Evaluation of auditory brainstem responses for hearing screening of high-risk infants

R. G. Aiyer · Bhavin Parikh

Abstract Auditory brainstem responses (ABR) were recorded in 30 normal and 60 high-risk neonates with gestational age between 30 and 45 weeks. The normative data of normal group as regard to age, sex and various parameters of ABR were compared with high-risk group. ABR parameters especially wave V and interwave V-I intervals were significantly prolonged in high-risk infants. An infant was considered to “pass” the ABR test if an identifiable and replicable wave V response was present at 30 dB HL in both ears. All the normal neonates had click thresholds consistent with normal hearing. 12 of the high-risk neonates showed mild to moderate hearing impairment (absent replicable wave V at 30–60 dB HL) and 2 of them showed severe to profound hearing impairment (absent replicable wave V at 70 dB HL). 9 of the “failed” group were reevaluated within 3 months and several times thereafter if the abnormal responses persisted. 2 (3.3%) infants showed persistent hearing loss, which was confirmed later by behavioral audiometry.

Keywords Auditory brainstem responses · Hearing screening · High-risk neonates

Introduction

Hearing is necessary to learn language and speech and to develop cognitive skills. Hearing helps the developing child to learn to recognize sounds, identify objects and events and internalize concepts. As hearing is so important for normal educational and social development, hearing loss can be devastating. The developing child must pass through critical periods of language acquisition and even a mild hearing loss can interfere with this natural growth. The harmful effects of hearing loss on the development of a child’s ability to learn, to communicate and to socialize have stimulated efforts to initiate rehabilitative procedures early in life. Essential to this goal is identification of infants with impaired hearing as early as possible by screening them for hearing loss.

During the past 30 years, infant hearing screening have been attempted with a number of different methods using behavioral and physiological measures. Auditory brainstem response is one of the objective methods of hearing screening. Auditory evoked potentials, when used and interpreted properly, provide a powerful method of obtaining reliable estimates of auditory sensitivity in infants, young children, and other individuals who cannot or will not provide reliable results on behavioral hearing tests.

Materials and methods

We, at ENT and Head and Neck Surgery Department, Sir Sayajirao General Hospital and Medical College, Baroda, carried out the present study to evaluate the utility of ABR as a tool for hearing screening in infants with high-risk factors for hearing loss. There were two groups of infants in this study. The control group consisted of 30 normal neonates without any high-risk factor for hearing loss. The high-risk group consisted of 60 infants with one or more high-risk factors for hearing loss. Infants were considered to be at risk for hearing loss based on the recommendations

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of Joint Committee on Infant Hearing, 1994 Position Statement [4]. These high risk factors include:

1. Family history of hereditary childhood sensorineural hearing loss.
2. Congenital perinatal TORCH infection.
3. Craniofacial anomalies.
4. Birth weight less than 1500 grams.
5. Hyperbilirubinaemia more than 15 mg/dl.
6. Ototoxic medications.
7. Bacterial meningitis or bacteriologic proven sepsis.
8. Mechanical ventilation lasting 5 days or longer.
9. Postnatal asphyxia (Apgar scores of 0 to 4 at 1 minute or 0 to 6 at 5 minutes).
10. Stigmata or other findings associated with a syndrome known to include a sensorineural and/or conductive hearing loss.

Only those infants who had one or more of the high risk factors were enrolled in the study for hearing screening using ABR test. 30 normal newborn infants were evaluated to obtain the normative data for the study group as regard to age, sex and various parameters used in auditory brainstem responses.

The ABR test was performed on each of the enrolled infants, one to two days prior to their discharge from the hospital. The babies were tested while they were in natural sleep or in a state of quiet rest. Sedation was not used, except in a few follow up studies where syrup Pedichloryl (trichlofos) was given at a dose of 25 mg/kg (0.25 ml/kg). In no patient general anaesthesia was used.

AMPLAID mk22 auditory evoked potentials system was used for testing the infants. After adequate preparation of skin, recording silver electrodes were attached to upper forehead (recording electrode), the ipsilateral mastoid process (reference electrode) and contralateral mastoid process (ground electrode). Thus the Fpz-M1-M2 electrode montage was used for recording the ABR.

