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DATE: 1986

The Comparison of Auditory Brainstem Response Wave Amplitude
Utilizing a Multi-Channel Recording with
Noncephalic and Cephalic Reference Electrode Placement

By

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B.A. University of Montana, 1983

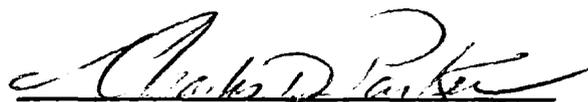
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for the degree of

Masters of Communication Sciences and Disorders

University of Montana

1986

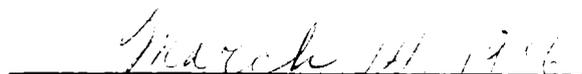
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Table of Contents

Chapters

I. Introduction	1
II. Methods	7
III. Results	9
IV. Discussion	15
Appendix	18
Bibliography	19

List of Figures and Tables

Figure 1.	11.
The Mean Amplitude Ratios (Waves V:I) of the Two Groups of Auditory Brainstem Responses (N = 16 each group), One Utilizing a Noncephalic Reference and the other a Cephalic Reference Point.	
Table 1.	12.
A Comparison of the Mean Wave V:I Amplitude Ratios of the Auditory Brainstem Response Using Cephalic and Noncephalic Electrode Reference Locations.	
Table 2.	13.
A Comparison of the Absolute Amplitude of Wave I Measured in Microvolts (μv) Using Cephalic and Noncephalic Electrode Reference Locations.	
Table 3.	14.
A Comparison of the Absolute Amplitude of Wave V Measured in Microvolts (μv) Using Cephalic and Noncephalic Electrode Reference Locations.	

Introduction

When stimulation is delivered to the auditory system via air or bone conduction, a specific response pattern of the auditory nerve from the cochlea and along the brainstem pathway can be measured via electrodes placed in various positions on the head and the rest of the body. The response, when isolated from a multitude of general EEG activity, is visualized as a series of waves. Seven waves generally occur in the first 8-10 milliseconds (msec) after stimulation. These early latency responses have come to be known as the auditory brainstem response (ABR). Jewett proposed a system of labeling these first seven waves by assigning the positive peaks with the Roman numerals I-VII (in Moore, 1983).

Elicitation of the auditory brainstem response has become a useful diagnostic tool in defining the integrity and sensitivity of the auditory system. Wave V is typically noted as the most robust and repeatable component of the ABR waveform and, thus this wave is often used in isolation or in conjunction with other waves in the analysis of the ABR. Glatcke (1983) outlined research indicating that the threshold of the ABR, which is measured by the intensity at which wave V can be detected, corresponds roughly to the auditory threshold in the mid to high frequency range. This estimation of auditory sensitivity is useful with populations from whom accurate behavioral responses cannot be obtained due to factors such as age or level of functioning.

The latency, amplitude and morphology of the waves comprising the auditory brainstem response are evaluated in order to determine the integrity of the auditory pathway from the cochlea through the level

of the brainstem. The latency of the various waves has often been compared to stimulus intensity when analyzing the ABR. Fria (1980) illustrated the variance from normal latency-intensity functions, utilizing wave V latency, that are apparent with various types of hearing losses. The slope of the latency-intensity curve in the case of a conductive hearing loss will parallel that of a normal curve, displaced upwards relative to the amount of hearing loss. With a relatively flat sensorineural hearing loss, the curve of the latency-intensity function will be similar to normal at high intensities. However, as intensity decreases the latency of wave V increases, and the slope of the latency-intensity function becomes increasingly different from that of a normal hearing subject.

