Acoustic Reflex Latency (ARL) Assessment in Malaysian Adults: The Effects of Age, Gender and Stimulus Frequency

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ABSTRACT

In the field of auditory neuroscience, acoustic reflex is a useful clinical test for hearing diagnosis and site of lesion assessment. Nevertheless, the latency measurement of acoustic reflex has not been widely studied and more research efforts are warranted. The present study aimed to determine the influences age, gender and stimulus frequency on acoustic reflex latency (ARL) among healthy adults. Seventy-two Malaysian adults (35 males and 37 females) participated in this prospective comparative study. They were categorized into three age groups: young adults (n = 30, mean age of 26.6 ± 4.3 years), middle-aged adults (n = 21, mean age of 45.8 ± 5.7 years) and older adults (n = 21, mean age of 58.2 ± 1.2 years). They underwent the standard ipsilateral acoustic reflex testing and ARL results were analyzed at 500, 1000, 2000 and 4000 Hz. The mean ARL values obtained are in line with the previous reports. While no significant influences of gender and stimulus frequency were found on ARL results, the mean ARL values were statistically higher in the older adults than in the other age groups. To conclude, a notable effect of age was found on the latency of acoustic reflex. In contrast, the ARL results do not appear to be influenced by either gender or stimulus frequency. The age-specific normative data for ARL gathered from the present study (n = 144) are useful for clinical and future research applications, particularly among Malaysian population.

Key Words: Acoustic reflex, Age, Gender, Onset latency, Stimulus frequency

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Introduction

Hearing is undoubtedly an important sense for humans in pursuing the daily life activities. If the hearing system is affected, hearing loss would occur. If the abnormality occurs on the outer ear (e.g. blockage of the ear canal by earwax) or on the middle ear (e.g. the presence of effusion in the middle ear), the affected individuals are said to have conductive hearing loss. If the inner ear (i.e. cochlea), eighth cranial nerve or organs within the central auditory nervous system (CANS) are compromised, sensorineural hearing loss would occur. As reported elsewhere, depending on the severity and type of hearing loss, hearing loss has adverse effects on the affected individuals in which proper treatments must be given in a timely manner (Katz *et al.*, 2015; McKee *et al.*, 2018). Peripheral and central hearing impairments are in fact common among adults and elderly (Cooper and Gates, 1991; Gong *et al.*, 2018; Turton and Smith, 2013; Quaranta *et al.*, 2014).

Clinically, for achieving an accurate hearing diagnosis, a test battery approach is used. Otoscopy, immitance audiometry and pure tone audiometry (PTA) are routine clinical tests used for hearing

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diagnosis and site of lesion assessment (Katz *et al.*, 2015). The immitance audiometry consists of two specialized objective tests: tympanometry and acoustic reflex. Tympanometry provides an objective documentation on the status of the middle ear (by measuring the mobility of the ear drum). Acoustic reflex testing, on the other hand, is useful to determine the function of auditory pathway up to the brainstem region (Katz *et al.*, 2015; Margolis and Levine, 1991).

Fundamentally, acoustic reflex is a mechanism to protect the inner ear when the ear is exposed to loud sounds. Upon the presentation of loud sounds, the stapedius muscles (in both ears) will contract causing the middle ear system to become stiff. Consequently, more sounds will be reflected rather than transmitted, to protect the vulnerable cochlea in the inner ear. By having a specialized device, this action can be conveniently recorded and documented. Fig. 1 shows an example of a typical acoustic reflex waveform recorded from a normal participant. This protective mechanism is typically absent in the conditions where the acoustic reflex pathway is affected such as conductive hearing loss, severe degree of sensorineural loss and impaired auditory brainstem (Katz *et al.*, 2015; Margolis and Levine, 1991).

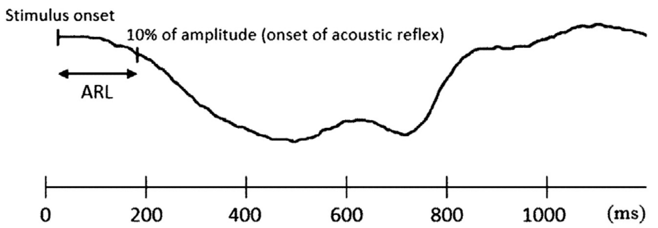

Figure 1. An example of typical acoustic reflex waveform and the onset acoustic reflex latency (ARL) calculation from a representative subject.

