ABR Audiometry: Application to the Paediatric Population

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ABSTRACT

This study examines the relationship between Auditory Brain Stem, Behavioural Observation and Impedance Audiometry in a paediatric population. Particular reference is made to the strengths and weaknesses of Auditory Brainstem Audiometry applied to this age group. Results indicate that in some cases diagnosis of hearing loss is made primarily on the basis of this test, while in other cases the test serves as an excellent check on Behavioural and Impedance Audiometry.

OPSOMMING

Die verhouding tussen ouditiewe breinstamoudiometrie, gedragswaarneming en impedans-oudiometrie is in 'n pediatriese groep ondersoek. Verwysing word gemaak na die voordele en nadele van breinstamoudiometrie vir hierdie ouderdomsgroep. Resultate dui daarop dat vir sommige pasiënte die diagnose van 'n gehoorverlies uitsluitlik berus op die uitslag van hierdie toets, terwyl dit in ander gevalle dien as 'n aanduiding van die betroubaarheid van gedragswaarneming en impedans-oudiometrie.

The impact of ABR audiometry has increased rapidly over the past five years (Hecox & Jacobson, 1984). Many more centres have introduced auditory nerve and brainstem evoked responses in addition to traditional behavioural procedures as a means of diagnosing hearing loss in infants and children (Levi et al, 1983).

Initial validation procedures for Auditory Brainstem Response (ABR)* audiometry i.e. the degree to which the auditory brainstem potentials are able to accurately predict auditory impairment, were undertaken in the adult population (Hecox & Jacobson, 1984). Finitzo-Hieber (1982) cites her research, where impairments predicted by ABR were confirmed by pure tone audiometric results, stating that the agreement between ABR and PTA was generally good with ABR/PTA discrepancies among subjects never greater than one category. In other words, while ABR could and did predict normal hearing in the presence of a mild loss, this discrepancy/error did not occur for moderate or greater impairment and a loss was never called severe to profound that was in fact normal or even mild in degree (Sohmer & Feinmesser, 1974 and Pratt & Sohmer 1978 cited by Levi et al, 1983). Hecox and Jacobson (1984) also, using the PTA as the validating reference criterion, report serious discrepancies in less than 1% of cooperative adults. Therefore, whilst the use of click stimuli in routine ABR testing does not allow for the prediction of information concerning the entire audiometric configuration, a methodological limitation generally accepted, one would usually still be able to identify patients in need of long term follow up (Hecox & Jacobson, 1984).

Recent studies have attended specifically to the use of ABR testing in the difficult-to-test population, namely the very young and multihandicapped. Cornacchia et al, (1982), comparing Brainstem Evoked Response Audiometry and Behavioural Audiometry in 270 infants and children (divided into those with and without reliable audiograms), found a higher agreement between the two methods in the former group but concluded that ABR (using the term BSERA) audiometry was reliable and enabled many diagnostic mistakes to be avoided. Levi et al., (1983) conducting a similar, but two part study where both infants and neonates were studied, state that ABR audiometry gave an earlier indication of the presence or absence of hearing and of hearing threshold. They recommended the use of ABR as early as possible, particularly for the "high risk" infant.

The purpose of this work was to analyze in more detail our own paediatric ABR clinical data. Specifically the aims were to examine and gain a better understanding of the relationships between ABR, Behavioural and Impedance testing in this population group.

METHOD

SUBJECTS

During the period 1982-1983, forty-five children under the age of two years, were tested at the Speech and Hearing Clinic, University of the Witwatersrand. Two years was taken as the arbitrary age cut-off point for the purpose of the study. Fourteen children in this group were assessed with ABR audiometry in addition to the conventional procedures and constitute the population under study. The children were referred by a variety of medical and educational sources for suspected or queried hearing loss. Since ABR testing was not administered routinely to all clinic patients in this age range, the majority of the children were those with associated problems or "at risk" infants. See Table 1 below for a detailed description of the subjects (Ss).

As Table 1 illustrates, eight of the Ss had definite associated problems or "at risk" factors for hearing loss. In the remaining Ss no "at risk" factors could be identified.

PROCEDURE

Retrospective analyses of assessment reports took note of the results of three procedures: Behavioural, Impedance and ABR Audiometry.