The effects of peripheral hearing loss must be accounted for before anything can be determined regarding the integrity of the brainstem auditory pathway (Glattke, 1983). If an external, middle or inner ear hearing loss is present, the latency of wave I will likely be prolonged with each latency of the following waves prolonged in corresponding fashion. Therefore, if one only observes the absolute latency of wave V when analyzing brainstem integrity, the results may be confounded by a peripheral hearing loss. Hall (1984) presented an abundance of research investigating the effects of retrocochlear pathology on the latency intervals between the various waves. Data of this kind helps account for prolonged wave V latency due to peripheral hearing loss. Auditory nerve lesions will likely prolong the latency between wave I and V (Fria, 1980). Trauma to the upper brainstem areas may actually obliterate waves beyond a certain point, for example waves IV and V (Sohmer, 1983). Demyelinating diseases such as multiple

sclerosis often result in prolonged interpeak latencies (Glattko, 1983). Interaural differences in wave V latency greater than 0.30 msec are also indicative of brainstem pathology (Hall, 1984).

Changes in wave amplitude are often detected in neurological disorders. Buchwald (1983) indicated that amplitude and latency are two independent factors in the ABR. She presented data indicating that multiple sclerosis and similar demyelinating diseases often result in increased latency of waves with little accompanying change in wave amplitude. On the other hand, she determined that administration of nicotine reduced wave amplitude with little or no effect on the latency of the waves. Hall (1984) presented studies suggesting that ischemia secondary to vascular disease often resulted in amplitude reduction, possibly due to changes in cell body neuroelectric activity.

When the auditory brainstem response was first studied, many thought that each wave represented the response from a particular neurological structure along the auditory pathway. Most research, as that summarized by Fria (1980), now indicates that one cannot be so specific in determining the origin of each wave. Moller et al. (1982) confirmed most hypotheses indicating that wave I does originate in the VIIIth nerve. However, he also presented indications that the second wave also has origins in this area. The negative peak of a compound action potential recorded from an intracranial part of the auditory nerve matched the latency of the second wave of an ABR measured from the scalp. Overall, at least waves III through VII likely have multiple origins. It may be, however, that waves III through VII do represent progressively higher groups of structures in the auditory brainstem (ie. from the cochlear nucleus to the medial geniculate body). Because of this

lack of specificity, most lesions can only be localized as auditory nerve, low brainstem or high brainstem lesions (Glatcke, 1983).

Many researchers have documented the several subject factors affecting normal variability of latency, amplitude and morphology in the ABR waveform, in both normal and hearing impaired populations (Fria, 1980; Vivion, 1980; Chiappa et al., 1979; Jerger and Hall, 1980; Stockard et al., 1979; Stockard et al., 1978). These variances are often not significant or indicative of pathology. For instance, Stockard et al. (1978) outlined several subject characteristics which will alter the ABR. Wave I amplitude in children is generally higher than in adults and infants below the age of 12 months will generally have longer interpeak latencies relative to adult norms (Schwartz and Berry, 1985). Stimulus parameters such as rate and intensity of stimulus have an effect on the amplitude and latency of the specific waves composing the ABR. (Stockard et al., 1978; Weber, 1985; Schwartz and Berry, 1985).

Absolute amplitude of waves is highly variable across subjects. Generally, amplitude has been measured in one of two ways. The first involves measuring the height of a peak in microvolts (μv) from the top of the peak to the lowest point of the following negative trough. The second involves taking into account both the negative point preceding and following the peak of the particular wave being measured. The negative troughs in the ABR waveform are highly variable. By joining the most negative points of the preceding and following troughs by a line and then measuring from the peak of the wave to the intersection of the line joining the troughs, an examiner can reduce the variability in the measurement of the amplitude (Wynne, 1985).

Another method designed to reduce variability in amplitude is to analyze the amplitude ratio of wave V to wave I. Hall (1984) stated that in a normal subject, the wave V:I ratio is greater than 1.0. Even this ratio is highly variable but an amplitude ratio which is greatly reduced to values of 0.5 or less is thought to have diagnostic significance. For example, patients with multiple sclerosis often show decreased wave V amplitude which, in turn would result in a decreased wave V:I ratio (Sohmer, 1983).

