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advisor - Dr. Rodianne Karzon

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Introduction

Visual reinforcement Audiometry (VRA) and Auditory Brainstem Responses (ABRs) are two different audiologic approaches for measurement of hearing sensitivity in infants 7 to 12 months of age. VRA is a behavioral technique which requires patient cooperation and cognitive abilities at approximately the 6 month level (Wilson & Thompson, 1984). ABR is an electrophysiologic technique frequently requiring sedation (Jerger et. al., 1980). Measures of hearing sensitivity in this procedure presume neurologic integrity of the brainstem.

The Department of Audiology at St. Louis Children's Hospital recommends that VRA be the initial audiologic approach for infants ≥ 6 months of age. If VRA results have poor reliability, questionable validity or if the index of suspicion of hearing loss is high they proceed with an ABR. However, physicians at Childrens hospital and in the community have begun to routinely order ABRs as the initial audiologic evaluation. It would seem that physicians have begun to prejudge the ability of infants to perform for VRA. In particular, they tend to refer for ABR, infants who have a severe illness (such as meningitis) and are at risk for hearing impairment.

Talbott (1993) assessed the validity of VRA with infants 6 to 27 months of age with a mean age of 14 months. In Talbott's (1993) study, children were initially tested using VRA and then retested at a later date by play audiometry. The mean interval between test procedures was 17.4 months. The threshold results for each frequency for each test were treated as a matched pair. In other words, the VRA threshold at 250 Hz was paired with the play audiometry threshold at 250 Hz. There were no significant differences for the matched pairs at any of the frequencies.

Thus, Talbott concludes that VRA is an effective technique for the assessment of hearing impaired infants, and can be used to begin early hearing aid management. Furthermore, VRA can be used to monitor fluctuating or progressive hearing losses (Talbott, 1993).

ABR is often used to evaluate individuals who cannot be tested by conventional audiometric methods. Typically, clinicians begin their assessment of pediatric patients with high frequency click stimuli. Some facilities such as St. Louis Children's hospital proceed with tone burst, tone pips or other stimuli to obtain frequency specific data.

In normally hearing subjects ABR thresholds obtained with a 500 Hz tone burst stimulus may be identified about 15-30 dB above behaviorally measured thresholds (Gorga, Kaminski, Beauchaine, & Jesteadt, 1988; Davis, H., Hirsh , S.K., Turpin, L.L., and Peacock, M.E., 1985). Jerger et. al. (1980) provided data on 157 children tested with ABR; of those, 141 were also tested by behavioral audiometry. They found that in 84% of the cases the ABR thresholds were consistent with the results from behavioral audiometry and/or impedance audiometry.

When performing ABRs one must be aware of a variety of subject related factors, which may affect accurate interpretation of auditory evoked responses from pediatric patients. In most cases, children between the ages of four months and six years of age have to be sedated during the test period for ABRs (Jerger et. al., 1980). Sedation ensures muscular relaxation, which in turn helps reduce the amount of nonstimulus related electrical activity. The presence of concomitant central nervous system (CNS) involvement may also lead to misinterpretation of ABRs. Jerger et al.(1980) found ABRs to be ambiguous in 17 of 31 children with CNS involvement. Additionally, even though ABR responses are present at birth, they are not adultlike until the child reaches 18 months (Hall, 1992).

The purpose of this study was to assess the relative clinical value of performing visual reinforcement audiometry versus ABR on infants between the ages of seven and twelve months. We were particularly interested in comparing VRA results for in-patient infants with meningitis to those of out-patient infants referred for audiological or otological evaluation by their parent or pediatrician. Furthermore, the results of VRA will be compared with ABR results obtained from age-matched infants.

We planned to use the data collected to explore the issues involved in choosing BHT versus ABR. These issues include the following: 1) patient risk as a result of some aspect of the procedure, 2) the amount of information obtained and the adequacy of that information for rehabilitation recommendations, 3) the index of suspicion for hearing impairment, 4) the availability of the client for further testing and the commitment of the parent or guardian, 5)or, finally, the monetary cost of the procedure.

Methods

Subjects

Group 1, 2 and 3 were tested by VRA. Subjects for Group 1(VRA-In-Patients),Group 2(VRA-ENT),Group 3(VRA-Private) and Group 4(ABR) were culled from clinic records for the years 1986-1992.

