Original Article

Presbycusis and presbyvestibulopathy: Balance improvement after hearing loss restoration

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Abstract

Objective: The aim of the present study was to define if hearing relief can improve vestibular function and risk-to-fall.

Methods: Fifteen hearing-impaired patients, 6 males and 9 females, aged ≥60 years (64–81 years, mean age 75.13 years), all affected by presbyvestibulopathy and presbycusis, with indication for bilateral hearing correction with hearing aids (HAs), underwent: the Conley Scale (for the fall risk assessment), the Dizziness Handicap Inventory (DHI) (quantifying dizziness-related physical and emotional symptoms and restrictions in daily activities), and the Corsi Blocks Task Test (assessing visuospatial working memory) before and 12 months after HAs fitting.

Results: Mean basal scores were 2.8 ± 1.9 (Conley Scale); 30.1 ± 14.6 (DHI); and 3.5 ± 0.7 (Corsi span). Mean scores posthearing loss (HL) correction were 2.0 ± 1.6 (Conley scale); 24 ± 12.9 (DHI); 4.7 ± 1.6 (Corsi span). Comparing the scores pre- and postHAs fitting, we found an improvement of Conley Scale ($P = 0.11$), DHI ($P = 0.11$), and Corsi span ($P = 0.05$) after 1 year.

Conclusions: The treatment of HL could be useful not only to reduce the risk of falls but also to improve the spatial memory and the quality of life related to imbalance.

Keywords: Balance, Conley scale, Corsi test, dizziness handicap inventory, hearing aid, hearing loss

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INTRODUCTION

In the last decades, life expectancy and global median age have increased as the interest in aging quality of life and related diseases. Presbycusis is the most common hearing disorder and a major cause of chronic disability in older age, affecting approximately one-third of adults aged between 61 and 70 years and more than 80% of those older than 85 years, with psychological, physical, and social consequences. Moreover, it is well-known that hearing loss (HL) can be associated with multiple comorbidities, such as poor physical health, anxiety,

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depression, isolation, cognitive decline, dementia, and imbalance.[1] For this last condition, the literature suggests two theories: age-related loss of labyrinthine function and the direct impact of the lack of auditory sensory information on postural stability.[2]

Presbyvestibulopathy (PVP) is a chronic vestibular syndrome characterized by unsteadiness, gait disturbance, and/or recurrent falls. The diagnosis is based on the clinical history, bedside examination, and functional evaluation showing a bilateral reduction of vestibulo-ocular reflex (VOR) gain.[3]

Only few data are available in the literature on the correlation, prevalence, and temporal patterns of the development of presbycusis and PVP.[4] In a cross-sectional study,[5] the prevalence of balance dysfunction reaches 69% while HL reaches 63% of the patients over 70 years of age. Different papers investigated the association between HL, postural control, and mobility in the elderly, highlighting a significant correlation between HL and postural control[6,7] and an increased fall risk.[8]

In recent years, several reviews have been published on the effects of hearing aids (HA) on balance;[2,9,10] however, the role of HA in balance is unclear due to the quality of records and poor reporting on hearing status and the quality of fit and use of HA.[9] Finally, a comprehensive randomized study is currently lacking. On the contrary, in patients with severe deafness and undergoing cochlear implant (CI), the effects of auditory rehabilitation on postural control, through the improvement of the perception of spatial signals, are the subject of study. The relationship appears to be closely related to age and the etiology of HL.[11] The balance improvement after CI showed contradictory results[9,12-14] due to several factors: adult subjects are often implanted unilaterally and, therefore, the benefit of spatiality is not effective; the preexisting vestibular pathology makes the results on balance further ambiguous; vestibular surgical trauma due to electrode insertion, labyrinthitis due to cochleostomy, or foreign body reaction.[9,15]

The aim of the present study was to evaluate HA-prescribed adults by means of questionnaires and tests to determine if hearing relief can improve balance and fall risk.

METHODS

Before enrolment, parents received complete and comprehensible information about the tests administered and gave their written consent to their execution, in agreement with the ethical standards of the Declaration of Helsinki. The study was approved by the Ethical Committee of the Catholic University and all patients gave their written informed consent to participate in the study.

