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Advances in Falls in the Elderly with Hearing Loss

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【Abstract】 The incidence of hearing loss among the elderly is increasing along with the acceleration of global aging. Hearing loss can limit the ability of the elderly to monitor and perceive auditory cues for spatial orientation, resulting in confusion of orientation and increasing the risk of falls. Based on the review of the latest relevant studies, we introduced the epidemiological characteristics of falls in the elderly with hearing loss, described the pathogenesis (including neuropathological mechanism, sensory deprivation mechanism and physical mechanism), summarized the influencing factors (including age, gender, degree of hearing loss, nature of hearing loss, gait performance, and the use of hearing aids), and put forward strategies for the prevention and treatment of falls. We found that the incidence of falls is increasing in the elderly with hearing loss, and its risk grows with the aggravation of hearing loss, age, aging-related hormonal changes (especially in elderly women), the decline in balancing ability and negative emotions. To reduce the incidence of falls to ensure quality of life and safety in elderly people with hearing loss, it is suggested to prevent or treat falls in this group by the use of hearing aids and auditory rehabilitation training, drug therapy, balance assessment and physical exercise, and psychological intervention.

【Key words】 Aged; Hearing disorders; Hearing loss; Fall; Health services for the aged; Review

Hearing is an ability to activate the auditory organs and receive sound information, and good hearing helps in spatial orientation and avoidance of the hazards of falls^[1]. Hearing loss refers to organic or functional abnormalities in the auditory system at all levels of the nerve centers that transmit, sense, and synthesize and analyze sound, resulting in varying degrees of hearing loss^[2]. Hearing loss can limit the ability of older adults to monitor and perceive auditory cues for spatial orientation, leading to disorientation and increasing the risk of falls^[3]. Falls are a common accidental event in the elderly and are caused by a combination of factors^[4]. According to the World Health Organization (WHO), falls are a major health problem faced by older adults worldwide, ranking first in the incidence and mortality rate of unintentional injuries in older adults, and falls not only cause physical trauma and disability in the elderly, but also lead to depression, anxiety, activity limitation, fear of falling, and other problems^[5]. Recent studies have found that the incidence of falls in elderly people with hearing loss is increasing^[6], and the causes of

falls in this group are different from those in the general elderly population, so it is necessary to conduct a study on falls and related damages in this group. In this study, we reviewed the epidemiological characteristics, mechanisms, influencing factors, prevention of falls and related damages in elderly with hearing loss, with the aim of providing a reference for the elderly with hearing loss to provide individualized fall prevention and control measures and reduce the incidence of their falls.

1 Occurrence of falls in older adults with hearing loss

Recent findings show that there is a causal relationship between hearing loss and falls in the elderly, and that patients with hearing loss are at risk of falling even in the absence of vestibular disease or balance disorders^[7]. Numerous studies conducted in different countries and regions on different ethnic groups have found a potential association between hearing loss and falls^[8]. Hearing loss, as one of the risk factors for falls in older adults, can lead to decreased balance, increased variability in stride length, and decreased postural control^[9]. In a systematic evaluation of 12 eligible papers, researchers found that the probability of falls in older adults with hearing loss was 2.39 times higher than in those with normal hearing [OR (95%CI) = 2.39 (2.11, 2.68)], while hearing loss was associated with 72% increased incidence of falls in a subgroup analysis^[10]. Moreover, it has been found that falls and related damage become a major cause of increased mortality in the elderly with increasing age, especially with the progression of senile hearing loss (sensorineural hearing loss)^[11], which is increasingly becoming an important public health concern worldwide^[12]. According to WHO, the annual fall rate of the Chinese elderly population has reached 6.5%-30.6% till now^[13]. The results of a 7-year longitudinal study showed that hearing loss was significantly associated with falls among Chinese older adults, with a relatively higher incidence of falls in the hearing loss group (17.40%) than in the non-hearing loss group (12.30%)^[14]. The prevalence of self-reported hearing loss among Chinese older adults (75.31%)^[15] was relatively higher than that in Western countries (66.53%)^[16], which was attributed to the traditional belief that hearing loss is a normal part of aging life and that Chinese older adults are prone to ignore hearing loss-related problems, leading to an increase in the prevalence of hearing loss and falls and related damage in the Chinese elderly population^[17].

