Hearing Impairment and Other Health Conditions in Older Adults: Chance Associations or Opportunities for Prevention?

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ABSTRACT

The prevalence of hearing impairment, as well as many other medical conditions, increases with age. Epidemiological evidence also suggests that the prevalence of hearing impairment, cardiovascular disease, and possibly dementia have declined during the 20th century. Differences in disease occurrence by birth year indicate that modifiable risk factors contribute to these diseases and that exposure to these risk factors changed over time. This article discusses the co-occurrence of chronic conditions at older ages, along with their shared risk factors and similar temporal trends. Recognition of these patterns is important for audiologists and other health care professionals who treat these complex patients, as well as for researchers investigating the underlying causes of these diseases. Various lines of evidence linking hearing impairment to other conditions and medication use point to the need for hearing health care to be better integrated with the broader health care system.

KEYWORDS: Hearing loss, sensorineural hearing loss, presbycusis, epidemiology, aging

Learning Outcomes: As a result of this activity, the participant will be able to (1) list at least three health conditions that may be more common in older people with hearing impairments and (2) identify findings from at least two studies that suggest that hearing impairment in older adults is at least partly preventable.

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With longer life expectancies, more people are experiencing the challenges of poor hearing for more years, either directly because of their own hearing problems or because a loved one has a hearing impairment. The auditory system is not the only part of the body experiencing age-related declines in function; many health problems present at older ages and, over time, multiple health conditions may affect an older person. Primary care clinicians need to be aware that many of their older patients have at least mild hearing losses and may find it more difficult to communicate effectively. Audiologists and otolaryngologists, in turn, need to be aware that their older patients are likely to have other health problems that may be contributing to the decline in hearing or the difficulty of adhering to treatment interventions (hearing aids, assistive listening devices, listening strategies, etc.). In today’s health care system, audiologists are important members of the health care team, reinforcing the importance of patients controlling and treating their other health problems, and educating other health care providers about the need to refer their patients for appropriate treatment for hearing problems. Furthermore, this increased comorbidity may reflect common causes and provide opportunities to slow or prevent the onset and progression of hearing impairment in aging adults. This article describes some epidemiological data about patterns, secular trends, and associations between age-related hearing impairments and other medical conditions.

HEARING IMPAIRMENT: INCREASES WITH AGE BUT DECLINES WITH TIME

Age-related hearing impairment usually has a gradual onset, first affecting hearing at higher frequencies and causing complaints of difficulties understanding speech in noisy conditions. Over time, lower frequencies become affected, requiring friends and family to speak louder to be heard. Hearing impairment is a common complaint among older adults. In a population-based study of adults ($n = 3753$) aged 48 to 94 years in Beaver Dam, Wisconsin, 21% of people 48 to 59 years had impaired hearing; among participants aged 80 years or older, 90% had hearing impairment. For every 5 years of age, the odds of having a hearing impairment increased (odds ratio [OR] = 1.88, 95% confidence interval [CI] 1.80 to 1.97). Men were more likely to have hearing impairments than women (age-adjusted OR = 4.42, 95% CI 3.73 to 5.24).

This cohort has been followed for many years, with repeat examinations every 5 years. After 10 years of follow-up, the cumulative incidence of hearing impairment was 37.2% among participants with normal hearing at the first examination ($n = 1925$). Risk of hearing loss increased with age (hazard ratio [HR] for 5 years = 1.81, 95% CI 1.69 to 1.94) and was higher for men than women (HR = 2.29, 95% CI 1.81 to 2.90). For most participants who had hearing impairments at the first examination, hearing thresholds continued to worsen.

The adult offspring of this population-based cohort were asked to participate in the Beaver Dam Offspring Study ($n = 3285$). Of the “children” (aged 21 to 84 years at examination in 2005 to 2008) participating in the examination phase, 14% had hearing impairments. Among the youngest age group (ages 21 to 34 years), 2.9% had hearing impairment, and 42.7% of the oldest group (ages 65 to 84 years) were hearing impaired. For every 5 years of age, the odds of hearing impairment increased (OR = 1.69, 95% CI 1.57 to 1.80), and men were three times as likely to have a hearing impairment as women (OR = 3.48, 95% CI 2.67 to 4.54).