Inclusion criteria were as follows:

- Age ≥60 years
- Recent diagnosis of presbycusis based on the detection of a progressive idiopathic moderate-to-severe bilateral sensorineural HL undergoing rehabilitation with bilateral air conduction HAs
- Presence of a chronic vestibular syndrome (at least 3 months duration) with postural imbalance or unsteadiness, gait disturbance, chronic dizziness, and recurrent falls; mild bilateral peripheral vestibular hypofunction documented by at least one of the following: VOR gain measured by video-HIT between 0.6 and 0.8 bilaterally or reduced caloric response (sum of bithermal maximum peak SPV on each side between 6° and 25°/s). The integrity of the acoustic and vestibular pathways was confirmed by radiological evaluation with gadolinium-enhanced MRI of the brain and brainstem. Consequently, all patients included were affected by PVP, according to the criteria of the Bárány Society.[3]

Exclusion criteria were a history of psychiatric disorders, depression and use of antidepressant treatments, neurodegenerative diseases, a history of cerebral ischemia, heart failure, and arrhythmia.

A comprehensive audiological evaluation was performed, including otoscopy, tympanometry, and acoustic reflex measurement (Grason-Stadler Tympstar), as well as standard pure tone audiometry, testing the conventional frequency range between 0.25 and 8 kHz (Amplaid 319 audiometer, Amplaid Inc.) in a double-walled, soundproofed room. The pure-tone average (PTA) (average of hearing threshold levels at 500, 1000, 2000, and 4000 Hz) was measured in both ears (R = right; L = left) in all patients. The mean gain of PTA with HAs was also measured.

All patients underwent the Conley Scale (for the fall risk assessment), the Dizziness Handicap Inventory (DHI) (quantifying dizziness-related physical and emotional symptoms and restrictions in daily activities), and Corsi Blocks Task Test (assessing visuospatial working memory) before HAs fitting and after 12 months of hearing rehabilitation to quantify the benefit of HAs on vestibular function.

The Conley Scale, first described in 1999, is a questionnaire structured in two parts, one concerning the previous falls through questions addressed to the patient or, in case of severe physical or cognitive deficits, to the caregiver; the second about cognitive impairment: walking, state of agitation, and that of judgment assessed by the nursing. The final total score defines the risk to fall: values between 0 and 1 indicate no risk; a score ≥2 (cutoff score) identifies a patient in a condition of risk.[16]

The DHI was used in its validated Italian version.[17] It is a questionnaire composed of 25 questions, each of which has three quantifiable answers (yes = 4, sometimes = 2, and no = 0). The final total score (0–100) defines the degree of subjective perception of dizziness/vertigo in the last week. It consists of the three subgroups of questions which investigate, respectively, the emotional (DHI-E), functional (DHI-F), and physical (DHI-P) impact that vertigo and imbalance have on the patient's life. Values >10 are considered borderline. A score between 16 and 34 shows a mild handicap, between 36 and 52, moderate, and >54, severe.[18]

The Corsi block-tapping test is probably the most important neuropsychological nonverbal test currently used to assess spatial memory. In this test, nine wooden blocks are affixed to a baseboard in a standard random configuration. On the experimenter's side of the baseboard, the blocks are numbered for easy identification. The examiner tapped a sequence of blocks at the rate of one block per second, and subjects attempted to reproduce the same sequence in the same presentation order. Sequences of increasing length (starting from 2-block sequences) were presented until the subject failed to reproduce three out of five trials of a given length. A span score was calculated corresponding to the larger sequence the subject was able to reproduce correctly.[19]

Statistical analysis was performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, United States). Continuous values, such as DHI score, were expressed as mean ± standard deviation. The qualitative variables were summarized with absolute frequency and percentage. Long-term results of the use of HAs on vestibular symptoms were measured with the DHI; hearing rehabilitation effects on fall risk with the Conley Scale and the spatial memory with the Corsi test. The mean scores obtained before hearing rehabilitation and after 12 months of HL correction were compared using the paired *t*-test. Results were considered significant for $P < 0.05$.

RESULTS

Fifteen hearing-impaired patients, six males and nine females, aged from 64 to 81 years, mean age of 75.13 years, were included. Table 1 shows patients' demographic characteristics and results of audiological evaluation. Preoperative PTA (average of hearing threshold levels at 500, 1000, 2000, and 4000 Hz) was measured on both ears (R = right; L = left) in all patients. The mean gain of PTA with HAs was also measured.

