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Comparison of Auditory Evoked Potentials between Younger and Older Adults

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Abstract

Background: Aging is a very important issue in our modern life. Auditory processing problems are common in older adults.
Purpose: There are different ways to study these problems. The aim of this study was to evaluate the pure processing effect of aging on auditory evoked potentials.
Methods: In this cross sectional study, the auditory brain stem response (ABR) and the auditory middle latency response (AMLR) were measured in 32 younger adults (mean age, 20.41±2.13 years) and were compared with those of 32 older adults (mean age, 68.16±6.20 years). Both groups had normal peripheral hearing sensitivity and normal cognitive status, according to pure tone audiometry and Mini Mental State Examination results. The group of older adults was selected from subjects with problems understanding speech in noisy places. Multivariate tests were used for the statistical analysis.
Results: Most ABR wave latencies increased and their amplitudes decreased in older adults ($P< 0.05$). The latency of AMLR waves was significantly prolonged only for the Nb component in the right and left ears and for the Pa component during binaural stimulation ($p < 0.05$).The amplitude of all AMLR waves increased significantly, except for Na in both ears ($p <0.05$).
Conclusion: Aging had a pure central effect on the processing ability of the entire neural auditory system. Aging reduced the central inhibition process at the cortical level.

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INTRODUCTION

Aging is a very important issue in modern life. The proportion of elderly subjects in all populations are growing at a much faster rate than the overall population (1). It is estimated that the proportion of people above 60 years will increase from 10 % in the year 2000 to 21.8 % in 2050 in all regions (2).

The most common otolaryngological disability affecting the elderly is hearing loss (3). Hearing loss make it difficult to understand speech, particularly in noisy places, but this difficulty occurs even in elderly subjects with normal peripheral hearing sensitivity and normal cognitive status (4, 5). In fact, degenerative changes are likely to occur in the central pathways with advancing age, including both sub cortical and cortical structures in addition to decreased hearing sensitivity and other peripheral changes (6). Different theories have been proposed to explain the problems older adults have in understanding speech in noisy places (7-9). These include the peripheral hypothesis, the central auditory hypothesis, and the cognitive hypothesis (10). Hearing loss is implicated (pesbycusis) in the peripheral hypothesis and special categories have been proposed, such as sensory, neural, metabolic, and cochlear conductive (11). The central auditory hypothesis states that any location in the entire auditory nervous system from the brain stem to the auditory cortex, and associated areas is implicated .In the cognitive hypothesis, the

cortex, which is responsible for information processing, and labelling, is implicated (10). Pechora-Fuller and Singh (2006) reported that changes in audibility and cognition are interrelated and causes difficulties understanding speech in older adults (7). In the present study, we focused on the central auditory hypothesis. We recruited older adults with normal peripheral hearing sensitivity and normal cognitive status Thus, their difficulty in understanding speech in noisy places was presumably related to age induced changes in the auditory portions of central auditory system which impacts auditory perception and speech communication performance and commonly named central presbycusis (7, 12-14). The effects of aging on different central auditory processing aspects can be monitored by auditory evoked potentials. We hypothesized that alterations in auditory evoked potentials specifications such as latency and amplitude, are because of the pure central effects of aging or from hearing impairment at high frequencies, which are related to aging. The elderly group in our study had no peripheral hearing impairment (pure tone average (PTA) $\leq$ 25 dBHL) Thus, we were able to evaluate the pure processing effects of aging on the auditory nerve, brain stem, sub cortical nuclei, and cortex. We evaluated possible degenerative central effects of aging on the auditory brain stem response (ABR) and the auditory middle latency response (AMLR).

The ABR is a series of five to seven peaks arising from the auditory nerve and brain stem structures that occur within 10 ms of the onset of a moderate-intensity click stimulus in normal hearing adults (15).

The AMLR is a series of four peaks arising from sub cortical nuclei and the auditory cortex that occur within 15 -70 ms of the onset of stimulus (16, 17).

We evaluated possible aging- induced declines in central processing ability by comparing the latencies and amplitudes of the ABR and AMLR between younger and older adults with normal peripheral hearing sensitivity.

PATIENTS and METHODS

Study Design:

In this cross sectional study, ABR and AMLR were evaluated in younger and older adult groups, and the effect of aging was evaluated by comparing the results.

Participants:

ABR and AMLR were evaluated in younger adults (group 1) and older adults (group 2). Group 1 consisted of 32 rehabilitation students (age range, 15-25 years; mean ± standard deviation [SD], 20.62 ± 2.13 years) recruited from The University of Social Welfare and Rehabilitation Sciences and Shahid Beheshti Medical University. They had the normal hearing sensitivity (PTA 20 dBnHl at frequencies of 500; 1,000; 2,000; and 4,000 HZ) and no recent middle ear problems. They were all right-handed, according to the Edinburgh Handedness Inventory, and were self- reported to be monolingual (18).

