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Articles

Automated and Conventional ABR Screening Techniques in High-Risk Infants

John T. Jacobson*
Claire A. Jacobson†
Robert C. Spahr‡

Abstract

Test validity is determined by the proportion of results that are diagnostically confirmed and predicted on the measures used to identify the disease process.This article summarizes the results of a series of 224 stable high-risk infants who were screened by automated (ALGO-1) and conventional (Bio-logics LT) ABR instrumentation. Failure criteria was defined as the absence or prolongation of a replicable wave V response (conventional) or *Refer* by the automated system. The overall failure rates at a 35 dB screening level were comparable between devices. Sensitivity and specificity measures for the ALGO-1 unit were 100 and 96 percent, respectively. Permanent hearing loss was demonstrated in 5 percent of the newborns screened in this study. Advantages of the automated system include a dual artifact rejection system, attenuating ear couplers, and a battery operated design. These findings suggest that the automated ABR screener is a viable alternative to conventional ABR instrumentation for the limited purpose of neonatal auditory screening.

Key Words: Auditory brainstem response (ABR), automated ABR, high-risk newborn hearing screening, NICU

The auditory brainstem response (ABR) is the electrophysiologic technique of choice in the early identification of newborn hearing screening (Durieux-Smith et al, 1985; Fria, 1985; Hall et al, 1988; Hyde et al, 1984; Jacobson and Jacobson, 1987; Schulman-Galambos and Galambos, 1979; Stein, 1984). Despite early concern (Davis, 1982; Murray et al, 1985), the ABR has proved to be a reliable and valid method of detecting hearing loss in the newborn population, particularly for high-risk infants (Cevette, 1984; Cox et al, 1982, 1984; Dennis et al, 1984; Galambos et al, 1984; Jacobson and Morehouse, 1984; Stein et al, 1983).

By necessity, a screening program must be simple, inexpensive, and ultimately, both valid and reliable. Recently, the advent of an automated ABR screener (ALGO-1), which provides only a *pass-refer* outcome, has been introduced as an alternative to screening with conventional ABR* apparatus. The ALGO-1 system meets the definition of a hearing screening measure; that is in this context, an *objective* assessment of the presence or absence of hearing at a given predetermined intensity level. Although other manufacturers (e.g., Grason-Stadler [GSI 55], Bio-logics Systems Corp [PASS]) allow screening parameters to be incorporated into diagnostic instrumentation, these protocols still require subjective interpretation of wave configuration and threshold determination on the part of the observer. Further, the use of a dedicated screening instrument also addresses several issues of concern associated with conventional ABR protocol in the newborn intensive care nursery (NICU) (Murray et al, 1985). With this

*Department of Otolaryngology-Head and Neck Surgery, Division of Audiology, University of Texas Health Science Center at Houston
†Department of Audiology, Geisinger Medical Center, Danville, Pennsylvania
‡Director, Newborn Medicine, Geisinger Medical Center, Danville, Pennsylvania
Reprint requests: John T. Jacobson, University of Texas Health Science Center at Houston, Department of Otolaryngology-Head and Neck Surgery M5B 6132, 6431 Fannin, Houston, TX 77030

*In this context, reference to conventional ABR recording suggests the use of hearing screening protocol (two intensities, right and left ears) using electrodiagnostic instrumentation. See methodology for a detailed description of recording parameters.

in mind, the following investigation was conducted to assess the results of a comparative study using a screening version of conventional ABR and automated ABR instrumentation on a group of high-risk for hearing loss infants. It was hypothesized that if the automated system proved both valid and reliable, it could be used with confidence as a *true* screening device in newborn early identification programs.

METHOD

Subjects

A total of 224 (448 ears) stable infants were subjects in the present study. Neonates were considered high risk for hearing loss due to their admission into the NICU or based on specific risk factors advocated by the Joint Committee on Infant Hearing (1982). All babies were tested in the Neonatal Special Care Unit (NSCU) immediately prior to hospital discharge. Newborns ranged in postconceptual age (PCA) between 34 and 64 weeks when tested. Testing was conducted in an open bassinet when the infant was in a state of natural sleep or resting quietly. Ambient noise levels did not exceed those recommended for neonatal auditory screening (Richmond et al, 1986).