Acoustic reflex threshold (ART) is the most common acoustic reflex parameter used for clinical and research purposes (Katz *et al.*, 2015; Margolis and Levine, 1991). The ART is simply defined as the lowest intensity level at which an acoustic reflex is elicited at a specific frequency. Normal ART is between 70 and 100 dB, while elevated ART (> 100 dB) or absent reflex has been reported in patients with various auditory disorders (Katz *et al.*, 2015; Margolis and Levine, 1991). The acoustic reflex latency (ARL), nevertheless, has not been widely studied. The ARL reflects the latency difference between the onset of auditory stimuli and the onset of stapedius muscle contraction. Limited studies on ARL have shown that this latency measurement has good potential when testing subjects with peripheral and central auditory disorders (Clemis and Sarno, 1980; Jerger and Hayes, 1983). In this regard, more research efforts are warranted to shed light on the essential aspects of ARL. As such, the present study was conducted to determine the effects of age, gender and stimulus frequency on ARL. Furthermore, this study also aimed to establish preliminary ARL normative data for Malaysian population.

Methods

Participants

Seventy-two eligible Malay adults participated in this prospective comparative study. They were selected randomly among students and staff members of University Hospital. They were then assigned into specific age groups: young (18-35 years), middle-aged (36-55 years) and older (≥ 56 years). All of them were healthy and reported no problems related to ear and hearing. Routine audiological tests including otoscopy, tympanometry and pure tone audiometry (PTA) were conducted to confirm their hearing status. As revealed, their audiological findings were all normal: clear ear canal and intact tympanic membrane in otoscopy, type A tympanogram (suggestive of normal middle ear function) and normal PTA thresholds (≤ 20 dB HL at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz) in both ears. Prior to the data collection, the consent form was obtained from each participant. All the study procedures were approved by the institutional ethics committee (USM/JEPeM/16100357), which is in accordance with the 1975 Declaration of Helsinki and its later amendments.

Acoustic reflex latency measurement

The GSI Tympstar Pro clinical middle ear analyser device (by Grason Stadler, USA) was used to record the acoustic reflex. It was calibrated in accordance with EN 60645-5/ANSI S3.39 (1987). During the testing, the participants were seated comfortably on a provided chair. They were instructed to relax and remain still as possible. By employing the standard clinical procedure and using the default settings, acoustic reflex threshold (ART) was measured ipsilaterally at 500, 1000, 2000 and 4000 Hz frequencies. The ART was taken as the lowest level (in dB) at which a repeatable waveform could be seen (with an amplitude value of at least 0.03 mmho). To measure the acoustic reflex latency (ARL), the acoustic reflex testing was performed again but the pure tone stimuli were presented at 10 dB above ART. As illustrated in Fig. 1, the ARL was measured by calculating the latency difference between the onset of stimulus and the latency at 10% of maximum AR amplitude. For each trial, two recordings were made and averaged to produce reliable responses. All recordings were performed in a dedicated sound proof room within the Audiology Clinic, University Hospital.

Data analyses

The numerical ARL values (in milliseconds) were computed for each participant. Mean, standard deviation (SD) and 90% range (5% to 95% percentile) were expressed as required. Since the data were found to be normally distributed ($p > 0.05$ by Kolmogorov-Smirnov test), parametric statistical analyses could then be performed. Paired t-test was conducted to compare ARL results between left and right ears. A three-way mixed ANOVA (with age and gender as the between-subject factors and stimulus frequency as the within-subject factor) was employed to determine the effects of age, gender and stimulus frequency on ARL results. The main and interaction effects were reported as applicable. For post-hoc analysis, Bonferroni method was used. The statistical significance level was set at $p < 0.05$. All data were analysed using the SPSS software version 22 (SPSS Inc, Chicago, IL).

Results

Of 72 participants, 41.6% fell into the young group (n = 30, mean age of 26.6 ± 4.3 years, 15 males and 15 females), 29.2 % were the middle-aged adults (n = 21, mean age of 45.8 ± 5.7 years, 7 males and 14 females) and 29.2% were the older adults (n =21, mean age of 58.2 ± 1.2 years, 13 males and 8 females). Overall, the gender distribution was nearly equivalent (35 males and 37 females).

When the ARL results were compared between left and right ears, the statistical results were not significant ($p > 0.05$). The left and right data were then pooled (n = 144) to be used in the subsequent analysis. Mean, SD and 90% range of the ARL data as a function of age, gender and stimulus frequency are shown in Table 1. As revealed, the mean ARL values were descriptively higher in the older group than in other age groups at all stimulus frequencies. This observation was then confirmed by the three-way mixed ANOVA result, i.e., a significant influence of age was found on ARL results [$F(2,138) = 8.556$, $p < 0.001$]. As shown by the post-hoc analysis, the older adults produced ARL results that were statistically longer than that of the young adults at 500, 1000 and 4000 Hz frequencies ($p < 0.05$). At these stimulus frequencies, no significant differences in ARL values were noted between the older and the middle-aged groups ($p > 0.05$), as well as between the middle-aged and the young adults ($p > 0.05$). Whereas at 2000 Hz frequency, the mean ARL results were significantly longer in the older adults relative to both the middle-aged ($p = 0.001$) and the young groups ($p < 0.001$). In line with other frequencies, the ARL results did not differ significantly between the middle-aged and the young adults at 2000 Hz ($p = 0.999$).

