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Original Article

Effect of Contralateral Noise on Acoustic Reflex Latency Measures

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OBJECTIVE: The present study was conducted to determine the effect of contralateral broadband noise on acoustic reflex latency (ARL).

MATERIALS and METHODS: Acoustic reflex latency changes for 10 and 90% on- and off-time acoustic reflexes with contralateral broadband noise were measured in 30 adults with normal hearing.

RESULTS: The results of the study demonstrate that there was a latency prolongation for reflex on-time (10 and 90%) and latency reduction for reflex off-time (10 and 90%). This effect was seen for 500, 1000, and 2000 Hz reflex-eliciting signals. The results also showed that there was no effect of gender on latency changes in acoustic reflexes.

CONCLUSIONS: Latency changes may explain efferent auditory system mechanisms used for the protection of the cochlea and improvement in speech perception. Thus, contralateral changes of ARL can serve as an additional tool to assess the efferent system functioning.

KEYWORDS: Acoustic reflex latency, efferent auditory system, on-time reflex, off-time reflex

INTRODUCTION

The efferent auditory system has an important role in human auditory perception. The medial efferent system is important for the localization of the sound source [1], auditory attention [2], protection of the cochlea against acoustic injury [3, 4], improved detection of acoustic signals, and improved speech perception in the presence of noise [5, 6]. The medial olivocochlear bundle (MOCB) originates from the nuclei in the medial olivary nucleus. These are myelinated fibers that directly innervate the outer hair cells [7]. The crossed medial efferent fibers predominantly project to the contralateral ear, and they are more readily stimulated than the lateral efferent fibers. The exact functional and clinical roles of the medial efferent system remain unclear. However, in general, the basic function of the medial efferent system is the suppression of afferent activity. It has been well established that the acoustic stimulation of one cochlea can change the afferent responses in the opposite ear mediated by the medial efferent system [8-10].

Efferent nerve fibers terminate at the base of outer hair cells and modulate their function. Hence, the functioning of outer hair cells can be directly modulated by the medial efferent system. Generally, the functioning of the medial efferent system in humans is assessed using the contralateral suppression of otoacoustic emissions (OAEs). OAEs are often reduced (1-4 dB) using a broadband suppressor stimulus [11]. The noise imparted to the opposite ear reduces the movement of outer hair cells in the regions of the test ear because of the inhibition induced by the efferent system; thereby, a frequency-specific reduction in the OAE amplitude occurs [11]. The absence of suppression is generally indicative of an abnormal medial efferent system. Abnormal MOCB (efferent) functioning is seen in individuals with a learning disability [12], auditory neuropathy spectrum disorder [13], and (central) auditory processing disorder [14]. MOCB functioning and stapedial reflexes are two mechanisms that elevate the threshold in the auditory periphery [15].

Acoustic reflexes are a protective mechanism by which the stapedius muscle contracts in response to a loud acoustic stimulus and reduces the intensity of the sound. In addition, Kumar and Barman [9] have reported that contralateral suppression of the acoustical reflex may also be used as an indicator to evaluate the functioning of the efferent system at high intensity input levels. Contralateral suppression of the acoustic reflex can be determined by an amplitude decrease or a threshold increase in the middle ear muscle reflex in the presence of a suppressor stimulus in the contralateral ear. Thus, both acoustic reflex threshold (ART) elevation and reduction in the reflex amplitude can be attributed to the inhibition caused by the efferent system. Mishra [14] reported that anti-masking is caused by inhibitory mechanisms at the level of the stapedius muscle. MOCB activation leads to the release of inhibitory neurotransmitters, which cause electrical/mechanical changes in the cochlea [15]. It is well known that the medial efferent system inhibits the auditory nerve responses by reducing the basilar membrane motion [16, 17]. Both basilar membrane motion alterations and reductions in neurotransmitter release by the inner hair cells because of efferent inhibition cause both an elevation in ART

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and a reduction in amplitude with contralateral noise [18]. It has been reported that efferent system functioning can be assessed using the contralateral suppression of acoustic reflexes [9]; however, no other researchers have attempted to determine the effects of contralateral noise on acoustic reflex latency (ARL) measurements.

