Accuracy of TB-ABR and 40-Hz Automated & Sinusoidal ASSR Thresholds in Normal-Hearing Adult Females using Kalman-Weighted Filtering

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Introduction

Although behavioral testing is the gold standard for hearing assessment, it has limitations in testing newborns, special populations, and uncooperative individuals. For these individuals, evoked potentials such as Auditory Brainstem Response (ABR) and Auditory Steady State Response (ASSR) are available to objectively and reliably estimate hearing thresholds (Kaf et al, 2006; Korczak et al, 2012). Conventional ABR, however, is very sensitive to physiological and electrical noise (Wheeler, 2011).

In efforts to bypass limitations of conventional ABR, Sokolov et al (2006) employed techniques to aggressively manage noise in ABR recordings including the Kalman-weighted filter and in-situ pre-amplification. Wheeler (2011) has reported that the Kalman-weighted filtering technique of the Vivosonic Integrity system measures ABR thresholds accurately in active individuals. However, little is known about the use of this technique to determine the accuracy of both 40-Hz automated and sinusoidal ASSR thresholds. This within-subject study compared 40-Hz ASSR automated and sinusoidal thresholds to tone-burst (TB) ABR and behavioral thresholds in awake, normal-hearing young adult females.

Objectives

1. To determine the accuracy of TB-ABR thresholds and both 40-Hz sinusoidal and automated ASSR thresholds compared to behavioral thresholds.
2. To establish normative data for TB-ABR and both 40-Hz & sinusoidal and automated ASSR correction factors in normal-hearing young adult females.

Methods

Participants

15 normal-hearing (PT thresholds ≤15 dB HL) females (ages 22-25 years) with normal middle ear status (Type A 226-Hz tympanograms) were recruited from Missouri State University to participate in this study. All participants have voluntary signed a consent form.

Procedures

Following otoscopy and tympanometry, ABR and ASSR testing preceded behavioral testing to restrict interpreter bias. Single-channel recording with three electrodes: high forehead (non-inverting), right mastoid (inverting) and low forehead (ground). Impedances were <5 kOhms.

Testing was conducted using the VivoSonic Integrity V500 EP System, responses for TB-ABR (27.5/s repetition rate; 100-1500 Hz filter) and 40-Hz Sinusoidal ASSR & 40-Hz Automated ASSR (40-Hz modulation rate; 100-300 Hz filter). Rarefaction Blackman tone burst and amplitude modulated 500 Hz, 2000 Hz, and 4000 Hz tones were delivered to right insert earphone and responses were recorded while participants were lying on a recliner, awake and alert. Random order of tests and frequencies was administered to each participant.