Instrumentation

Neonates were tested with both conventional (Bio-logics LT) and automated (ALGO-1) ABR electrodiagnostic instrumentation. The ALGO-1 is a battery-operated microprocessor dedicated solely for newborn ABR screening. This device uses a statistical model for objective response detection and incorporates a number of unique design features that include: (1) a disposable circumaural foam cushion with an adhesive back that is sealed around the infants' ears resulting in a noise reduction in excess of 14 dB SPL at 2000 Hz; (2) an artifact-rejection system that is designed to control for increased ambient noise as that experienced in the NICU; (3) to improve the myogenic rejection capabilities of the system, a series of parallel filters were designed to allow for separate filtering characteristics for signal processing and for myogenic-artifact detection; and (4) in order to extract signal response (wave V for the ABR) embedded in EEG activity, a template-matching detection algorithm is used (Thornton, 1978; Thornton and Obenour, 1981). The template is based on the grand average of ABR traces from 35 normal hearing newborns from which a weighted mathematical model is derived (Fig. 1). A detailed account of the operation and principles of the ALGO-1 are described elsewhere (Kileny, 1987, 1988; Peters, 1986).

Stimuli

The ALGO-1 employs a 35 dB alternating click stimulus presented monaurally at a rate of 37 pulses per second. Unfiltered clicks offer an acceptable auditory signal for infant ABR testing by providing optimum stimuli for eliciting synchronized neural discharge patterns. A presentation rate of 37/sec offers a reasonable compromise between wave morphology and test duration. That is, at 37/sec it will take about 45 sec to complete a total of 2000 repetitions (given the absence of any artifact rejection) without sacrificing wave peak amplitude and shape.

Conventional ABR instrumentation was programmed to produce stimulus parameters as similar as possible to the automated device given inherent differences between the two systems. Stimuli were transduced by an Etymotic ER-3A insert earphone with modified impedance tip adapters inserted directly into the ear canal. Intensity was expressed in decibels normal hearing level (nHL) relative to a group of normal hearing young adults. The peak equivalent sound pressure level for 0 dB nHL was 31 dB.

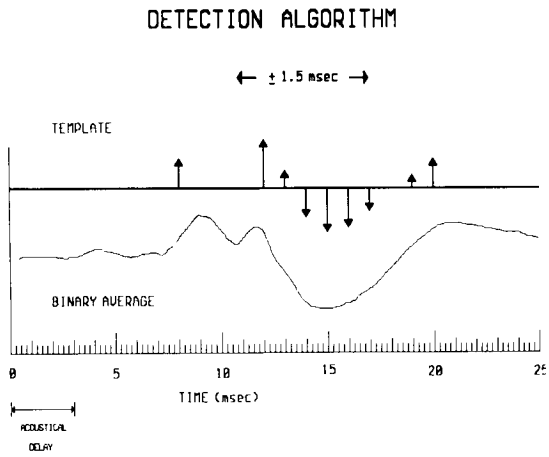

Figure 1 A template derived from the grand average of 35 infants used in the detection algorithm.

Data Acquisition

Every infant was tested in sequence within an hour of the completion of the first test. Test order was arbitrary, but relied on the: (1) number of infants to be seen; (2) length of test time; (3) feeding patterns; and (4) other complications associated with routine NSCU care.

Silver-silver chloride cup electrodes were attached to the forehead, midline, and just anterior to the fontanelle (noninverting/positive), the ipsilateral (inverting/negative), and contralateral (ground) earlobe. Once attached, electrodes remained in position for both tests. Interelectrode impedance was maintained at ≤ 5 kΩ for both systems throughout testing. It should be noted that the automated device will not "average" if electrode impedance exceeds 12 kΩ. The electrical activity recorded between the forehead and ipsilateral earlobe was amplified, filtered, and digitized prior to averaging. Table 1 summarizes the recording and data acquisition protocol used in this study.

