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Tzu Chi Medical Journal

ELSEVIER

Original Article

Susceptible Frequencies and Audiometric Configurations of Hearing Loss in Subjects With Coronary Artery Disease and Hypertension

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Article info

Article history:
Received: March 5, 2010
Revised: August 9, 2010
Accepted: September 28, 2010

Keywords:
Audiometric configurations
Coronary artery disease
Hearing thresholds
Hypertension

Abstract

Objective: Cardiovascular diseases are associated with age-related hearing impairment. But the affected frequencies and audiometric configurations have rarely been studied simultaneously. This study aimed to assess the susceptible frequencies and audiometric configurations in subjects with coronary artery disease (CAD) and hypertension (HTN).

Materials and Methods: From August 2007 to September 2008, the records of 908 adult participants who underwent pure tone audiometry (PTA), who were older than 50 years of age, and who were in the non-CAD, non-HTN group or who had CAD and/or HTN were collected. The associations of CAD or HTN with average PTA level at low (0.25 and 0.5 kHz), middle (1 and 2 kHz), and high (4 and 8 kHz) frequencies and audiometric configurations were analyzed.

Results: The presence of CAD, HTN, or both was associated with poor hearing thresholds at all frequencies before adjusting for age and sex. Using multivariate linear regression analysis, CAD or HTN alone did not show a significant association with PTA; but comorbid CAD and HTN showed a significant positive association with PTA, especially at the middle and high frequencies. "Mild sloping" was the most common audiogram pattern in the non-CAD, non-HTN group and in those with both CAD and HTN, and the audiometric configurations were not significantly different between the two groups.

Conclusion: Comorbid CAD and HTN had a negative impact on hearing function, especially at the middle to high frequencies. However, the effect of cardiovascular disease on hearing was not strong enough to change the audiogram patterns. (*Tzu Chi Med J* 2010;22(3):141–145)

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1. Introduction

Cardiovascular disease (CVD) and age-related hearing impairment (ARHI) are very common and closely related in elderly individuals (1,2). Previous reports have shown that ARHI is associated with myocardial infarction (MI) in women (3), and low-frequency hearing loss is associated with an advanced stage of CVD (4).

Retinopathy, a sign of retinal microvascular damage, is also associated with hearing impairment in women, particularly with low-frequency loss [5]. However, hypertension (HTN) is associated with hearing loss in the low and middle frequencies in elderly women [6,7], and at 1 kHz (middle frequency) only [8]. Therefore, it is generally accepted that CVD is associated with hearing impairment, but the detailed relationship between the affected frequencies and the severity of CVD remains a matter of debate. It seems that patients with mild forms of CVD, such as HTN, have poorer hearing in the low to middle frequencies; whereas those with advanced CVD, such as MI, or retinopathy, show hearing loss mostly in the low frequencies.

The cochlea is supplied primarily by a spirally oriented internal auditory artery in which the proximal portion supplies the basal turn and the distal portion supplies the apex. So, it seems reasonable to expect that the cochlea apex, which is responsible for low-frequency hearing, would be more prone to ischemic injury. However, this may not be completely true because of the existence of complex anastomoses and autoregulation in the cochlea. Also, direct evidence of blood flow disturbance in the cochlea is still lacking in most cases [9]. Instead, deterioration of the endocochlear potential affected all the turns of the cochlea in a model of angiopathy [10]. Thus, it is still reasonable to hypothesize that CVD at either an early or advanced stage might also be associated with loss of hearing in the middle and high frequencies.

The association between CVD and ARHI has been studied extensively. However, the affected frequencies and audiometric configurations have never been analyzed simultaneously, especially in patients with coronary artery disease (CAD) and HTN. We hypothesized that the presence of both CAD and HTN as comorbidities might be associated with hearing loss not only at the low frequencies, but also at the middle or high frequencies. In addition, comorbid CAD and HTN might result in specific audiometric configurations. In this study, we determined the frequencies of hearing loss and audiometric patterns among patients with CAD, HTN, or both, and non-CAD, non-HTN individuals.