The acoustic stimuli consisted of unfiltered full square wave pulses of 100 microseconds duration and with alternating polarity. The clicks were delivered monaurally by a hand held TDH-49 headphone, at a rate of 31/sec. The analysis time was 15 milliseconds. The recording bandwidth for click threshold determination was 100–2500 Hz. The electrode and inter electrode impedance were ensured to be below 5 kHz and 2 kHz respectively. Each run consisted of

summing the responses to 2000 clicks.

The ABR protocol consisted of testing each ear at 70, 60, 50, 40 and 30 dB HL. If a response was not observed at 70 dB HL, testing was performed at 80 and 90 dB HL. An infant was considered to have passed the ABR test if a replicable wave V response was present at 30 dB HL in both the ears.

Those who failed the initial test received recommendations to return for a follow up evaluation after 3 months. If the results were consistent with the original study for two subsequent follow-ups hearing loss was confirmed. The parents were informed of the results prior to the discharge from the hospital and advised that further testing was necessary to confirm the exact status of their child's hearing. Specific follow up appointment was arranged in conjunction with the child's routine pediatric visit.

Results

The demographic data (Table 1) obtained showed that there was statistically significant difference in the sex of the infant among two groups with male infants more likely to have high-risk factors for hearing loss. Though the gestational age of birth was statistically significantly lower among the high-risk infants, the age (in gestational weeks) at time of initial screening was not significantly different. The birth weight of the two groups did not differ significantly from each other.

The normative data was collected from 30 normal full term neonates (Table 2). The data obtained from high-risk neonates (Table 3) was compared with the normative data. An analysis of the figures obtained revealed an increased latency of wave I in the high-risk group as compared to the control group (with p value < 0.05) at 70 to 30 dB HL. It also showed a significant increase in wave V latency in the high-risk group at all intensities with p value < 0.05 . However, a prolonged I-V interpeak interval was observed at all intensities and the difference was statistically highly significant with p value < 0.001 . The analysis of wave III, interpeak latency V-III and III-I did not reveal a significant or consistent alteration in the values of high-risk group as compared to control group.

Hearing thresholds of both the groups were established and compared (Table 4). Abnormal ABR findings in each ear were classified based on the ABR threshold. The degree

Table 1 Demographic data (Mean $\pm$ SD)

Demographic data	Control group	High-risk group	P value
Male	16	37	<0.01
Female	14	23	
Birth weight (in grams)	2478 ± 402.5	2256 ± 680	>0.05
Age in gestational weeks at time of screening	38 ± 0.8	39 ± 3.12	>0.05
Gestational age (in weeks) at birth	38.4 ± 1.3	35.75 ± 2.97	<0.01

of auditory deficit was estimated as mild, moderate and severe to profound. Mild deficits were identified among ears with unidentifiable wave V at 30 dB HL but an identifiable and replicable wave V at 40 dB HL. Moderate deficits were identified with an absent wave V at 40 to 60 dB HL but an identifiable wave V at 70 dB HL. Ears were labeled to have severe to profound deficits if they failed to show any identifiable wave V at 70 dB HL.

All the 30 normal neonates showed a consistent and well recognizable response at all the stimulus intensities. Hence 100% of the control ears had a hearing threshold better than 30-dB HL. In the high-risk infants, only 46 infants (76.67%) showed a clear and reproducible wave V at 30 dB HL. Rest of the 14(23.33%) infants were having varying degrees of hearing loss. 5 (35.7%) of the infants had unilateral hearing loss and 9(64.3%) of them had bilateral hearing loss. 6(10%) of the affected infants had a hearing threshold of 40 dB HL (mild hearing loss), 2 of them having unilateral hearing loss and 4 bilateral. In 6 (10%) of them, the threshold was between 40 to 70 HL (moderate hearing loss), 3 of them having unilateral hearing loss and 3 bilateral. 2 (3.33%) of the infants failed to show any response at the highest intensity i.e. 90 dB HL (severe to profound hearing loss). Both of them had bilateral affections.

Statistics for infants who failed versus those who passed auditory screening was compared (Table 5). There was no apparent difference in the proportion of infants with or

without any of the risk factors for either group. These data suggest that only one of the Joint Committee risk factor (craniofacial anomaly) is clearly related to the likelihood of hearing impairment. There was also statistically significant difference among the two groups with regard to gestational age. There was no statistically significant difference among the two groups with regard to sex, birth weight and age at the time of initial screening (i.e. days in the NICU).

