Tone-evoked brainstem responses and auditory steady state responses to 40hz and 80hz amplitude modulated stimuli with different frequencies – a comparative study

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Abstract Tone burst evoked auditory brainstem responses and auditory steady state responses with 40 or > 80 Hz modulation can be used to determine frequency specific threshold.

Aim The present study was taken up to check for the efficacy of estimating hearing thresholds by tone burst ABR and ASSR. The frequency effect (low, mid and high) on estimating the threshold was also focused upon.

Methods 20 normal hearing adults (40 ears) in the age range of 16 to 30 years participated in the study. The pure tone audiometry and immittance was initially done. Subsequently, tone-burst ABR, 80Hz ASSR and 40Hz ASSR to estimate the threshold with three frequencies 500Hz (low), 2000Hz (mid) and 4000Hz (high) was done. The data was analyzed statistically using pair sample t- test.

Results ASSR threshold for 80Hz and 40Hz was almost comparable. ASSR was superior to estimate the threshold than tone-burst ABR. For the low frequency the discrepancy between the behavioral threshold and frequency-specific evoked audiometry was more when compared to mid and high frequency.

Conclusion Present study showed that steady-state responses were efficient means of threshold detection than visual detection of ABR wave-V. In awake adult subjects, 40Hz and 80Hz amplitude modulated produced similar results. For the threshold estimation ASSR was better than tone-burst ABR.

Keywords ASSR · Tone burst ABR · Amplitude modulation

Introduction

Auditory brainstem response (ABR) measurements with click stimuli are generally considered to be the first option for assessing hearing in young children objectively [1]. Click evoked ABR evaluates the auditory function in the frequency range of 1000 to 4000Hz [2]. Another option for obtaining frequency-specific threshold is to measure the auditory steady-state responses (ASSRs) as has been shown by Herdman et al, [3]. First reports on ASSR could be observed in early eighties [4].

Attempts to find frequency-specific responses have shown that the ABR can also be evoked with short tones or tone bursts [5, 6, 7, 8, 9 & 10]. Several studies have shown that tone-burst ABR thresholds and behavioral thresholds are well correlated [7 & 9]; however, the morphology of the response to tone-burst ABRs was reported to be poor [10, 11, 1 & 12]. The recordings should be made of a larger number of responses for tone burst ABR than is the case with the standard click ABR as has been suggested by Stapells, [1]. This implies relatively long recording times.

The Auditory steady response is scalp recorded potentials that arises in response to amplitude and frequency modulated tone [13, 14]. The response is a complex periodic wave and is phase locked to the modulation envelope of the stimulus. ASSR can be elicited

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by a wide range of modulation frequencies, but rates around 70 to 100 Hz has been most effective for testing hearing sensitivity. The resulting potential has an equivalent latency of approximately 10 msec, suggesting brainstem generators [15], and like the transient ABR, is relatively unaffected by subject state (Sleep/sedation) [15, 16].

Galambos et al, [4] recorded responses to 250Hz tone-bursts at repetition rates of 10Hz and 40Hz. A clear amplitude maximum was found at a repetition rate of 40Hz and it was suggested that the 40Hz potential was mainly the result of super-positioning of middle-latency responses (MLRs). However, tonotopic organization of steady-state magnetic-field sources contradicts on overlapping MLRs but show N1m potential [17, 18, 19].

Despite initial attention paid to the 40Hz ASSR, it has hardly been used in clinical practice. One reason is that the response is adversely affected by natural sleep or drug-induced sleep [20]. Cohen et al, [15] demonstrated that although smaller & maximum between 80Hz and 100Hz in contrast to 40Hz responses, ASSRs with higher modulation frequencies (80-100Hz) can be recorded even in sedated subjects [21]. This may be an important reason why the former has not yet received wide application as a clinical tool. However, the response to 80-100Hz modulation frequencies is relatively smaller compared to the 40Hz response and a much lower signal to noise ratio (SNR) is obtained. Consequently, relatively larger recording times are needed to find a significant response (above the background noise level) at modulation frequencies of 80Hz and above.

Studies reporting ASSR thresholds across various degrees of hearing loss agree that closer correlation exists between ASSR and behavioral thresholds for more severe degrees of hearing impairment [21]. Rance and colleagues demonstrated that the ASSR predicted severe to profound thresholds to within 10 dB on 96% of occasions.

As tone ABR and ASSR are the two approaches that help us to estimate the thresholds, having their own merits & demerits, studies have compared the threshold estimation in both. Cone-Wesson et al, [12] reviewed a study in which ASSR and tone ABR were compared at 500 Hz and 4000Hz in normal adults. Results showed a good correlation between ASSR and tone-burst ABR threshold when objective technique (Fsp) was applied in the detection of tone-burst ABR. But tone-burst ABR was better than ASSR in the detection of thresholds when subjective methods were used to determine thresholds in tone-burst ABR. The ASSR thresholds were poorer by 8 to 27dB. There are different systems used to record the tone-burst ABR and ASSR. The recording times also differed significantly between the two methods, namely 240s for the tone-burst ABR and 95s for the ASSR. However, Aoyagi et al, [22] reported that ASSR is more accurate when compared to tone ABR, in determining thresholds in younger children. This conclusion was based on an investigation comparing

tone ABR and ASSR at 1000Hz in subjects with different configuration of hearing loss. Statistical analysis showed no significant difference between tone-ABR and ASSR threshold. However, hearing prediction using 80Hz ASSR was more accurate than auditory brainstem response elicited by tone.