Results of the Conley test highlighted that 10 (66.6%) patients showed a fall risk at the baseline before HA, despite the risk persistence after HA, the score was lower by at least 1 point (two patients had an increase of two points, number 2 and number 4) [Table 2].

The DHI data show that the average score improvement was 6.1 ± 3.9. In detail, at the first observation, 3 (20%) patients showed a normal DHI (only one patient with

Table 1: Patient's demographic characteristics and results of audiological evaluation

Patients	Age	Sex	MMSE	PTA (right)	PTA (left)	PTA HA (right)	PTA HA (left)
N1	76	Male	26	47.5	47.5	25	25
N2	70	Male	21	73.7	91.2	40	40
N3	70	Female	29	66.2	48.7	30	30
N4	78	Female	28	52.5	55	25	25
N5	73	Male	28	46.2	43.7	25	25
N6	81	Female	29	56.2	42.5	25	25
N7	72	Female	26	53.7	55.5	25	25
N8	81	Female	29	48.7	40	20	20
N9	80	Female	19	85	55	40	40
N10	74	Male	28	61.2	71.2	30	30
N11	76	Female	26	53.7	58.7	25	25
N12	75	Male	8	42.5	43.7	20	20
N13	79	Female	29	57.5	58.7	25	25
N14	78	Male	25	38.3	36.6	20	20
N15	64	Female	26	46.6	31.6	12	12
Mean±SD	75.1±4.7		25.1±5.5	55.3±12.2	52.0±14.8	25.8±7.2	25.8±7.2

Preoperative PTA (average of hearing threshold levels at 500, 1000, 2000, and 4000 Hz) of both ears with and without HA. PTA: Pure-tone average, HA: Hearing aids, MMSE: Mini mental score examination

Table 2: Results of Conley Scale and Dizziness Handicap Inventory before and after use of hearing aid

Patients	Conley before	Conley HA	DHI before	DHI HA
N1	4	3	40	35
N2	2	2	42	40
N3	4	3	34	24
N4	0	0	8	6
N5	3	2	26	16
N6	4	3	50	35
N7	5	5	42	38
N8	0	0	6	4
N9	3	2	36	30
N10	1	0	12	10
N11	1	0	18	14
N12	5	4	28	18
N13	6	4	50	40
N14	4	2	40	36
N15	1	1	20	14

DHI: Dizziness Handicap Inventory, HA: Hearing aids

a borderline value, number 10), 5 (33.3%) subjects had a mild handicap while 7 (46.6%) were moderate. At the control after HA, all patients improved the score, and the categorization changed as follows: 5 (33.3%) normal, 6 (40%) mild, and 4 (26.6%) moderate, with a change in five patients (two mild became normal and three moderate became mild) [Table 2].

Half of the patients show a significant improvement of Corsi span.

Statistical analysis of data patients showed that mean basal scores were 2.8 ± 1.9 (Conley scale); 30.1 ± 14.6 (DHI); and 3.5 ± 0.7 (Corsi span). Mean scores post-HL correction were 2.0 ± 1.6 (Conley Scale); 24 ± 12.9 (DHI); and 4.7 ± 1.6 (Corsi span). Comparing the scores before and after the use of HAs for 12 months with *t*-test, we found a statistically significant improvement of DHI ($P = 0.11$), Corsi span ($P = 0.05$), and Conley scale ($P = 0.11$) after 1 year [Figure 1].

DISCUSSION

Our results demonstrated that HA could have a positive effect not only for auditory function as obvious but also for other functions as showed by the improvement of scores of three tests analyzed.

The Conley Scale is routinely used in our hospital. In the current study, it proved effective in showing that hearing-impaired patients over the age of 60 years are at significant risk of falls. In our opinion, this is a very important finding, because, through information to patients and caregivers, we can suggest procedures and precautions for the prevention of falls. To our knowledge, there are no other studies describing the Conley Scale in elderly deaf patients. Only an article investigated the impact of

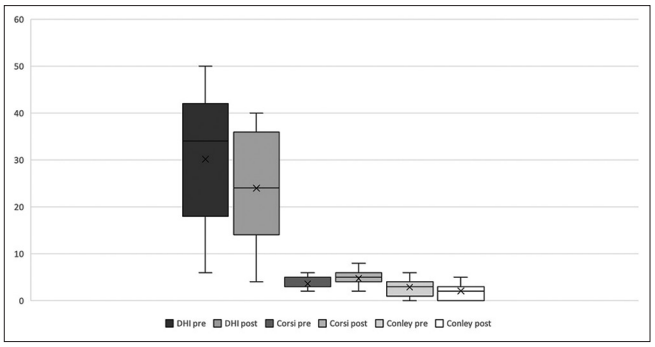

Figure 1: Mean scores before and after hearing loss correction (Corsi span, Dizziness Handicap Inventory and Conley Scale).