Failure Criteria

For conventional ABR screening, a failure was considered the absence of an identifiable and replicable wave V peak for either ear at 60 or 35 dB nHL. Automated test failure criteria was predicated on a statistical likelihood ratio (LR) model. If the data collected did not exceed a predetermined LR (i.e., 160), a *Refer* message was displayed on the instrument suggesting additional follow-up measures. All traces derived from conventional screening protocol were collected by one author (CJ) and reviewed by another (JJ). A caveat ensures: as in all subjective assessment, preestablished personal criteria based on several factors including background and experience of the observer must be taken into account. Thus, every subjective interpretation has inherent bias. The intent is that for each judgment there is a minimal degree of variability and a considerable amount of consistency.

Table 1 Recording and Data Acquisition for the Two Instruments

Automated	*Conventional Screening ABR*
Stimulus	
Alternating click	Alternating click
37.3/s	37.3/s
100 μsec	100 μsec
35 dB nHL	35 and 60 dB nHL
Data Acquisition	
500–15K sweeps	2000 sweeps
0.05–1.5 kHz bandpass	0.03–1.5 kHz bandpass
25 msec time base	15 msec time base
Notch filter 60 Hz, −12 dB 50 Hz, −12 dB	Notch filter–disabled
Artifact Rejection Myogenic Ambient	Artifact Rejection Myogenic

Follow-Up Procedures

Any infant who failed either the conventional screening ABR protocol at 60 or 35 dB or was *referred* by the automated system was rescheduled for conventional screening ABR testing to coincide with either the first or second visit to their attending physician. In every case, this was accomplished within a 4-week period post-hospital discharge. Retest evaluation used identical protocol with the exception that testing was performed in a quiet, although not sound treated, environment. If an infant failed retest evaluation, a complete diagnostic assessment was conducted that included behavioral testing, an ABR threshold search, immittance audiometry when appropriate, and an otolaryngology examination.

RESULTS AND DISCUSSION

Risk Criteria

A total of 231 high-risk newborns* were initially tested. During the investigation, seven infants were lost to follow-up for various reasons including parental refusal to return for further testing, family relocation, and infant death. Of the remaining 224 infants, 201 were NICU graduates identified with high-risk perinatal conditions that included asphyxia, sepsis, respiratory distress syndrome, persistent fetal circulation, intraventricular hemorrhage, meconium aspiration, maternal preeclampsia, and hypoxic encephalopathy. All infants admitted to the NICU required some form of respiratory support ranging from an oxyhood to mechanical ventilation.

Using a strict interpretation of the 1982 Joint Committee on Infant Hearing recommen-

*At our facility, in addition to the use of the high-risk register, admission to the NICU automatically places an infant at risk for hearing loss.

dations, Table 2 presents a break down of risk categories for infants in this study. As evident, the largest proportion of infants (23%) presented with low birth weight, whereas bacterial meningitis resulted in the lowest prevalence (< 1.0%). Note that family history of hearing loss was only 5 percent and is likely due to the small number of families (N=137) that were confidently interviewed. That is, the interviewer felt that the parent or guardian had sufficient knowledge of the biologic sides of both families and was able to answer competently. This rate may not accurately reflect the true number of infants with a family history of hearing loss in the present study as defined by the Joint Committee.

Pass-Fail Outcome

The number and percent of babies who passed and failed conventional ABR screening (60 and 35 dB nHL) and the *pass-refer* outcome for the automated ABR protocol (35 dB nHL) are presented in Table 3.

Fail 60 dB level. Conventional ABR at 60 dB failed 5.1 percent (23/447 ears) of the 224 newborns screened. All infants who failed initial ABR testing at 60 dB were as previously indicated, retested serially. Audiologic and otologic findings confirmed permanent cochlear end-organ dysfunction in all 23 ears. Eleven infants had bilateral sensory hearing loss and one infant was unilaterally hearing impaired. Every infant who failed conventional screening at 60 dB also failed the automated screen at 35 dB.

