PHYSIOLOGIC MEASURES IN PEDIATRIC AUDIOLOGY

by

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ABSTRACT

Physiological techniques such as brainstem and impedance audiometry have been utilized as measures of auditory sensitivity. These techniques are especially useful with young "difficult to test" populations when any doubt exists regarding the accuracy of behavioral audiometric techniques. In addition, physiological techniques provide valuable information useful in habilitation. Our procedures in using these physiological measures are briefly outlined and are followed by three case presentations, which illustrate how these tests are incorporated into a useful test battery.

In order to ensure early habilitative measures for young hearing impaired children, early identification of hearing impairment is imperative (Gerber & Mencher, 1978). Furthermore, an accurate audiological profile is necessary for the selection of suitable amplification and/or referral for medical treatment. The evaluation of "difficult to test" infants and children has been facilitated by the usage of physiological measures such as brainstem and impedance audiometry.

The purpose of this paper is to review the objective physiological techniques most frequently employed in our clinic. The emphasis will be placed on brainstem evoked response audiometry and tympanometry with acoustic reflex testing. These techniques are utilized to verify behavioral audiometry and to obtain information that may be inaccessible through conventional sound field testing. In addition, several clinical cases will be discussed to illustrate how these tests, in addition to behavioral audiometry, are incorporated into a useful test battery.

PROCEDURES

Infants referred to our clinic for audiological evaluations are initially assessed by means of behavioral techniques: sound field testing using visual reinforcement techniques and localization responses to speech, warble tone and narrow band noise stimuli.

Routine impedance testing is subsequently administered to all patients. The impedance test battery is comprised of several measures that estimate hearing sensitivity and suggest site of lesion. Impedance measures are obtained using an Amplaid 702, or a Madsen ZO-72 impedance bridge. This battery includes tympanometry and acoustic reflex threshold testing to further evaluate the function of the middle ear. If possible, acoustic reflex decay measurement is also performed using a stimulation period of 30 seconds (Lilly, 1978; Oviatt & Kileny, 1979).

Acoustic reflex thresholds are also used to estimate hearing sensitivity by using prediction equations (Jerger et al., 1974; Niemeyer & Sesterhenn, 1974). As this is not a routinely utilized clinical procedure, its underlying rationale is briefly discussed. The basis of pure tone thresholds lies in the difference between pure tone and white noise acoustic reflex thresholds (Niemeyer & Sesterhenn, 1974). In the presence of a sensorineural hearing loss, white noise thresholds become elevated as the extent of the loss increases. Thus the normal difference which usually ranges between 20 and 30dB (Djupesland et al., 1966; Deutsch, 1968) diminishes when there is a sensorineural loss—theoretically due to an abnormal widening of the acoustic reflex critical band (Zwicker et al., 1957; Flottorp et al., 1971). The equations we are currently using to predict pure tone averages are shown in Table 1 (Lilly, 1978).

TABLE 1

Equations used to predict puretone averages from acoustic reflex thresholds (ART), (Lilly, 1978).

Predicted Hearing Level = 1.11 (ART for white noise) - .81 (ART for 500 Hz) + .85 (ART for 1000 Hz) - .43 (ART for 2000 Hz) + .25 (ART for 4000 Hz) - 65.
Predicted Hearing Level = 2.4 (ART for white noise) - 1.4 (X ART for 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz) - 62.50.

In those cases where behavioral results are unreliable, the child is referred for brainstem audiometry. The auditory brainstem response (ABR) is utilized as the preferred auditory evoked potential, due to its relative independance of arousal state, attention and sedation (Amadeo & Shagass, 1973; Picton & Hillyard, 1974; Goff et al., 1977). Testing is performed in a quiet room with the child reclining in a crib. Sedation in the form of Chloral Hydrate or EEG sedation, (consisting of Meperidine HCl, Chlorpromazine and Promethazine) prescribed by the hospital paediatrician, is usually administered to the patient prior to testing.

