Research Article

Is Pattern of Acceptable Noise Level Growth for Apparently Normal Contralateral Ear Similar to Affected Ear in Unilateral Meniere's Disease?

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Citation: Nasiri E, Jalilvand H, Yazdani N, Mahdavi ME, Akbarzadeh Baghban A. Is Pattern of Acceptable Noise Level Growth for Apparently Normal Contralateral Ear Similar to Affected Ear in Unilateral Meniere's Disease?. Aud Vestib Res. 2023;32(2):121-7.

https://doi.org/10.18502/avr.v32i2.12182

Highlights

- Meniere's Disease (MD) affects the individuals' noise performance
- In unilateral MD, the ANL and its growth changed differently with presentation level
- Contralateral ear of patients with unilateral MD has abnormal performance in noise

Article info:
Received: 29 Aug 2022
Revised: 10 Oct 2022
Accepted: 07 Nov 2022

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ABSTRACT

Background and Aim: The Acceptance Noise Level (ANL) which determines the tolerable noise level while listening to running speech, is related to factors such as hearing loss and speech presentation level. This study aims to investigate the effect of speech presentation level on the ANL in people with unilateral Meniere's Disease (MD) compared to the normal-hearing people.

Methods: In this study, 33 people aged 32–60 years with unilateral MD and 38 normal-hearing people aged 20–46 years participated. The ANL growth was evaluated unilaterally at four different speech presentation levels: Most Comfortable Level (MCL), –10 dB lower than the MCL, +10 dB higher than the MCL, and a range between MCL and uncomfortable level.

Results: In MD patients, the ANL of the affected ear was significantly different from that of the contralateral ear ($p<0.010$). Compared to the normal-hearing people, the pattern of ANL growth in MD patients was significantly different, but the ANL growth patterns were similar between the affected and contralateral ears.

Conclusion: ANL and its growth pattern are different between the affected and contralateral ears of patients with unilateral MD, but are similar compared to normal-hearing people. Despite the apparently normal hearing thresholds, the performance of the contralateral ear in noise at various speech presentation levels in patients with unilateral MD seems to be similar to that of the affected ear.

Keywords: Meniere disease; hearing loss; acceptable noise level

Introduction

First introduced by Prosper Meniere in 1861 [1], Meniere's Disease (MD) is an inner ear disorder that is associated with increased endolymphatic pressure. It is rare in children; it most commonly appears after the age of 30 [2]. The exact cause of this disease is not clear yet, but it may be due to a disorder in the production and absorption of endolymphatic system, vascular disorders, and blockage of endolymphatic sac [3]. This disease is associated with symptoms such as dizziness, Sensorineural Hearing Loss (SNHL), tinnitus, and aural fullness in the ear [4]. In the early stages of this disease, changes in the fluid volume or elastic changes in the cochlear membrane may increase the hearing threshold at low frequencies and lead to rising configuration in the audiogram. Over time and with the involvement of other frequency ranges, the audiogram configuration becomes peak or flat in the last stages [5]. The changes in the membrane and hair cells caused by MD can lead to changes in the function of the cochlea in the affected ear, resulting in abnormal loudness growth with increasing intensity and decreasing dynamic range, which affects noise tolerance [6].

Introduced firstly by Nabelek et al., the Acceptance Noise Level (ANL) quantifies the maximum amount of noise a person can tolerate while listening to a running speech [7]. To obtain ANL, the patient first determines the Most Comfortable Level (MCL) for the presented running speech. Then, a babble noise is added and patients is asked to determine the maximum Background Noise Level (BNL) that is tolerable to him/her while listening to the running speech. The ANL is obtained by subtracting the BNL from the MCL. ANL is not related to age, gender, type of background noise, cochlear responses, and middle ear condition [7], but is related to the individual characteristics (e.g. personality type), auditory sensitivity, the audiogram slope, and speech presentation level [8-13]. With the increase of hearing loss, the ANL increases; it is higher in people with severe hearing loss than in those with moderate hearing loss [9]. A study showed that the normal-hearing people with lower ANL had less ANL growth by increasing the speech presentation level compared to the normal-hearing group with higher ANL [14]. A study reported that, in individuals with SNHL, the ANL changed as the speech presentation level increased; for every 1 dB increase of the presentation level, the ANL increased by 0.16 [15].

