Chapter

Presbycusis-Related Tinnitus and Cognitive Impairment: Gender Differences and Common Mechanisms

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Abstract

Presbycusis-related tinnitus and cognitive impairment are common in the elderly and generate a massive burden on family and society. Except for age, the study explored the gender differences in the prevalence of the three diseases. We found that women have an advantage in maintaining better cognitive and auditory functions. Recent studies suggest the complex links among the three diseases. Peripheral hearing loss can affect sound coding and neural plasticity, which will lead to cognitive impairment and tinnitus. The deficits of the central nervous system, especially central auditory structures, can, in turn, cause the presbycusis. The interaction among three diseases indicated that comprehensive assessment, intervention and treatment in consideration of hearing loss, tinnitus and cognitive impairment are important to decay aging.

Keywords: presbycusis, tinnitus, cognitive impairment, elderly, gender

1. Introduction

Presbycusis-related tinnitus and cognitive impairment are common diseases in the elderly. The three diseases coexist and affect each other.

Presbycusis, also called age-related hearing loss (ARHL), is one of the most frequent hearing disorders among the elderly population. Presbycusis is defined as a bilateral, symmetrical, chronic, and progressive hearing loss, which occurs gradually and initially affects the function of the higher pitched (higher frequency) region [1]. The prevalence of presbycusis is increased rapidly with age increase. Approximately one-third of adults from 61 to 70 years old and more than 80% of populations older than 85 years old in the world complain about the hearing loss [2]. Presbycusis is one of the most common disability conditions, according to the Second China National Census on Disability in 2006. The prevalence of elderly with audition deformity is about 15.4 million, accounting for 34.59% among all types of deformity in people at 60 years and above [3]. Presbycusis is a multifactorial age-related disease that may relate to the interaction among genetic, environmental, and comorbid factors.

Not only the damage of peripheral auditory organs but also the dysfunction of the central auditory nervous system contributes to the sensation of sound.

Therefore, many authors focus on the association between defects in central auditory processing and neurodegenerative diseases [4]. Alzheimer's disease (AD) is the commonest neurodegenerative dementia that occurs in population after 40 years. With the increase of age, the incidence of AD is increased rapidly among the population. Epidemiological surveys show that the prevalence of AD between the ages of 40 and 65 is 1 in 5000 [5]. However, the overall prevalence of dementia increased to 8.5% after 65 years old. By the 85 years old, the prevalence is >20% and creates a devastating burden between family and society [6]. In addition to age, gender, education level, and disease states, such as cardiovascular disease, hyperlipidemia, etc., are all considered as the critical factors of AD [7]. Hearing loss is reported as the independent risk factor for the development of dementia, and 46.4% of dementia was related to hearing loss [8].

Presbycusis can contribute to the emergence of tinnitus. In an epidemiological cohort study, participants were 17% more likely to have tinnitus with every 5-dB increase in pure tone audiometry (PTA) [9]. Tinnitus is charactered as the conscious perception of an abnormal sound in the ears or head either unilaterally or bilaterally, without any external acoustic stimulus [10]. The prevalence of tinnitus increases with increasing age and hearing loss [11, 12]. The etiology of tinnitus remains mostly elusive. Presbycusis-related tinnitus increases cognitive load, including mental balance, attention, concentration, and immediate recall [13]. However, the evidence between tinnitus and cognitive impairment has not been found yet. As lifespans lengthen, the prevalence of elderly populations with presbycusis, dementia, and tinnitus increases rapidly. This review aims to figure out the characters and gender differences of elderly populations with presbycusis-related tinnitus and cognitive impairment and investigate possible mechanisms and treatments.

2. The gender difference in presbycusis

Apart from age, gender seems to be one of the reasons accounting for hearing loss. Numerous epidemiological evidence have suggested that women have better auditory function than men. However, the sexual dimorphism of the function of auditory is tended to converge with aging [14]. Men demonstrate a higher prevalence of presbycusis compared to women. In the 20–69 years old age group, more American men suffer bilateral hearing loss than women [15]. Above 70 years old, men also show independently associated with a higher prevalence of hearing impairment in the United States [16]. For Asian people, similarly, men show higher associated with high frequency hearing loss in the Korean. However, after the age of 60, the level of hearing decline between men and women is similar to age [17]. Pearson et al. found the evidence that the hearing sensitivity decreases with age in both men and women, more rapidly in men than women in young ages or frequencies, in which the decrease begins between age 30 in men and later in women. Though women maintain better auditory function at a young age, they tend to decline fast after menopause. By age 80, the rates of hearing loss are similar between men and women. Sexual dimorphism may be due to the loss of estrogen and progesterone protection [18]. Sexual hormones help women to have benefits in high frequencies. Compared to women at the same age (after menopause), a large cohort study of the healthy population showed that older men had a 10–25 dB worse hearing threshold in the high frequencies [19]. While women have shorter latencies in auditory brainstem response [20], the difference from sex and age cannot be simply explained by the effects of anatomical abnormalities or occupational noise, but it may be related to the decrease of endogenous estrogen that lost the protective effect of estrogen on the auditory system.