Unfiltered clicks and 500 HZ tone pips are utilized as stimuli. The clicks consist of 100 μsec pulses alternated in polarity and generated by a NIC-1007 noise masking module; a presentation rate of 10 or 17/sec is generally employed. The 500 Hz tone pips are generated by a NIC-1002 tone generator; rise and fall times of the tone pips are 4 msec with no plateau at a constant polarity. These are presented in phase in the presence of high-pass filtered white noise with a cutoff frequency of 1500 Hz (Kileny, 1979). The stimuli are presented through a TDH-39 earphone encased in a MX/41AR cushion, which is hand-held to the child's ear. A vertex-mastoid surface electrode configuration, with the contralateral mastoid serving as ground, is used to record responses. The responses are averaged after 2048 presentations by a Nicolet CA-1000 averager with a bandpass of 150-3000 Hz. The averaged period is 20 msec. The averaged responses are recorded with an X-Y recorder. Stimulus intensity is reported in HL re normal adult threshold. ABR threshold is defined as the lowest intensity level at which wave V can be consistently identified. The utilization of unfiltered clicks and 500 Hz tone pips to elicit ABRs allows for a closer approximation of the audiogram. Clicks appear to indicate auditory thresholds in the 2000 to 4000 Hz region; 500 Hz tone pip thresholds indicate auditory thresholds below 1500 Hz (Kileny, 1979).

CASE REPORTS

The following three cases illustrate the use of these physiological measures in our clinic.

Case 1.

This one year old female infant was referred for an audiological assessment because inconsistent responses to sound were reported by her parents. Medical and psychological investigations indicated a marked psychomotor delay of undetermined etiology. She was initially assessed behaviorally. No consistent localization responses were observed; cessation of vocalization was noted for speech presented at levels of 80 dB HL and above. Similar responses to warble tone and narrow band noise stimuli were obtained at levels of 65 dB to 80 dB HL. Tympanometry suggested normal middle ear pressure and tympanic mobility bilaterally. Contralateral acoustic reflex thresholds were obtained for both ears and are shown in Figure 1. The results of the prediction equations suggested average pure tone thresholds of less than 10 dB bilaterally. Brainstem audiometry was also completed; ABRs for the right ear are also shown in Figure 1. Responses for clicks and 500 Hz tone pips were noted as low as 10 dB HL. Latencies of waves I and V, as well as waves I-V interwave intervals were within normal limits (Salamy & McKean, 1976).

Similar responses were obtained for the left ear. Clearly, no reliable behavioral audiological thresholds could be obtained in this case due to a substantial psychomotor delay. However, based on acoustic reflex thresholds and ABRs, normal bilateral hearing acuity was suggested. Conventional audiometry will be repeated at a later date in an attempt to establish behavioral thresholds.

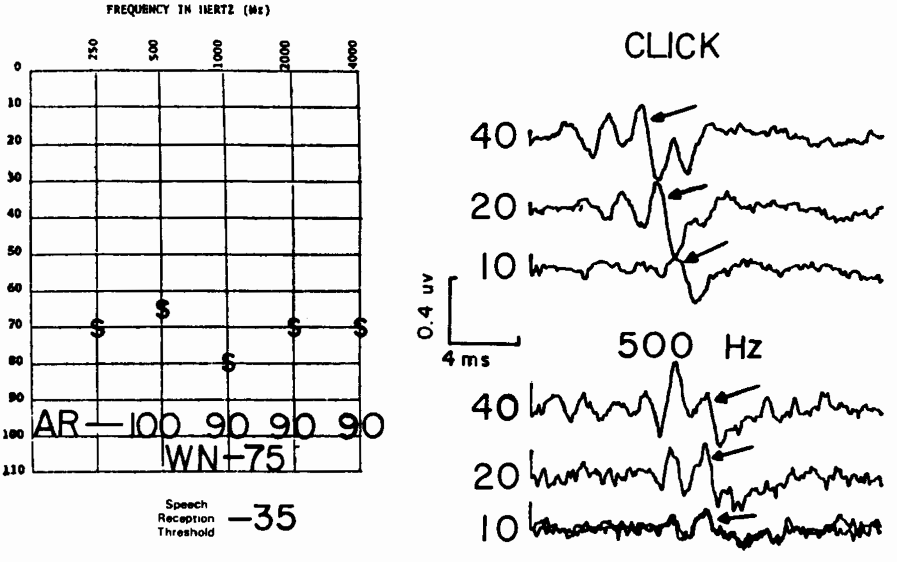

Figure 1. Soundfield warble tones (s); right ear acoustic reflexes (AR) and right ear ABRs for case 1.