Since the ANL test is usually applied at the MCL in clinical and research settings, the ANL in MD patients is evaluated only at a fixed speech presentation level [12, 16]. It has been shown that the ANL is affected by low-frequency thresholds and the slope of the audiogram [17]. A question that arises is whether the increase of speech presentation level has different effect on the ANL growth in patients with unilateral MD. No study has been performed on the ANL growth in MD patients. Therefore, this study aimed to investigate the effect of speech presentation level on the ANL of patients with unilateral MD and compare the results of the affected ear with those of the contralateral ear and the ear of normal-hearing people.

Methods

Participants

Thirty-three people with unilateral MD (21 females and 12 males) aged 32–60 years with mean(SD) age=47(9.69) years participated in this study (12 with right-ear affected and 21 with left ear affected). For inclusion criteria, we used the 2020 guideline of the American Academy of Otolaryngology-Head and Neck Surgery and the approval of MD diagnosis by an Otolaryngologist. The samples had MD for at least one year with a mean disease duration of two years, ranged from one to eight years. The mean of hearing thresholds at frequencies 250–8000 Hz in the affected ear and the contralateral ear of patients are presented in Figure 1. For having a control group, 38 normal-hearing people with hearing thresholds≤15 dB HL at frequencies of 250–8000 Hz (17 males and 21 females) aged 20–46 years with mean(SD) age=24.10(5.66) years, were recruited. Using an otoscope (HEINE, Optotechnik Co, Germany) and tympanometer (AT235, Interacoustic Co., Denmark), the normal conditions of the outer and middle ears in both groups was confirmed. Written informed consent was obtained from all participants.

Acceptable noise level test

The Persian version of ANL test [18] was used. For uncomfortable loudness level (UCL) of the subjects, a part of the running speech stimuli in the Persian ANL test was used. In order to assess the UCL of individuals in each ear, the speech stimulus was presented monaurally through a headphone. The speech presentation level was first increased in 10 dB steps and then in 5 dB steps to such an extent that the subjects expressed the maximum speech level that was intolerable to them. After explaining the ANL test process to all participants, the speech stimulus with an initial intensity level of 30 dB HL was presented by a calibrated audiometer (AC40, Interacous-

tic Co., Denmark) through a headphone. The intensity of the speech stimulus was first increased and decreased in 5 dB steps. The intensity was then increased or decreased in 3 dB steps and then in 1 dB steps so that the subjects could express the intensity level at which it was comfortable to them (MCL). After obtaining the typical MCL, the other levels were calculated based on it and as follows: lower level of typical MCL=typical MCL–10 dB; higher level of typical MCL=typical MCL+10 dB; highest level of typical MCL=(typical MCL+UCL)/2.

While presenting the running speech at each presentation level, the babble noise was added which was increased and decreased firstly in 5 dB and 3 dB steps, and then in 1 dB steps so that the subject could express the maximum BNL in which s/he was able to put up with it. The ANL for different levels was then calculated. The ANL test for normal-hearing and MD subjects at various speech presentation levels was conducted randomly.

Statistical analysis

Collected data were analyzed in SPSS 17 software (IBM Corp., USA). Kolmogorov-Smirnov test was used to evaluate the normality of data distribution. The paired sample t-test was used to compare the means at different presentation levels, BNL, and ANL. Pearson correlation test was used to investigate the relationship of ANL growth with typical ANL and Pure Tone Average (PTA) at 500, 1000 and 2000 Hz. The three-way repeated measures analysis of variance (ANOVA) was used to determine whether there was any statistically significant difference in the ANL test results at different levels between the two ears and between the study groups, followed by Bonferroni post hoc test for pairwise comparison. The ANL growth in each individual was determined by using linear regression analysis.

Results

Speech presentation levels, background noise levels, and acceptable noise levels

Mean and standard deviation of the ANL and BNL scores at different speech presentation levels are presented in Table 1. At all presentation levels, the ANL score was lower in normal-hearing people than in MD patients (both affected ear and contralateral ear).

The three-way ANOVA was conducted for the ANL score. The factors were group (normal-hearing people and patients), speech presentation level (lower, typical, higher, highest) and ear (affected and contralateral ears in patients and right and left ears in normal-hearing people). The main effects were significant in terms of group ($F(1,16)=84.5$, $p<0.010$), speech presentation level ($F(1.73,105.6)=6.46$, $p<0.004$), and ear ($F(1,61)=43.71$, $p<0.010$).