Traditionally, the ABR has been recorded utilizing three recording electrodes. Often the reference electrode has been placed on the earlobe of, or on the mastoid behind the test ear with a ground electrode in a corresponding position on the nontest ear. The active electrode has been placed somewhere along the midline of the skull such as at the vertex or on the high center area of the forehead. From this array, a waveform of the ABR is recorded and waveform latencies, wave amplitude and morphology have been observed and recorded for diagnostic uses.

The use of a multiple channel recording of the ABR utilizing more than one electrode array at the same time has become popular in research and clinical settings (Rossini et al., 1980; Terkilson and Osterhammel, 1981; Hall et al., 1984; Hall, 1984; Stockard et al., 1978). The ABR waveform varies depending upon the particular electrode montage from which it has been recorded. Hall (1984) reported that recordings of the ABR from different electrode montages in a 26 year old male revealed a lower amplitude wave I utilizing the sternum (noncephalic) as a reference point as compared to the test ear as a reference. However, a more distinct wave IV/V complex was observed with the

noncephalic reference as well as when utilizing a recording taken comparing the ipsilateral (test) ear and contralateral (nontest) ear. Hall found that the amplitude of wave V was greatest when a noncephalic reference was used. Stockard et al. (1978) observed a similar increase in wave V amplitude with a noncephalic reference. A group of researchers at the University of Texas School of Medicine (Hall et al., 1984) investigated the ABR measured from various electrode placements with a large number of severely brain injured persons. They also found increased amplitude for wave V and a more distinct IV/V complex utilizing a noncephalic reference point. Terkildson and Osterhammel (1981) compared the ABR measured using the ipsilateral (traditional) recording situation. Moller et al. (1982) reports an enhanced wave I when a recording was measured with an electrode placed directly on the auditory nerve. This enhancement of wave I is also seen with recordings obtained utilizing an electrode in the ear canal or on the promontory.

These studies suggest that a clear representation of all of the waves in the ABR will be observed if responses from various electrode positions are observed in conjunction with each other. Therefore, the diagnostic value of the ABR will be increased. The advantages of using a noncephalic reference have been reported by several researchers (Hall, 1984; Hall et al., 1984; Stockard et al., 1978; Rossini et al., 1980; Terkildson and Osterhammel, 1981). The noncephalic placement (ie. clavicle or sternum) for the reference electrode is an essentially neutral placement. The neural activity of the skull may interfere with the auditory brainstem response if all of the electrode placements are on the head, resulting in a noisy response which would be difficult to analyze. Thus, a noncephalic reference will often provide a clearer representation of the ABR, especially the later waves (ie. IV-VII)

of which the identification of wave V is especially important.

The purpose of this study was to determine whether the absolute amplitude of wave V would significantly increase utilizing a noncephalic reference location versus a cephalic reference point and if this increase would be reflected in a significant increase in the amplitude ratio of waves V:I utilizing a noncephalic reference point. It is my contention that the absolute amplitude of wave V will increase when a noncephalic reference point is used.

Methods

Subjects

Data was obtained using eight subjects (sixteen ears) between the ages of 22 and 40 (mean age, 29.6 years). Of these subjects, five (63%) were female. All of the subjects had normal hearing and no indications of retrocochlear pathology. This was documented by pure tone thresholds at the frequencies of 250 Hz through 8000 Hz of at least 20 dB HL in both ears, excellent speech discrimination, normal tympanograms, acoustic reflex thresholds at normal hearing levels and no pathological acoustic reflex decay. Case history information was also contraindicative of hearing loss, retrocochlear or central pathology. Analysis of each subject's ABR revealed peak latencies (waves I, III and V) and the interpeak intervals (I-III, III-V and I-V) within the norms developed for the instrumentation used in the testing. There were no significant asymmetries between the ABR responses with the right test ear and the left test ear for any of the subjects. These analyses indicated normal neural transmission time through the level of the brainstem.

