Critical Review:
Is there evidence that auditory steady-state response measures provide a more accurate electrophysiological estimate of behavioural thresholds in infants than tone-burst auditory brainstem response measures?

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This critical review examines the accuracy of threshold estimation using auditory steady-state response (ASSR) and tone-burst auditory brainstem response (TB-ABR) in infants. Overall, results of the three studies reviewed indicate a lack of sufficient evidence to suggest that ASSR measures provide a more accurate estimate of behavioural thresholds than TB-ABR measures. A review of the literature shows promise in using ASSR for estimating thresholds in the infant population, however, until further research supports its accuracy, ASSR measures should only be used in conjunction with TB-ABR measures.

Introduction

Behavioural audiometric procedures, which offer the best indication of hearing thresholds, are not applicable in infants less than six months of age due to their inability to provide reliable responses to stimuli. Audiological assessment must be based on electrophysiological measures for estimating hearing thresholds in young infants for early hearing detection and communication development options. Namely, tone-burst auditory brainstem response (TB-ABR) and auditory steady-state response (ASSR) are the most common evoked-potentials appropriate for threshold estimation.

Currently, the Ontario Infant Hearing Program uses TB-ABR to obtain frequency-specific information from infants less than 6 months of age who are suspected of hearing loss. The TB-ABR is a series of electrical potentials that are recordable from the scalp to give frequency-specific estimates of hearing level. Definitive results through TB-ABR may require several test sessions for audiometric completeness as a result of the procedure's long testing time.

The ASSR is another auditory evoked potential capable of estimating thresholds that are elicited by continuous amplitude and frequency-modulated tones. The ASSR has shown clinical potential due to its ability to simultaneously test multiple frequencies in both ears; a major advantage given the time constraints in infant testing. Nonetheless, time efficiency is only useful if the ASSR procedure provides evidence of being accurate in its threshold estimations.

The discrepancy between evoked-potential measures and behavioural thresholds must be considered for hearing instrument fitting purposes. With the universal goal of identification and management of infants with significant hearing loss by six months of age, audiological assessment must be as accurate as possible.

Objectives

The primary objective of this review was to critically evaluate the research literature that examines the accuracy of ASSR and TB-ABR in estimating behavioural thresholds of infants. The secondary objective was to generate recommendations for clinicians and for future research based on evidence-based results.

Methods

Search Strategy

Database searching of CINAHL, PubMed, and MEDLINE-OVID were investigated using the following strategy:

((auditory steady-state response) or/and (tone-burst auditory brainstem response) or (evoked-potentials)) and (threshold estimation)

The search was limited to articles with infant subjects. This search strategy was unsuccessful as most of the articles investigated the click ABR; an electrophysiological measure that lacks frequency specificity. I then consulted with a couple of faculty members with backgrounds in evoked-potential testing regarding current studies in this area. The reference lists of the articles gathered lead to more relevant resources.

Selection Criteria

Studies selected for inclusion in this review paper were required to investigate the accuracy of ASSR and TB-ABR estimations of thresholds in the infant population.

Research Design

Results of the literature search yielded three articles congruent with the aforementioned selection criteria: retrospective (2), longitudinal (1). Two of the three studies used large samples obtained via convenience sampling from screening referrals, laboratories, clinical facilities, and other outside agencies. The exclusion criteria included infants with evidence of middle ear pathology, auditory neuropathy, or evidence of progressive hearing loss. The final study reviewed used a small sample size recruited from one particular nursery in an Australian hospital which may result in a selection bias. The studies reviewed involve no random selection of the participants and do not illustrate an attempt to ensure that the sample is an accurate representation of the infant population; an indication of reduced external validity.

Results

The first two studies by Rance and Rickards (2002) and Stapells, Gravel, and Martin (1995) are evaluations of ASSR and TB-ABR testing respectively, and look at the efficacy of the two measures in estimating thresholds for infants with normal hearing and varying degrees of sensorineural hearing loss. The final study is conducted by Rance, Tomlin, and Rickards (2006) and compares ASSR and TB-ABR in infants during the first six weeks of life.

Rance and Rickards (2002)

The retrospective study used ASSR to test 211 infants who were mostly all referred for diagnostic testing following failure on click-evoked ABR screening. The infants were aged 1 to 8 months, with a mean age of 3.2 months. Behavioural thresholds using visual reinforcement audiometry (VRA) were conducted approximately 6 months after ASSR testing. ASSR testing used carrier frequencies of 500, 1000, 2000, and 4000 Hz with single stimuli presented monaurally. Both ASSR and behavioural testing were performed in a sound-attenuated room using insert earphones or TDH-39 headphones. A total of 809 comparisons were made between ASSR and behavioural thresholds across the tested frequencies.

Results suggest that ASSR and behavioural thresholds are highly correlated for each frequency with the overall Pearson r value of .97. In a previous study by Rance et al. (1995), a linear regression equation was applied to older children and adults' ASSR thresholds to predict behavioural thresholds. When the linear regression lines were fitted to the data from the infants from this study, behavioural thresholds were typically 10-15 dB better than the predicted level of infants with normal hearing. More accurate threshold predictions were obtained through ASSR measures for infants with greater degrees of SNHL. If this regression formula was used for infants with near-normal hearing, there would be a number of false positives. This provides evidence that ASSR procedures are still rudimentary in predicting infants' true hearing levels.