The results of paired t-test showed that the mean ANL at all speech presentation levels was significantly different between the two ears of MD patients ($p<0.010$ for all speech presentation levels), but there was no statistically significant difference in the mean ANL between the two ears of normal-hearing people ($p=0.790$, 0.460, 0.360, and 0.920 for lower, typical, higher, and highest levels, respectively).

Comparing acceptable noise level growth

Linear regression analysis results showed that the mean ANL growth for normal-hearing people was 0.05 dB in both right and left ears. For the MD patients, it was –0.03 dB and –0.17 dB in the affected and contralateral ears, respectively. As shown in Figure 2, the ANL growth pattern in the affected and contralateral ears of patients was different from that in the right and left ears of normal-hearing subjects. Moreover, the ANL growth pattern of the contralateral ear in patients (despite having normal hearing thresholds) was similar to the growth pattern of their affected ear. The two patterns were exactly the same in shape, but there was a distance between them which was due to the difference in the hearing thresholds of the affected and contralateral ears. Although the contralateral ear seemed to be normal only in hearing thresholds, it was similar to the affected ear in terms of noise tolerance and ANL growth.

Relationship of acceptable noise level growth with typical acceptable noise level and pure tone average

The results of Pearson correlation test showed a significant negative relationship between ANL growth and PTA in the affected ear of patients ($r=–0.51$, $p<0.004$) and between ANL growth and typical ANL in the affected ear ($r=–0.59$, $p<0.01$).

Discussion

The purpose of this study was to investigate the ANL growth pattern by increasing speech presentation level in patients with unilateral MD. Given the effect of auditory sensitivity and audiogram configuration on ANL, we hypothesized that the ANL growth changes individually as the speech presentation level increases. As

Table 1. The means and standard deviations of presentation levels, background noise levels, and acceptable noise levels of normal listeners and participants affected by Meniere disease

Affected ear		Meniere disease group		Normal group	
		Contralateral ear	Right ear	Left ear	
Presentation level (dB HL)	Highest	82.97(6.33)	77.27(5.74)	76.05(6.05)	74.34(6.99)
	Higher	72.27(9.85)	63.33(6.20)	61.32(7.50)	59.74(7.88)
	Typical	62.27(9.85)	53.33(6.20)	51.32(7.50)	49.74(7.88)
	Lower	52.27(9.85)	43.33(6.20)	41.32(7.50)	39.74(7.88)
Background noise level (dB HL)	Highest	80.58(5.96)	78.03(6.15)	77.95(6.35)	76.21(7.01)
	Higher	69.41(7.06)	64.97(6.35)	63.84(7.47)	62.29(7.94)
	Typical	59.39(8.23)	54.58(6.36)	54.63(7.68)	52.92(7.86)
	Lower	47.00(8.77)	43.67(6.96)	76.05(6.05)	43.47(8.19)
Acceptable noise level (dB)	Highest	0.77(2.16)	–0.79(2.11)	–2.00(1.91)	–2.03(1.82)
	Higher	1.00(2.46)	–1.64(1.76)	–2.61(1.68)	–2.84(1.53)
	Typical	2.58(3.38)	–1.27(1.77)	–3.18(1.54)	–3.32(1.29)
	Lower	5.29(5.52)	–0.18(2.09)	–3.74(1.96)	–3.82(1.50)

expected, the mean typical MCL, BNL and ANL at all levels, was higher in the affected ear than in the contralateral ear of patients and higher than in the ears of normal-hearing subjects, which is consistent with the results of a previous study [12]. In both ears of normal-hearing people, the ANL increased with the increase of speech presentation level. There was no statistically significant difference in the ANL growth between their two ears (p=0.630). Although this finding on absolute ANL is consistent with the results of previous studies [14, 15, 19, 20], the ANL growth and its pattern were significantly different in MD patients in the present study. The difference in the ANL growth of affected and contralateral ears of patients in our study compared to the subjects in the above-mentioned studies can be related to the difference in the ANL of subjects, ear pathologies, and the methods of determining speech presentation levels.