Acoustic reflex latency is a special test of acoustic reflexes that can be used to identify retrocochlear pathologies [19, 20]. It refers to the time between the onset of high-intensity acoustic stimuli and stapedial reflex generation [21]. ARL has been measured in individuals with normal hearing and in those with sensorineural hearing loss and has been used for the differential diagnosis of cochlear and retrocochlear pathology [19, 20, 22, 23]. ARL depends on the integrity of the auditory system from the level of the external auditory canal to the low brainstem. ARL studies have shown that ARL does not depend on the ear (left or right) or gender involved [24, 25]. Stimuli such as frequency, intensity, duration, rise-time, and bandwidth can affect ARL. However, the effects of contralateral noise on ARL measurements have not yet been reported. The efferent auditory system-induced changes on ARL need to be examined. Hence, the present study aimed to determine ARL changes with contralateral noise. The study also attempted to determine the differences in ARL for different stimuli. Furthermore, we attempted to determine whether gender influences ARL changes with contralateral noise.

MATERIALS and METHODS

Participants

A total of 30 individuals (15 males and 15 females) 17-30 years old (mean age: 19.2 years) participated in the study. All the participants had pure-tone thresholds within 15 dB HL from 250 to 8000 Hz. None of the subjects reported a previous history of ototoxic drug use, long-/short-term exposure to high levels of noise, or otological/neurological diseases. An informed consent was obtained from all study participants.

Procedure

Pure-tone air conduction (AC) and bone conduction (BC) thresholds were estimated using the Modified Hughson and Westlake procedure [26]. AC thresholds were obtained for pure tones from 250 Hz to 8 kHz and for BC thresholds from 250 Hz to 4 kHz in octave frequencies. Unaided speech identification scores were obtained for phonemically balanced words developed for adults in Kannada by Yathiraj and Vijayalakshmi [27]. Recorded word lists were routed from a PC through a two-channel diagnostic audiometer (Inventis Piano; Padova, Italy) through TDH 50 headphones at 40 dB SL (re: SRT).

Baseline Measurements

The Grason Stadler Inc.-Tympstar (Minnesota, USA) (version 2) middle ear analyzer was used to assess both the middle ear functioning and suppression. A tympanogram was recorded for all participants prior to the ARL measurement of the acoustic reflex. ART was determined at 500 Hz, 1 KHz, 2 KHz, and broadband noise (BBN) for both right and left ears in 5-dB steps in each individual with a 226-Hz probe tone. In addition, ARLs were noted at 10 dB SL with respect to ART obtained for all the stimuli. The middle ear analyzer produced a short-duration tonal stimuli and recorded latencies at which the reflexes were 10 and 90% of the maximum reflex amplitude. In addition, when the stimulus was stopped, 10 and 90% latencies for the off-time reflex were recorded. The reflexes were elicited five times and averaged to obtain the appropriate latencies. The stimulus duration for ARL measurements was 300 ms on-time with the average of five measurements. Thus, the initial latency from onset to 10 and 90% of the maximum acoustic reflex amplitude was noted, and the terminal latency from offset of the signal to 10 and 90% of the acoustic reflex amplitude was also noted.

Measurement of ART in the Presence of Contralateral Noise

Without altering the probe placement, ARLs at 10 dB SL (ref: ART) were established again for all the stimuli in the presence of BBN in the contralateral ear. The BBN threshold was found using a calibrated audiometer, and the contralateral noise was presented through the ER-3A insert receiver at 40 dB SL. The BBN frequency spectrum was 125-4000 Hz administered through an audiometer and middle ear analyzer. It was ensured that the intensity of white noise was lower than the ART for BBN in the contralateral ear for all the participants. The presentation order of the stimuli and selection of the tested ear were randomized.

Ethical Considerations

In the present study, all testing procedures used non-invasive techniques, and all the procedures were explained to the participants before testing. Informed consent was obtained from all the participants. The study was approved by the ethical committee of the institution.

RESULTS

The study results were statistically analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows (Version 20.0. Armonk, New York: IBM Corp.). The mean ARLs for 500, 1000, and 2000 Hz showed that there were latency prolongations for 10 and 90% on-time reflexes and latency reductions for 10 and 90% off-time reflexes with contralateral noise. ARL mean and standard deviation (SD) across stimuli for all the four conditions are shown in Table 1. The paired sample t-test with and without noise showed that this differ-

Table 1. Mean and SD of the amount of acoustic reflex latencies for both on-time and off-time reflexes for all three frequencies