Risk factor evaluation in affected infants (Table 6) shows that the four most frequent risk factors observed in the failed screen group were hyperbilirubinaemia >15mg%, craniofacial abnormalities, septicaemia/meningitis and ototoxic drugs. Among the infants with particular risk factor chances of having hearing loss was higher for those infants with family history of hearing loss, those having craniofacial abnormality and those having TORCH infections. However, as there was only a single case of family history and two cases of TORCH infection, they were not considered statistically evaluable. These data suggest that only one of the joint committee risk factors (craniofacial anomaly) is clearly related to the likelihood of hearing impairment.

Follow-Up Study of Infants Who Failed Initial ABR Screening (Fig. 1):

Follow-up evaluation was performed in 8 of the 14 infants who failed initial screening. One infant died during the first three months of life, during the initial hospitalization and five of them were lost to follow-up. A further

Table 2 Normative data [Mean (SD) in Msec]

Level in dB HL	Peaks			Interpeak latency (IPL)		
	I	III	V	V-I	V-III	III-I
70	1.992 (0.270)	4.506 (0.268)	6.880 (0.288)	4.889 (0.276)	2.374 (0.207)	2.515 (0.244)
60	2.34 (0.333)	4.828 (0.277)	7.224 (0.362)	4.823 (0.382)	2.396 (0.261)	2.388 (0.273)
50	2.753 (0.308)	5.097 (0.297)	7.495 (0.404)	4.642 (0.392)	2.398 (0.280)	2.382 (0.248)
40	3.178 (0.284)	5.521 (0.359)	7.941 (0.420)	4.685 (0.552)	2.355 (0.203)	2.302 (0.352)
30	-	-	8.48 (0.408)	-	-	-

Table 3 Data of high-risk infants

Level in dB HL	Peaks			Interpeak latency (IPL)		
	I	III	V	V-I	V-III	III-I
70	2.130 (0.258)	4.593 (0.356)	7.132 (0.526)	5.102 (0.467)	2.540 (0.414)	2.462 (0.350)
60	2.481 (0.300)	4.940 (0.408)	7.478 (0.556)	5.096 (0.473)	2.538 (0.477)	2.458 (0.392)
50	2.944 (0.334)	5.314 (0.431)	7.885 (0.614)	4.983 (0.854)	2.538 (0.436)	2.369 (0.382)
40	3.31 (0.385)	5.643 (0.423)	8.244 (0.562)	4.934 (0.502)	2.537 (0.598)	2.333 (0.378)
30	-	-	8.800 (0.662)	-	-	-

Table 4 Classification of threshold groups according to minimum stimulus-level evoking wave V

Group	Normal hearing (<30 dB HL)	Mild hearing loss (30–40 dB HL)	Moderate hearing loss (40–70 dB HL)	Severe hearing loss (> 70 dB HL)
Normal infants (ears)	30 (60)	0 (0)	0 (0)	0 (0)
High risk infants (ears)	46 (97)	6 (10)	6 (9)	2 (4)

Table 5 Comparison of statistics for infants who failed versus those who passed auditory screening

Characteristic		Group	
		PASS(n=46)	FAIL(n=14)
Gender	Male	30	7
	Female	16	7
Weight (gms)	Mean	2290	2144
	SD	690	615
Risk factors*		No. of infants (%)	No. of infants (%)
	Apgar score <7 at 5 min	13 (28.3)	2 (14.3)
	Low Birth weight(<1500 gm)	11 (23.9)	3 (21.4)
	Hyperbilirubinaemia >15 gm/dl	18 (39.1)	7 (50)
	Septicaemia/meningitis	14 (30.4)	4 (28.6)
	Ototoxic drugs	15 (32.6)	5 (35.7)
	TORCH infection	1 (2.2)	1 (7.1)
	Craniofacial abnormalities	3 (6.5)	4 (28.6)
	Family history of childhood deafness	0	1 (7.1)
	Syndromic child	1 (2.2)	0
	Mechanical ventilation>4 days	0	0
Gestational age			
	At birth (weeks)		
	Mean	38.2	37
	SD	3.24	1.68
	At screening (weeks)		
	Mean	39	39
	SD	3.24	2.78

*Note: Total percentage exceeds 100%, some infants had more than one factor. Among the infants who passed the screening, 19 % had two risk factors, and 19 % had more than two risk factors. Among infants who failed the screening, 29% had two risk factors, and 21% had more than two factors.