2. Materials and methods

2.1. Patients

From August 2007 to September 2008, the records of 908 adult patients who were older than 50 years of age and who received routine pure tone audiometric (PTA) examinations were collected from the Department of Otolaryngology, Buddhist Dalin Tzu Chi General Hospital. The institutional review board of Buddhist Dalin Tzu Chi General Hospital approved the study protocols.

2.2. Inclusion criteria

The inclusion criteria were age >50 years and normal hearing or symmetric sensorineural hearing loss as determined by an audiogram (defined as 15 dB or less asymmetry at two or fewer frequencies).

2.3. Exclusion criteria

The exclusion criteria were cognitive dysfunction, pregnancy, hormone replacement therapy, and a history of any of the following: external or middle ear disease, conductive hearing loss and a 4-kHz dip on audiography, acoustic trauma, exposure to high environmental noise or ototoxic drugs, any neurologic or psychiatric disease, brain tumor or vestibular schwannoma, MI, stroke, claudication, diabetes mellitus, chronic hepatitis, liver cirrhosis, chronic renal failure, cancer, radiation exposure, heavy smoking, and alcoholism or substance abuse. Patients who received coronary artery bypass grafting or peripheral artery bypass surgery were considered to have severe CVD and were excluded as well.

2.4. Definitions of CAD and HTN

CAD was defined as a history of angina pectoris or confirmed by exercise electrocardiography (early-onset angina, ST-segment depression ≥2 mm, ST-segment elevation, failure to increase systolic blood pressure or a sustained decrease in blood pressure after an appropriate rise during exercise, and low exercise tolerance) [11] or positive treadmill exercise test, or positive coronary angiography or positive MI study. HTN was defined as a systolic blood pressure ≥140 mmHg and/or a diastolic blood pressure ≥90 mmHg [12].

The participants were divided into four groups: non-CAD, non-HTN group; patients with CAD; patients with HTN; and patients with both CAD and HTN. All patients with CAD and/or HTN were treated regularly in the outpatient department of the Department of Cardiology of our hospital. The non-CAD, non-HTN group was selected from the study population and met all of the inclusion and exclusion criteria but was free of CAD, HTN, and other systemic diseases.

2.5. Hearing levels

Six frequencies were tested on routine PTA. An average threshold of 250 Hz and 500 Hz in both ears was defined as the average pure tone hearing level at low frequencies (PTA-low); that of 1 kHz and 2 kHz in both ears was defined as the average pure tone hearing level at middle frequencies (PTA-mid); and that of 4 kHz

and 8 kHz in both ears was defined as the average pure tone hearing level at high frequencies (PTA-high). In addition, hearing impairment was defined as a PTA ≥ 20 decibel hearing level (dB HL).

2.6. Audiometric configurations

We initially classified the audiometric configurations of hearing impairment into six types according to the following patterns: flat, mild sloping, moderate sloping, abrupt middle-tone loss, abrupt high-tone loss, and reverse sloping. These six audiometric configurations were defined as follows: flat, violation of the hearing threshold at all frequencies was within 10 dB HL; mild sloping, the average of the middle two frequencies (1 and 2 kHz) was greater than that of the lower two frequencies (250 and 500 Hz) and smaller than that of the higher two frequencies (4 and 8 kHz) within 10–20 dB HL; moderate sloping, the average of the middle two frequencies (1 and 2 kHz) was greater than that of the lower two frequencies (250 and 500 Hz) and smaller than that of the higher two frequencies (4 and 8 kHz) within 20–30 dB HL; abrupt middle-tone loss, the average of the middle two frequencies was 30 dB HL or greater than that of the lower two frequencies, but the difference between the average of the middle two and higher two frequencies was within 10 dB HL; abrupt high-tone loss, the average of the higher two frequencies was 30 dB HL or greater than that of the middle two frequencies, but the difference between the average of the lower two and middle two frequencies was within 10 dB HL; and reverse sloping, the average of the lower two frequencies was 10 dB HL or greater than that of the middle two frequencies (2).

We found only four types of audiometric configurations (there was no abrupt high-tone loss or reverse sloping) in the individuals in this study.

