Response Criterion for Determining Ipsilateral and Contralateral Acoustic Reflex Thresholds Using a 1000-Hz Probe Tone

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INTRODUCTION

Acoustic Reflex (AR): The middle-ear cavity in between the eardrum and the inner ear houses two muscles and three small bones. When a loud sound enters the ear, contraction of the stapedius muscle occurs, which reduces the acoustic admittance of the middle ear by stiffening the boney chain, helping shield the inner ear from damage. This is known as the acoustic reflex (AR). Clinical AR measurements have been applied to help diagnose dysfunctions in the auditory system.

Acoustic Reflex Threshold (ART): During AR testing, a pure tone is presented in the ear canal as the probe signal and another loud sound, to activate the reflex, is presented in the same ear (ipsilateral test) or the other ear (contralateral test). The lowest level of the activator that causes a criterion change in admittance is known as AR threshold (ART).

Motivations: ART testing in adults is conventionally conducted with a 226-Hz probe tone. However, the 226-Hz ART is not pervasive and should not be included in certain applications as a criterion (McGregor et al. 2018). The resonant frequency of the middle ear is approximately 1000 Hz in adults (Fowler & Shanks, 2002), at which the acoustic admittance of the middle ear is much higher. Unfortunately, data for ARTs with a 1000-Hz probe tone is scarce (Rawool, 1998; Ferekidou et al., 2008). The response criterion is critical for determining ARTs. The previous studies just adopted the criteria from the user manual of an instrument, for example, 0.02 mmho change in admittance for 226 Hz and 0.09 mmho for 1000 Hz probe tone (Grason-Stadler, 2011), which was arbitrarily selected on the basis of the quotient of 1000 versus 226. Nevertheless, a few studies recommended a response ≥ 0.03 mmho for testing the 226-Hz ART as a screening parameter (Sells et al., 1997) or as diagnostic tool (Pitek & Sun, 2017). More research on 1000-Hz ARTs in adults is warranted.

Objective: This study aimed to identify the optimal response criterion for determining ARTs using a 1000-Hz probe tone.

METHODS

Participants:

46 participants were recruited. Data were collected from 28 qualified participants (18–35 years, mean age 24.6 years, ±3.7, 24 females and 4 males) who met inclusion criteria for normal hearing and normal middle ear function. For each subject the test ear was randomly selected. This study was approved by the University Institutional Review Board.

Instrumentation:

GSI Tympstar Tympanometer (Version 2); For AR testing, GSI probe assembly and contralateral inset earphone were used, with 1000-Hz selected as probe tone.

Procedure:

Testing was performed inside a double walled, sound treated booth. Ipsilateral AR tests were run with five activators: four tones (0.5, 1, 2, and 4 kHz) and broadband noise (BBN). The ipsilateral test with BBN was repeated once immediately after the first test to assess test-retest reliability. Contralateral tests were conducted with 4-kHz tone and BBN. Testing order was randomized. The activator was presented at 60 dB HL, then increased in 5-dB steps up to 105 dB HL, or the upper limit (100 dB HL for 4000 Hz, 95 dB for BBN) of the instrument. Three ARTs were determined per test as the lowest activator level that caused a repeatable criterion change of 0.03, 0.09, and 0.13 mmho, respectively ($ART_{0.03}$, $ART_{0.09}$, and $ART_{0.13}$). The relationship between 0.09 and 0.13 mmho is mathematically equivalent to that between 0.02 and 0.03 mmho.

RESULTS

I. Ipsilateral and Contralateral ARTs

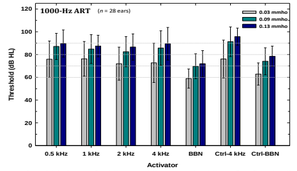

Figure 1. Mean (± 1SD) data of $ART_{0.03}$, $ART_{0.09}$, and $ART_{0.13}$ for five ipsilateral activators and two contralateral activators, respectively.