Instrumentation

A dual channel recording was conducted utilizing a Nicolet model CA-1000 clinical averager and an HGA-200A physiological amplifier. The active electrode was placed on the forehead with reference electrodes on both the right clavicle and the mastoid process behind the test ear. The electrode on the mastoid process behind the nontest ear served as the ground electrode. Because of the dual channel capabilities, two independent recordings were obtained simultaneously, one using the cephalic reference and the other channel, the noncephalic reference point.

Procedure

Several parameters were held constant throughout the testing of all of the subjects. The subjects were tested in a quiet, darkened room. Although the subjects were not sedated or in a natural sleep, they were instructed to close their eyes and relax as they were seated comfortably. Electrode impedance at each placement was determined to be less than 5000 ohms. Auditory brainstem responses were obtained utilizing monaural stimulation by a negative click delivered at a rate of 11.1/second, for a total of 1000 repetitions. The clicks were at an intensity of 80 dB nHL. A preamplifier filter setting of 150-3000 Hz was utilized. The sensitivity scale of the instrumentation was also held constant at 25 across subjects. Each test condition was repeated two times to determine the consistency and repeatability of the response.

The latencies of waves I, III and V were measured to ensure that they were within a normal range established for the test instrumentation. The main consideration was the relative amplitude of wave V vs. wave I.

Amplitude of waves I and V was determined by measuring the height of each wave from the peak of the wave to the following negative trough. As stated before, each test condition was repeated. The greatest amplitude for each wave I and wave V was used in the final analysis. The amplitude of each wave was measured in microvolts (μv) via a computer mechanism within the instrument itself. The ratio of waves V to I (V:I) was determined for each waveform and the mean of the summed ratios for each condition was determined. The absolute amplitude of waves I and V for both the cephalic and noncephalic reference conditions was also analyzed individually to determine if a significant change in amplitude occurred. t-tests for independent means were used to determine the significance of the difference in amplitude ratios or in the absolute amplitude of wave I or wave V with the two different reference points.

Results

Appendix 1 lists the absolute amplitudes for wave I and wave V as well as the amplitude ratios of wave V to wave I for all test ears using the noncephalic reference and the cephalic reference points. The hypothesis of this study contended that the amplitude ratio of wave V to wave I would be greater utilizing a noncephalic reference point versus a cephalic reference. A t-test for independent means was used to determine whether or not the mean waves V:I amplitude ratio was significantly greater with the noncephalic reference. The absolute amplitudes of both wave I and wave V for all subjects were also analyzed by means of a t-test to determine if a significant difference existed between those two sets of data.

In 9 out of 16 ears (56%) the V:I amplitude ratio was greater for the noncephalic reference than for the cephalic reference. In 2 out of 16 ears (13%) the ratios for the two reference points were equal. The mean V:I amplitude ratio for the noncephalic reference was 2.20 (+/- 1.35) and for the cephalic reference was 1.67 (+/- 1.01).

(Insert Figure 1 here)

The t-score that was computed indicated that the amplitude ratio with the noncephalic reference was not significantly greater than with the cephalic reference (significance level = 0.10).

(Insert Table 1 here)

The mean absolute amplitudes for wave I utilizing the cephalic reference was 0.27 (+/- 0.12) and utilizing the noncephalic reference was 0.30 (+/- 0.14).

The mean absolute amplitude for wave V utilizing the cephalic reference was $0.38\mu\text{v}$ (+/- $0.18\mu\text{v}$) and for the noncephalic reference $0.51\mu\text{v}$ (+/- $0.24\mu\text{v}$). t-scores determined for each revealed no significant differences for the absolute amplitude of wave I utilizing the noncephalic reference versus the cephalic reference point (level of significance = 0.10).