3. The gender difference in tinnitus

Elderly Women suffered a lower prevalence of hearing loss and tinnitus loudness than men did, but tinnitus annoyance was stronger in older women than men [21]. However, the underlying mechanism of the difference between men and women is still mysteries. Nondahl et al. reported that an epidemiological cohort study containing 3267 participants from 21 to 84 years old demonstrated that the prevalence of tinnitus was higher for men than for women (11.9 vs. 9.4%, $p = 0.02$), and higher for older (age from 55 to 84 years old) than younger participants (14.4 vs. 9.0%, $p < 0.001$). However, adjusted for factors related to tinnitus, it showed no association between sex and tinnitus [9]. An epidemiological study of 6333 population in China showed no significant difference in prevalence between men and women age >60 years [22]. For the loudness of tinnitus, some found a low correlation of gender [23], while others reported significantly higher loudness in men compared to women. However, older women tend to report a higher level of an emotional reaction than men with tinnitus [20] and frequently more severe, accompanied by vertigo [24].

4. The gender difference in cognitive impairment

The majority of epidemiological research indicated that women with aging are sensitive to dementia even after controlling for increased life span and education level, which show a rapid decline in a cognitive deterioration compared with age-matched men [25]. The animal experiment indicated that follicular depletion might initiate age-related impairments for cognitive flexibility [26]. The postmenopausal women have a two-fold higher lifetime risk of developing AD than men and demonstrate a faster cognition decline [27, 28]. However, some clinical evidence show that older women performed better on the global function test while men at the same age on the executive function test, respectively [29], and found more significant risk for men [30]. Other studies suggested that gender does not play a role in the prevalence of AD [31, 32].

5. The association between presbycusis and tinnitus

Several researches suggest that hearing loss contributes to the higher prevalence of tinnitus [33]. At present, the following two reasons are mostly considered. One reason is the sensory deprivation of the auditory system. The decrease in auditory stimulation leads to the unbalance between excitation and inhibition in the auditory nervous system [34]. The auditory nervous system has both suppression and excitation response region. Once a sound is inputted, excitation action will be activated and lateral inhibition appears consequently. Hearing loss reduces the activity of cochlear and downregulates inhibitory neurons processes, thereby activating the central auditory structures, increasing the spontaneous firing rate of neurons, resulting in the awareness of tinnitus. Sound stimulation at different frequencies can inhibit the formation of tinnitus. Studies have shown that high frequency sounds have a stronger suppression of tinnitus, and the decline of high frequency is a common and typical symptom in the ARHL [35]. The activation of neural plasticity in the central auditory system plays a vital role in maintaining the sensory of tinnitus [36]. Because when the auditory nerve was removed, the tinnitus persists [37]. Neural plasticity can change the processing of sounds, reroute auditory signals in the central nervous system, increase neural synchrony, and promote coherent

firings of activity in many neurons [38]. Another reason is that hearing loss and tinnitus share the same common risks, including age, cardiovascular disorders, and noise exposure [39].

6. The association between presbycusis and cognitive decline

Clinically, patients with presbycusis usually perform worse than others in function of speech and communication, resulting in negative psychosocial endings such as social isolation and social frailty [40]; depression, poor cognitive performance and even induce cognitive decline [33, 41]; and low physical performance and physical frailty [42, 43]. A meta-analysis of 36 epidemiological studies and 20,264 participants showed that the decline of cognitive domains are significantly associated with ARHL [44]. Hearing loss is considered as the independent risk factor for the development of dementia, and 46.4% of patients with dementia were accompanying hearing loss [8]. There may be a bidirectional connection between presbycusis and dementia. On the one hand, it is more likely for the elderly with hearing impairment to suffer dementia than the healthy elderly [45], and on the other hand, the hearing threshold of the elderly with dementia is significantly lower than the healthy elderly [45–47]. A large cross-sectional study in the UK shows the association between hearing aid use with better cognitive function [48]. The hearing intervention significantly improves the auditory and cognitive function in the elderly [49].