2 Mechanisms of falls in elderly people with hearing loss

2.1 Neuropathological mechanisms

Hearing loss is a common chronic condition in the elderly population caused by the accumulation of sensory cell damage in the inner ear^[2]. Development, anatomical and physiological similarities between vestibular and auditory organs and their associated nerves, overlap between pathways and general sensitivity to environmental risk factors^[18] lead to the coexistence of vestibular dysfunction and balance dysfunction in older adults with hearing loss^[19]. Both systems are also susceptible to age-related changes in calcium

metabolism, which is also associated with falls and related damage in older adults with hearing loss^[20].

2.2 Mechanisms of sensory deprivation It has been shown that long-term sensory deprivation due to age-related hearing loss can have lasting detrimental effects on brain structure and function, leading to cortical redistribution, deafferentation or atrophy, resulting in reduced speech perception processing and alterations in key brain regions for high-level cognitive processing, such as reduced cortical volume, brain pathology changes (amyloid load, neuronal loss, etc.)^[21], which leads to reduced auditory and spatial awareness of the surroundings in older adults with hearing loss^[22], further reducing their level of cognition to maintain balance during walking and their ability to respond to emergencies^[23]. The information degradation hypothesis suggests that reduced sensory input requires higher information processing abilities, including higher cognitive processing and semantic encoding^[24], which requires higher hearing levels and hearing demands, especially higher demands on attention, memory, and executive functions, and that increased hearing demands will lead to impaired balance function^[25], making patients more susceptible to falls and related impairments.

2.3 Physical mechanisms MOHAMMADI et al^[26] found that white noise via auditory input was associated with a reduction in head postural sway compared to the quiet state, including a reduction in sway area, sway amplitude, and sway frequency. ROSS et al^[27] used stochastic resonance to explain this phenomenon by exploring the role of auditory white noise in the control of participants' standing posture with eyes open or closed and found that when auditory noise was introduced, especially when participants stood with eyes closed, postural sway variability was reduced, and this reduction was attributed to stochastic resonance, i.e., signal amplification in the presence of noise, and the signal, noise, and nonlinear stochastic system produced a synergistic phenomenon, while in the case of hearing loss, the auditory afferent signal capacity was reduced, the area, amplitude, and frequency of body and head postural sway increased, the effect of stochastic resonance was reduced, and postural increased variability in control, making them more susceptible to impaired balance function and fall-related conditions.

3 Influencing factors of falls in older adults with hearing loss

3.1 Age A study has shown that for every 1 year increase in the age of older adults with hearing loss, the probability of postural instability leading to falls and related damage increases by 1.13 times^[28]. This is attributed to the fact that hearing loss as the growth of age, there will be reduced attention, orientation dysfunction and other physiological function decline^[29], and the degree of hearing loss increases with age, severe hearing loss can limit the ability of older adults to monitor and perceive spatial orientation, leading to impaired balance and orientation, and reduced stability of postural control, thus increasing the incidence of falls and related damage in older adults with hearing loss^[30]. This is different from the general causes of falls in the elderly.

3.2 Gender Some studies have shown that women are 1.65 times more likely than men to experience postural instability leading to falls and related damage [95%CI (1.12, 2.42)]^[28]. The reasons are the changes in hormone levels in the body after menopause, which affect both the cochlear structure and cochlear cell integrity of elderly women with hearing loss, which in turn affects the function of their auditory system^[31]; and the significant decrease in their skeletal muscle protein balance, reduced protein anabolic capacity and protein turnover, which in turn leads to the loss of their skeletal muscle size and mass^[32]. Some studies have shown that for every 10% decrease in bone mineral density, the risk of falls and fractures increases two to three times^[33], which is a problem faced by all older women. On the other hand hearing loss is more likely to cause social isolation, anxiety and depression in women, which in turn leads to their cognitive dysfunction, which further increases their risk of falls and related damage^[34]. Therefore, it is extremely important for elderly people with hearing loss, especially elderly women, to pay attention to early screening, diagnosis and treatment of hearing loss with appropriate exercise, nutritional support and psychotherapy to increase muscle mass, improve bone density, negative emotions and reduce the incidence of falls and related damage.