(Insert Table 2 here)

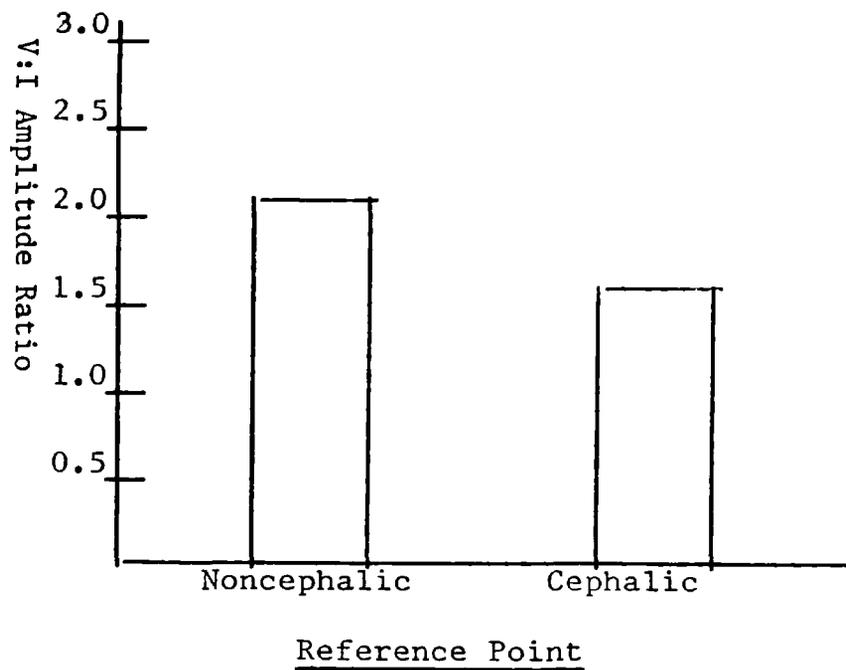
However, the absolute amplitude of wave V was significantly greater utilizing a noncephalic reference versus a cephalic reference point (level of significance = 0.10).

(Insert Table 3 here)

Overall, a significant increase was found in the absolute amplitude of wave V using a noncephalic reference electrode. However, that increase did not reflect itself in a significant increase in the amplitude

Figure 1.

The Mean Amplitude Ratios (Waves V:I) of the Two Groups of Auditory Brainstem Responses (N = 16 each group), One Utilizing a Noncephalic Reference and the other a Cephalic Reference Point.



A Comparison of the Mean Wave V:I Amplitude Ratios of the Auditory Brainstem Response Using Cephalic and Noncephalic Electrode Reference Locations.

	N	Mean	Standard Deviation	t	p
Noncephalic	16	2.20	1.35	0.93	N.S.
Cephalic	16	1.67	1.01		

$t = +/-1.341, df = 15 \quad p = 0.10$
N.S.: Not Significant

Table 2.

A Comparison of the Absolute Amplitude of Wave I Measured in Microvolts (μv) Using Cephalic and Noncephalic Electrode Reference Locations.

	N	Mean	Standard Deviation	t	p
Noncephalic	16	0.30	0.14		
Cephalic	16	0.27	0.12		
$t = \pm 1.341$, $df = 15$, $p = 0.10$ N.S.: Not Significant					

Table 3.

A Comparison of the Absolute Amplitude of Wave V Measured in Microvolts (μv) Using Cephalic and Noncephalic Electrode Reference Locations.

	N	Mean	Standard Deviation	t	p
Noncephalic	16	0.51	0.24	1.65	p 0.10
Cephalic	16	0.38	0.18		

$t = +/-1.341, df = 15 p = 0.10$

ratio of waves V:I using a noncephalic reference.

Discussion

The results of this study revealed a significantly larger wave V absolute amplitude utilizing a noncephalic reference point versus a cephalic reference point. Although the increase in the absolute amplitude of wave V was not reflected in a significant increase in the V:I ratio, these results support those results obtained by Hall and his associates at the University of Texas (1984). They found that eighty-two percent of their brain injured patients had larger ABR wave V amplitude with a noncephalic reference compared to the other montages utilized. Their research advised that recordings from multiple electrode arrays resolved some uncertainties regarding brainstem function in their patients with CNS pathology and that ABR analysis would coordinate more closely with damage indicated by a CT scan.