		10% On time		90% On time		10% Off time		90% Off time	
Stimuli used		**Mean (ms)**	**SD**	**Mean (ms)**	**SD**	**Mean (ms)**	**SD**	**Mean (ms)**	**SD**
500 Hz	Without noise	93.7	5.2	160.1	9.8	291.16	9.2	169.7	12.8
	With noise	108.9	10.5	183.04	13.7	254.32	7.5	135.41	17.6
1000 Hz	Without noise	100.5	8.4	183.89	10.06	274.54	1.4	152.18	19.19
	With noise	114.5	5.6	207.62	14.9	234.54	8.6	104.33	15.78
2000 Hz	Without noise	114.29	4.3	206.12	11.85	296.12	7.7	147.3	17.9
	With noise	127.5	5.5	229.91	12.3	261.34	10.5	107.4	16.5

SD: standard deviation; MS: miliseconds

Table 2. Mean and SD of the amount of latency shift (increase or decrease) for both on-time and off-time reflexes for all three frequencies

	10% On time (Increase in latency)		90% On time (Increase in latency)		10% Off time (Decrease in latency)		90% Off time (Decrease in latency)	
Stimuli used	**Mean (ms)**	**SD**	**Mean (ms)**	**SD**	**Mean (ms)**	**SD**	**Mean (ms)**	**SD**
500 Hz	11.58	5.35	21.74	6.93	36.8	6.29	26.49	7.1
1000 Hz	11.63	4.21	18.4	8.72	40	7.90	35.64	5.7
2000 Hz	12.41	3.20	22.46	3.79	34.9	8.41	26.62	9.87

SD: standard deviation; ms: milliseconds

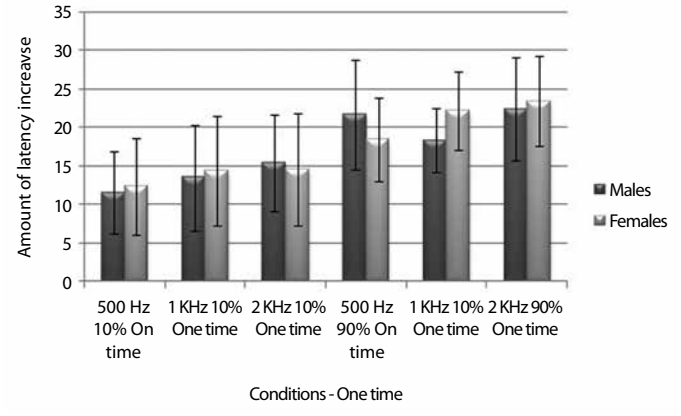

Figure 1. Mean and SD for the amount of latency increase for all three frequencies (on time reflex) across gender

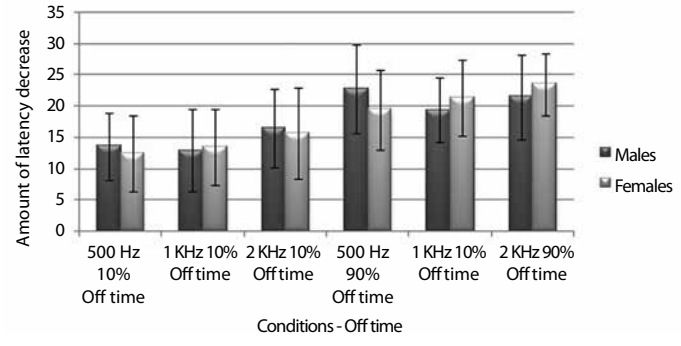

Figure 2. Mean and SD for the amount of latency increase for all three frequencies (off-time reflex) across gender

ence was significant ($p<0.05$) for all of the tested three stimuli. Furthermore, the difference in ARL values across all stimuli and between the four conditions were calculated. The results show that there is an increase in latencies corresponding with an increase in frequencies for on-time conditions. The mean and SD of the difference in ARL values for the different stimuli and the four conditions are shown in Table 2. For all three frequencies, the results show that the differences in ARL were more for the 90% on-/off-time reflex than for the 10% on-/off-time reflex for all the three frequencies. The data showed a high SD, particularly for 90% on- and off-time, which suggests variability in the ARL measurements across populations.

The ARL shift was measured in both genders for both on- and off-time reflexes. The mean and SD of latency shift for 10 and 90% on-time reflexes for all the three frequencies across genders are shown in Figure 1. The mean and SD of latency shifts for 10 and 90% off-time reflexes for all the three frequencies for both genders are shown in Figure 2.