Presbycusis and dementia may share some common pathophysiological mechanisms [50, 51] once degradation on one pathway may accelerate the degradation on each other disease. The hypothetical mechanistic pathways are still uncertain. However, some authors may agree that hearing loss can impair speech perception and distort peripheral encoding of sound by the cochlea. Besides, peripheral hearing loss has a negative influence on the measurements or process of central auditory; finally, it increases cognitive load, depletes cognitive reserve, alters brain structure and function, and affects global cognition [52, 53]. Hearing loss will cause social isolation and loneliness associated with chronic stress and depression. The psychosocial outcomes contribute to hippocampal atrophy and cognitive decline through the hypothalamic-pituitary-adrenal (HPA) axis [8, 54]. The dysfunction of HPA axis results in the atrophy of pyramidal cell dendrites, thereby reducing the ability of hippocampal structural plasticity and synapse generation.

7. The association between cognitive decline and tinnitus

Little research focuses on the association between presbycusis co-occurring with tinnitus and dementia. However, central nervous degenerative diseases such as dementia will affect central auditory systems (i.e., temporal and adjacent frontal lobes) and cause central auditory disorders, which is an essential physiological pathway of the diseases. Not only the central auditory structure but also the non-auditory brain areas (i.e., frontal cortex or the limbic system) play a vital role in sound perception, understanding, and emotional awareness [55]. Inflammation and ischemia will cause disturbances to the central nervous system [56]. When the neural substrates of tinnitus (i.e., medial temporal lobe, primary auditory, and frontal cortices) are involved, tinnitus and hearing allergies occur [57]. Meanwhile, inflammation and ischemia can develop neurodegeneration disease of AD in frontoparietotemporal [58]. AD shares the same pathological basis with

tinnitus, although targets in different areas. On the other hand, chronic tinnitus is significantly associated with anxiety and depression. The limbic system was proved to contribute to the emotional burden. Presbycusis co-occurring with tinnitus may accompany vestibular/balance difficulties, similar to anxiety and depression; it will reduce social activity and finally leads to late-life cognitive decline [53].

8. The treatments in the coexistence of presbycusis-related tinnitus and cognitive impairment

Presbycusis-related tinnitus and cognitive impairment are complex diseases without any effective treatment by far. However, compared to age-matched men, women before menopause seem to have a better auditory and cognitive function, while the different fades away with age. Sex hormones may play an important role. The association among the diseases indicates the feasibility of intervening in the hearing loss to ameliorate the tinnitus and cognitive impairment. A comprehensive assessment is a prerequisite for treatment. Hearing aid and cochlear implantation are the most important treatment of hearing loss.

Emerging studies suggest that the use of hearing aid or cochlear implants can not only focus on auditory rehabilitation but also improve the symptom of cognitive function and tinnitus [59–62]. However, the prevalence of hearing aid use is low [63]. Only 14.2% of Americans 50 years old with hearing loss wear hearing aids, not to mention the populations in developing countries [64]. Many patients with hearing loss tend to ignore the hearing loss as normal aging until the accelerated deterioration of the auditory function. Furthermore, the expensive cost of hearing aid and cochlear implantation hold back the eager of intervention.

In turn, advanced technology and equipment (i.e., virtually reality) can be designed to improve cognitive function and central auditory disorder through reasonable and repeated cognitive and behavioral treatment for functions such as sensation, cognition, emotion, and motor control [65, 66].

9. Conclusion

Presbycusis-related tinnitus and dementia are a common disturbance to the elderly but always be unnoticed at an early stage. Age is the most important factor for the diseases. Apart from age, most epidemiological evidence suggest that women have a better auditory and cognitive function and less prevalence of tinnitus than men; however, the advantages disappear with age. The three diseases interact and promote each other with decreased peripheral hearing perception and central nervous system dysfunction. The elderly should pay attention to auditory function carefully. Maintaining normal peripheral and central auditory function can reduce cognitive decline and tinnitus. Conversely, the elderly with cognitive decline or tinnitus should actively participate in cognitive and behavioral treatment to enhance central auditory function.

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