2.7. Statistical analysis

The data are presented as mean ± standard deviation, unless otherwise indicated. ANOVA or the χ^2 test was used to test the differences in variables between groups. A multivariate linear regression model using the least squares approach was performed to test the association of age, sex and diseases with PTA-low, PTA-mid and PTA-high. The distribution of audiometric configurations in the non-CAD, non-HTN group and groups with CAD and/or HTN was analyzed by Fisher's exact probability test. A p value <0.05 was considered to be statistically significant. All analyses were performed using STATA version 10.0 (StataCorp LP, College Station, TX, USA).

3. Results

There were 605 participants in the non-CAD, non-HTN group, 42 patients in the CAD group, 191 in the HTN group, and 70 in the CAD+HTN group. Mean age was 62.6±9.02 years (range, 50–93 years); mean age and female-to-male ratio were not significantly different among groups (Table 1).

The PTAs in the four groups without adjustment for age and sex are shown in Table 2. The PTA-low, PTA-mid and PTA-high were all slightly higher in the HTN group and obviously higher in the group with both CAD and HTN compared to the non-CAD, non-HTN group ($p<0.0001$, ANOVA).

Multivariate linear regression analyses for PTA-low, PTA-mid and PTA-high by age, sex, and disease are shown in Table 3. PTAs were significantly affected by age and sex. The presence of both CAD and HTN, but not CAD alone or HTN alone, had a significant positive association with PTA-mid (β±SE=6.31±2.247, p=0.005) and PTA-high (β±SE=7.80±2.612, p=0.003). But the positive association of both CAD and HTN as comorbidities with PTA-low showed only borderline significance (β±SE=4.07±2.142, p=0.058).

Table 1 — Age and sex in different disease entities

	n (%)	Sex* (F/M), n	Age*†
All patients	908 (100)	536/372	62.6±9.02 (50–93)
CAD only	42 (4.6)	27/15	64.7±8.04 (50–81)
HTN only	191 (21.0)	104/87	65.1±9.07 (50–89)
CAD+HTN	70 (7.7)	39/31	69.5±10.07 (50–93)
Non-CAD, non-HTN	605 (66.6)	336/239	60.9±8.35 (50–91)

*Sex and age distribution were not significantly different among groups (p=0.393 for sex, χ^2 test; p=0.097 for age, ANOVA); †data presented as mean±standard deviation (range). CAD=coronary artery disease; HTN=hypertension.

Table 2 — Pure tone audiometry (dB HL)*

	Non-CAD, non-HTN	CAD only	HTN only	CAD+HTN	p†
PTA-low	23.1±17.28	28.0±20.87	28.0±20.64†	36.2±23.82†	<0.0001
PTA-mid	25.0±18.62	29.4±22.37	31.8±23.37†	41.9±25.47†	<0.0001
PTA-high	38.6±25.03	44.5±25.26	48.1±26.02†	60.1±27.05†	<0.0001

*Data presented as mean±standard deviation; †ANOVA. CAD=coronary artery disease; HTN=hypertension; PTA=pure tone audiometry.

Table 3 — Multivariate linear regression analysis for PTA-low, PTA-mid and PTA-high by age, sex and comorbidity*

	PTA-low	PTA-mid	PTA-high
Age	1.04±0.064 (<0.001)	1.207±0.067 (<0.001)	1.50±0.078 (<0.001)
Sex†	1.89±1.120 (0.091)	5.67±1.174 (<0.001)	14.71±1.365 (<0.001)
Non-CAD, non-HTN‡	–	–	–
CAD only	0.97±2.631 (0.712)	0.06±2.760 (0.983)	0.60±3.208 (0.851)
HTN only	0.52±1.388 (0.707)	1.50±1.456 (0.303)	2.34±1.692 (0.166)
CAD+HTN	4.07±2.142 (0.058)	6.31±2.247 (0.005)	7.80±2.612 (0.003)
Adjusted R^2	0.2625	0.3286	0.4146

*Data presented as β±standard error (*p*); †male versus female; ‡data for the CAD only, HTN only and CAD+HTN groups are shown compared to the non-CAD, non-HTN group with statistical adjustment of the other variables. β=coefficient; PTA=pure tone audiometry; CAD=coronary artery disease; HTN=hypertension.