On the other hand, the ARL results were not statistically influenced by either gender or stimulus frequency. That is, no significant differences in ARL results were found between males and females [$F(1,138) = 1.406$, $p = 0.238$], as well as between the stimulus frequencies [$F(3,136) = 0.054$, $p = 0.983$]. It is worth noting that no interaction effect

Table 1. Mean, standard deviation (SD) and 90% range (5th to 95th percentile) of acoustic reflex latency (in milliseconds) as a function of age, gender and stimulus frequency.

Age Group	Gender		Stimulus frequency			
			500 Hz	1000 Hz	2000 Hz	4000 Hz
Young (n=60)	Male (n=30)	Mean (SD)	92.1 (39.7)	101.7 (40.8)	90.3 (32.2)	99.9 (30.1)
		90% Range	36.0-144.0	45.0-153.0	45.0-140.0	62.1-149.0
	Female (n=30)	Mean (SD)	99.9 (36.5)	105.6 (40.6)	105.9 (35.0)	97.5 (35.5)
		90% Range	49.1-149.0	53.1-158.0	54.0-153.0	54.0-149.0
Middle-Aged (n=42)	Male (n=14)	Mean (SD)	113.1 (41.6)	99.6 (36.4)	97.1 (39.2)	115.7 (30.7)
		90% Range	47.7-153.0	44.6-144.0	44.6-147.2	65.7-153.0
	Female (n=28)	Mean (SD)	100.6 (37.3)	100.6 (37.4)	97.4 (32.0)	99.0 (37.5)
		90% Range	54.0-153.0	54.0-153.0	54.0-153.0	57.2-158.9
Older (n=42)	Male (n=26)	Mean (SD)	111.8 (39.7)	119.8 (26.9)	130.5 (31.9)	135.0 (37.3)
		90% Range	36.0-159.8	69.8-153.0	74.3-175.5	74.3-171.0
	Female (n=16)	Mean (SD)	120.9 (31.5)	113.1 (28.6)	111.4 (29.4)	93.9 (30.6)
		90% Range	67.5-155.3	76.5-155.3	54.0-146.3	54.0-128.3

was found between the three variables (p = 0.228) indicating that the main effect analyses were indeed appropriate.

Discussion

In the field of auditory neuroscience, the clinical usefulness of acoustic reflex has been well documented (Katz *et al*., 2015; Margolis and Levine, 1991). Nevertheless, as mentioned earlier, the latency features of acoustic reflex have not been extensively studied and require further investigations. In the present study, the acoustic reflex latencies were recorded and calculated according to the recommended protocol (Clemis and Sarno, 1980; Colletti, 1974; Narayanan, 2017; Prabhu *et al*., 2015). As an effort to obtain reliable acoustic reflex waveforms, the recordings were made at 10 dB above ART. As reported elsewhere, this suprathreshold stimulation level would produce the most optimal contraction of stapedius muscle and waveforms with good morphology (Colletti, 1974; Narayanan, 2017). In particular, we recorded the onset latency of acoustic reflex, i.e., the latency difference between the onset of stimulus and the onset of acoustic reflex (10% of maximum amplitude). This onset measure was chosen as it has been shown to be sensitive in detecting auditory disorders (Clemis and Sarno, 1980; Jerger and Hayes, 1983; Jerger *et al*., 1978). Other latency measures including late latency (the latency difference between the stimulus onset and 90% of maximum amplitude), initial recovery (the latency difference between the stimulus offset and 90% of maximum amplitude) and terminal recovery (the latency difference between the stimulus offset and 10% of maximum amplitude) have also been reported (Clemis and Sarno, 1980; Jerger and Hayes, 1983; Narayanan, 2017; Prabhu *et al*., 2015). The mean onset ARL values obtained in the present study are in fact consistent with the previous studies on Caucasian adults (Clemis and Sarno, 1980; Jerger and Hayes, 1983; Narayanan, 2017; Prabhu *et al*., 2015). In line with the outcomes of previous studies, an insignificant ear effect was also noted when the ARL results were compared between left and right ears (Narayanan, 2017; Qiu and Stacker, 1998).