1. Behavioural Observation Audiometry (BOA)
All Ss had been tested behaviourally in a sound field setting using

* Suggested nomenclature at the International Conference on Standards for Auditory Brainstem Response Testing, cited by Sohmer, H. (1984).

Table 1 Description of Subjects

SUBJECTS	SEX	AGE	ASSOCIATED PROBLEMS	AT RISK FACTORS
1	M	6 weeks	—	Family history
2	F	5 months	—	
3	M	5 months	—	
4	M	7 months	—	
5	M	8 months	—	
6	F	10 months	Downs Syndrome	
7	M	16 months	—	
8	M	18 months	—	
9	F	20 months	Pierre Robin Syndrome	
10	F	20 months	Mental retardation	
11	F	20 months	Reyes Syndrome	
12	M	22 months	Cerebral Palsy	
13	F	22 months		Post Meningitis
14	M	24 months		Family history

the methods reported by Downs and Sterrit (1967) cited and summarized by Levi et al., (1983). Essentially this is based on the use of higher intensity stimuli for younger infants: neonates – 90-100 dB HL; 6 week-old infants – 50dB HL (to which a gross motor reaction is expected); 4-5 months – 30dB HL; and 7-9+ months – 10-20dB HL (to which the expected response is a turning of the head to the source of sound). Responses were categorized according to the following general descriptive categories: absent responses, queried responses and expected responses. In some cases a more detailed description of the expected responses was possible in terms of the intensity range.

2. Impedance Audiometry (Imp)
Where available these results were described according to tympanometric configuration and acoustic reflex results. Tympanograms were classified according to Jerger's classification (Jerger, 1970 cited by Northern, 1984). Reflexes were described as being absent or present at normal or elevated hearing levels.

3. ABR Audiometry (ABR)
ABR testing had been conducted at both the National Institute of Personnel Research and at the Speech and Hearing Clinic, University of the Witwatersrand. The test was carried out in an electrically shielded, sound-attenuated room. All children were sedated and slept through the entire test. The responses were elicited by clicks of rarefaction polarity with an electrical duration of 100 micro secs. delivered through a TDH-39 earphone monaurally. Stimulus rate was 11.1/sec.

Electrodes were placed as follows: Vertex (Ev = active electrode); Earlobe (Er = reference electrode); and Forehead (Eg = Ground electrode). The electrical signals were fed into a pre-amplifier, filtered through a band-pass filter (150-3000Hz), amplified by a low-noise wide band amplifier and then averaged. Averaging was initiated at stimulus onset and continued for 10 ms. The averaged signals were printed on an x-y plotter.

The procedure for threshold estimation was as follows: stimulus intensity was decreased in 5-10 dB steps until no identifiable Peak V was obtained. For the purpose of this study only the presence of Peak V was used to estimate thresholds (Chiappa, 1983). The site of impairment was not identified as the results for each individual were not compared to a normal latency intensity curve (Hecox and Jacobson, 1984).

RESULTS

Results are discussed as follows:
- Agreement between BOA and ABR audiometry
- Agreement between Impedance and ABR audiometry
- Agreement among all three tests: BOA, Impedance and ABR Audiometry.

AGREEMENT BETWEEN BOA AND ABR

As can be seen in Table 2 these infants (with the exception of Subjects 10 & 12) had either normal or severe to profoundly impaired hearing, with no associated problems. This observation is consistent with the findings of Cornacchia et al., (1982) who found in their group of children without associated problems (Group A) that there was increasing agreement between BOA and ABR in those classified as profoundly deaf or no/mild hearing loss. Specifically they noted that when audiograms revealed a hearing loss of at least 70 dB in the frequencies of the speech range, the correlation between these two tests was perfect.

Ss 10 & 12 reflect how gross threshold 'estimates' (i.e. not completely frequency specific) from behavioural testing were more or less in agreement with the extent of loss suggested by ABR audiometry, despite the many queried responses. Agreement between behavioural and ABR test results should however take into account frequency specific responses.