Group 1. was limited to in-patients with meningitis. Group 1 consists of 18 infants ranging in age from 7 to 11 months. All subjects in the remaining groups were matched for age and date of evaluation with the subjects in Group 1(VRA-in-patients). Group 2(VRA-ENT) subjects were referred for audiologic services by an otolaryngologist in the Department of Otolaryngology at Children's hospital. Group 3(VRA-Private) subjects were referred for audiologic services by their parent or pediatrician. Subject age was determined by comparing the date of evaluation relative to the infant's date of birth. For example, if the date of evaluation relative to the infants date of birth was greater than seven months and less than eight months then the age was listed as seven months. In the event the prospective subject was born prematurely, the date of evaluation was compared to the estimated full-term date of birth. Subjects matched for age also had to match for date of evaluation. For example, if the date of evaluation of subject 1 was within ± 1 year of subject 2, they would be considered a match. **Table 1.** shows the number of subjects in each group by age in months. Because of the small number of subjects they were divided into two age categories: younger infants (7-9 months), and older infants (10-11 months). Group 3(VRA-Private) was incomplete due to lack of available records for all age groups.[1]

[1] In many cases, parents or pediatricians do not suspect hearing loss unless there is a developmental delay of language. This would explain the fewer number of private referrals below the age of 12 months. We were able to find 7 matches for the children in the 7-9 month age category, and 4 matches for the 10-11 month age category.

Procedure

The amount of information obtained from each infant(n=65) was quantified. In the case of the VRA subjects we decided that each "threshold" (e.g. speech reception, speech awareness, 500, 1000, 2000 and 4000 Hz via soundfield, earphones or bone conduction) counted as one data point. For the ABR group each "threshold"(e.g.. Click, AC, BC and Tone Bursts) counted as one data point. The total number of data points ("thresholds") obtained for each infant were calculated. **Table 2.** illustrates typical results from three subjects.

Reliability was rated for each subject evaluated by VRA. For those subjects tested by VRA, Reliability ratings of poor, fair, or good were circled on the audiogram. We assigned a score of 1.0 for a good rating, 2.0 for a fair rating, and 3.0 for a poor rating. In the event the tester circled two ratings the two scores were averaged. For example, if the tester circled fair and poor a score of 2.5 was assigned.

To examine the effects of hearing loss on test performance, the average hearing loss was estimated. For those subjects tested by VRA, speech awareness thresholds determined degree of hearing loss. For example, subjects 1 and 2 in **Table 2.** both have an average hearing loss of 15 dB. If speech awareness thresholds were different for each ear the threshold of the better ear was used. For subjects tested by ABR click thresholds determined degree of hearing loss. For example, subject 3 of **Table 2.** has an average hearing loss of 10 dB. In the event click thresholds were different for each ear we took the better threshold.

Results

Results are summarized in **Table 3.** Mean number of data points obtained for each subject group are depicted. ANOVA (group x amount of data points) was significant at the .05 level (F=28.6, p=.0001) for Groups 1,2 and 4. The mean number of data points obtained for Group 1(VRA-in-patient) and Group 2 (VRA- ENT) 3.9 and 4.6, respectively, were significantly lower than the mean number of data points obtained from Group 4(ABR) 9.1. However, there were no significant differences between the groups tested by VRA, Group 1 and Group 2, for amount of data points. Group 3(VRA-Private), the partial group, was not part of this analysis. **Figure 1** illustrates the differences among each subject group by age category for mean data points obtained.

Analysis of variance indicated that there is no significant difference between mean number of data points obtained from in-patients and out-patients tested by VRA. Differences between Group 1 and Group 2 were significant due to age category (p=.02), but were not significant for subject group (p=.34) or the interaction between subject groups and age category (p=.79).

With subjects for Group 3(VRA-Private) (11-infants) included in the ANOVA there was a significant difference due to subject group ($p < .05$) and age category ($p < .05$), but not by group age interaction (p= .66).

With respect to reliability scores, no significant difference was observed between Groups 1 and 2. **Table 4** depicts the mean reliability scores and the standard deviations for Groups 1 and 2.

Average hearing loss recorded for Groups 1,2 and 4 are depicted in **Table 5**. Differences were significant due to subject group ($p < .05$). Average hearing loss for Group 4(ABR) was significantly greater than for Group 1 and 2 (the VRA tested groups). There was no significant difference for age category ($p= .93$) or interaction between age category and subject group ($p= .87$).

Discussion

This study indicated a significant difference in the number of data points obtained from subjects tested with ABR as compared to those tested by VRA. Not surprisingly, more data points can be obtained when using ABR as the test procedure. **Figure 1** shows the results for the two complete groups(18 infants) tested by VRA. There was no significant difference in the amount of information obtained from these two groups. This suggests that in-patients post-treatment for meningitis, perform as well as infants in reasonably good health (out-patients). Visually one can see that VRA yields about half as much information as ABR, in fact, the means are 4.2 and 9.1 respectively. Clearly, ABR is a superior technique for collecting data, however, other factors must be considered-- invasiveness and direct correlation with hearing sensitivity. In most pediatric cases, especially with infants, the patient must be sedated to ensure muscle relaxation. Furthermore, ABR requires neural integrity of the auditory pathway up to the inferior colliculus.