Table 2 Prevalence of High Risk for Hearing Loss Factors According to the Joint Committee on Infant Hearing

Category	*Number*	*Percent*
Asphyxia (Apgar 0-3)	10/217*	4.6
Bacterial meningitis	2/224	0.9
Congenital perinatal infections–TORCH	11/224	4.9
Defects of ears, nose, and throat	16/224	7.1
Elevated bilirubin	11/224	4.9
Family Hx of HL	7/137*	5.1
Gram Wt (<1500)	50/219*	22.8

*Data not available on all infants.

Table 3 Failure Rates for Conventional and Automated Newborn Screening

ABR Screen	*Conventional*		*Automated*
Initial Test	60 dB	35 dB	35 dB
(Fail/Refer)	23/447 (5.1%)	37/447 (8.3%)	50/448 (11.2%)
Retest ABR			
Pass	0	14	27
Fail	23	23	23
Total	23	37	50

Fail 35 dB level. Initial failure rate for conventional ABR protocol at 35 dB was 8.3 percent (37/447 ears; one ear of one infant was not tested due to activity level and lost to follow-up). This initial percent failure rate is lower than most reported studies (Cevette, 1984; Cox et al, 1984; Galambos et al, 1984; Jacobson and Morehouse, 1984; Marshall et al, 1980; Mjoen et al, 1982; Stein et al, 1983; Swigonski et al, 1987) and probably due to the use of tubal insert earphones that decrease the likelihood of collapsing ear canals and reduce ambient noise levels resulting in an improved signal-to-noise ratio (Gorga et al, 1988; Schwartz et al, 1989).

Of the 37 ear failures, 14 ears passed subsequent ABR follow-up (35 dB). Of those 14, all passed at 60 dB, failing only at the lower presentation level. Thus, those who passed retest screening were confined to transient hearing loss by ABR, probably middle ear effusion self-resolved prior to retest evaluation. Given the testing protocol and environment, it is unlikely that the ambient noise levels contributed to the failure rate (Richmond et al, 1986). Our results support the findings of others that suggest an abnormally high prevalence of conductive pathology in high-risk infants (Balkany et al, 1978; McClellan et al, 1967; Zarnoch and Balkany, 1978).

In comparison to conventional ABR, of 448 ears tested by the ALGO-1, there were 50 failures, a yield of 11.2 percent. The 3 percent difference in *failure/refer* rate between systems may be a function of the ALGO-1 predetermined mathematical specificity rate strategy. Nonetheless, the *refer* rate remains small compared to cited literature, and as in the conventional protocol, modified ear couplers that reduced ambient noise levels and potential ear canal collapse likely contributed to the lower yield.

Table 4 Clinical Characteristics and Perinatal Status

Infant	Weight	GA	PCA	Perinatal History	APGAR 1	APGAR 5	Hearing Loss
N.L.	3450	40	61	Family hx of hearing loss	7	9	bilateral
B.H.	1330	38	46	Trisomy 18, asphyxia, RDS,* maternal herpes BILI-23,† low set ears	2	8	unilateral
E.D.	2390	32	55	Cyanosis, RDS,* heart, renal and liver disease BILI-20† (exchange 3X)	5	8	bilateral
G.S.	4080	40	40	Family hx of hearing loss, maternal seizures and trauma, facial asymmetry	6	9	bilateral
K.G.	2970	40	48	Congenital heart disease, RDS,* malformed pinnae, cleft and soft palate	7	8	bilateral
T.T.	3020	40	41	Trisomy 13, cleft palate, asphyxia, agenesis of corpus callosum	9	9	bilateral
J.W.	2300	37	39	Trisomy 18, abnormal pinnae, congenital heart defect, cyanosis, apnea	3	7	bilateral
A.F.	2770	40	64	Pierre Robin syndrome, cleft palate	7	9	bilateral
W.D.	2180	36	36	Jervell and Lange-Nielson syndrome, asphyxia, congenital heart defect, RDS*	1	5	bilateral
S.D.	1900	36	37	Jervell and Lange-Nielson syndrome, asphyxia, congenital heart defect, RDS*	8	9	bilateral
D.D.	3500	40	43	Paternal and maternal substance abuse	7	8	bilateral
D.G.	2900	40	44	Family hx of hearing loss	8	9	bilateral