Mixed analysis of variance was performed considering the latency shift for the three frequencies as a within-subject factor and gender as a between-subject factor for all four conditions. The results showed that there were no significant main ARL suppression effects across different reflex-eliciting stimuli. There were no significant main effects of gender on ARL suppression. There were also no significant interactions between gender and ARL suppression for all conditions. Our results suggest that the amount of ARL suppression does not change across the reflex-eliciting stimuli and that there were no gender effects on the contralateral ARL suppression.

DISCUSSION

Reflex latency prolongation for on-time reflexes may be attributed to the inhibitory effect caused by the efferent system. This inhibitory effect was absent when the MOCB was sectioned in animals [4]. In humans, the inhibitory effects of the efferent system were lost when the vestibular nerve was sectioned; this nerve contains the cochlear efferent fibers [28]. It has been shown that inhibitory neurotransmitters are released when the MOCBs are activated, which may cause electrical/mechanical changes in the cochlea. It is well known that the medial efferent system inhibits the auditory nerve responses by reducing the basilar membrane motion [16, 17]. There is also a report of reduction of cochlear activity with electrical MOCB stimulation in animals [17]. Thus, it appears that efferent inhibition reduces the overall intensity of sound reaching the cochlea. The contralateral BBN used in this study appears to have induced the release of efferent inhibitory neurotransmitters and caused a delay in the movement of the basilar membrane, which affected the overall intensity of sound generated from the cochlea. Thus, the presented sound intensity may have decreased because of medial efferent inhibition, which led to prolonged latencies. This supports the notion that the efferent system helps protect the cochlea from loud sound [3, 4].

This study also reported that the latencies decreased for acoustic off-time reflexes with contralateral noise. This suggests that the efferent system attempted to quickly restore normal functioning when a loud sound was absent and also to enhance speech perception. It has been reported that the efferent system plays an important role in the improved detection of acoustic signals and improved speech perception in the presence of noise [5, 6]. The inhibitory effects of the MOCB have been described in terms of the effects on fast and slow efferent fibers [29-31]. Slow efferent activity has been associated with the slow release of calcium and has been shown to cause a decrease in OHC axial stiffness. Fast efferent fibers have been shown to reduce the basilar membrane movement and cause inhibition by reduced

auditory nerve activity [31]. The fast and slow medial olivocochlear efferent fibers have been shown to have opposite effects on basilar membrane displacement; this in turn led to phase leading for fast efferent and phase lagging for slow efferent nerve fibers [32]. Thus, in this study, the decreased latency observed for off-time reflexes could be because of the effects of fast efferent fibers, and increased latencies observed for on-time reflexes could be because of the effects of slow efferent fibers. This is only a speculation, and the actual mechanism involved in the reduction and prolongation of ARLs needs to be further examined. This study showed that there were no significant effects of stimulus frequency on the latency shift for on-and off-time reflexes. These results suggest that efferent-induced changes in ARL do not vary across frequencies. The contralateral suppression of distortion product OAE studies has also shown that there were no effects of frequency on the amount of suppression [33, 34]. This study also showed that there were no gender effects on the contralateral ARL suppression. These results suggest that efferent-induced changes do not vary depending on the left or right ear and gender. These results are in agreement with previous reports on the contralateral suppression of OAE, which also suggested that gender did not affect this suppression [35].

The present study showed ARL changes with contralateral BBN. Latencies were prolonged for on-time reflexes and were reduced for off-time reflexes. The efferent system appears to cause changes in ARLs, which can be used to assess the functioning of the efferent system. The acoustic reflexes were shown to be less sensitive to the degree of hearing loss when compared with OAE. Thus, ARL contralateral changes may serve as an additional tool to assess the efferent system functioning. This study also emphasized the role of the efferent auditory system in the protection of the cochlea from loud sound and improvement in speech perception. However, the exact mechanism for these changes still needs to be examined in detail.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of All India Institute of Speech and Hearing, Mysore.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - P.P., K.N.D., R.N., S.A.; Design - P.P., K.N.D., R.N., S.A.; Supervision - P.P.; Resources - P.P., K.N.D., R.N., S.A.; Materials - P.P., K.N.D., R.N., S.A.; Data Collection and/or Processing - P.P., K.N.D., R.N., S.A.; Analysis and/or Interpretation - P.P., K.N.D., R.N., S.A.; Literature Search - P.P., K.N.D., R.N., S.A.; Writing Manuscript - P.P., K.N.D., R.N., S.A.; Critical Review - P.P., K.N.D., R.N., S.A.

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