HA use on falls (not fall risk), showing that in examining self-reported hearing status, HA use does not impact the association between self-reported hearing status and falls or falls-related injury.[20] It is well known great interest of geriatric societies for the causes and prevention of falls in the elderly population. In the US, more than 14 million falls are reported in adults aged 65 years and older every year with consequences relating to morbidity, mortality, and health-care costs.[21] Falls are due to age-related physiological changes and different intrinsic and extrinsic factors. The main modifiable risk factors include gait and balance disorders, orthostatic hypotension, sensory disorders, drugs, and environmental risks. A recent review by Colón-Emeric[21] includes Gait abnormality and Vertigo/dizziness in the major risk factors while hearing impairment in moderate ones, confirming the importance of our study, in which we find an increased risk of falls in elderly deaf patients. After rehabilitation with HA, our patients demonstrated a statistically significant improvement in the Conley Scale, even in the presence of a persistent fall risk. We can hypothesize that the improvement may be due to the auditory intervention and the persistence to other age-related risk factors (including possible coexisting PVP).

As reported above for the Conley test, there are no studies in the literature about the evaluation of dizziness handicap on the quality of life for patients with presbycusis. At our first observation, we highlighted a significant dizziness handicap in approximately 80% of the patients. This is a high value, confirming the importance of the evaluation by questionnaire. We suggest the use of the DHI in all individuals with HL, particularly in elderly patients. Dizziness is an important symptom closely related to the fall risk, and therefore, it should not remain unrecognized because it could be due to a PVP to be investigated through a battery of vestibular tests. Furthermore, after using HA, patients showed a statistically significant improvement in DHI: all patients improved the score with a change in categorization in 33% of them. Several

studies suggest the interaction between hearing and the balance regulation system with stabilizing potential effect.[2,7,22] Our results agree with Lacerda *et al*.[23] who highlighted the improvement in the quality of life and reduction of fear of falling after HA fitting. However, they used different tests: the SF-36 questionnaire for the evaluation of the quality of life, the FES-I questionnaire for the evaluation of fear of falling, and the Berg Balance Scale as a balance test. Regarding the functional and instrumental assessment of balance, a recent review by Lavie *et al*.[9] highlighted that five of the eight studies considered demonstrated a correlation between the use of HAs and the results of balance tests. However, they stressed that the quality of the studies was limited to moderate. On the other hand, Borsetto *et al*.[2] concluded from their review that despite the demonstration of a possible improvement in balance in patients with HA, the overall benefit is still unclear, being able only to hypothesize an improvement in the static, dynamic, or subjective perception of balance function.

Unlike the other tests analyzed in this study, in two previous personal articles, we evaluated the Corsi test in deaf patients. In the first, we showed no differences between the performances of the deaf subjects and the control group.[24] In the second, we demonstrated the improvement of short- and long-term memory performance and the improvement of executive and attentive functions after auditory rehabilitation using HA and CI.[25] Despite the considerations on the possible recovery of the higher cognitive domains, through a reallocation of cortical resources altered by auditory deprivation, the current result combined with the improvement in the other tests emphasizes the component of visuospatial improvement assessable with the Corsi test. Similarly to what happens after vestibular rehabilitation which has been shown to improve visuospatial memory,[26] in our opinion, the restoration of auditory input through auditory rehabilitation with HA could have an improving interference on this cognitive function.

Unfortunately, this study presents some important limitations: the small sample size and the absence of a functional assessment of balance did not consent to certainly conclude that the treatment of HL is useful not only for reducing the risk of falls but also for improving the spatial memory and the quality of life related to imbalance. In any case, we highlight the potential role of the Conley Scale and Corsi test in both the audiological and geriatric fields. Further studies are needed to confirm our data about the hypothesis that early hearing restoration could improve vestibular function and balance.

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Conflicts of interest

There are no conflicts of interest.

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