Reijden et al, [23] had compared tone-evoked auditory brainstem responses and ASSR with 40Hz and 90Hz amplitude modulation, using the same equipment and recording parameters, to determine which of these three methods was most accurately correlated with the behavioral hearing thresholds in response to 500Hz and 2000Hz stimuli in eleven awake adults with normal hearing. Estimated thresholds obtained with the three methods were 10, 18, and 26dBSL at 500Hz and 10, 12, and 22 dBSL at 2000Hz, using 40Hz, 90Hz ASSR and tone-burst ABR, respectively. ASSRs with 40Hz amplitude modulated stimuli produced significantly better results, where as tone-burst ABR produced the poorest results. 40Hz ASSR showed superior results especially at 500Hz.

It is clear from the above discussion that there is equivocal finding in the estimation of hearing threshold between tone-burst ABR and ASSR. Moreover there is scarcity of details on low, mid and high frequencies effect on threshold estimation. The present study was taken up to check for the efficacy of estimating hearing thresholds by different methods such as ASSR and tone burst ABR. The frequency effect (low, mid and high) on estimating of the hearing threshold was also focused upon.

Method

Subjects

20 adults in the age range of 16 to 30 years participated in the study. All the subjects had normal hearing sensitivity (within 15 dB across 250Hz to 8 KHz). All the subjects had 'A' type tympanogram with acoustic reflexes present bilaterally.

Procedure

The following procedures were carried out in sequence in a sound treated room within the hospital premises.

- Initially behavioral hearing thresholds were determined for each participant using a two channel pure tone audiometer GSI 61.
- Middle ear function was evaluated using GSI TYMP STAR (version II) middle ear analyzer.
- GSI Audera was used for getting the ASSR. ASSR was carried out at three carrier frequencies i.e 500Hz (low), 2000Hz (mid) and 4000Hz (high). These carrier frequencies were modulated in terms

of amplitude and frequency. Amplitude modulation (depth 100%) and frequency modulation (10%) of the carrier frequencies was used to maximize the response. The test signal was modulated at rates of 40 Hz & 80 Hz. Subsequently tone burst ABR was performed. Trails were initiated at the level of 60dB, and if the samples met the phase-locked criterion (p,01), then the stimulus level was decreased by 10dB. Whenever the samples did not meet the criterion for phase-coherence (response present), the stimulus was increased by 5dB until a phase-locked response was obtained. The threshold was determined as the lowest stimulus level that met the phase-locked response criterion.

- To evoke tone burst ABR, 500Hz, 2000Hz and 4000Hz tone burst were applied linearly gated with one cycle plateau and two cycles rise and fall times. The tone bursts were presented at a repetition rate of 11.1Hz with rarefaction polarity and total number of sweeps presented was 1500. The time window was taken as 20 milliseconds. Trails were initiated at the level of 60dB, and if the response were present, then the stimulus level was decreased 10dB. Visual response detection was done with three expert audiologists. Whenever the response was not present, the stimulus was increased by 5dB until response was detected. The threshold was judged to be the lowest stimulus level at which an ABR (wave V) was visually detected in the waveform.
- Differential recordings for both the ASSR and tone burst ABR were made with electrodes placed on the high forehead (FZ) or vertex (CZ) and the ipsilateral mastoid. A third electrode was placed on either the low forehead or the contralateral mastoid to serve as ground.

- The data obtained was analyzed statistically using paired sample t- test.

Results

The data comprised of recordings from 20 normal-hearing volunteers (40 ears) about the behavioral threshold, threshold of tone burst ABR and ASSR with 80Hz and 40Hz amplitude modulated stimuli for different frequencies.

Table 1 shows the main outcome of the study for various measurement methods across three test frequencies. Mean threshold of 4 KHz was better in estimating the hearing threshold objectively when compared to 500Hz and 2 KHz for all the test methods. 500Hz frequency was poorest in estimating the hearing threshold. As can be seen in table 1, the mean threshold of 40Hz and 80Hz ASSR was better in comparison with tone-burst ABR threshold for all the frequencies.

The mean threshold for the 40Hz and 80Hz ASSR were found approximately same for all the tested frequencies between i.e. 500Hz, 2000Hz and 4000Hz. The difference observed between 80Hz ASSR threshold and tone-burst ABR threshold was 15, 13, and 14 dB across 500Hz, 2000Hz and 4000Hz respectively. 40Hz ASSR was superior to 80Hz ASSR in threshold estimation. The difference was more for low frequency than for high & mid frequency.