Results & Discussion

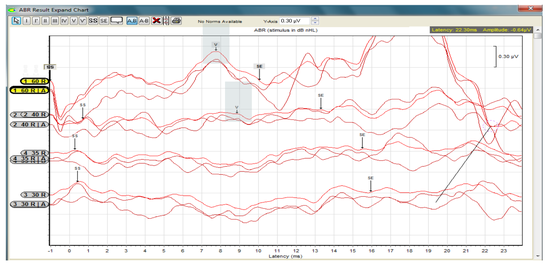

Figure 1: Representative TB-ABR for 500 Hz

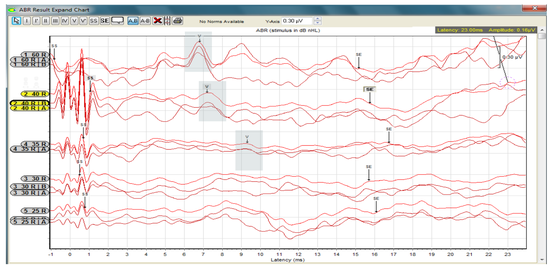

Figure 2: Representative TB-ABR for 2000 Hz

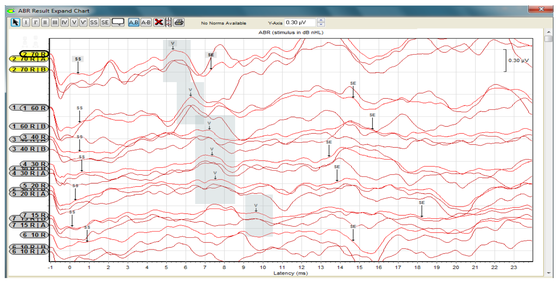

Figure 3: Representative TB-ABR for 4000 Hz

Results & Discussion

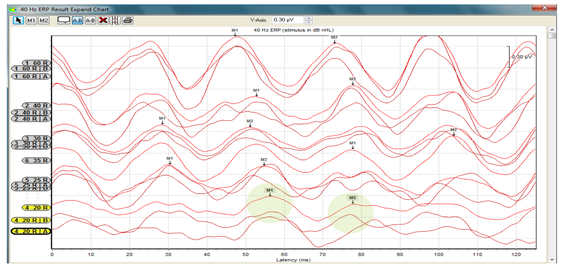

Figure 5: Representative Sinusoidal 40-Hz ASSR for 500 Hz

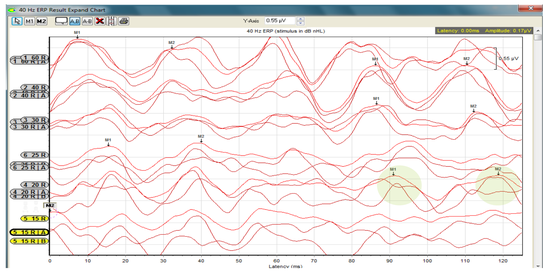

Figure 6: Representative Sinusoidal 40-Hz ASSR for 2000 Hz

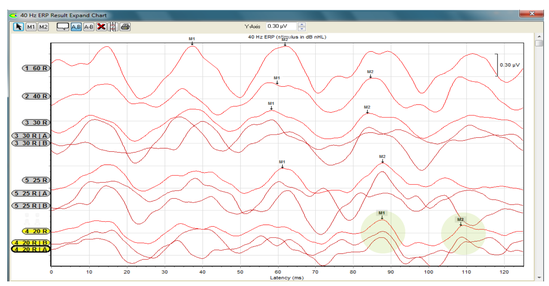

Figure 7: Representative Sinusoidal 40-Hz ASSR for 4000 Hz

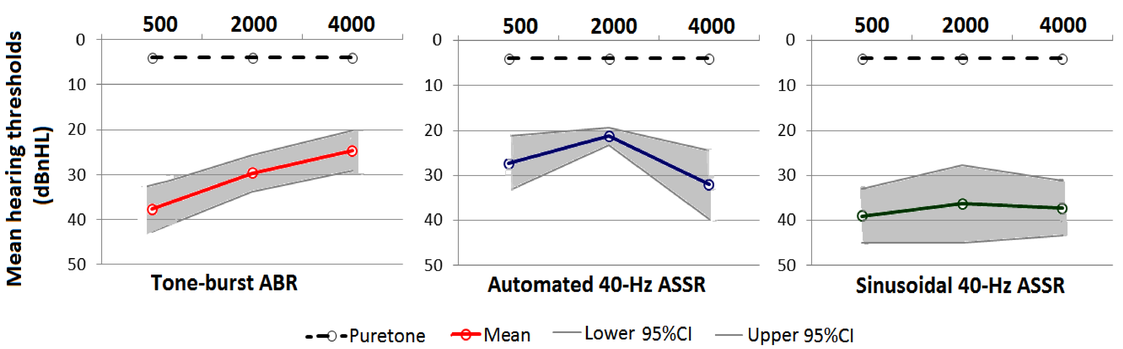

Figure 4: The figure illustrates the mean and the 95% CI of estimated thresholds using TB-ABR, automated 40-Hz ASSR and sinusoidal 40-Hz ASSR. As expected, the mean estimated TB-ABR and both ASSR thresholds are poorer than the mean pure tone thresholds; however, sinusoidal 40-Hz ASSR thresholds are more elevated across frequencies with wide variability. The mean correction factors for TB-ABR (ABR – behavioral) are 31, 26, & 21 dB at 500, 2000, & 4000 Hz, respectively. The mean correction factors for 40-Hz automated ASSR are 23, 17, & 28 dB, and 34, 32, & 33 dB for 40-Hz sinusoidal ASSR at 500, 2000, & 4000 Hz, respectively.

Results & Discussion

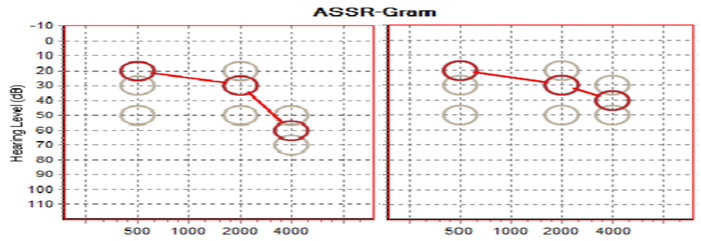

Figure 9: ASSR-grams for Automated ASSR from Participant #8 and #9

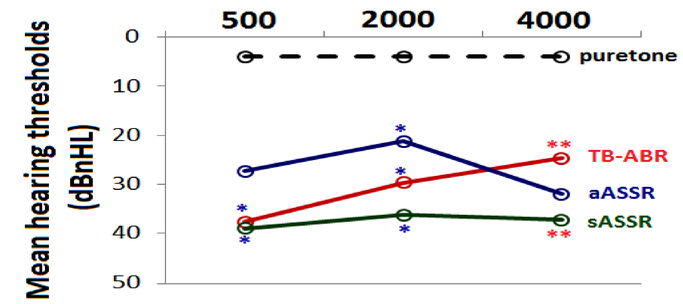

Figure 10: Three one-way ANOVAs were conducted to compare ABR, automated 40-Hz ASSR, and sinusoidal 40-Hz ASSR estimated hearing thresholds at 500, 2000 & 4000 Hz. As shown in Figure 10, ANOVA findings revealed significant difference between estimated thresholds due to lower automated ASSR thresholds than both TB-ABR and sinusoidal ASSR thresholds at 500 Hz ($p < .01$) and 2000 Hz ($p < .001$), and lower TB-ABR threshold than sinusoidal ASSR threshold at 4000 Hz ($p < .005$).

Conclusion & Limitations

The overall findings indicate that automated 40-Hz ASSR followed by TB-ABR are better measures for objective estimation of hearing thresholds than sinusoidal 40-Hz ASSR. Automated ASSR estimated low-frequency thresholds better than TB-ABR which is most accurate at higher frequencies. Correction factors, on average, were 21-31 dB (TB-ABR), 17-28 dB (automated ASSR), & 32-34 dB (sinusoidal ASSR). However, these findings are based on data from only 15 normal-hearing female participants. The use of Kalman filter seems more advantageous in noisy participants for ABR recordings, but ASSR recordings still require participants to be very quiet. Therefore, future sinusoidal 40-Hz ASSR studies should be conducted with more sweeps and while participants are in an alert, but quiet state.

References

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Acknowledgements

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