Case 2.

This is the case of a two year old male with a severe psychomotor delay and congenital anomalies. He was seen for behavioral audiometry on several occasions. Speech awareness thresholds were obtained between 30 to 40 dB HL. Localization responses to speech were of fair reliability. Warble tone threshold testing was incomplete with some inconsistent responses between 60 and 70 dB HL. Tympanometry suggested abnormal middle ear pressure and substantially reduced tympanic mobility bilaterally. Acoustic reflexes were absent for both ears. Otological examination indicated thickened and retracted tympanic membranes with decreased pallor. Brainstem audiometry yielded responses to unfiltered clicks at 40 dB HL and above (see Figure 2 for left ear responses). Latencies for both waves I and V were slightly delayed compared to normative data. Wave I-V interwave interval was within normal limits for this age at all intensity levels (Salamy & McKean, 1976; Galambos & Hecox, 1978). Thresholds for 500 Hz tone pips were obtained at 40 dB HL. In this case, behavioral thresholds were inconclusive in identifying the extent and nature of this child's hearing impairment. Tympanometry suggested the presence of bilateral middle ear effusion. The delayed wave I latencies further characterized a conductive hearing loss (Berlin & Gondra, 1976; Sohmer & Cohen, 1976). Appropriate medical treatment was prescribed by the otologist. Audiological follow-up to monitor middle ear functioning and to repeat behavioral testing was recommended.

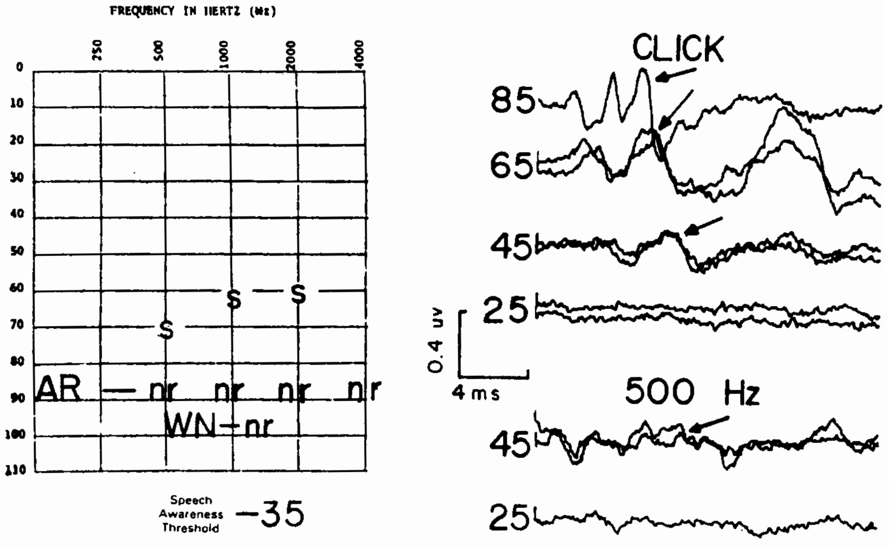

Figure 2. Soundfield warble tones (s); absent (nr) acoustic reflexes (AR) and left ear ABRs for case 2.

Case 3.