The “t” value of paired sample t-test shows that there was significant difference in the hearing threshold between the tone-burst ABR and ASSRs in low, mid and high frequencies tested. And it also shows that there was significant difference between the 80Hz and 40Hz auditory steady state responses at 500Hz and 2000Hz.

Table 1 Showing the mean threshold and standard deviation of tone-burst ABR, ASSR (80Hz) and ASSR (40Hz) for three test frequencies

Test	Frequency(Hz)	Mean (Threshold)	Standard deviation
Tone-burst ABR	500	42.37	3.57
	2000	36.87	4.89
	4000	34.12	3.90
ASSR(80Hz)	500	27.75	5.76
	2000	23.62	3.75
	4000	20.75	4.74
ASSR(40Hz)	500	25.37	3.64
	2000	21.87	4.76
	4000	20.25	4.37
Behavioral threshold	500	7.87	4.51
	2000	6.50	4.69
	4000	6.87	4.48

Table 2 depicting the t-values and significant levels

Pair	Frequency(Hz)	“t” value	Sig.(2-tailed)
TBABR – ASSR(80)	500	16.74	.000*
TBABR – ASSR(40)		18.69	.000*
ASSR(80) – ASSR(40)		4.51	.031*
TBABR- ASSR(80)	2000	15.15	.000*
TBABR – ASSR(40)		16.95	.000*
ASSR(80) – ASSR(40)		3.30	.029*
TBABR- ASSR(80)	4000	16.96	.000*
TBABR – ASSR(40)		16.71	.000*
ASSR(80) – ASSR(40)		.550	.586

Discussion

In the present study, comparison of the hearing threshold estimation for different test methods with tone-burst ABR and ASSR (80Hz and 40Hz) in response to 500, 2000 and 4000Hz stimuli was evaluated. The 80Hz and 40Hz ASSR threshold produced the best results and threshold was approximately same for the 80Hz ASSR and 40Hz ASSR thresholds. But the tone-burst ABR threshold was poorer in threshold estimation when compared to ASSR threshold with 80Hz and 40Hz.

The thresholds obtained in the present study were comparable for the 40Hz & 80Hz but were different from the tone burst ABR as detailed in table 1. Reijen et al, [23] had reported that the thresholds obtained were 10, 18, and 26dBSL at 500Hz; and 10, 12 and 22dBSL at 2000Hz; using 40Hz ASSR, 90Hz ASSR, and tone-burst ABR, respectively. In the present study threshold obtained with three methods were 17, 19 and 34dBSL at 500Hz; 15, 17 and 30dBSL at 2 kHz and 13, 13, 27dBSL at 4 kHz; using 40Hz ASSR, 80Hz ASSR and tone-burst ABR respectively. In the present study, 80Hz and 40Hz ASSR threshold was almost same, but in contrast, Raijen et al.[23] reported 40 Hz ASSR threshold was superior to estimate than 80 Hz ASSR. The alert state of the subject may have had a major influence on the better results with the 40Hz ASSR and on the poorer results with the 90Hz ASSR. The influence of the arousal state of the subjects has already been demonstrated by Cohen et al. [15]. It is likely that the ABR would also have been better if the subjects in the present study had been asleep. Moreover 40Hz ASSR is having better SNR than 80Hz ASSR. It is important to note here that the instrument used to record the ASSR in Raijen’s study was MASTER system in which the SNR can be recorded but in present study the AUDERA system was used with no facility to record SNR. In the all subjects, the 40Hz ASSRs with the 500Hz and the 2000Hz carrier frequencies, the average lowest response levels were found at 10dB SL with a standard deviation of 0. This suggests that the average 40Hz lowest response level may have been even lower if

presentation levels lower than 10dBSL was used as reported by Raijen et al.[23].

Direct comparisons were made between tone-burst ABRs and ASSRs (40 and 95Hz AM) in a study conducted by Cone-Wesson et al, [12] using 500Hz and 4000Hz stimuli with subjects who were asleep. They reported a mean ABR threshold 11dBSL for 500Hz tone-bursts. But in present study, the ABR threshold to 500Hz tone-bursts was approximately present at 25 to 35dBSL. The discrepancy between present and Cone’s study can be attributed to different measurement systems used and state of arousal of the subject. In the present study the subjects were awake through out the testing but in Cone’s study, subjects were sleeping. The analysis procedure used for wave-V latencies may also be contributing towards the difference in results.

The results of the present study showed that steady-state responses were more efficient means of threshold detection than visual detection of ABR wave-V. In awake adult subjects, 40Hz and 80Hz amplitude modulated stimuli produced similar results. It was also observed that for the threshold estimation, ASSR is better than tone-burst ABR. Mid and high frequencies were having better in estimating hearing threshold than low frequency stimuli. The results of the present study have valuable impact on clinical decisions on threshold estimation.

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