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(RESEARCH ARTICLE)

Correlation between ABR and ASSR in Children with Severe to Profound Hearing Loss: A Study of 153 Cases

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Abstract

This study evaluates the correlation between Auditory Brainstem Response (ABR) and Auditory Steady-State Response (ASSR) thresholds in children with severe to profound hearing loss, aiming to verify the clinical reliability of ASSR as a complementary diagnostic method. Conducted as a retrospective analysis over a four-year period from January 2022 to November 2025, the investigation included a cohort of 153 children with a mean age of 41.8 months. The analysis revealed a significant high correlation between the two electrophysiological techniques, yielding a Pearson coefficient of r = 0.94 in the 2000–4000 Hz frequency range. Although ASSR demonstrated a moderate tendency to overestimate thresholds by 5 to 10 dB compared to ABR, a strong concordance was established between ASSR and behavioral audiometry across all tested frequencies. Consequently, these findings confirm that ASSR is a reliable and reproducible tool that effectively complements ABR, particularly by providing crucial low-frequency data necessary for optimizing hearing aid fitting and cochlear implant indications.

Keywords: Auditory Brainstem Response; Auditory Steady-State Response; hearing loss; Children; Electrophysiology; Audiometry

1. Introduction

The accurate and early assessment of hearing in the pediatric population is a fundamental challenge in audiology, relying on a complementary combination of both subjective (behavioral) and objective tests. Among objective measures, the Auditory Brainstem Response (ABR) has historically been established as the "gold standard" in objective audiometry. It provides critical data regarding auditory pathway integrity and threshold estimation. However, ABR presents a significant clinical limitation: it predominantly explores the high-frequency range, specifically between 2000 and 4000 Hz, leaving lower frequencies largely unassessed.

To address this gap, Auditory Steady-State Responses (ASSR) have emerged as a more recent and advanced technique. Unlike standard click-evoked ABR, ASSR allows for a comprehensive multifrequential analysis, capable of assessing thresholds at 500, 1000, 2000, and 4000 Hz simultaneously. This capability is theoretically advantageous for constructing a complete audiogram, which is essential for precise hearing aid fitting.

Despite these advantages, the clinical interchangeability of these two methods requires rigorous validation. Therefore, this study aims to evaluate the correlation between ABR and ASSR thresholds specifically in children suffering from severe to profound deafness. The primary objective is to verify the reliability of ASSR as a complementary method, determining if it can effectively augment standard ABR testing to provide a more holistic estimate of auditory thresholds in this specific patient population.

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2. Materials and Methods

2.1. Study Design and Population

We conducted a retrospective, descriptive, and analytical study at the ORL-CCF service over a period of 4 years (January 2022 – November 2025). The study included 153 children with a mean age of 41.8 months and a sex ratio of 1.18 (male predominance).

2.2. Inclusion and Exclusion Criteria

Inclusion criteria required confirmed severe to profound hearing loss, with both ABR and ASSR performed within the same clinical period. Behavioral audiometry was included when the child's age permitted. Exclusion criteria included neurological or syndromic pathologies affecting responses and recordings of poor quality (artifacts, lack of sleep, or non-reproducibility).

2.3. Data Acquisition

Tests were performed under natural sleep (infants) or light sedation (non-cooperative children) with impedances kept below 4ω.

2.3.1. ABR Protocol

Broadband clicks (100 µs, 200 Hz–11 kHz) were used as stimuli. The analyzed zone was 2000–4000 Hz, with a reproducible Wave V serving as the threshold criterion.

2.3.2. ASSR Protocol

Frequencies tested were 500, 1000, 2000, and 4000 Hz. Thresholds were determined by automatic statistical detection ($p < 0.05$) at the lowest significant intensity.

2.4. Statistical Analysis

The correlation between ABR and ASSR thresholds was analyzed using the Pearson correlation coefficient (r).

3. Results

3.1. Study Population Characteristics

The study included a total of 153 children diagnosed with severe to profound hearing loss. The demographic analysis revealed a mean age of 41.8 months. The sex distribution showed a slight male predominance, with a sex ratio of 1.18. This substantial sample size strengthens the statistical validity of the correlation analyses presented below.

3.2. Correlation Between ABR and ASSR Thresholds

A primary objective was to compare the electrophysiological thresholds obtained via ABR (Auditory Brainstem Response) with those obtained via ASSR (Auditory Steady-State Response). The analysis demonstrated a very high global correlation between the two techniques.

3.2.1. High-Frequency Correlation

In the frequency range of 2000–4000 Hz, where ABR is most effective, the Pearson correlation coefficient was extremely strong ($r = 0.94$). Specifically at 4000 Hz, the correlation remained robust with $r = 0.91$.