In the present study, all normal-hearing people had a low mean ANL at all speech presentation levels (<–2). In the study by Tampas and Harkrider, people with lower ANL showed a smaller increase in ANL growth by increasing the speech presentation level compared to the people with higher ANL [19]. In present study, the ANL growth was 0.05 dB for both normal ears. The ANL growth for the affected and contralateral ears of MD patients was –0.03 dB and –0.17 dB, respectively. This is completely different from the ANL growth shown by Tampas and Harkrider [19]. They found that the ANL growth was 0.15 dB and 0.44 dB for individuals with low and high ANLs, respectively [19]. This discrepancy maybe be due to difference in the hearing status of subjects (normal hearing subjects in their study and MD subjects in our study). In addition, they used just two fixed presentation levels (35 and 70 dB HL), whereas we used a more adaptive presentation level (10 dB lower or higher than MCL). Other factors can be involved which needs more studies.

While the previous studies used a fixed speech presentation level, we applied different presentation levels based on each subject's typical MCL. This might be resulted in different ANL growth patterns. In the affected ear of MD patients, the ANL growth pattern was totally different from that of normal-hearing subjects. It seems that the method in our study used for selecting the presentation levels is effective for evaluating the unilateral MD patients and comparing them with other pathologies in clinical and research settings. Previous studies have shown that the ANL is associated with audiogram slope and thresholds at low frequencies [17]. Considering the relationship of typical ANL and ANL growth with PTA in present study, it seems that the difference in ANL growth pattern for MD patients is due to the pattern of

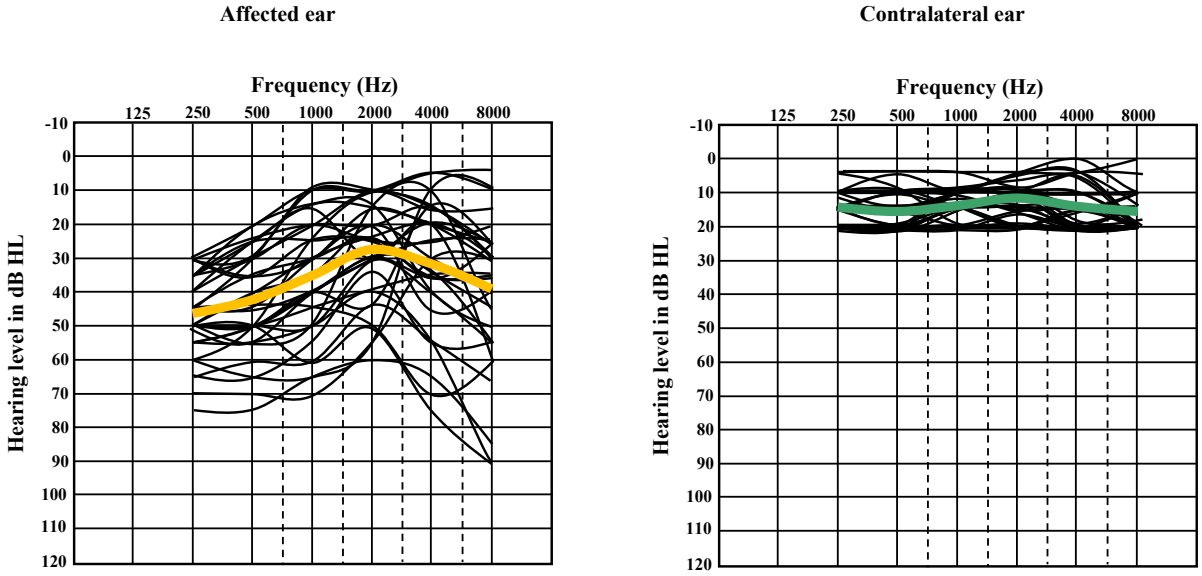

Figure 1. Mean hearing thresholds in the affected and contralateral ears of individuals affected by unilateral Meniere disease

hearing loss such that, as the disease progresses with the increase of hearing loss, the ANL growth in the affected ear decreases. Our findings suggest that we can use the ANL test and the ANL growth in clinical practice for MD patients, especially for evaluating their hearing status and monitoring the medical treatments.