This eighteen month old boy was referred for audiological testing due to delayed speech and language development. Gross and fine motor development, and intellectual development, were progressing normally. Responses to warble tone and speech stimuli in sound field were obtained between 60 and 70 dB HL. Considering age level, these results suggested a moderate hearing loss. Because this child had great difficulty localizing, behavioral test accuracy was fair at best necessitating more objective methods of hearing assessment. Tympanometry suggested normal functioning middle ear systems bilaterally. Contralateral acoustic reflexes could not be elicited for the right ear for all stimuli at the intensity limits of our equipment. Reflexes were elicited by pure tones in the left ear at 85 to 95 dB HL, as shown in Figure 3. The acoustic reflex threshold for white noise was 100 dB. The results of the prediction equation for the left ear suggested a pure tone average of 30 dB HL, which was inconsistent with behavioral results. Brainstem audiometry was performed the next day. No responses were obtained from the right ear for click stimuli at the limits of the equipment (95 dB HL). Responses were obtained from the left ear at 35 dB HL and above; 500 Hz tone pip threshold in the left ear was 40 dB HL. This case illustrates the need for verification with brainstem audiometry and acoustic reflex prediction in auditory assessment and rehabilitation. Objective measures indicated a milder hearing loss than behavioral sound field testing suggested. ABRs indicated a profound hearing loss in the right ear. Impedance results, suggesting normal middle ear functioning and absent acoustic reflexes on the right, were consistent with ABRs. A mild hearing loss in the left ear was indicated by both brainstem audiometry and reflex prediction formulae. This asymmetrical hearing loss would have been missed by sound field behavioral testing alone. Thus, accurate hearing aid fitting could not have been performed without objective measures; these helped in the determination of hearing aid gain and avoided aiding a "dead" ear. Behavioral follow-up testing continues in order to determine frequency specific bilateral and aided soundfield thresholds.

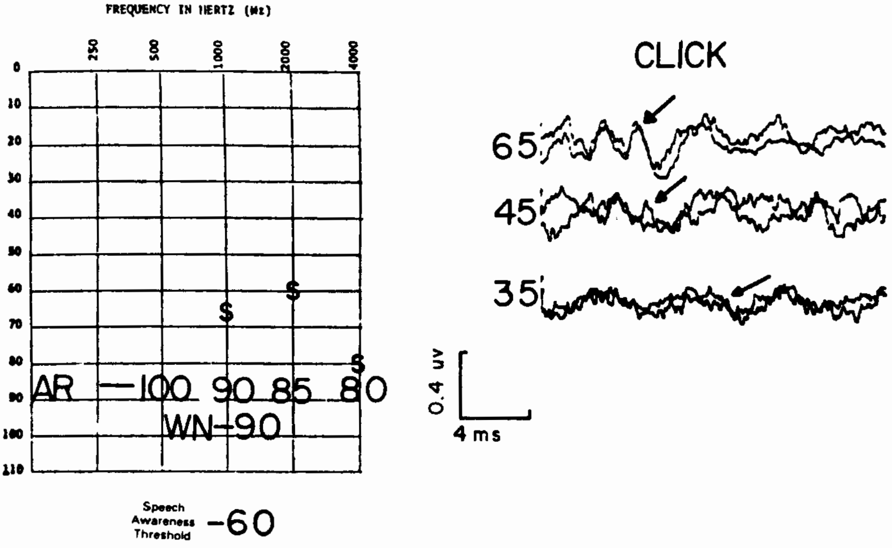

Figure 3. Soundfield warble tones (s); left ear acoustic reflexes (AR) and left ear ABRs for case 3.

These cases illustrate that independent physiological measures of hearing are clinically feasible and serve to verify behavioral findings. It was gratifying to find how well ABR and ART prediction results coincided. We have found that behavioral testing alone is not sufficient when there is any doubt about the accuracy of conventional audiometric methods. Furthermore, objective measures are invaluable to accurate hearing aid fitting especially in cases with asymmetrical losses when accurate bilateral threshold testing under earphones cannot be completed. Physiological measures also accelerate the habilitation process of a patient who otherwise is subjected to repeated, time consuming behavioral testing. On the other hand, after brainstem audiometry and reflex prediction methods are successfully completed, follow-up behavioral testing is continued to ascertain behavioral auditory awareness.

There are difficulties that only further investigation can overcome. In the event of a unilateral conductive hearing loss, acoustic reflex prediction may be impossible, or may be inaccurate due to the absence or elevation of the reflexes. Norms for ipsilateral acoustic reflex prediction must be developed for use in these audiometric configurations. In conductive hearing losses, ABRs are difficult to interpret and brainstem audiometry using bone conduction may also be of clinical value.