3.2.2. Threshold Discrepancy

A comparative analysis of intensity levels showed that ASSR tends to slightly overestimate auditory thresholds compared to ABR. This difference ranged from +5 to +10 dB. This phenomenon is attributed to the nature of the continuous stimuli used in ASSR versus the transient clicks in ABR. However, this moderate overestimation is considered to have no significant clinical impact on patient management.

3.3. Correlation Between ASSR and Behavioral Audiometry

To validate the clinical accuracy of ASSR, thresholds were cross-referenced with behavioral audiometry, which remains the reference standard. The results showed a very strong concordance across the entire frequency spectrum, confirming the reliability of ASSR as a predictor of behavioral thresholds.

The Pearson correlation coefficients (r) by frequency were as follows:

- 500 Hz: r = 0.85
- 1000 Hz: r = 0.89
- 2000 Hz: r = 0.92
- 4000 Hz: r = 0.90

Notably, the correlation was strongest at 2000 Hz (r = 0.92). The graph of Pearson correlation factors further illustrates a clear trend: while correlations are moderate at very low frequencies, they become "Strong" to "Very Strong" as frequencies increase, stabilizing above r = 0.90 for frequencies ≥ 1000 Hz.

3.4. Specific Contribution of ASSR in Low Frequencies

A critical finding of this study is the ability of ASSR to provide reliable data for low frequencies (500–1000 Hz). Standard click-evoked ABR does not reliably explore this range. The strong correlation found at 500 Hz (r = 0.85) and 1000 Hz (r = 0.89) validates ASSR as an essential tool for completing the audiological profile. This low-frequency data is vital for:

- Precise hearing aid fitting (which requires gain adjustments at specific low frequencies).
- Early and accurate decision-making regarding cochlear implantation

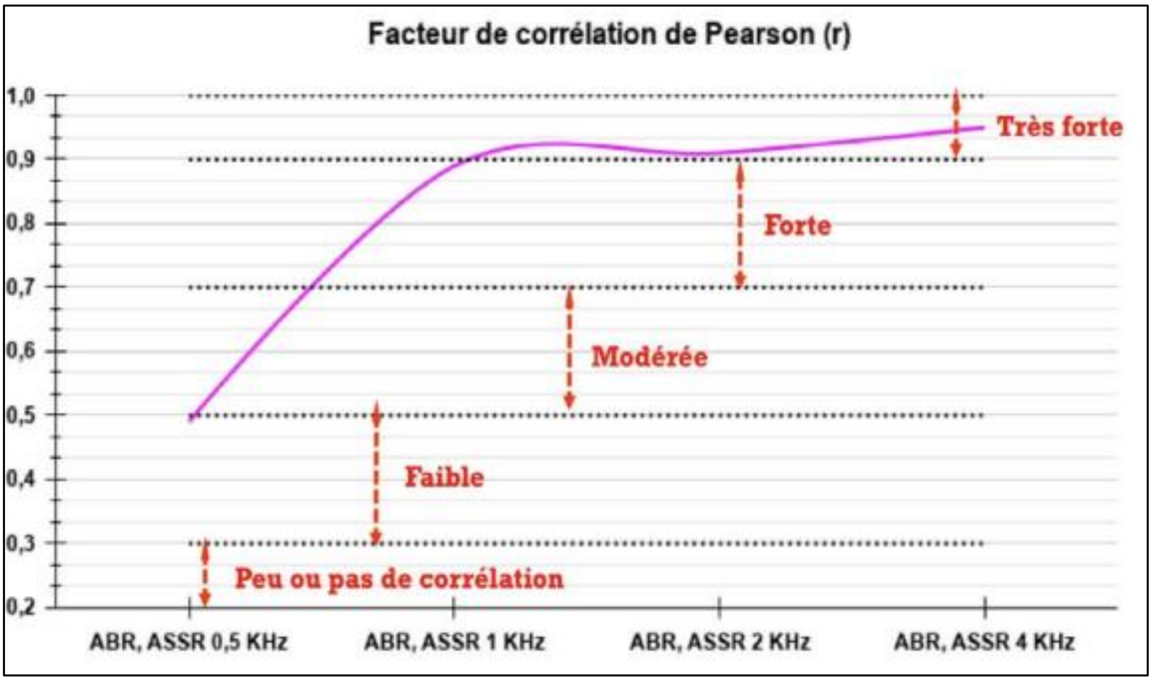

Figure 1 Auditory thresholds determined using the Interacoustics Eclipse EP15 platform**(**X-axis: Frequency (Hz),Y-axis: Threshold (dB HL))

Auditory thresholds were determined using the Interacoustics Eclipse EP15 platform with a two-channel recording montage. First, ABR thresholds were identified visually using broadband clicks (200 Hz - 11 kHz) presented at a rate of 44.1/s; the threshold was defined as the lowest intensity eliciting a reproducible Wave V. Subsequently, ASSR thresholds were obtained binaurally using the Multiple Auditory Steady-State Response (MASTER) paradigm, allowing for the simultaneous assessment of four carrier frequencies (500, 1000, 2000, and 4000 Hz) in each ear.