3.3 Degree of hearing loss Some studies have shown a significant dose-response relationship between the degree of hearing loss and the incidence of falls in older adults, i.e., as the degree of hearing loss increases, the incidence of falls and related damage becomes higher^[35]. This was also confirmed by relevant studies, where older adults with hearing loss [pure tone hearing threshold test (PTA) \geq 25 dB HL] were associated with threefold increase in the incidence of reported falls in the most recent year and a 1.4-fold increase in the probability that an individual reported a fall in the past year for every 10 dB HL increase in hearing loss^[36], with 12.2% and 11.9% incidence of falls due to postural instability and related impairments in older adults with severe and very severe hearing loss^[28], and severe hearing loss increases the risk of fractures of the distal radius, hip and spine throughout the life cycle of the elderly^[37]. The reasons for this are, on the one hand, the increasing degree of hearing loss leading to increasing levels of executive and orientational impairment in older adults, as evidenced by greater center-of-pressure displacement and velocity, as well as poorer postural control and balance, which are associated with an increased incidence of falls^[38]; on the other hand, older adults with moderate or greater hearing loss exhibit difficulties in daily verbal communication, which in most cases may require the speaker to repeat the content of the speech or even need to shout in the ear in order to understand part of the content, which largely leads to the reduction of speech perception and communication impairment of elderly people with hearing loss, and the increasing aggravation of communication impairment makes elderly people with hearing loss more reluctant to communicate with others, generating loneliness, depression, anxiety and social isolation^[39], and even causes different degrees of cognitive dysfunction, which further increases

the incidence of their falls and related impairments.

3.4 Nature of hearing loss Binaural asymmetric hearing loss (AHL) is a risk factor for falls and related damage in the elderly. Asymmetric hearing loss is defined as severe and above hearing loss in the worse ear and mild and moderate hearing loss in the contralateral ear^[40], mainly manifested as difficulty in sound source localization, reduced speech recognition in noise, and impaired cognitive function. If asymmetric hearing loss exists for a long time, the brain will sacrifice the sound source localization ability in exchange for enhanced hearing for a period of time, but this compensation is not beneficial to the recovery of bilateral hearing and sound source localization ability in the future, and even causes the deterioration of the degree of hearing loss in both ears^[41]. On the one hand, it will cause severe disorientation, cognitive dysfunction, speech communication impairment, and poor mood in elderly with hearing loss, and these conditions will largely increase their risk of falls and accidents; on the other hand, especially for elderly with occupational noise hearing loss (NIHL), the existence of asymmetry in binaural hearing loss is more obvious, and generally the degree of hearing loss in the right ear is higher than that in the left ear^[42], which is related to the fact that the right hemisphere is considered to be specialized in processing auditory information and has an advantage in speech^[43], and the more severe the degree of hearing loss in the right ear compared to the left ear, the more pronounced the increase in variability of gait parameters in elderly people with hearing loss, which deteriorates inter-limb coordination and balance control mechanisms, leading to an increased incidence of falls and related damage in elderly people with the presence of AHL. This is consistent with the findings that severe NIHL (≥ 52.5 dB HL), which is a risk factor for hospitalization after falls in retired workers [OR (95%CI)=1.97 (1.00, 3.88)]^[44].

3.5 Gait performance Auditory feedback modulates gait performance by providing temporal and spatial information. Gait performance is generally evaluated by gait parameters, including stride length, stride frequency, stride speed, foot clearance from the ground, swing period, double support time, and standing sway. With the increase of age and hearing loss, the gait parameters of the elderly change, including slower gait speed, reduced stride length, and lower gait frequency^[12]. The gait parameters change with age and hearing loss, including slower gait speed, less stride length, and lower gait frequency^[12, 45]. It has been found that for every 10 dB HL increase in high-frequency hearing thresholds in the left and right ear, the variability of double support time (the time period when the swing leg touches the ground and the weight is transferred from the support leg to the swing leg and the feet are in contact with the ground) in gait parameters increases by 1.022 and 0.759 percentage points, respectively, while the increase in hearing thresholds in the right ear is greater than the increase in double support time variability in the left ear, so the variability of double support time can be used as a mediating variable to explain the correlation between hearing loss and falls^[46]. It has also been found that there is a significant difference between the gait speed of older adults with

normal hearing and older adults with hearing loss, with slower gait speed in older adults with moderate and higher hearing loss leading to a higher incidence of falls^[45]. This further suggests that auditory feedback is important for leg coordination during walking and that hearing loss leads to impaired interlimb coordination, increased variability of gait parameters and deterioration of balance control mechanisms as a cause of falls in older adults^[46].