Table 4 — Audiometric configurations in the non-CAD, non-HTN and CAD+HTN groups*†

	Pattern				Total
	Mild sloping	Moderate sloping	Abrupt middle tone loss	Flat	
Non-CAD, non-HTN	286 (47.3)	138 (22.8)	130 (21.5)	51 (8.4)	605 (100)
CAD+HTN	25 (35.7)	17 (24.3)	24 (34.3)	4 (5.7)	70 (100)

*Data presented as *n* (%); †difference between groups was insignificant (p=0.086, Fisher's exact probability test).

In the subgroup analysis by sex, PTA-low was not significantly affected by the presence of CAD alone, HTN alone, or both in either sex (β±SE=3.71±2.562, p=0.149 for women; β±SE=4.82±3.643, p=0.187 for men) (data not shown). PTA-mid was significantly affected by the presence of both CAD and HTN as comorbidities in women (β±SE=6.75±2.793, p=0.016), but the effect was of borderline significance in men (β±SE=6.10±3.674, p=0.098) (data not shown). The presence of both CAD and HTN as comorbidities was significantly associated with elevated PTA-high in women only (β±SE=8.61±3.321, p=0.010), but not in men (β±SE=6.93±4.208, p=0.100) (data not shown).

There were no abrupt high-tone loss or reverse sloping patterns among the audiometric configurations in this study. "Mild sloping" was the most common audiometric pattern in the non-CAD, non-HTN (47.3%) group and in the CAD+HTN group (35.7%) (Table 4). The distribution of audiometric patterns was not significantly different between the two groups (p=0.086, Fisher's exact probability test), although the "abrupt middle-tone loss" pattern was slightly more prevalent in the CAD+HTN group. The same results were obtained in a subgroup analysis by sex (data not shown).

4. Discussion

This cross-sectional study provides new insight into the characteristics of hearing impairment in patients with both CAD and HTN. We found that the presence of CAD or HTN alone was not significantly associated with hearing loss in elderly individuals, but the presence of both of these two diseases was. However, we could not find an audiometric configuration that was specific to the presence of CAD and HTN as comorbidities.

Previous studies showed that CVD is associated with ARHI, especially in older women [3–5,7,8]. It has been shown that the incidence of heart disease among women rapidly approaches that in men [13], and women lose the protective effect of estrogen on hearing after menopause [14–16]. Therefore, it is reasonable to conclude that the hearing of women could be more obviously affected by CVD. Our results support these findings [3–5,7,8].

CVD has been reported to be associated with low-frequency [6,8] and middle-frequency hearing loss [5,8]. From the pathophysiological perspective, it is reasonable to expect that the cochlea apex, which is responsible for low-frequency hearing, would be more prone to ischemic injury. But angiopathy could also lead to reduction of the endocochlear potential [10], which could affect all turns of the cochlea. Thus, the observation that CVD is associated with middle- and high-frequency loss is also reasonable. However, it is still unknown which mechanisms are dominant or which frequencies would be affected first and which later as CVD deteriorates.

In this study, we excluded patients with MI, stroke, coronary artery bypass graft, peripheral artery bypass surgery, and other systemic diseases. We found that hearing loss was significant in the middle and high frequencies among women who had both CAD and HTN as comorbidities and who were not receiving hormone replacement therapy. In contrast, the audiometric configuration analysis did not support our findings at the affected frequencies. In fact, the findings of the affected frequencies could not be directly applied to the

audiometric configurations. The audiogram patterns of most participants with both CAD and HTN were still of the "mild sloping" type and were not significantly different from those of the non-CAD, non-HTN patients, although some frequencies worsened because of CVD status. In other words, we suggest that the effect of CVD on hearing is not strong enough to change the audiogram pattern.

The results of this cross-sectional study by chart review might be weakened by information bias and classification bias. Therefore, a large-scale prospective cohort study should be conducted to classify the actual susceptible frequencies in both early-stage and advanced-stage CVD. Also, audiogram patterns should be classified into more categories and be linked to specific diseases.

The hearing thresholds were not affected by CAD or HTN alone, but hearing at middle to high frequencies was negatively associated with comorbid CAD and HTN in elderly women. However, the effect of CVD on hearing was not strong enough to change the audiogram patterns.

Acknowledgments

The study was supported by funding from Buddhist Dalin Tzu Chi General Hospital (DTCRD-96 (2)-09).

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