ASSR responses were automatically detected based on statistical probability. For this study, the 'speed' recording mode was utilized, corresponding to a significance level of $p \le 0.05$ (95% confidence limit). Comparison of the behavioral

ABR thresholds with the electrophysiological ASSR thresholds reveals significant correlations across the tested frequencies. The specific relationships between the click-evoked ABR and the ASSR thresholds at 0.5, 1, 2, and 4 kHz are illustrated in the scatter plots below.

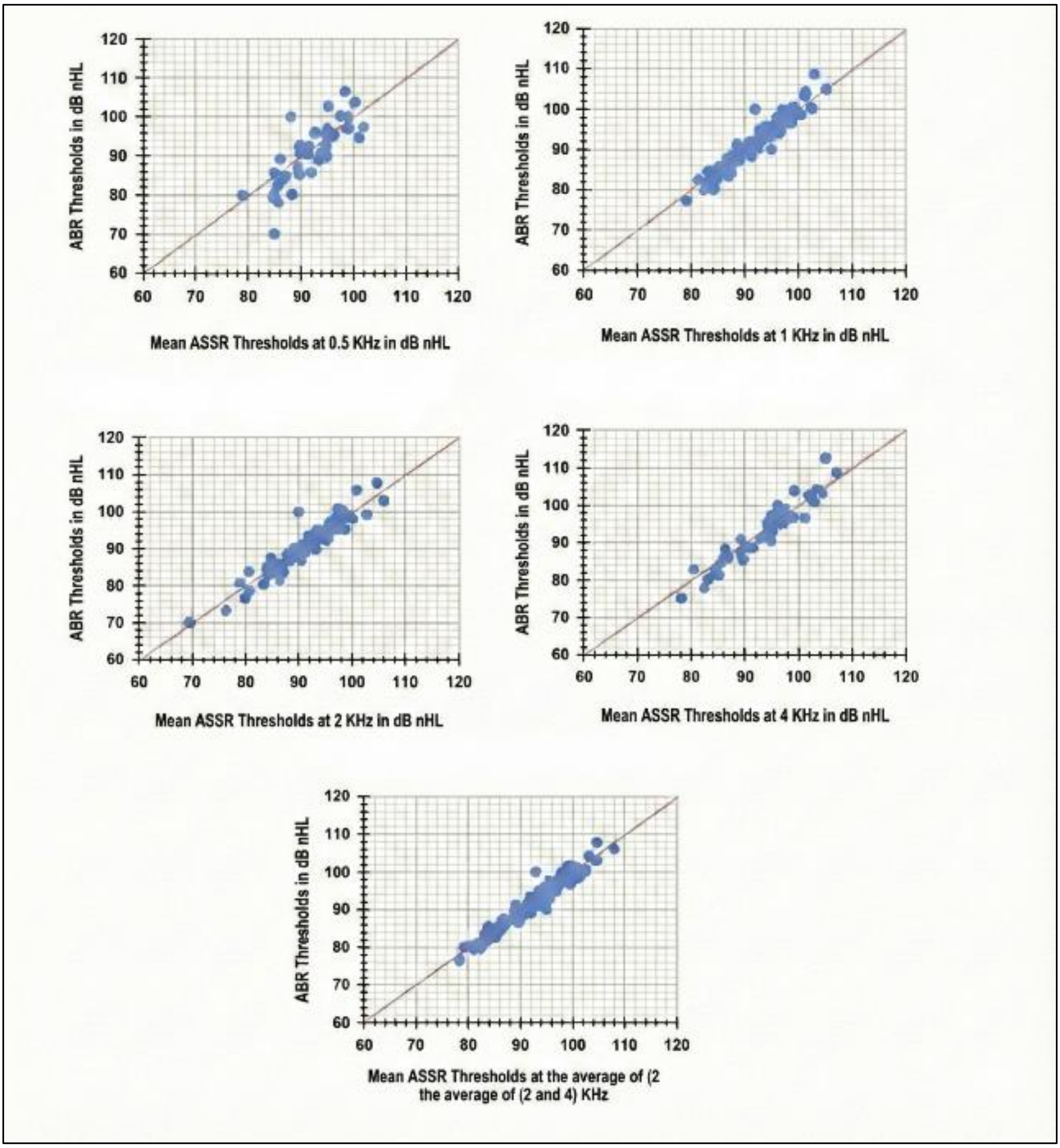

Figure 2 Scatter plots of correlation between ABR and ASSR thresholds(X-axis: ABR threshold (dB HL),Y-axis: ASSR threshold (dB HL))

4. Discussion

4.1. Demographic Profile and Study Representativeness

The reliability of clinical findings in pediatric audiology is heavily contingent upon the representativeness of the study cohort. In this investigation, we analyzed a population of 153 children, a sample size that provides robust statistical power and exceeds that of many comparable retrospective studies. The demographic analysis revealed a mean age of 41.8 months (approximately 3.5 years) and a sex ratio of 1.18, indicating a slight male predominance.

