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Review Article

Measurement Variables Affecting the Evaluation of Acoustic Reflex in Humans

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ABSTRACT

Acoustic reflex threshold, reflex decay, reflex growth function and reflex latencies are the various measures of acoustic reflex. All these measures have proved to be useful measures in the assessment of peripheral and central (lower brainstem) auditory system and also the functioning of middle ear muscles in humans. These auditory physiological measures are influenced by subject and procedural variables. This review article aimed to highlight all the procedural variables that may affect the measures of acoustic reflexes. Methods used in various studies for the measurements of acoustic reflexes were studied and compared. This article will help researcher and clinical in designing/selecting a strong theoretical based framework and procedural guidelines to improve measurement of acoustic reflexes in their respective settings.

Keywords: Acoustic reflex threshold, Acoustic reflex growth function, Acoustic reflex latency, Acoustic reflex decay

INTRODUCTION

The acoustic reflex (AR) also known as middle ear muscle reflex, auditory reflex, stapedius reflex, attenuation reflex, is one of the primary feedback mechanisms of the auditory system. [1] The AR results largely from the contraction of middle ear involuntary muscles which are stapedius and tensor tympani muscles, following acoustic stimulation of the ears. In most animals both the stapedius and tensor tympani muscles contribute to the AR in response to auditory stimuli. [2] In humans, it is predominantly the stapedius muscle while the contraction of the tensor tympani muscle occurs primarily during the startle response to intense sounds or to non-auditory stimuli. [1, 3] The reflex pathway is a polysynaptic network of relay stations comprising both ipsilateral and contralateral path ways.

Acoustic reflex threshold, reflex decay, reflex growth function and reflex latencies are the different measurable characteristics of acoustic reflexes. All these measures have been extensively used in the assessment of auditory disorders affecting the periphery or brainstem. It has been observed that clinician use different procedure in terms of stimulus type, stimulus frequency, stimulus intensity, temporal aspects of stimulus, probe tone type and step size for the measurements of acoustic reflexes. As a result clinicians end up reporting different results even for the same degree and type of auditory disorder. Therefore the authors observed the necessity to investigate and highlight the effect of the different procedural variable on acoustic reflex threshold, reflex decay, reflex growth function and reflex latencies.

1. Acoustic reflex threshold (ART)

Acoustic reflex threshold is the minimum stimulus intensity level at which the AR activates. The activation of acoustic reflex is estimated as the change in acoustic compliance by a certain criterion value. While using a 226 Hz probe tone, a decrease of 0.02 mmho or 0.03 mmho in acoustic compliance is usually considered as the result of reflex activation. [4, 5] The effects of several subjective and methodological factors on ART are described below:

1.1 Measurement procedures: ARTs can be estimated using ascending, descending or bracketing procedures. [6] No significant difference has been reported between ARTs measured using different procedures. [6-8] Step size of 1-, 2- or 5- deciBel (dB) can be used to measure ART. It is suggested that the use of smaller step size result in precise measure of ART. [6] However, clinically the most adapted step size to estimate ART is 5 dB. The reason for this could be the fact that ART estimation is done at high intensity levels and the threshold search using 1- or 2- dB step might be uncomfortable and consume more time.

1.2 Probe tone effect: Various probe tones have been used in the investigation of ARTs (226, 660, 800 and 1000 Hz). It has been suggested that low frequency probe (226 Hz) is ideal for measuring ARTs in older children and adults. In contrast, the use of higher probe tones (660, 800 and 1000 Hz) is more effective in estimating ARTs in infants and newborns. This is due to a mass dominated middle ear system in infants and newborns in comparison to stiffness dominated middle ear system in older children and adults. [9, 10] The effect of probe tone on ART is however uncertain. Peterson and Liden found lowest ART at 220 Hz probe tone followed by 800 Hz and the ART were greatest for 660 Hz. They used pure-tones (250, 500, 1000, 2000 and 4000 Hz), narrowband noise (centered at 500, 1000, 2000 and 4000 Hz) and white noise as reflex activators. [11] Rawool used broad band clicks to elicit ART using 226, 678 and 1000 Hz probe tones. [12] She reported higher ARTs for 668 Hz probe tone in comparison to 226 and 1000 Hz probe tone. Similar results were reported by Parra et al. [4] On the contrary, Beattie et al. and Wilson et al. have reported better thresholds for 660 Hz in comparison to 226 Hz probe tone. In both of these studies pure-tones and broadband noise were used as stimuli to activate reflex. [13, 14] These discrepancies between the studies are suggested to be due to the use of different criterion for mark the presence of reflex. [4, 12]

1.3 Stimulus type and frequency: Gelfand summarized crossed ARTs from various clinical studies. [6] ARTs measured with broad band noise were always lower than for pure-tone stimuli. Difference between the ARTs of broad band noise and pure-tones varied from 6 to 33 dB SPL across studies. There are several hypotheses on the differences in threshold between broad band stimuli and pure-tones. Jerger et al. suggested that it could be because of the greater loudness summation for broad band noise in comparison to pure-tones. [15] Alternatively, it could be because of the wider bandwidth or power spectrum of the broadband noise than pure-tones and is rather independent of the loudness summation of reflex activator stimuli. [16] Popelka et al. and Flottorp et al. found that increasing the bandwidth of noise centered at different frequency causes a decrease in ARTs. These results confirmed the effect of stimulus bandwidth on ARTs. [17, 18]