As can be seen in Table 3 agreements between ABR and BOA in these subjects is generally poor. As in the case of group B Ss in the study by Cornacchia et al., (1982) these children were those with associated brain damage and/or behavioural problems, which render behavioural test results less reliable, especially in cases with severe handicaps. Specific test results in this group are examples of how critical the contribution of ABR testing was for clarifying the peripheral auditory status. In Subject 6 where severe retardation may have confounded any impression of auditory functioning, ABR results ensured that the problem of a concomitant severe hearing handicap was recognized and followed up much earlier.

In Subject 11, a child with multiple problems, normal results as reflected on ABR testing excluded a hearing problem and she could thus be referred accordingly. While these examples illustrate the serious discrepancies that may occur between the two tests, Subject 14 is a good example of partial discrepancy between the two tests. Here,

Table 2 Results of BOA and ABR in Subjects reflecting good inter-test agreement

SUBJECTS	AGE	ASSOCIATED PROBLEMS	BOA	ABR
1	6 weeks	—	expected responses	normal bilateral
3	5 months	—	no responses	severe-prof. s/n loss bilateral
4	7 months	—	expected responses	normal bilateral
7	16 months	—	responses to low freq. only (70dB HL)	severe-prof. s/n loss bilateral
8	18 months	—	SAT L:95dB HL R:85dB HL	severe-prof. s/n loss bilateral
10	20 months	Queried Retardation	response to 40-65 dB HL many responses queried	mild/mod s/n loss bilateral
12	22 months	Cerebral Palsy	1x:response at 70dB HL many queries. 2x:response at 50-60dB HL	1x:severe loss bilateral 2x:mod. mixed loss bilateral
13	22 months	Post Meningitis	response at 90dB HL	severe-prof. s/n loss bilateral

SAT = Speech Awareness Threshold
s/n = Sensori-neural
severe-prof. = Severe-profound

Table 3 Results of BOA and ABR in cases reflecting inter-test discrepancy.

SUBJECTS	AGE	ASSOCIATED PROBLEMS	BOA	ABR
2	5 months	Prematurity	response to medium intensity. Many responses queried.	normal bilateral
5	8 months	—	expected responses	mild cond. loss bilateral
6	10 months	Downs Syndrome	queried responses	severe/prof. s/n loss bilateral
9	20 months	Pierre Robin Syndrome	queried responses	mild cond. loss bilateral
11	20 months	Reyes Syndrome	all responses queried	normal limits bilateral
14	24 months	Family history	responses at 60dB HL	severe/prof. s/n loss bilateral

cond. = conductive
s/n = sensori-neural
severe/prof. = severe-profound

Table 4 Results of Impedance and ABR Audiometry

SUBJECTS	AGE	ASSOCIATED PROBLEMS	IMP	ABR
1	6 weeks	—	Bilateral Type A	Normal bilateral
2	5 months	premature	Bilateral Type A ARs at normal HLS	Normal bilateral
3	5 months	—	—	Severe-profound loss bilateral
4	7 months	—	Bilateral Type A ARs at normal HLS	Normal bilateral
5	8 months	—	Bilateral Type A ARs at normal HLS	Mild loss bilateral
6	11 months	Down Syndrome	Grommets	Severe-profound loss bilateral
7	17 months	—	Grommets	Severe-profound loss bilateral
8	18 months	—	Grommets	Severe-profound loss bilateral
9	21 months	Pierre Robin Syndrome	Bilateral Type B	Mild loss bilateral
10	22 months	Query retardation	Grommets	Mild-moderate loss bilateral
11	24 months	Reyes syndrome	Bilateral Type A ARs at normal HLS	Normal bilateral
12	22 months	Cerebral Palsy	1 x Bilateral Type B 2 x Grommets	Severe-profound loss bilateral Moderate loss bilateral
13	20 months	Post meningitis	—	Profound loss bilateral
14	24 months	Family history	Type A bilateral ARs present up to 1KHz, absent from 2-4 KHz	Severe-profound loss bilateral

Key: AR = acoustic reflex
HL = hearing level

behavioural testing gave the impression of a less severe loss than that indicated on ABR, and probably yielded information about low frequencies that is not available with the use of the 'broad-band' click stimulus which reflects high frequency fibre activity (Hecox & Jacobson, 1984).