Age and gender are important fundamental variables in clinical studies. As such, depending on the study outcomes, specific normative data based on age or gender might be required to enhance the diagnostic accuracy of a specific clinical tool (Jalaei *et al*., 2017; Zakaria *et al*., 2018). In the present study, a significant age effect was found on ARL results. That is, the mean ARL results were significantly longer in the older adults than in the young group at all tested frequencies. It is worth noting that the literature on the effect of age on ARL is extremely limited. The present study finding, nevertheless, is consistent with the ARL data reported by Bosatra *et al.* (1984). In their study on adults with normal hearing in both ears, the latencies of acoustic reflex were greater in older adults (aged 60-79 years) compared to that of younger adults (aged 20-29 years) (Bosatra *et al.,* 1984). In this regard, the aging process may have altered the "normal" physiological process of the auditory system. As such, the effectiveness of signal transmission within the acoustic reflex pathway would be affected. As reported elsewhere, apart from the peripheral hearing contribution, the acoustic reflex pathway also consists of retrocochlear portions: afferent 8th nerve motor neurons, ventral cochlear nucleus, superior olivary nucleus, efferent 7th nerve motor neurons and the stapedius muscle (Clemis and Sarno, 1980; Katz *et al*., 2015; Margolis and Levine, 1991). Since all participants in the present study had normal hearing in both ears (suggestive of an intact peripheral hearing pathway), the prolonged latencies of acoustic reflex in the older adults might be due to the "aging alteration" within the retrocochlear pathway. In line with this, reduced size and loss of ganglion cells in ventral cochlear nucleus and superior olivary nucleus have been reported in older patients (Kirikae *et al*., 1964). Likewise, in auditory brainstem response (ABR) studies, longer latencies of the major ABR waves were found in older adults than in younger adults, emphasizing the notable age effect on the auditory brainstem region (Burkard and Sims, 2001; Burkard and Sims, 2002). Moreover, the aging process may also affect the involuntary contraction of the stapedius muscle itself. The stapedius muscle is composed of striated (skeletal) muscle tissue that can be degraded due to aging (Andrew, 1975; Jepsen, 1963). The significant age effect was also noted for other parameter of acoustic reflex such as ART (Jerger *et al*., 1978; Thompson *et al*., 1980). In the present study, the age effect was found to be more prominent at 2000 Hz frequency. That is, the ARL results for the older adults were significantly longer than those of the middle-aged and young groups, implying that the 2000 Hz stimulus frequency is mostly sensitive to the aging process. In line with this finding, Clemis and Sarno (1980) reported that the inclusion of high frequency stimulus (i.e. 2000 Hz) would increase the sensitivity of ARL to detect retrocochlear disorders. This is because high frequency nerve fibres are typically compromised in these disorders (Clemis and Sarno, 1980; Hall, 2007).

In terms of gender, comparable ARL results were found between males and females, indicating an insignificant influence of gender on ARL. This finding is consistent with the previous studies on ARL (Prabhu *et al*., 2015) and ART (Bauch and Robinette, 1978; Rawool, 1998). Prabhu and colleagues (2015) recorded ARL in 30 normally hearing adults (15 males and 15 females) with and without the presentation of contralateral broadband noise. They then found that the ARL results did not differ significantly between sexes in both test conditions.

It was also of interest to know whether the ARL results would be affected by the stimulus frequency. As shown, no significant influence of stimulus frequency on ARL was found in the present study. This finding is in line with the previous study findings (Narayanan, 2017; Prabhu *et al*., 2015). However, the ARL values have also been reported to be longer at high frequencies (Clemis and Sarno, 1980; Qiu and Stacker, 1998). The methodological differences between the studies might have contributed to this discrepancy and further large-scale research is essential to verify this issue.

The present study was not without limitations. Firstly, the sample size was modest and perhaps more favourable outcomes would be gathered if the sample size is larger. It is worth noting that as an effort to increase the statistical power, the left and right data were pooled to be used in the main analysis. Secondly, only the onset latency of acoustic reflex was studied. Other latency measures of acoustic reflex were not determined and this is subject to future research.

Conclusion

A notable effect of age was found on the onset latency of acoustic reflex. In contrast, the ARL results do not appear to be influenced by either gender or stimulus frequency. Consequently, the age-specific normative data for ARL provided by the present study (n = 144) can be beneficial for clinical and research applications involving Malaysian population. As such, further research is warranted to verify these data when testing patients with peripheral and central auditory disorders.

Authors' Contribution

Mahamad Almyzan Awang – study design and concept, data analysis and writing of the article

Nurliyana Nasuha Zamri – data collection, writing of the article

Maziah Romli – critical review of the article

Mohd Normani Zakaria – data analysis, writing and critical review of the article

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