Group 2 consisted of 32 older adults. (age range, 55 -85 years; mean ± standard deviation [SD], 68.16 ± 6.20 years). They were all right- handed and monolingual (18). All of the older adults had Mini Mental Sate Examination scores (19) > 21, so no apparent cognitive decline was observed. The inclusion criteria for the older adults were normal hearing sensitivity (PTA $\leq$ 25 dB nHl) and problem understanding speech in a noisy situation despite normal pure tone sensitivity. The speech understanding issues were evaluated with a three-item questionnaire that asked about understanding speech in a noisy environment; three choices of yes, no, or sometimes were included. Those who responded yes were entered into the study.

All participants gave written consent to participate in this study. The local ethics committee of the University of Social Welfare and Rehabilitation Sciences approved all study procedures.

Stimuli, Data Acquisition and Recording:

ABR: Rarefaction clicks of 0.1 ms duration were presented monaurally (right and left) and

binaurally through insert phones (580 SINSER) at a rate of 13.30/s and intensity of 80 dB nHL.

The recording was using the Navigator Pro (Biologic Co. Willow Hill, PA, USA) instrument through one channel using a horizontal electrode montage (non- inverting: non- stimulus ear, ground: FpZ, inverting: stimulus- ear). Epoch time was 10.66 ms and amplifier gain was set to 100,000. The electroencephalogram (EEG) was filtered with a 100-1,500 band pass filter. Averaging was performed with 2,000 clicks during two runs. The components quantified included waves I, II, III, IV, and V. Two separate audiologists labelled the waves, and the instrument calculated latency and amplitude automatically.

AMLR: Alternating polarity clicks of 0.1 ms duration were presented monaurally (right and left) and binaurally through insert phones (580-SINSER) at a rate of 7.10 /sec and an intensity of 70 dBnHL. The recording was done using the Navigator Pro instrument through one channel arrangement using the horizontal electrode montage (non-inverting: non-stimulus ear, ground: FpZ, inverting: stimulus- ear). Epoch time was 106.6 ms and amplifier gain was set to 75,000. The EEG was filtered with a 10- 1,500 band pass filter. Averaging was performed with 1000 clicks during two runs. The components quantified included Na (measurement window, 10_ 25 ms), Pa (22_40 ms), Nb (35_ 50 m), Pb (40_60 ms). Two separate audiologists labelled the waves, and the instrument calculated latency and amplitude automatically.

Statistical Analysis:

The Kolmogorov -Smirnov test was performed to test the normality of the distributions. The ABR and AMLR results (latency and amplitude) were analyzed using multivariate tests. Missing data were eliminated from the analysis. A p-value $\leq$ 0.05 was considered significant. Statistical analyses were performed using SPSS 16 software (SPSS Inc., Chicago, IL, USA).

RESULTS

Data of the younger and older adult population were normally distributed. Therefore, multivariate tests were utilized to compare the findings.

ABR RESULTS:

Tables 1 and 2 show the means, SD, and the significance of the multivariate test results for ABR (right ear, left ear, and bilateral stimulation).

Latencies are compared between the younger and older adults for right, left and binaural stimulation in table 1. All mean values increased but the differences were significant only for waves I, III, and V on the right side, wave V on the left side, and wave I during binaural stimulation.

Table 2 summarizes the ABR amplitude results for right, left, and binaural stimulation.

There was a significant decrement in all components except amplitude of waves I and V on binaural stimulation.

AMLR:

Tables 3 and 4 show the means, SDs, and significance of the multivariate test results for AMLR. (right ear, left ear, and bilateral stimulation).

Table 3 summarizes the latency of all AMLR waves for right, left and binaural stimulation.

The latency prolongation difference was significant only for the Nb wave in the right ear. The latency was prolonged in older adults compared to that in the younger adults. Pa showed significantly prolonged latency in older adults under binaural stimulation compared to that in the younger adults.

Table 4 summarizes the amplitude of all AMLR waves for right, left and binaural stimulation.

Surprisingly the Pa and Nb amplitudes increased in the older adults under right, left and binaural stimulation.