AGREEMENT BETWEEN ABR AND IMPEDANCE AUDIOMETRY

Robier et al., (1983) discuss the value of using precise acoustic impedance measures to rule out middle ear effusion before administering electro-physiological tests to reveal sensori-neural deafness. Levi et al., (1983) include Impedance together with ABR Audiometry as a check on Behavioural Observation Audiometry. Neither of these studies, however, specifically examine the relationship between acoustic reflex threshold and ABR measures.

A comparison of the results of these two tests revealed how they may complement each other. It was possible to observe, in Subjects 2 and 11, how ABR results were able to lend support to the suggested normal hearing observed on the acoustic reflex subtest. In these cases, the presence of the reflexes at normal HLs was ambiguous in the light of the queried behavioural responses. Furthermore, in Subject 14, while absent ABR tracings suggested a severe to profound loss, the pattern of reflex threshold results obtained (absent in the higher but present in the lower frequencies), suggested some hearing in the lower frequencies. Since it is known that correlations between ABR prediction of hearing loss and audiometric thresholds suggest that ABR best approximates hearing thresholds at high frequencies (2-4 kHz), and poorly reflects the integrity of hearing at less than 500 Hz (Galambo and Hecox 1978, Jerger and Mauldin, 1978, cited by Hecox and Jacobson, 1984), acoustic reflex measures in this case, gave us information about possible residual hearing, otherwise unavailable from isolated standard ABR testing.

AGREEMENT AMONG ABR, IMPEDANCE AND BOA

In general the findings of the results of these infants reflected a familiar phenomenon facing the audiologist, namely that inter-test results are not always in perfect agreement. It is clear that where agreement is perfect the diagnosis of the extent and type of loss can be made more definitely, and that as agreement lessens diagnoses are made more tentatively. Extending this to ABR audiometric interpretation the use of adjunctive audiological information is crucial if one is to use ABR results to effectively diagnose and manage, in particular the paediatric and unco-operative patient (Hecox & Jacobson, 1984).

Subject 12 best illustrates how the integration of results from all three tests avoided the possibility of a critical diagnostic error. On initial assessment ABR together with BOA results gave the impression of a bilateral severe hearing loss, while impedance results indicated the presence of some conductive component. Subsequent to the medical treatment of the middle ear condition, ABR and BOA results together reflected a mixed but predominantly mild-moderate rather than severe loss, which was managed accordingly. Although this is an isolated case it illustrates effectively how the exclusive use of ABR audiometry cannot accurately predict permanent hearing loss. This is an important consideration when dealing with the paediatric population where the incidence of middle ear pathology is at its highest.

CONCLUSIONS

There is no end to the combinations of the types and extent of hearing losses that an audiologist may encounter. Certainly the small size and age range of this sample does not allow finite conclusions about the relative importance of ABR, Behavioural and Impedance testing in the overall audiological test battery. Nevertheless, closer inspection of the results and relationships between these tests provides an appreciation of the strengths and weaknesses of the use of ABR audiometry in the paediatric population.

Assuming that the ABR threshold is a reliable indicator of the hearing threshold of a subject (Sohmer & Feinmesser, 1974; Pratt & Sohmer, 1978 cited by Levi at al., 1983) five of the Subjects in the study were diagnosed on the basis of ABR results alone. These subjects were those with associated brain damage and/or behavioural disorders which made them less amenable to behavioural testing, and those where the presence of gronimets prevented the use of objective impedance measurements. In these two instances ABR testing enhanced earlier diagnoses of the peripheral auditory status and thus appropriate habilitation measures.

In the remaining nine Subjects, particularly those with normal hearing or severe losses in the absence of associated problems, ABR audiometry served as an excellent check on both behavioural and impedance test results. Of particular interest was the fact that the acoustic reflex sub-test served as a useful complement to ABR results, at times providing information about possible residual low frequency hearing, which is not available from standard ABR testing.

While the ultimate validation of these ABR test results would depend on follow-up audiograms, as was included in the study by Levi et al., (1983), these results suggest nevertheless that ABR audiometry can be seen as a logical component of paediatric testing.

ACKNOWLEDGEMENT

The authors wish to thank Brian Mallinson, Chief Researcher, NIPR, Human Sciences Research Council, who assisted with some of the ABR audiometric testing.

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