3.6 Use of hearing aids Wearing hearing aids can improve the degree of hearing loss. A study examining postural stability (using Romberg foam pads and tandem gait checks in a white noise environment) in hearing loss patients over 65 years of age with and without hearing aids found that older adults with hearing loss who used hearing aids had better postural stability^[47]. This was also confirmed by a 2016 study that used a Nintendo Wii balance board and foam pads to test the postural stability of study subjects in four acoustic environments and found that compared to those without hearing aids, hearing aid wearers had higher postural stability and fewer falls than those without hearing aids^[48]. It has also been found that elderly people with hearing loss who wear hearing aids have a significantly improved quality of life and a reduced fear of falling^[49-50]. Cochlear implants are also a way to restore hearing levels. One study evaluated the effects of cochlear implants on balance control and sensorimotor modalities and found that cochlear implant recipients were able to achieve near-normal balance function, improved gait stability, and a reduced overall risk of falls^[51-52].

3.7 Others Several studies have found that cerebrovascular disease, use of ≥ 5 medications, reduced social functioning scores, and elevated levels of depression and anxiety are associated with the occurrence of falls and related impairments in older adults with hearing loss^[45, 53-54]. However, the sample size, study methods, and research instruments of the relevant studies differ, resulting in high heterogeneity of findings and leading to lower quality of evidence and reliability of the relevant studies. Follow-up studies should be improved and refined to address these issues in order to enhance the reliability and generalizability of the findings.

4 Prevention and control measures for falls in older adults with hearing loss

4.1 Hearing aids and auditory rehabilitation training Hearing aids can improve the hearing level of elderly with hearing loss, which not only helps to improve their speech perception and communication ability and delay the development of cognitive impairment^[55], but also helps to improve their balance function and postural control ability, thus further reducing or avoiding the occurrence of fall-related situations^[56]. Hearing aids generally include hearing aids and cochlear implants: traditional hearing aids, as the main hearing rehabilitation intervention, are mostly used for elderly people with mild or moderate hearing loss in both ears; cochlear implants are high-tech biomedical engineering devices developed in recent years and are mostly used for elderly people with severe or profound hearing loss in both ears^[57]. Based on the results of comprehensive assessment of the etiology of hearing loss, the indications

for fitting or surgery of hearing devices, the elderly's own wishes, family situation, and the type and degree of hearing loss, a personalized fitting plan for hearing devices should be formulated for the elderly with hearing loss, timely and effective commissioning and evaluation should be conducted after the use of hearing devices to achieve a high degree of individual fit and user satisfaction^[58]. Auditory rehabilitation training aims to improve auditory skills, and it is advocated that patients should undergo auditory rehabilitation training in the first few weeks of hearing aid use, which can enhance the acceptance and adaptation of hearing aid users and improve the speech perception, auditory cognition, and communication skills of patients with hearing loss in a more effective way ^[59]. This can improve both the acceptance and adaptation of hearing aid users and the speech perception, auditory cognition, and communication skills of patients with hearing loss^[59].

4.2 Medication Medication measures include administration of antioxidants, restriction of caloric intake, avoidance of exposure to ototoxic drugs, and aggressive treatment of systemic diseases that can cause hearing loss^[58]. Studies have confirmed that antioxidant supplementation and caloric intake restriction can reduce oxidative DNA damage in cochlear cells and prevent cochlear lesions, delaying the onset and progression of hearing loss, and older adults with higher antioxidant vitamin supplementation showed better hearing levels^[60]. Studies have also confirmed the efficacy of combining Chinese and Western medicine in the treatment of hearing loss in the elderly, combining antioxidants and energy supplements with microwaves and ultrashort waves in Chinese medicine, and the results showed that such methods can regulate vascular function, relieve deep vascular spasm, dilate small arteries and capillaries, accelerate blood circulation, improve inner ear hypoxia, promote nerve fiber regeneration and repair its conduction function, and thus improve hearing levels^[61]. Hormonal (including estrogen, progesterone, aldosterone, melatonin, growth hormone, thyroid hormone and cortisol) therapy can also be used, especially for elderly women with hearing loss. Some studies have found that postmenopausal use of hormone therapy can slow the age development of age-related hearing loss and reduce the incidence of hearing loss in older women^[62]. It has also been found that postmenopausal women not treated with estrogen have lower hearing levels than postmenopausal women treated with estrogen^[63]. Since progestins have potential negative effects on hearing, including downregulation of estrogen receptors or reduction of cochlear blood flow^[63], whether progestins can be used in treatment needs to be further investigated. In the meantime, it is also possible to improve the skeletal and muscular status of the elderly, enhance the balance stability and coordination control of the body, and reduce the incidence of falls and serious damage by maintaining and increasing the bone mass and bone density of the elderly with hearing loss, using anti-osteoporosis drugs^[64] and participating in appropriate physical exercise^[65].