*Respiratory distress syndrome—moderate to severe
†Direct bilirubinemia

Clinical characteristics for the 12 sensory hearing impaired infants are shown in Table 4. For the group, gestational age ranged between 32 and 40 weeks with birth weight from 1300 to 4080 g. Ruling out admission to the NICU, the single most common high-risk category was family history with 3 of 12 newborns presenting. Two twins (WD and SD) were the product of Jervell and Lange-Nielsen syndrome, two infants were diagnosed as Trisomy 18, and one as Trisomy 13. Conspicuously absent are those infants of low birth weight (<1500 g) and low APGAR (0-3) scores. Only one infant (BH) met low birth weight criteria.

Operating Characteristics

Initial ABR Screening Results

To compare the automated ABR screening results with conventional screening ABR outcome, test results were submitted to a decision matrix analysis using conventional ABR as the standard. Figure 2 illustrates the operating characteristics of the initial ALGO-1/ABR findings. ALGO-1 resulted in an 89.2 percent sensitivity rate or reciprocally, a 10.8 percent false negative rate. This finding suggests that at 35 dB, about 1 in 10 hearing impaired infants were not confirmed by the screening measure. Specificity of the ALGO-1 was about 96 percent indicating that less than 1 in 25 infants tested resulted in a false-positive outcome. Thus, infants having normal hearing for click stimuli will pass the screen. Finally, the overall efficiency of the test, indicating the accurate proportion of correctly identified normal and hearing impaired infants, was 95 percent.

Retest Analysis

Of the 50 ears that were referred by the automated screen, plus the additional four ears that were considered false-negative (passed ALGO-1, failed conventional ABR at 35 dB), all babies returned for ABR reassessment. Infants

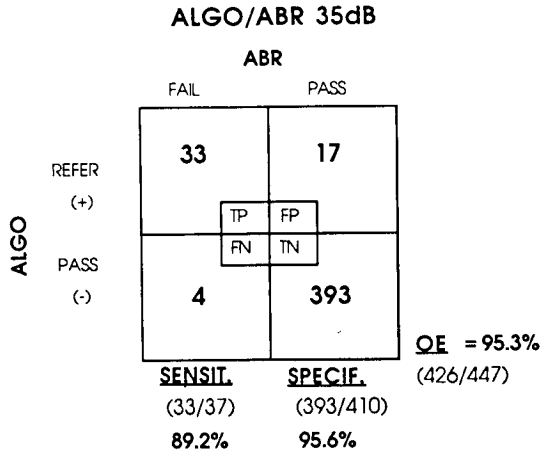

Figure 2 Operating characteristics for initial ALGO-1/conventional ABR screen.

were tested approximately 2–4 weeks post-discharge to coincide with neonatology follow-up clinic. During the reevaluation, only conventional ABR testing was performed.

Of those 54 rescreened ears, there was a total of 23 failures. The remaining 31 ears passed conventional retest screening at 35 dB including the four ears that were considered to be false-negative from the first evaluation. As previously indicated, initial failure at 60 dB (conventional ABR protocol) was confirmed in all 23 cases.

In retrospect, results from the retest evaluation raises some questions regarding the initial comparative ABR/ALGO-1 operating characteristics. First, the specificity of the ALGO-1 was stated to be about 96 percent indicating that less than 1 in 25 infants tested resulted in a false-positive outcome. A discrepancy exists between the 54 initial ear failures and the subsequent 31 ears that passed the retest evaluation. One cause of this discrepancy between the screen and the follow-up test is that the auditory status may have changed in the interim between tests. Several authors (Galambos et al, 1984; Hecox and Jacobson, 1986; Hyde et al, 1984; Sprague-Herrmann, 1987) have argued that ABR test results correctly reflect auditory status at the time of testing but cannot predict change from unforeseen transient auditory or neurologic pathology. In fact, the initial specificity results may not be an accurate predictor of the "true" false-positive findings if babies are tested shortly after birth. The prevalence of middle ear effusion in high-risk infants as well as the presence of mesenchymal tissue are inclined to affect test outcome. In the authors' opinion, an ABR screen accurately reflects existing auditory status including the middle ear condition or any other sensory intrinsic abnormality. Thus, any change in the physical condition of the auditory system between the initial and retest evaluation will alter comparative pass-fail results and, ultimately, operating characteristics.