In conclusion, we have found brainstem audiometry and impedance measures to be of substantial clinical value in the auditory assessment and rehabilitative process of our difficult-to-test population. It is emphasized however, that these objective measures in no way replace the traditional behavioral approach to hearing assessment. Clinically, audition refers both to a central nervous system and to a behavioral response to acoustic stimulation.

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REFERENCES

Amadeo, M., and Shagass, C., Brief latency click-evoked potentials during waking and sleep in man. **Psychophysiology,** 10, 244 - 250, (1973).

Berlin, C. I., and Gondra, M. A., Extratympanic clinical electrocochleography with clicks. In R. J. Ruben, C. Elberling, and G. Salomon (Eds.) **Electrocochleography.** Baltimore: University Park Press, 457 - 471, (1976).

Deutsch, L. J., **The Threshold of the Stapedial Reflex to Selected Acoustic Stimuli in Normal Ears.** (Rep. No. 546) U.S. Naval Submarine Medical Centre, Submarine Base, Groton, Conn., (1968).

Djupesland, G., Flottorp, G., and Winther, F., Size and duration of acoustically elicited impedance changes in man. **Acta Otolaryngologica,** Suppl. 224, 220 - 228, (1966).

Flottorp, G., Djupesland, G., and Winther, F., The acoustic stapedius reflex in relation to critical bandwidth. **Journal of the Acoustical Society of America,** 49, 457 - 461, (1971).

Galambos, R., and Hecox, K., Clinical application of the auditory brain stem response. **The Otolaryngologic Clinics of North America,** 11, 709 - 722, (1978).

Gerber, S. E., and Mencher, G. T. (Eds.), **Early Diagnosis of Hearing Loss.** New York: Grune & Stratton, (1978).

Goff, W. R., Allison, T., Lyons, W., Fisher, T. C., and Conte, R., Origin of short latency auditory evoked potentials in man. In J. E. Desmedt (Ed.) **Auditory Evoked Potentials in Man. Psychopharmacology Correlates of Evoked Potentials.** Basel: S. Karger, 30 - 44, (1977).

Jerger, J., Burney, P., Maudlin, L., and Crump, B., Predicting hearing loss from the acoustic reflex. **Journal of Speech and Hearing Disorders,** 39, 11 - 22, (1974).

Kileny, P., Early averaged auditory electric responses to tone pips. Paper presented at the convention of the American Speech, Language & Hearing Association, Atlanta, Georgia, (1979).

Lilly, D. J., Current developments in clinical acoustic — immitance standards and measurements. Paper presented at the meeting of the Speech and Hearing Association of Alberta, Edmonton, Alberta (1978).

Niemeyer, W., and Sesterhenn, G., Calculating the hearing threshold from the stapedius reflex threshold for different sound stimuli. Paper presented at the eleventh International Congress of Audiology, Budapest, Hungary, (1972).

Oviatt, D. L., and Kileny, P., Adaptation patterns of the crossed and uncrossed acoustic reflex. Paper presented at the convention of the American Speech, Language and Hearing Association, Atlanta, Georgia, (1979).

Picton, T. W., and Hillyard, S. A., Human auditory evoked potentials. II. Effects of attention. **Electroencephalography and Clinical Neurophysiology,** 36, 191 - 200, (1974).

Salamy, A., and McKean, C. M., Postnatal development of human brain stem potentials during the first year of life. **Electroencephalography and Clinical Neurophysiology,** 40, 418 - 426, (1976).

Sohmer, H., and Cohen, D., Responses of the auditory pathway in several types of hearing loss. In R. J. Ruben, C. Elberling, & G. Salomon (Eds.) **Electrocochleography.** Baltimore: University Park Press, 431 - 439, (1976).

Zwicker, E., Flottorp, G., and Stevens, S. S., Critical band width in loudness summation, **Journal of the Acoustic Society of America,** 29, 548 - 557, (1957).