Another notable finding in this study was that, with the increase of speech presentation level, the ANL in the contralateral ear of unilateral MD patients (which had normal hearing thresholds) had a pattern similar to that of the affected ear. It suggests that the condition of the contralateral ear in unilateral MD may be normal in terms of hearing threshold status, but abnormal in terms of performance in noise (noise tolerance); its pattern was also similar to the pattern of the affected ear, but had different elevations due to the difference in the hearing thresholds between the two ears. Therefore, in patients with unilateral MD, we should not define the criteria for normal or abnormal hearing only based on having normal hearing thresholds; we should consider the function of the ear in auditory processing such as noise tolerance. Moreover, it has long been proven that, in unilateral MD, the contralateral ear cannot be considered as a normal ear to compare with the affected ear, because the contralateral ear has functional abnormalities [21]. Consistently, the results of a histological study on the temporal bone of the contralateral ear in patients with unilateral MD in comparison with normal-hearing individuals showed the significant reduction of inner hair cells, outer hair cells,

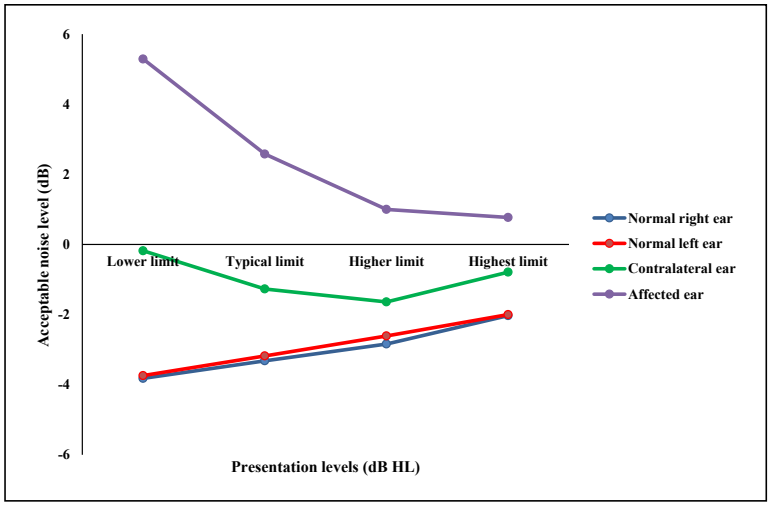

Figure 2. Mean acceptable noise levels as a function of presentation level for normal listeners and participants affected by unilateral Meniere disease

and spiral ganglion cells as well as small stria vascularis, which play a vital role in the performance in noise [22]. Based on the findings, it can be said that the ANL test at different speech presentation levels can be used to determine the function of both ears in patients with unilateral MD, especially the function of their contralateral ear which seems to have normal hearing thresholds.

Studies have shown the involvement of the contralateral ear in patients with unilateral MD and the worsening of its hearing thresholds in the future can lead to transformation from unilateral to bilateral MD [23-26], although the deterioration of hearing thresholds take more time [4]. In this study, two years had passed since the initial diagnosis of MD in patients; hence, the hearing threshold of contralateral ear might not yet be involved or elevated; however, it seems to be involved in terms of noise processing and consequently performed completely different compared to a normal-hearing ear. The ANL test may be a better test for determining the function of the contralateral ear in unilateral MD compared to conventional audiometry, as the distortion product otoacoustic emission input/output functions have also been shown to be a better criterion for evaluating inner ear function in MD patients compared to conventional audiometry [27]. It seems that in people with MD, due to the changes in the cochlea of inner ear, signal processing in noise is different than in normal-hearing people and people with SNHL [21-26], but there is a need for further studies on how this processing pattern changes and what criteria are used for these patients in determining their ANL that lead to a difference in the ANL growth patterns.

Conclusion

In unilateral Meniere's Disease (MD), although the contralateral ear seems to have normal hearing thresholds, its noise tolerance is similar to that of the affected ear. We used different speech presentation levels when testing the acceptable noise level growth. This method can be used when evaluating patients with unilateral MD in clinical settings.

Ethical Considerations

Compliance with ethical guidelines

This study approved by the Research Ethics Committee of Shahid Beheshti University of Medical Sciences (Code: IR.SBMU.RETECH.REC.1400.1233).

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors' contributions

EN: Study design, acquisition of data, statistical analysis, interpretation of the results, drafting the manuscript; HJ: Study design and supervision, interpretation of the results, and critical revision of the manuscript; NY and MEM: Interpretation of the results, and validation the final revision of the manuscript; AAB: Validation of data acquisition and statistical analysis.

Conflict of interest

The authors declare that they have no conflict of interest.

Acknowledgements

The authors would like to thank all participants for their cooperation in this study.

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