We have shown that the ABR produces approximately twice as many threshold estimates as VRA. Therefore, if the subject is tested on two occasions by VRA the amount of information collected would be nearly equal to that of an ABR. Two VRA test sessions may be a feasible solution for some patients. Furthermore, one must consider the adequacy of the collected data for making habilitative decisions. With respect to VRA, the concern is that one may not get ear specific information if the infant does not tolerate earphones. With respect to ABR, the concern is that minimum response levels are supra-threshold. A study conducted at the University of Virginia has shown that VRA results for infants over 4 months of age are significantly lower than ABR thresholds. Although ABR minimum response levels are sufficient for habilitative purposes(Ruth et. al., 1983), they appear to be less predictive of threshold.

Availability of the client for testing is an issue. If the client has to travel some distance to reach a diagnostic testing facility, then making two trips in a short time span (e.g. two weeks) may not be desirable. This situation brings up the issue of parent/guardian commitment. Level of commitment may be a factor in the clinician's decision to use ABR or VRA. If one only has a single opportunity to get information and the index of suspicion for hearing loss is high, then ABR may be the best approach. On the other hand, if the suspicion for hearing loss is low then, VRA would be the more optimal choice.

Table 5 illustrates the differences in average hearing loss for patients tested by ABR versus VRA. The average hearing loss for patients in the ABR group was 42 dB, which is significantly higher than the average loss measured for Group 1(VRA-IN-Patient) of 22dB and Group 2(VRA-ENT) of 19dB. Group 4(ABR) patients were referred for ABR, because medical history or prior behavioral test results created a high index of suspicion for hearing loss. **Table 5** also shows that degree of hearing loss was essentially the same for younger(7-9 months) and older(10-11 months) infants.

Therefore, statistical analysis which showed that more information was obtained from older infants, cannot be attributed to the effects of hearing loss.

A major disadvantage of ABR is that infants in the age range of this study must be sedated. There is always a degree of risk involved with sedation. This risk may be minimal, but it can be eliminated all together by using a behavioral test procedure.

Finally, in this day of rising health costs and shrinking insurance coverage, our objective should be to reduce the number of unnecessary costly procedures. At Childrens Hospital a behavioral hearing test costs approximately $83.00 per session. If it is necessary for the client to come for two sessions then the total cost is approximately $166.00. The cost of an ABR test session is approximately $400.00. From a cost perspective it may be seen that two sessions of VRA will produce an equivalent amount of information for less than half the cost of ABR.

In summary, test selection depends on several factors: the index of suspicion for hearing loss, the degree of risk sedation poses for the patient, the burden of cost, and the level of commitment expressed by the parent or guardian.

Historically, pediatric audiologists have supported the position that behavioral hearing tests should be undertaken before initiating an ABR study (Northern & Downs, 1991). In those cases in which the index of suspicion is high or the commitment of the parent is low, ABR may be appropriate. However, even in those cases an attempt at VRA is worthwhile and will, at some point, be necessary to confirm ABR results.

Table 1. Number of subjects in each group by age.

	Age in Months				
	Younger			Older	
	seven	eight	nine	ten	eleven
Subject Groups					
Group 1 *VRA-in-patients*	**5**	**2**	**3**	**3**	**5**
Group 2 *VRA-ENT*	**5**	**2**	**3**	**3**	**5**
Group 3 *VRA-Private*	**4**	**2**	**1**	**0**	**4**
Group 4 *ABR*	**5**	**2**	**3**	**3**	**5**

Table 2. Exemplary data for three subjects. Subject 1 is from Group 1(VRA-In-patient), Subject 2 is from Group 2(VRA-ENT) and Subject 3 is from Group 4(ABR). Mimimum Response Levels in dB HL for VRA were obtained with warble tones and Narrow Band Noise. ABR data in dB nHL were in response to tone pips and clicks.

		250	500	1000	2000	4000	CLICK	SAT*	Total DATA Points
Subject 1(L.W.)	right ear				15	15			**5**
VRA	left ear					15			
	soundfield			15				15	
Subject 2(E.M.)	right ear								**5**
VRA	left ear								
	soundfield		15	15	15	15		15|	
Subject 3(R.B.)	right ear		15	10	10	10	10		**10**
ABR	left ear		10	10	10	10	10		

*Speech Awareness Threshold

Table 3 A & B. Mean number of data points recorded for each subject group by age category.

A.