Table 6 Risk factor evaluation in affected infants

Sr. no.	Risk factor	Total number of infants	Number of infants with hearing loss	Percentage of infants with risk factor having hearing loss	Percentage of total abnormal infants (n = 14)
1.	Apgar score <7 at 5 min	15	2	13.3	14.3
2.	Low birth weight (<1500 gm)	14	3	21.4	21.4
3.	Hyperbilirubinaemia >15 gm/dl	25	7	28	50
4.	Septicaemia/meningitis	18	4	22.2	28.6
5.	Ototoxic drugs	20	5	25	35.7
6.	TORCH infection	2	1	50	7.1
7.	Craniofacial abnormalities	7	4	57.1	28.6
8.	Family history of childhood deafness	1	1	100	7.1
9.	Syndromic child	1	0	0	0
10.	Mechanical ventilation >4 days	0	0	0	0

Fig. 1

classification was based on retest findings of eight of the infants who failed during initial screen. Two of them continued to have severe persistent hearing loss. Repeated ABRs confirmed an abnormal follow-up testing in both of them within six months and finally by behavioral audiometry. Both the patients with persistent abnormal ABR were initially classified into severe hearing loss threshold group on initial screening test. Follow-up testing of remaining six infants revealed no abnormality on ABR study. These six infants were having mild to moderate hearing loss on initial screening.

Discussion

The normative data described here relate to normal term infants (gestational age between 37–40 weeks) and tested under ideal conditions. The measurement parameters used for obtaining normative data were as suggested by Hall². As such, the data are particularly relevant to clinical decision-making in high-risk groups, for their hearing screening. With regard to ABR latencies, the amount of variation observed is remarkable. So it is cautionary against over-interpretation of latency ‘abnormalities’ found in high-risk groups.

The purpose of comparison of various parameters of ABR in control and high risk infants was to determine the presence or absence of correlation of the abnormalities of

ABR with the various forms of neonatal insults, which an infant may undergo in early postnatal life. We compared the individual wave latencies and the interpeak latencies of the normal neonates and high-risk infants.

Wave I

Wave I indicates cochlear function per se and an increase in this parameter signifies a lesion at the level of the middle or inner ear. The latency values in the study did not show any significant difference from the control group at the lower intensity level of 40 dB HL. But, at the higher intensity levels we have seen a significant difference in the wave I latencies. This may be explained on the basis of the observation that with increasing intensity levels, there is shortening of the wave latencies due to the rapid firing and the quicker rising of synaptic potentials and, therefore, a decreased latency of transmission. It can be hypothesized that this increase in the firing rate with increasing intensities in compromised babies does not equal that of normal babies [11]. Hence, though the latencies may be comparable at lower intensities due to normal cochlear function, difference occurs at the higher intensities.

Wave V

The absolute latency of wave V is a consistent and stable parameter that is why it has received primary attention as a

valuable factor in response evaluation. It is suggested that all the risk factors which bring the neonate under intensive care induce a certain amount of hypoxia of the cochlea and brainstem, which leads to various cellular changes such as edema, degeneration and necrosis. Hence, they predispose to hearing impairment, which may be reversible following reversal of the hypoxic changes [9]. Our study demonstrated significantly prolonged wave V latency.

I-V interpeak latency

Our study demonstrated a significant prolongation of interpeak latency. The interpeak latency is a reflection of the neural conduction time between the auditory nerve and the brainstem nuclei and reflects upon the efficiency of the auditory pathway. Prolonged I-V interpeak latency is a feature of neurological impairment and is indicative of delay in neural conduction within the brainstem. Evidence that both the peripheral and central components of the ABR may be abnormal during the early stages and that the impairment may be temporary in some infants is provided by Kileny⁵.

The hearing threshold in term infants has been thought to be within the range of normal adult levels [7]. Our results showed the hearing threshold of all the normal neonates to lie within 30-dB HL. However, in 77% of high-risk neonates thresholds were below 30 dB HL. The elevation in threshold in high-risk infants may be associated with neurological problems in such infants secondary to hypoxia, hyperbilirubinaemia, ototoxic drugs etc. and higher incidence of middle ear effusion among neonatal intensive care unit infants.