Stapells, Gravel, and Martin (1995)

This study includes a total of 88 infants and young children, aged 1 week to 8 years with a mean age of 31 months. The TB-ABR procedure used stimuli of 500, 2000, and 4000 Hz tones presented in notched-noise. Behavioural thresholds were obtained within a mean of 2.2 ± 18.0 months of TB-ABR testing, with some behavioural testing being performed before the ABR. A combination of VRA, conditioned play audiometry (CPA), and conventional audiometry were used. The difference between thresholds was calculated by subtracting behavioural thresholds from TB-ABR estimated thresholds.

Results were analyzed using descriptive statistics, frequency distributions, linear regressions, and t-tests and were considered significant when $p<0.01$. Results of the study conclude that TB-ABR provide accurate predictions of behavioural thresholds with correlations exceeding .94 across all subjects. There was no discrepancy between threshold differences as a result of age, degree of hearing loss, or audiometric configuration.

Rance, Tomlin, and Rickards (2006)

This longitudinal study compares the developmental course of babies with normal hearing using two electrophysiological measures. TB-ABR and ASSR estimated thresholds were measured at 500 and 4000 Hz at 4 intervals ranging from birth to 6 weeks in 17 normal babies. The subjects were recruited from the well-baby nursery from the Mercury Hospital for Women and Children in Melbourne. All of the babies were full term with no risk factors for hearing loss. Transient-evoked otoacoustic emissions (TEOAE) were measured at the beginning of each test session to confirm normal hearing. Testing began at 3 to 6 days after birth in the mothers' hospital rooms and subsequent tests were conducted in the family home.

Tukey's post hoc analysis revealed that on each test occasion, ASSR thresholds were significantly higher than those obtained using TB-ABR. Analysis of variance indicated a significant test effect at 4000 Hz with mean ASSR thresholds 16.2 to 21.4 dB higher than the mean TB-ABR thresholds at each interval. Results of the two techniques were more similar at 500 Hz, with ASSR thresholds being significantly higher than TB-ABR thresholds at birth only. Analysis of variance measures indicated no significant difference in group mean thresholds over time for either test, with the spread of evoked potential thresholds broader for ASSR compared to TB-ABR. However, mean thresholds for TB-ABR and ASSR results are similar when the stimuli were calibrated in the same units (dBpeSPL). The researchers note that the threshold level of the evoked potential does not determine its accuracy of one's true threshold; however, it is the consistency of the response across time that is important.

A four-way repeated-measures analysis of variance was performed to investigate within-subject trends. A significant test effect indicated that ASSR thresholds exceeded TB-ABR thresholds by 12.1 dB on average with the test difference greatest at 4000 Hz. Overall, analyses of variance showed that within each subject, ASSR thresholds are more affected by maturational development across the recording period than TB-ABR thresholds. The maturational changes in ASSR thresholds were subtle enough within each subject to not reveal a difference in mean thresholds between tests. TB-ABR threshold levels showed no measurable changes across the recording period and were consistently lower than ASSR levels for 500 and 4000 Hz.

Summary

The present literature suggests that ASSR threshold estimations are affected by degree of hearing impairment and maturational development in infants. In addition, there is a lack of standardization and uniformity across various ASSR systems. These factors make it difficult to measure the relationship of the ASSR estimated thresholds to behavioural thresholds. At this point in time, there is insufficient evidence to suggest that ASSR is a more accurate estimate of behavioural thresholds than TB-ABR.

A major limitation of the studies aforementioned was a lack of consideration for individual ear canal acoustics. Accurate comparisons are not possible without accounting for maturational changes in ear canal resonance and real-ear probe measurements of the SPL in the ear canal should be obtained. Therefore, the results of the aforementioned studies should be interpreted with caution.

Recommendations for Further Research

Further analysis comparing TB-ABR and ASSR procedures as well as large-scale clinical trials of the latter are necessary to evaluate the accuracy and usefulness of ASSR in assessing infants less than six months of age. Conversion of HL data to real-ear SPL using RECD measurements should be applied to account for individual ear canal acoustics and are necessary for accurate comparison amongst values. This is especially important when evoked-potential threshold estimations are compared with behavioural thresholds that are obtained months later as there will be significant changes in the growing infants' ear canal resonance. In addition, correction factors for ASSR need to be better defined amongst infants at different ages with varying degrees of hearing loss for various systems.

Recommendations for Clinical Practice

Clinical utility for using ASSR to estimate hearing thresholds in infants is promising, yet further research supporting its accuracy is warranted within the infant population. ASSR procedures are still rudimentary and without further support for its clinical accuracy, they should only be used in conjunction with TB-ABR. TB-ABR is the method used in the Ontario Infant Hearing Program's protocol due to its sufficient research, clinical database, and accuracy of estimating thresholds in young infants and should continue to be the primary measure for estimating thresholds in this population.

References

Note: References marked with an asterisk indicate studies included in the critique.

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