The identification of wave V is extremely important in the estimates of auditory sensitivity by ABR audiometry. The results of this study indicate that the use of a noncephalic reference electrode will enhance the absolute amplitude of wave V and therefore, make it easier to identify. Hopefully, this enhancement in amplitude could also be generalized to progressively lower intensity levels for latency-intensity functions. However, this study did not address the nature of ABR amplitudes at lower intensity levels.

The ratio of waves V:I has been used in an attempt to dispel some of the variability that occurs when measuring amplitude (Hall, 1984). The results of this study demonstrated that varying the placement

of the reference electrode from a cephalic to a noncephalic location^{16.} did not significantly alter the waves V:I ratio. Several characteristics of the study may have accounted for the lack of significant results. The sample size was very small (N=16) which requires large value differences in order that these differences become significant. In addition, all subjects were required to have normal hearing with no apparent neurological deficits. Perhaps the best utility for determining a relative amplitude ratio (V:I) would be more apparent in a pathological group of subjects. With such subjects, the overall morphology (including amplitude and latency) of the waves are much more variable than in normal subjects. Perhaps the amplitude variability would be reduced in such groups utilizing the measurement of an amplitude ratio obtained utilizing a noncephalic reference location. This is a major area which needs further research.

The overall increase in wave V amplitude found in this study indicates that the techniques described have a significant impact in ABR measurement. Despite the inherent variability of ABR wave amplitude, utilizing a noncephalic reference electrode should increase the opportunities to clearly visualize wave V. Since wave V parameters are often the basis for many diagnostic uses of the ABR, electrode montages that make wave V more apparent should be employed. Diagnosticians will have a constant need for methods of determining auditory sensitivity in patient populations unable to respond behaviorally. The ABR analysis will help to fulfill this need. Analysis of the ABR will also continue to benefit the diagnosis of otoneurological deficits despite such procedures as CT scans and magnetic resonance imaging. The latter two procedures may document structural damage while the ABR analysis

may document any accompanying physiological changes within the same system.

Finally, the results of this study failed to eliminate the variability observed in ABR wave amplitude. While this was not the objective of this research, the reduction in variability should be a constant goal. Increasing the sample size and analyzing the ABR of otoneurologically impaired subjects may indicate how the results of this study can be generalized. A higher than usual alpha level was employed in this study due to its exploratory nature. Under this assumption, the cost of maintaining a null hypothesis which is false will be far greater than rejecting a null hypothesis which is true.

Appendix 1.

Absolute Amplitude (in microvolts) and Relative Amplitude Ratios (V:I)
for all Ears Utilizing Noncephalic and Cephalic Reference Locations.

Subject	Wave I Cephalic	Wave I Noncephalic	Wave V Cephalic	Wave V Noncephalic	V:I Cephalic	V:I Noncephalic
1.	.20	.19	.33	.41	1.65	2.16
	.11	.13	.23	.34	2.09	2.62
2.	.41	.30	.50	.81	1.22	2.70
	.56	.40	.63	.68	1.13	1.70
3.	.31	.46	.11	.14	0.36	0.30
	.24	.08	.28	.26	1.17	3.25
4.	.23	.38	.68	.54	2.96	1.42
	.43	.60	.21	.21	0.49	0.35
5.	.28	.18	.24	.63	0.86	3.50
	.34	.25	.26	.51	0.77	2.04
6.	.15	.16	.65	.76	4.30	4.75
	.24	.19	.56	1.00	2.30	5.26
7.	.25	.36	.54	.61	2.16	1.69
	.30	.49	.39	.53	1.08	1.08
8.	.13	.24	.19	.35	1.46	1.46
	.11	.38	.30	.33	2.73	0.87