II. Comparison in ART Between Response Criterion

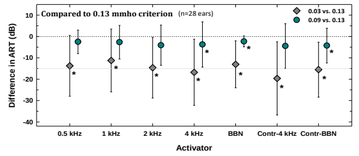

Figure 2. Mean difference (± 1SD) of $ART_{0.03}$ and $ART_{0.09}$ vs $ART_{0.13}$, respectively, for all test sets. * indicates statistically significant difference (p<0.05 one-way Friedman repeated measures ANOVA on ranks).

III. Correlation Between Response Criterions in ART

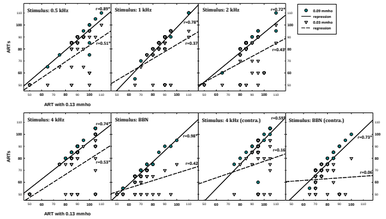

Figure 3. Correlational analysis between $ART_{0.03}$ and $ART_{0.13}$ and between $ART_{0.09}$ and $ART_{0.13}$, respectively. * indicates statistically significant correlation coefficient (p<0.01, Pearson product-moment correlation).

RESULTS

IV. Detectability of ARTs

Table 1. Detectability in percentage of ARTs determined with three response criterions for all tests.

	Ipsi-ART					Contra-ART	
Activator	**0.5k**	**1k**	**2k**	**4k**	**BBN**	**4k**	**BBN**
0.03 mmho	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
0.09 mmho	*96.4%*	*92.9%*	*96.4%*	*85.7%*	*100%*	*78.6%*	*96.4%*
0.13 mmho	*96.4%*	*92.9%*	*92.9%*	*71.4%*	*96.4%*	*75.0%*	*96.4%*

V. Test-Retest Comparison of Ipsilateral ART

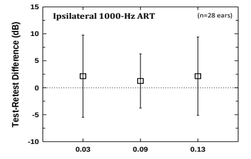

Figure 4. Mean (± 1SD) difference of test-retest ARTs using BBN for three response criterions. No statistical significance was found (p>0.05, Wilcoxon signed rank t-test).

VI. Comparison of Ipsilateral and Contralateral ARTs

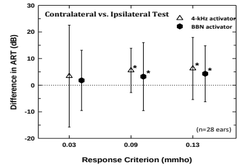

Figure 5. Mean (± 1SD) difference between ipsilateral and contralateral ARTs for two activators and three response criterions. * indicates statistically significant difference (p<0.05 one-way Friedman repeated measures ANOVA on ranks).

DISCUSSION AND CONCLUSIONS

1. The ipsilateral $ART_{0.13}$ is approximately 85 to 90 dB HL on average for tonal activators and 75 dB HL for BBN (Fig. 1).

2. The $ART_{0.09}$ is slightly lower (< 5 dB) than $ART_{0.13}$ for all activators (Fig. 1 and 2). Their standard deviations are similar for most testing conditions and the standard deviation of the difference is relatively small. The $ART_{0.03}$ is substantially lower (~10 to 20 dB) than $ART_{0.13}$, but the standard deviation is much larger, as is the standard deviation of the difference.

3. $ART_{0.09}$ strongly correlates with $ART_{0.13}$ in all conditions (r=0.59–0.98), but the correlation between $ART_{0.03}$ and $ART_{0.13}$ is much weaker (r=0.06–0.53) (Fig. 3)

4. Detectability of $ART_{0.03}$ was 100% across all conditions (Table 1), it was between 78.6–100% for $ART_{0.09}$ and 71.4–96.4% for $ART_{0.13}$.

5. Test-retest variability of ARTs was not statistically significant (Fig. 4).

6. The contralateral $ART_{0.13}$ was significantly higher (~5 dB) than the ipsilateral ART for both 0.09 and 0.13 mmho criterions (Fig. 5).

Conclusions

- The ART using 1000-Hz probe tones can be a reliable test in adults.
- We recommend using the 0.09 mmho response criterion in conducting 1000-Hz ART tests.
- Our results imply the necessity of further investigations on response criterions lower than 0.09 mmho.

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