Older Infants (10-11 months of age)

	Subject Groups			
	1 VRA-Inpt.	**2** VRA-ENT	**3** VRA-Pvt.	**4** ABR
Number of Subjects	8	8	4	8
Number of Data Points				
mean	4.8	5.6	6.3	9.8
standard deviation	2.9	2.1	2.1	1.7

B.

Younger Infants (7-9 months of age)

	Subject Groups			
	1 VRA-Inpt.	**2** VRA-ENT	**3** VRA-Pvt.	**4** ABR
Number of Subjects	10	10	7	10
Number of Data Points				
mean	3.2	3.7	3	8.5
standard deviation	1.8	1.7	1.8	2.5

Table 4. Mean reliability scores and standard deviations for groups 1-3. A 1.0 is a good reliability rating , a 2.0 is a fair reliability rating and a 3.0 is a poor reliability rating. Statistical analysis did not reveal a significant difference in reliability scores for the three groups.

	Reliability ratings		
	No. of Subjects	Mean	Standard deviation
Group 1 (*VRA-in-patients*)	**18**	**1.7**	**.60**
Group 2 (*VRA-ENT*)	**18**	**1.5**	**.47**
Group 3 (*VRA-Private*)	**11**	**1.6**	**.71**

Table 5. Mean hearing loss for Groups 1-4. Average hearing loss in dB HL for those subjects tested by VRA were determined by taking the better speech awareness threshold. Average hearing loss in dB nHL for those subjects tested by ABR were determined by taking the better click threshold.

		Number	Average Hearing Loss	Std. Deviation
Group 1	*younger*	7	20	14
VRA-Inpt.	*older*	10	24	12
	total	17	22	13
Group 2	*younger*	8	20	4
VRA-ENT	*older*	8	19	18
	total	16	19	12
Group 3	*younger*	6	21	21
VRA-Pvt.	*older*	4	11	3
	total	10	17	18
Group 4	*younger*	8	44	31
ABR	*older*	10	40	28
	total	18	42	29

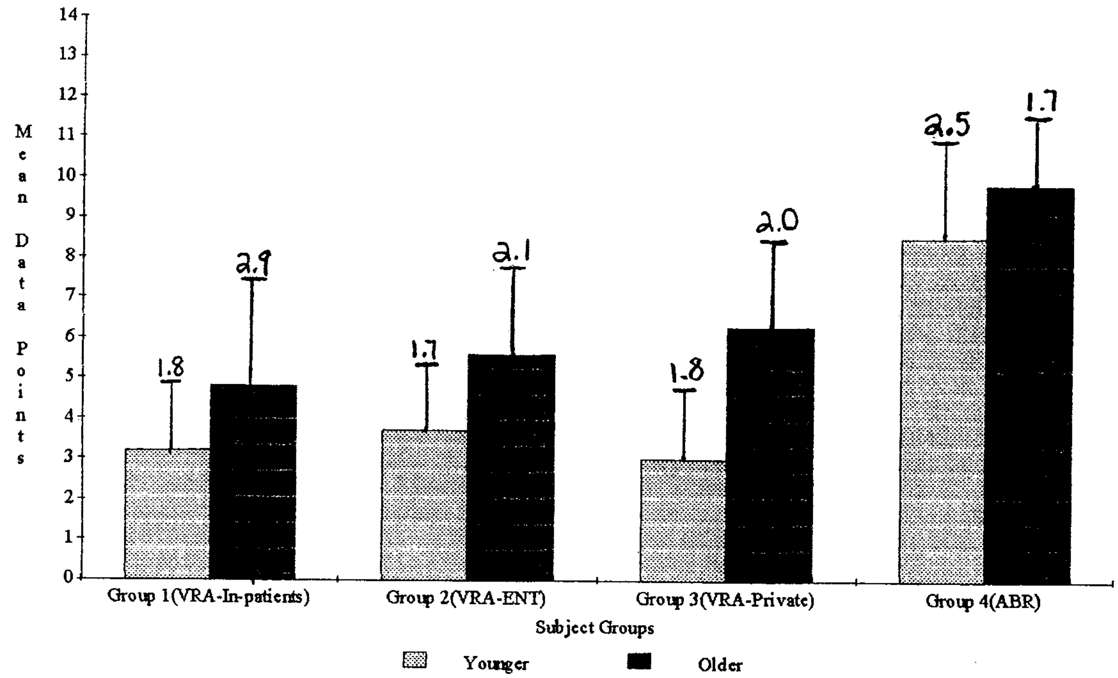

Figure 1. Mean number of data points obtained from each subject group. The first bar represents the mean scores for the younger infants (7-9 months of age). The second bar represents the mean scores for the older infants (10-11 months of age). Vertical lines represent +1 standard deviation.

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