This demographic profile is consistent with global epidemiological data regarding childhood hearing impairment. The observed male preponderance aligns with trends reported by Van Naarden et al. [1] and Morton [2], who attribute this disparity to higher susceptibility to perinatal complications and X-linked genetic factors. Furthermore, the mean age of our cohort places this study in a critical diagnostic window—the "hard-to-test" toddler and preschool age group. This is the developmental stage where behavioral audiometry is often unreliable, making objective testing indispensable, as highlighted in guidelines by the Joint Committee on Infant Hearing [3].

4.2. Clinical Validity: ABR vs. ASSR Correlation

The central finding of this study confirms that Auditory Steady-State Response (ASSR) is a highly reliable objective tool for estimating hearing thresholds in children with severe to profound hearing loss. Our data demonstrated a very high global correlation (r = 0.94) between ASSR and the gold-standard ABR in the high-frequency range of 2000–4000 Hz.

This result corroborates the findings of several pivotal studies. Kandogan and Dalgic [4] reported similar strong correlations (r > 0.90) specifically in candidates for cochlear implantation, validating ASSR as a predictor of physiological thresholds in severe deafness. Similarly, Han et al. [5] and Swanepoel and Ebrahim [6] demonstrated that ASSR thresholds significantly correlate with both ABR and behavioral thresholds across various degrees of hearing loss. Our finding of r = 0.94 sits at the upper end of these reported ranges, reinforcing the consensus that ASSR provides threshold estimates clinically equivalent to ABR for high-frequency assessment.

4.3. Analysis of Threshold Discrepancies

Despite the strong correlation, a systematic analysis of intensity levels revealed that ASSR tends to overestimate thresholds by 5 to 10 dB compared to ABR. This "overestimation" is a consistent finding in electrophysiological literature and is attributed to the different neural mechanisms involved: ABR utilizes transient click stimuli eliciting synchronized onset responses, whereas ASSR uses continuous modulated tones requiring neural phase-locking, as detailed by Picton et al. [7].

Clinically, this difference is considered acceptable and manageable. Rance et al. [8] established that regression equations can accurately predict behavioral thresholds from ASSR data, effectively neutralizing this gap. Furthermore, Luts et al. [9] suggest that this stable difference can be easily accounted for during hearing aid fitting by applying correction factors, ensuring that the physiological difference does not lead to management errors.

4.4. The Low-Frequency Advantage and Clinical Implications

The most significant contribution of this study is the validation of ASSR for low-frequency assessment (500–1000 Hz), an area where standard click-ABR is notoriously limited due to its broad-spectrum nature. Our results showed a strong concordance between ASSR and behavioral audiometry at 500 Hz (r = 0.85) and 1000 Hz (r = 0.89).

This capability addresses a critical gap in pediatric diagnostics. As Stapells et al. [10] emphasize, relying solely on click-ABR can result in missed "dead regions" or underestimated residual hearing in the low frequencies. By providing a frequency-specific audiogram, ASSR facilitates precise hearing aid fitting and is crucial for cochlear implant candidacy. Distinguishing between total deafness and usable residual low-frequency hearing allows for the selection of hearing preservation surgical techniques, optimizing long-term outcomes for the child.

5. Conclusion

In conclusion, this study establishes Auditory Steady-State Response (ASSR) as a reliable and essential complementary tool to the gold-standard ABR for evaluating children with severe to profound hearing loss. The strong correlation observed confirms the clinical utility of ASSR, particularly for its unique ability to provide precise threshold estimates in the low-frequency range where ABR is limited. By filling this diagnostic gap, the routine integration of ASSR significantly improves diagnostic accuracy. Ultimately, this comprehensive electrophysiological assessment optimizes the therapeutic management pathway, ensuring more accurate hearing aid fitting and timely decision-making regarding cochlear implantation, especially in difficult-to-test populations where behavioral audiometry is limited or impossible.

Compliance with ethical standards

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Disclosure of conflict of interest.

The authors have no relevant financial or non-financial interests to disclose.

Statement of ethical approval

Ethics Approval and Consent to Participate Informed consent was obtained from all individual participants included in the study.

Statement of informed consent

Informed Consent Written informed consent was obtained from all subjects (patients) in this study.

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Consent to Publish

The authors affirm that human research par- ticipants provided informed consent for publication of the images in all Figures.

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