4.3 Assessment of balance and physical exercise Assessment of balance in older adults with hearing loss and

timely and effective related interventions are essential to prevent falls and related impairments. Some studies have shown that the balance ability of older adults can be assessed and interventions can be developed in terms of static and dynamic homeostatic balance, active balance, reactive balance, and limb muscle strength^[66]. Simple, quick, and low-cost tests and scales [closed-eye/one-leg upright test, Berg Balance Scale (BBS), Unified Balance Scale (UBS), etc.^[67-69]] can be used for assessment, as well as precise and objective assessment by sophisticated instruments (computerized dynamic balance, wearable devices)^[66]. The assessment can also be performed with precise and objective instruments (computerized dynamic balance, wearable devices)^[70]. The elderly with hearing loss are usually unable to recognize the direction and content of sound sources effectively, which reduces their ability to react, pay attention, and avoid danger in the face of emergency situations, such as not being able to accurately perceive the speed and distance of cars coming from a distance, and not being able to hear car horns, sirens, and other people's alerts, which increases the risk of falls and accidents in the elderly^[71]. Therefore, comprehensive interventions (physical exercise, health education, and environmental improvement) should be provided for older adults with hearing loss^[72]. Some studies have found that physical exercise in older adults is a protective factor for falls, and appropriate physical exercise helps to enhance their skeletal toughness and muscle level, improve balance function and enhance postural control and gait stability^[73]. In addition, community medical resources can be fully utilized to health education on hearing care, fall prevention risk management strategies and strategies to cope with complex environments can be provided to elderly with hearing loss who are at risk of falling and their families to improve their self-perceived hearing level, fall prevention awareness and ability to cope with or avoid exposure to complex environments. At the same time, patients' families and surrounding groups should increase the level of prevention of falls or unexpected situations in this group and focus on the safety of their interpersonal and living environments^[74] to reduce or avoid the number of falls in older adults with hearing loss.

4.4 Psychological interventions Psychological interventions have a positive impact on all aspects of older adults with hearing loss. In an auditory rehabilitation program, the help from family, friends, and society, as well as the active participation and subjective feelings of the individual patient have a positive effect on the recovery of psychological and physiological functions of the elderly with hearing loss, thus reducing the occurrence of falls due to psychological reasons. Medical staff should have a comprehensive understanding of the psychological, physiological and social conditions of the elderly with hearing loss, know the real thoughts and psychological needs of the patients, and develop psychological intervention plans according to the different psychological states and the development of the patients' conditions ^[75]; at the same time, medical staff and family members should always pay attention to and channel the negative emotions and fear of fall-related damage of the elderly with hearing loss, ensure

the safety of the patients' surroundings. They should also ensure the safety of the patient's surroundings, provide adequate care and security, eliminate the sense of loneliness and social isolation, and help patients maintain a calm and optimistic state of mind so that they can better integrate into interpersonal communication and society and have confidence in their future life. Especially during the period of hearing aid use and auditory rehabilitation training, the tension and anxiety of elderly people with hearing loss should be eliminated in time, and they should be guided to actively cooperate with the hearing rehabilitation training, and relaxation therapy can be adopted to let patients listen to music with soothing and light rhythm to relieve their tension and anxiety^[76].

In conclusion, this paper reviewed the epidemiological characteristics, occurrence mechanism, influencing factors and prevention of falls in elderly people with hearing loss, and found that the increased incidence of falls in elderly people with hearing loss, increased hearing loss, aging, changes in hormone levels in elderly women, decreased balance, and negative emotions are risk factors for falls in elderly people with hearing loss. It is suggested that the prevention and treatment of falls in elderly with hearing loss should be carried out in four aspects: use of hearing aids and aural rehabilitation training, medication, balance assessment and physical exercise, and psychological intervention, so as to reduce the incidence of falls in elderly with hearing loss. Meanwhile, this study found that there are more findings related to the factors influencing falls in elderly with hearing loss, and the findings are inconsistent, so it is recommended to add experimental studies to increase the accuracy and reliability of the results based on the literature studies.

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