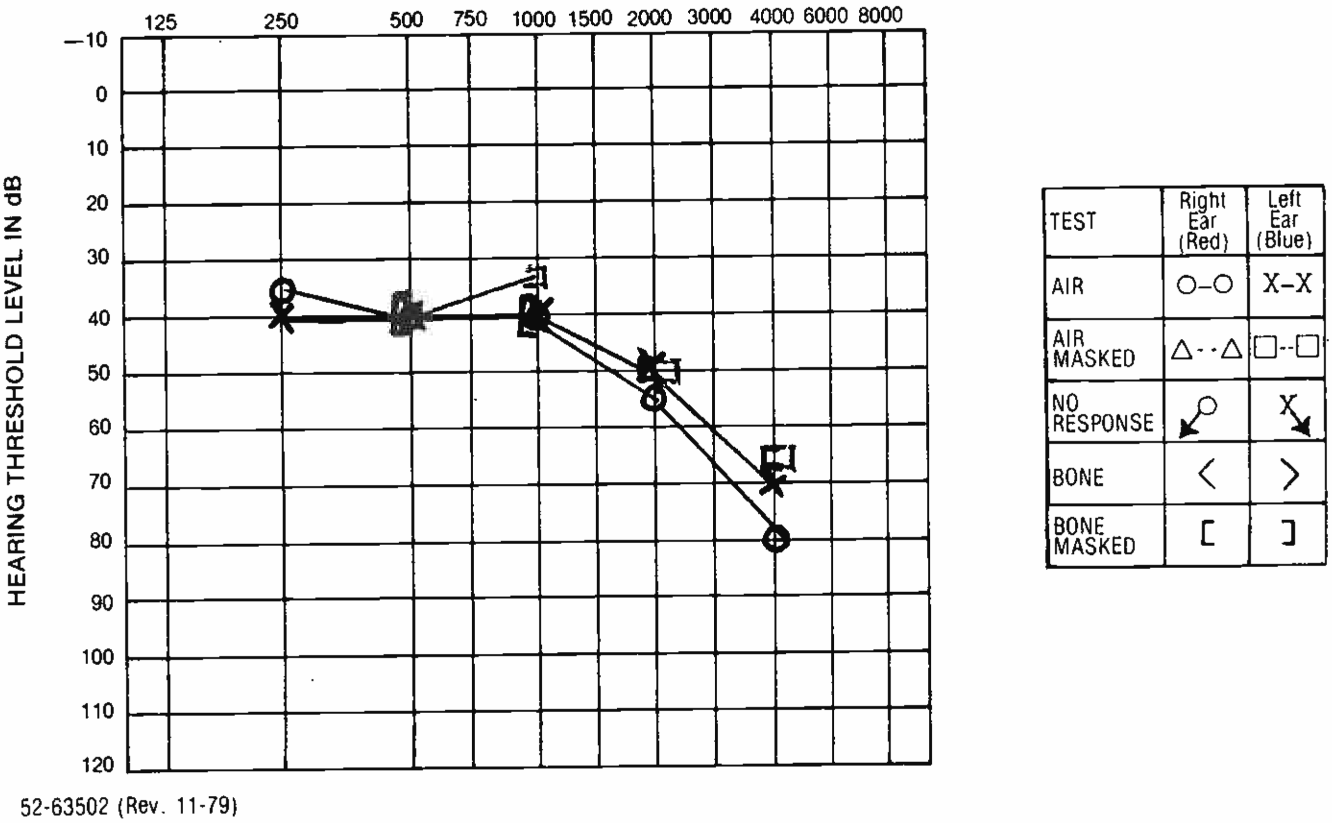


Fig. 7 The audiometric results of this 5-year old boy in Case 4, who subsequently responded to pure-tone audiometry.

Case 5
This lad was first referred to our ENT Clinic at the age of 6 years old from the Child Psychiatric Clinic for slow and indistinct speech. Antenatal history revealed that he had a forceps delivery for prolonged labour and a mild neonatal jaundice. Postnatally, he was well and all his physical milestones were normal. He had an average IQ of 101.

Our ENT examination was essentially normal except that his speech was indistinct. He was able to respond to conversational stimuli. Numerous pure-tone audiograms were done but the results were inconsistent. Therefore ABR testing was indicated and the results showed positive responses above 100 dB SPL clicks for the left ear and no response on the right side. Our impression was that because of his hearing handicaps, his speech acquisition and development are delayed. Subsequently, he was referred for speech therapy and auditory training.

Case 6
A 10 year old girl who was perfectly normal before, had a history of measle encephalitis and had become mentally retarded. During her initial audiological evaluation, it was impossible to condition her to respond using play audiometry. Localized responses to sound field stimuli were inconclusive due to her hyperactivity. The ABR test was requested and she was sedated prior to the test. Results demonstrated normal waveforms and Wave V latencies bilaterally at 115 dB SPL with Clicks. The ABRs in intensity series for her left and right ears showed responses at 60 dB SPL. These results suggested that the peripheral auditory system and the brainstems (up to the inferior colliculi) were within normal limits.

PROBLEMS IN USING ABRs

A subject whose hearing loss is restricted to the low frequency may show normal ABR results. The ABR recorded with a click stimulus reflects mainly activation of the base (high frequency portion) of the cochlea and therefore, may fail to detect a loss limited to frequencies below 1000Hz. Another problem is in subjects with high frequency loss which show relatively normal ABR measurements. The reasons for this are still unknown but factors such as the decibel per octave roll off of the hearing loss, the co-existence of recruitment, the click stimulus intensity relative to the subject's threshold are given (10).

Any pathological condition that, for example, either destroys synchrony and/or reduces the number of elements activated can also affect drastically the peak detection in the ABRs. Therefore, it is imperative to perform behavioural audiometry and other objective testings to confirm the degree and extent of the hearing loss.

CONCLUSION

This series of patients had shown the clinical usefulness of ABR method in evaluating auditory functions in children. The clinician is cautioned against the use of ABR as the sole indicator. Instead, he must correlate all information - case history, otological findings, behavioural hearing test results and other objective tests before arriving at a conclusion. The determination of hearing loss in many children is an ongoing process and may require more than one test session.

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