Table 1: Comparison of auditory brain stem response (ABR) latencies in younger and older adults

Ear / Variable	Younger Adults group (n=32) Mean ± SD(ms)	Older Adults group (n=32) Mean ± SD(ms)	P
R / I Latency	1.61± 0.10	1.71± 0.22	0.003*
R / III Latency	3.64± 0.20	3.78 ±0.25	0.015*
R / V Latency	5.49±0.26	5.68± 0.29	0.007*
L / I Latency	1.63±0.10	1.72±0.17	0.231
L / III Latency	3.72±0.10	3.78±0.21	0.141
L / V Latency	5.50±0.24	5.75±0.21	0.000*
Bin / I Latency	1.63±0.12	1.73±0.21	0.037*
Bin / III Latency	3.63±0.21	3.70±0.31	0.258
Bin / V Latency	5.46±0.29	5.58±0.39	0.186

Table 2: Comparison of auditory brain stem response (ABR) amplitudes in younger and older Adults

Ear / Variable	Younger Adults group (n=32) Mean ± SD(µvolt)	Older Adults group (n=32) Mean ± SD(µvolt)	P
R / I amplitude	0.14± 0.08	0.10± 0.07	0.050*
R / III amplitude	0.27± 0.12	0.16 ±0.07	0.000*
R / V amplitude	0.29±0.15	0.18± 0.10	0.001*
L / I amplitude	0.12±0.09	0.06±0.04	0.002*
L / III amplitude	0.25±0.10	0.16±0.09	0.001*
L / V amplitude	0.25±0.12	0.15±0.14	0.003*
Bin / I amplitude	0.17±0.16	0.11±0.07	0.078
Bin / III amplitude	0.33±0.12	0.25±0.09	0.006*
Bin / V amplitude	0.34±0.17	0.27±0.13	0.055

Table 3: Comparison of auditory middle latency response (AMLR) latencies in younger and older Adults

Ear / Variable	Younger Adults group (n=32) Mean ± SD(ms)	Older Adults group (n=32) Mean ± SD(ms)	P
R / Na Latency	15.69± 1.92	16.58± 2.68	0.134
R / Pa Latency	25.01± 2.79	25.66 ±4.41	0.485
R / Nb Latency	37.21±2.78	39.94± 6.42	0.024*
L / Na Latency	15.78±2.04	15.92±2.66	0.821
L / Pa Latency	25.38±2.56	25.98±4.37	0.511
L / Nb Latency	35.54±4.67	37.98±5.11	0.051
Bin / Na Latency	16.29±1.88	17.39±3.97	0.163
Bin / Pa Latency	25.70±2.75	27.28±3.59	0.015*
Bin / Nb Latency	38.05±2.32	39.48±5.96	0.211

Table 4: Comparison of auditory middle latency responses (AMLR) amplitudes in younger and older Adults

Ear / Variable	Younger Adults group (n=32) Mean ± SD(ms)	Older Adults group (n=32) Mean ± SD(ms)	P
R / Na Latency	15.69± 1.92	16.58± 2.68	0.134
R / Pa Latency	25.01± 2.79	25.66 ±4.41	0.485
R / Nb Latency	37.21±2.78	39.94± 6.42	0.024*
L / Na Latency	15.78±2.04	15.92±2.66	0.821
L / Pa Latency	25.38±2.56	25.98±4.37	0.511
L / Nb Latency	35.54±4.67	37.98±5.11	0.051
Bin / Na Latency	16.29±1.88	17.39±3.97	0.163
Bin / Pa Latency	25.70±2.75	27.28±3.59	0.015*
Bin / Nb Latency	38.05±2.32	39.48±5.96	0.211

DISCUSSION

A pure effect of aging was observed in the present study. As older adults with normal peripheral hearing sensitivity and normal cognitive status were enrolled in this study, the confounding effects of hearing loss and cognitive problems were minimized.

Interesting findings were observed by comparing the latencies and amplitudes of the three main ABR waves between the two groups. All latencies increased and all amplitudes decreased although the difference was not significant for some components. This finding explains the pure central aging effect on processing ability of the auditory system, and confirms that aging-induced deterioration begins at the auditory nerve.

Another interesting finding was the different kinds of central aging effects on the amplitudes and latencies of the ABR waves. The aging effect was more robust in the amplitude study. Only three waves showed significantly prolonged latency in the older adults group and significant decreases in amplitude were observed in seven components. These decreases in ABR wave amplitudes of older adults are an important finding that must be considered as electrophysiological evidence of central aging effects.

Other studies on the effects of aging on ABR amplitudes in humans have demonstrated decreased amplitude in older adults (1, 3, 15). The difference between our results and those of previous studies is that previous studies tried to account for threshold elevations but the older adults participating in our study had normal peripheral hearing sensitivity in the 4,000 Hz.