There is uncertainty about the effect of stimulus frequency (of pure-tones) on ARTs. Most studies have reported ARTs for crossed stimulations. [19-24] Data from these studies suggested that 1000 Hz pure-tone results in lowest thresholds and 250 Hz pure-tone results in highest threshold followed by 4000 Hz. Between 500 and 2000 Hz, some studies showed lower thresholds at 500 Hz and others at 2000 Hz. However, the effect of frequency was significant in some studies while not in others. The effect of stimulus frequency on un-crossed reflex thresholds is rarely reported. Reflex data in Wiley et al. suggested ARTs in the un-crossed condition were increased as the stimulus frequency increased from 500 to 4000 Hz. [25]

2. Acoustic reflex decay (ARD)

This characteristic of acoustic reflex is known as acoustic reflex decay (ARD). Several factors have found to affect reflex decay measures. Reflex decay can be estimated through different methods. [26, 27] One method involves estimating the time for certain drop in reflex amplitude, for example 50% of its maximum amplitude. It can also be measured in terms of the amount of decrease in reflex amplitude after a given time. Clinically a decrease of reflex amplitude by 50% within 10 sec of the stimulus presentation is used an indication of retro cochlear pathology. Subjective and methodological factors that can affect ARD are discussed below:

2.1 Stimulus type, frequency, level and temporal characteristics: Pure-tones and broad band noise are commonly used stimuli to measure acoustic reflex decay. [14, 26, 28, 29,30] Considerably early onset and greater rate of reflex decay is found at higher frequencies (2000, 3000 and 4000 Hz) in comparison to lower frequencies (500 and 1000 Hz). Reflex decay for broadband noise is found to be similar to low frequency pure-tones. Only little or no reflex decay occurs at low frequency and broadband noise in individuals with normal brainstem functioning.

There are discrepancies over the effect of stimulus intensity level on ARD. Wilson et al. reported that increase in intensity level of stimulus causes an increase in the onset of reflex decay for low frequencies pure-tones and noise while at high frequency pure-tones onset remain unchanged. [14] In contrast, stimulus intensity did not affect the rate of reflex decay. Similar decrease in onset time of reflex decay at high intensity levels of noise was noticed by Dallos. [31] But contrary to the findings of Wilson et al., Dallos found a reduced rate of reflex decay with the increase in stimulus intensity. [14] A reverse effect of stimulus intensity on reflex decay for 500 Hz pure- tone was reported by Wiley and Karlovich, they found an early onset and greater rate of reflex decay with the increase in stimulus intensity. [32] Kaplan et al., on the other hand, found no effect of stimulus intensity either on the onset or the rate of reflex decay. [28]

It is also suggested that continuous stimulus results in rapid reflex decay when compared to pulsed stimulus. [33] Similar reduction in reflex decay was found when amplitude modulated stimulus was used to measure ARD. [34] These findings highlight the dependence of ARD on temporal characteristics of the stimulus.

3. Acoustic reflex growth function (ARGF)

Acoustic reflex growth functions are estimated by measuring the increase in acoustic reflex amplitude with the increase in stimulus intensity level. There are several measurement factors that affect the ARGF. They are discussed below

3.1 Probe tone frequency: Shallower ARGF were suggested when high frequency probe tone was used for reflex measurements in comparison to low frequency probe tone. [35] In normal hearing adults the middle ear system is stiffness dominated. Acoustic stiffness is the main determiner of acoustic compliance at low probe tone frequency, but as the probe tone frequency increases and approaches resonant frequency of the middle ear, the acoustic compliance becomes less influenced by the acoustic stiffness. This results in the measurable decrease of the acoustic compliance, thereby decreasing the growth rate of the ARGF.

3.2 Stimulus frequency: Sprauge et al. reported similar ARGFs for pure-tones of frequency range from 500 to 2000Hz but comparatively shallower ARGFs were found at 4000 Hz pure-tone. [35] Similar effect of stimulus frequency was also suggested by Wilson and McBride. [14]

4. Acoustic reflex latencies (ARL)

ARL describe the temporal characteristics of an acoustic reflex which illustrate the time course of the reflex. Factors that affect ARL are described below

4.1 Stimulus frequency: There are conflicting results about the effect of stimulus frequency on ARL. Hung and Dallos reported shorter onset latencies at 1000 Hz when compared to the frequencies below 300 Hz. [36] Clemis and Sarno found smaller onset latency for 1000 Hz as compared to 2000 Hz. [37] Borg reported shorter onset latencies but longer offset latencies at 500 Hz in comparison to 2000 Hz. [38,39] Gorga and Stelmachowicz showed similar onset latencies at 500 and 1000 Hz but latencies got prolonged as the stimulus frequency was increased from 2000 Hz to 4000 Hz. Offset latencies, on the other hand, were similar at 500, 1000, 2000 and 4000 Hz. [40] Qiu and Stucker found shorter ARL (10% On Latency, 90% On Latency, 10% Off Latency, 90% Off Latency, rise time and fall time) at 500 and 1000 Hz in contrast to 2000 and 4000 Hz. [41]

4.2 Stimulus intensity: There is a general agreement that ARL decreases as the stimulus intensity increases. [42]

4.3 Rise time of the stimulus: One important factor that affects ARL is the rise time of stimulus. Mcpherson and Thompson found that ARL increases as the stimulus rise time increases. [43]

CONCLUSION

This study concluded that the activation of acoustic reflex depends on the measurement systems and is influenced by variations in stimulus parameters such as bandwidth, frequency, intensity level, duration, rise and fall time of the signal. We advocate that these procedural and stimulus factors need to be monitored and control more carefully while testing for acoustic reflex so that their impacts are only minimal.

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