Halpern [3] in an investigation of 799 high-risk infants concluded that most high-risk factors were associated with hearing loss. However, only four variables were found to be important for predicting hearing loss. They were (1) length of stay in the NICU, (2) gestational age, (3) craniofacial anomalies and (4) TORCH infections. Our study found craniofacial anomalies and gestational age to be clearly related to the hearing impairment. However, individual risk factors do not carry equal weight and interactive effects between the risk factors are extremely complicated.

Follow-up study of infants who failed initial ABR screening

The problem of retesting is a major concern reported by all that have attempted follow-up studies. Despite the variances reported in the percentages of high-risk infants failing initial screening, there is little if any difference in the percentage found on retest to have severe hearing loss. The incidence of severe to profound hearing loss confirmed on follow-up ranges from 2 to 4% and we had an incidence of 3.33%. Although the latency-intensity series in the patients with unilateral and lower intensity failures used to determine the ABR abnormality was consistent with conductive

loss, the low follow-up rate and inability to perform impedance audiometry simultaneously in the follow-up patients prevented us from estimating the prevalence of hearing loss attributable to conductive component.

Available evidence indicates that the prevalence of middle ear effusion in NICU infants may be as high as 25 to 34% [8]. ABR abnormality indicative of a conductive deficit (wave I prolongation and moderate threshold elevation) is found in many preterm infants [10]. These findings indicate that a substantial number of high-risk infants fail a 30 dB HL screening level because of conductive hearing loss in one or both ears. The apparent recovery of ABR on retest could also be due to reversibility of neuropathology of the brainstem associated with the hypoxic episodes. The frequently transitory nature of such a loss may account in substantial part for the initial high failure rate relative to hearing loss confirmed on retest (high false positive rate).

Conclusion

After looking to the observations and results of our study, we came to following conclusions. No child is too young for hearing evaluation. The identification of any magnitude of hearing loss in infants is possible using ABR measures. ABR is a reliable method for estimating hearing threshold in infants. Almost all the normal neonates had click thresholds consistent with normal hearing. ABR parameters, especially wave V and interwave V-I latency, are significantly prolonged in high-risk infants as compared to normal neonates. High-risk infants (having one or more of high-risk factors as defined by the Joint Committee of Infant Hearing) have a substantially higher incidence of hearing loss as compared to normal neonates. So all the high-risk infants must be screened for hearing impairment prior to discharge from the hospital using ABR. Though transient hearing impairment is not uncommon in these infants, the incidence of persistent severe to profound hearing loss is considerable. Retesting of infants with abnormal initial ABR within three months, and several times within the first year if abnormal responses persist, is important.

References

1. Galambos R, Hicks G, Wilson M (1984) The auditory brainstem response reliably predicts hearing loss in graduates of a tertiary intensive care nursery. *Ear Hear* 5:254–260
2. Hall JW III (1992) *Handbook of Auditory Evoked Responses*. Boston, MA: Allyn & Bacon
3. Halpern J, Hosford-Dunn H, Malachowski N (1987) Four factors that accurately predict hearing loss in “high risk” neonates. *Ear Hear* 8:21–25
4. Joint Committee on Infant Hearing. 1994 position statement. *ASHA* 1994; 36:38–41

5. Kileny P, Magathan M (1987) Predictive value of ABR in infants and children with moderate to profound hearing loss. *Ear Hear* 8:217–221
6. Kramer S, Dianne R, Marie C (1989) Auditory Brainstem Responses and Clinical Follow-up of High-risk infants. *Pediatrics* 83(3):385–392
7. Lary S, Briassoulis G, De Vries L, Dubowitz V (1985) Hearing threshold in preterm and term infants by auditory brainstem response. *J Pediatr* 107(4):593–599
8. McClellan MS, Strong JP, Vautier T, Blatt L (1967) Otitis media in the newborn. *Arch Otolaryngol* 85:380
9. Shahnaz D, Charles MS, Kimberley KB, Ronald LG (1986) Neonatal screening with auditory brainstem responses: results of follow-up and risk factor evaluation. *J Pediatrics* 108(2):276–281
10. Stockard JE, Kleinberg F, Westmoreland BF (1984) Prognostic value of brainstem auditory potentials in neonates. *Arch Neurol*
11. Yang EY, Stuart A, Mencher GT, Mencher LS, Vincer MJ (1993) Auditory brainstem responses to Air- and Bone-conducted Clicks in the audiological assessment of At-risk infants. *Ear & Hearing* 14(3):175–182