Bibliography

1. Buchwald, J.S. Generators. In Moore (Ed.), Bases of Auditory Brainstem Evoked Responses. New York: Grune and Stratton, 1983.
2. Chiappa, K.H., K.J. Gladstone, and R.R. Young. Brainstem Auditory Evoked Responses: Studies of Waveform Variations in 50 Normal Human Subjects. Archives of Neurology, 36; 1979, 81-87.
3. Fria, T.J. The Auditory Brainstem Response: Background and Clinical Applications. Monographs in Contemporary Audiology, 2; 1980.
4. Galambos, R. and K.E. Hecox. Clinical Applications of the Auditory Brainstem Response. Otolaryngologic Clinics of North America, 11; 709-722, 1978.
5. Glattke, T.J. Short-Latency Auditory Evoked Potentials: Fundamental Bases and Clinical Applications. Baltimore:University Park Press, 1983.
6. Hall, J.W. Auditory Brainstem Response Audiometry. In Jerger (Ed.), Hearing Disorders in Adults. College-Hill Press, Inc., 1984.
7. Hall, J.W., S.H. Morgan, J. Mackey-Hargadine, E.A. Aguilar and R.A. Jagrsdoerfer. Neuro-otologic Applications of Simultaneous Multi-Channel Auditory Evoked Response Recordings. Laryngoscope, 94; 883-889, 1984.
8. Hecox, K. and G. Moushegian. Brainstem Auditory Evoked Potentials: I. Methods and Norms. for reprints: Waisman Center on Mental Retardation and Human Development. 1500 Highland Ave., Madison, WI 53706 No date.
9. Jerger, J. and J. Hall. Effects of Age and Sex on Auditory Brainstem Response. Archives of Otolaryngology, 106; 387-391, 1980.

10. Jewett, D.L. Introduction. In Moore (Ed.), Bases of Auditory Brain-Stem Evoked Responses, New York: Grune and Stratton, 1983.
11. Moller, A.R., P. Jannetta and M.B. Moller. Intracranially Recorded Auditory Nerve Response in Man. Archives of Otolaryngology, 108; 77-82, 1982.
12. Parker, D.J. Dependence of the Auditory Brainstem Response on Electrode Location. Archives of Otolaryngology, 107; 367-371, 1981.
13. Rossini, P.M., D. Gambi, L. Marchionno, P. David, and D. Sallazzo. Cephalic and Noncephalic References in Brain Stem Evoked Potential Recording. Applied Neurophysiology, 43; 313-323, 1980.
14. Schwart, D.M. and G.A. Berry. Normative Aspects of ABR. In Jacobson (Ed), The Auditory Brainstem Response, College Hill Press, Inc., 1985.
15. Sohmer, H. Neurologic Disorders. In Moore (Ed.), Bases of Auditory Brain-Stem Evoked Responses, New York: Grune and Stratton, 1983.
16. Stockard, J.E., J.J. Stockard, B.F. Westmoreland and J.L. Corfits. Brainstem Auditory-Evoked Responses: Normal Variation as a Function of Stimulus and Subject Characteristics. Archives of Otolaryngology, 36; 823-831, 1979.
17. Stockard, J.J., J.E. Stockard and F.W. Sharbrough. Nonpathological Factors Influencing Brainstem Auditory Evoked Potentials. American Journal of EEG Technology, 18; 177-209, 1978.
18. Ten-Twenty Electrode System. Electroencephalography and Clinical Neurophysiology. 10; 371-375, 1958.
19. Terkildson, K. and P. Osterhammel. The Influence of Reference Electrode Position on Recordings of the Auditory Brainstem Responses. Ear and Hearing, 2; 9-14, 1981.

20. Vivion, M.C. Clinical Status of Evoked Response Audiometry.
The Laryngoscope, 1980 (March), 437-447.

21. Wynne, M. University of Montana, Department of Communication
Sciences and Disorders. Personal Communication, November, 1985.