Although resolution of hearing loss between evaluations may produce unnecessary follow-up efforts and potential parental anxiety, it is not as alarming as a false-negative finding (in this context, pass ALGO-1, fail conventional ABR) as was the case in four infants (four ears) tested. Importantly, in all four cases, each *passed* follow-up conventional testing at 35 dB confirming ALGO-1 results. The absence of false-negative findings are consistent with the results of others. Hall et al (1987) reported the results of a group of 189 infants meeting accepted risk criteria for hearing impairment at three University Medical Centers. Methodology was similar to that described in the present study. These authors reported sensitivity and specificity rates for the ALGO-1 of 100 and 96.7 percent, respectively. The true positive (both ALGO-1 and operator ABR fail) rate was 5.4 percent.

A second phase of the Hall et al (1987) study was reported by Kileny (1988). The major difference in protocol was that EEG epochs averaged by the ALGO-1 were stored on magnetic tape and their off-line averaging through playback was fed into a standard commercial evoked response device. A minimum of three actual runs was collected for each ear. A total of 507 ears were assessed under these conditions from this multicenter project. There were 22 ear failures (4.3%) and again, no false-negative findings with only a 3.85 percent false-positive outcome in this group. The conclusions of these manufacturer supported studies indicated that the ALGO-1 device was a feasible alternative to operator ABR measurement for newborn auditory screening. Comparatively, their test result findings are nearly identical to the follow-up outcome reported in the present independent study.

It is interesting to speculate on the initial four false-negative traces. First, it should be noted that although protocol was devised to match as closely as possible, differences existed between the two systems. For example, the number of averaged responses in the conventional device was limited to 2000 repetitions, whereas the automated system is designed to average as many as 15000 responses in seeking a mathematical template match. In these four cases, the averaged number of responses by the automated system was 7625, or nearly four times greater than the routine conventional recording parameter. The additional number of records may have been sufficient to improve the signal-to-noise ratio, thereby increasing the probability of reaching the preestablished automated *pass* criteria.

Second, the two-stage filtering sequence that enhances the efficiency of EEG artifact rejection and the extended myogenic rejection (one sweep preceding and four sweeps following the rejection are excluded from the average) may also have contributed to the response detection not observed in conventional ABR protocol. These techniques are designed to improve the signal-to-noise ratio thus enhancing the extraction of the response of interest.

Third, as stated in the Methods section, the criteria for a conventional pass was the presence of a repeatable wave V peak at 35 dB. Whereas the ALGO-1 template (see Fig. 1) is weighted most heavily toward the wave V peak and following trough, the analysis window allows a measure of variability. That is, the template shifts in 0.25 msec steps across a 3 msec range "searching" for the latency domain of best fit (Peters, 1986). It is possible that a robust wave III response that is latency delayed (e.g., due to a conductive component or significant maturational delay) may reside within this shifting 3 msec analysis time frame. Therefore, the automated system may calculate any time-locked wave peak and trough of sufficient amplitude within the 3 msec period. Thus, a screening pass would be predicated on the presence of a measurable response that dwells in this selected time period regardless of its peak designation.

Recall that the pass criterion (wave V) used in ABR screening protocol has been based on historical precedence, primarily because of the stability of wave V under varied pathologic and nonpathologic conditions. However, current theory suggests that waves I and II represent peripheral (compound cochlear-action potentials) generation whereas later responses represent more rostral neural activity (Moller and Jannetta, 1982). Obviously, the absence of peripheral auditory function will preclude the measurement of any ABR component. Thus, if the "true" goal of an auditory screening program is to rule out significant hearing loss, or as the ABR has been used, to measure lesser degrees of peripheral auditory abnormality, then pass-fail criterion should embrace the presence of any major wave peak component.