The absolute latencies of all AMLR waves tended to be prolonged but the right Nb, left Nb and Binaural Pa were the only significantly prolonged latencies. Chambers and colleagues (1992) also established a consistent tendency for prolonged Pa latency in older subjects (19). This finding is similar to those of ballweber and Dobie (1984) and Woods and Clayworth (1986) (19-22).

Surprisingly, the amplitudes of some of the AMLR waves increased in older adults group. This increase was more obvious in the Pa and Nb waves of the right ear, left ear and binaural stimulation. This result is consistent with those of Ballweber and Dobie (1984) and Woods and Clayworth (1986) (20, 22). However, Amendo and Diaz (1998) reported an increase in Na amplitude in older adults (16). Woods and Clayworth explained that the increase in Pa in older adults is because of reduced central inhibition of afferent stimulation (22). Therefore, a lack of central inhibition from higher centers on lower centers occurs with aging, which may have caused the increase in Na and Pa amplitudes in older adults (12).

Chambers (1992) also evaluated Pa and Pb in younger and older adult's women. The women were selected based on normal hearing sensitivity, as in our study. They designed their recording procedure and the rate of stimulation to record Pa and Pb simultaneously. They concluded that absolute and peak-to-peak amplitudes increased in the older adult's women at different stimulus rates which is consistent with our results (19).

Chambers (1992), referred to Woods and Clayworth (1986) to discuss the increases in amplitudes (19, 22). According to Chambers (1992), the increase in Pb amplitude may be because of a reduction in central inhibition mediated by higher centers (12).He added that an enhanced response of the arousal system to repeat stimulation in the older population, as reflected by the larger Pb, is consistent with the notion of central disinhibition in these subjects (12).

Another possible explanation for the age group differences is an apparent positive baseline shift in the older subjects, reminiscent of diminished negativity (21). However both the present study and the study by Chambers (19). reported increased Pa and Pb amplitudes in older adults; thus, this explanation is not suitable.

Some studies have reported that the midline Pa originates from the primary auditory cortex , although an origin in the thalamic medial geniculate nuclei or in the thalamo-cortical radiations has been suggested by human lesion studies (23, 24). Considering the generators of Na and Pa, the age dependence of the Na and Pa amplitudes may be attributable tone or two causes, according to Amendo and Diaz (1988) (16). The first is a reduction in inhibitory feedback connections from layer IV of the auditory cortex to the inferior colliculi or from layer v to the medial geniculate body which have been suggested to play a role controlling the attention to auditory input by reducing the activities of these mid brain and diencephalic structures in response to irrelevant stimuli (16).

The loss of projecting neurons in neocortical areas including the temporal region and loss of more than half the neurons in the superior temporal gyrus have been reported in some studies (12, 25).These losses may significantly reduce communication between the auditory cortex and subcortical auditory structures and therefore, reduce the capacity of inhibitory activity generated in these structures in response to repetitive stimuli requiring no attention. The second possible cause for the age-related increases in the Na and Pa amplitudes is the decrease in thalamic gamma amino butyric acid (GABA) levels with age (12, 26) which has been attributed to the differences between the Pa amplitudes of young and elderly subjects (22). As the thalamic reticular nucleus is one of the main sources of GABAergic projections that inhibit the medial geniculate nuclei, which is another thalamic relay nucleus a GABA deficiency would tend to reduce inhibition of waves originating in these nuclei (26). Diaz and co authors (1990) reported that abstinent chronic alcoholics have greater Na and Pa amplitudes than healthy controls, which has been attributed to reduction of thalamic GABA levels (25).

Another possible cause for the age related increase in AMLR amplitudes may be the known loss of white matter from prefrontal areas in the elderly (12, 27, 28).As prefrontal cortical lesions cause a significant increase in the Pa amplitude, it seems likely that the age-related increase in response to repetitive unattended stimuli may have been partly because of the demonstrated degeneration of this region in elderly subjects (29).

CONCLUSION

Our results show a pure central effect of aging on the entire auditory nervous system beginning from the distal part of the auditory nerve to higher parts of the auditory cortex. Prolonged latencies and reduced amplitudes are very good indicators of functional changes in this system. These changes include slower neural conduction velocity, which is concluded mostly from latency reduction and decreased

amount of potentials recorded which is understood from amplitude reduction.

We observed the significant jump in Pa and Nb amplitude in older adults as age-related changes in the central part of the auditory system. This phenomenon seems to confirm the central disinhibition that may be associated with other behaviors of older adults such as difficulties in understanding speech in noisy situations.

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None to declare.

CONFLICT of INTEREST

The authors declare no conflict of interest.

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