COMMENTS

There are at least two caveats that must be considered when correlating the two techniques discussed in the present study. First, the comparative analysis of this study used an acceptable screening version of conventional ABR as the "gold standard." Although ABR has been acknowledged as the most accurate measure of auditory sensitivity in the newborn population, there has been a report of absent ABR measures in quantifiable hearing (Worthington and Peters, 1980). Although rare, the possibility exists that in some infants, ABR traces are not observed in the presence of normal hearing. In this study, the ABR results from four ears did not meet conventional criteria; however, upon retest evaluation, ABR traces were present at 35 dB nHL.

Second, the protocol of this study was designed to follow only those infants that failed initial hearing screening. It is important to recognize that operating characteristics are based on the assumption that infants with true negative outcomes (normal hearing and passed the screen) have normal hearing. The results of a 1-year follow-up study on those infants who passed initial screening have shown that to date none have been identified with cochlear pathology.

There are other tangible factors that must be taken into account when considering practical applications associated with the acquisition of an ABR instrument for newborn screening. Perhaps the single leading objection to the automated system is that the ALGO-1 does not provide visual representation of ABR waveforms. Based on the findings of the present study and those by Hall et al (1987) and Kileny (1988), the concern of automated test validity should no longer be a factor. Therefore, the absence of visual ABR traces is more likely related to one's philosophic approach to newborn screening. Let's say that a facility introduces an auditory newborn screening program where threshold measures or neurologic interpretation is not a concern. Under these circumstances, an automated system may be a practical alternative to conventional apparatus. For example, many hospitals use technicians, nurses, or volunteers rather than audiologists to perform and assess ABR records. Screening failures are then referred to an in-house audiology department or outside agency. From a practical sense, removing the decision process from untrained personnel may be more appropriate than allowing their input. Frankly, there are many audiologists who are asked to interpret newborn ABR traces without adequate training and whose judgment is, at best, questionable. On the other hand, if audiologists are asked to support pediatric programs including newborn screening, neurologic assessment, pediatric ICU monitoring, and other aspects related to ABR measures in the pediatric population, then a more versatile instrument is obviously required. In our institution, audiologists and trained research assistants perform screening tests. All screening failures from the automated device are referred for retest evaluation using convention-

al ABR electrodiagnostic systems. Perhaps the reality of the matter is that given our training, no one is willing to trust a little "black box." To alleviate the concerns of the most ardent disbelievers and to expand the flexibility of the system, the new ALGO-1 plus is equipped with a lap top computer that will produce visual traces as well as interface for hard copy prints of all records.

As described in the Method section, the ALGO-1 uses an artifact rejection system designed to monitor ambient noise at ear level. Briefly, a microphone and noise peak detector will sample noise and accept or reject each evoked response based on a 10 dB signal-to-noise ratio. The noise design was based on the premise that environments are less than ideal where newborn screening is conducted. On the surface, this is an excellent dimension because of the reason mentioned; however, this can also be a limiting factor because at present, the noise rejection system cannot be overridden. Thus, in settings where noise produces substantial interference, the monitoring of evoked responses may be extended because of the incompatibility of the stated signal-to-noise ratio. Each screening environment is different and the use of the ALGO-1 system may require a special dedicated area. Our experience suggests that in similar settings, the automated system is as efficient as conventional ABR screening protocol.

CONCLUSIONS

The results of our comparative analysis suggest that the use of the automated ABR screener described in this article is a viable alternative to conventional newborn ABR hearing screening techniques. The NICU is a *hostile* environment to establish a newborn hearing screening program. Difficulties associated with good test protocol include the elimination of electric interference and excessive noise levels, and the appreciation of the general compromised condition of high-risk infants. With today's new technology, these variables can be controlled and should not be a deterrent in the consideration or continuation of any newborn auditory screening program.

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