One opportunity afforded by studying these two cohorts using the same standardized procedures was to determine if the prevalence of disease changed over time; participants in the combined studies were born between 1902 and 1992 and thus may reflect the generational experiences across the 20th century. Doll and Peto proposed a model in cancer epidemiology, which suggested that rapid changes in the occurrence of disease over time, either increases or decreases, were strong indicators that the disease was preventable because genetic changes accrue slowly and impact health over long periods of time, but environmental or behavioral factors can change suddenly. Because
hearing impairment prevalence varies with age and sex, it is important to compare the prevalence of hearing impairment while controlling for age and gender (i.e., comparing age-/sex-specific prevalence). Zhan et al. analyzed all the examination data for participants in either study who were 45 to 94 years of age (n = 5725 participants tested at least once). Adjusting for age, sex, repeated measures of hearing, and the family clusters, the prevalence of hearing impairment declined by year of birth (13% among men and 6% among women, for every 5 years). Thus, a man born in the 1950s would be half as likely to have a hearing impairment at a given age, as a man born 20 years, or a generation, earlier. This dramatic decline suggests that hearing impairment is highly preventable. Zhan et al. estimated that, by 2030, this trend would result in a lower prevalence equivalent to saving 14.6 million people from hearing impairment. Compared with people in the 20th century, more people will maintain good hearing until greater ages in the 21st century.

What accounts for this decline in hearing impairment in younger generations? It is well known that prolonged exposure to loud noise can harm hearing. During the latter part of the 20th century, there was a tremendous shift from blue collar jobs to white collar jobs, and occupational noise controls were instituted in the United States. Would changing patterns of occupational exposure to noise explain the trend in men and women? In addition to changes in noise exposure over past decades, many health-related behaviors, exposures, and conditions have improved. Zhan and colleagues reported in a subsequent article that higher education, exposure to occupational noise, history of ear infections, smoking, and history of cardiovascular disease (CVD) were all associated with the prevalence of hearing impairment. Changes in exposure to occupational noise did not explain the temporal trend. Only education level modified the birth cohort effect previously reported. When education was included in the model, the birth cohort effect remained statistically significant but was reduced, leaving a 7% decline for every 5 years. Thus, improvements in education contributed to the declining trend for hearing impairment in later generations. Education may represent a marker of socioeconomic status, which is indicative of better access to health care, healthier environments, lower workplace stress, or other differences in environmental, behavioral, or psychological factors.

In summary, our studies revealed a pattern of increasing risk of hearing impairment with aging, greater risk for men than women, and a trend for less hearing impairment by birth period during the 20th century, a trend only partly explained by improvements in educational attainment.

Importantly, these patterns (increased risk with age, greater prevalence in men than women, and lower risk over time) are similar to what has been seen for certain other chronic diseases of aging. Among adults aged 60 to 79, the prevalence of CVD is greater than 70% and is higher among those 80 years and older. Men are more likely than women to have CVD. Atherosclerosis, a slowly progressing change in blood vessel walls, is a major part of the causal pathway. Yet, despite increasing adiposity and sedentary behavior, the risk of CVD appears to have declined in the 20th century. The Framingham Heart Study has shown that the incidence of CVD declined more than 20% for women and 6% for men born in the 1970s compared with those born in the 1950s. This decline in CVD is similar to that found in the National Health and Nutrition Examination and Survey (NHANES) Epidemiologic Follow-up Study. It has been estimated that reductions in traditional cardiovascular risk factors (cholesterol, blood pressure, and smoking) may account for half of the decline, but others suggested that the improvement was first observed before large changes in these risk factors occurred.

Similarly, dementia risk may be declining over time, although it also clearly increases with age. Rocca et al. analyzed data from the Health and Retirement Study and concluded that the prevalence of cognitive impairment in 2002 was lower (OR = 0.65) than in 1993. Education level accounted for a large portion of this decline, but the prevalence of cognitive impairment remained 20% lower in 2002 after adjusting for age, sex, and education. Using data from the Rochester Epidemiology Project, Rocca et al. found a suggestion of a 30% decline in incidence of dementia from 1985 to 1994.
but two other epidemiological studies showed no temporal trends. Declines in blood pressure, cholesterol levels, cigarette smoking, and improvements in housing and access to nutritious food experienced during the 20th century may contribute to improvements in cognitive health as well as cardiovascular health in aging.

AGE-RELATED HEARING IMPAIRMENT AND NOISE

Although Zhan et al. found that changes in occupational noise exposure did not explain the decline in hearing impairment over time, these results are limited by the cross-sectional nature of the study. There have been few longitudinal studies of noise exposure and hearing threshold changes with aging. Lee et al.10 studied changes in hearing thresholds in 188 subjects aged 60 years and older with an average of 6 years of follow-up. They found similar rates of change among participants with positive noise histories compared to those with negative histories. In the Framingham Heart Study, however, among men with two hearing examinations 15 years apart, the presence and severity of audiometric notches was associated with faster decline at 2 kHz.11 An expert panel (as part of a study of noise and hearing loss in the military) considered both animal and human studies and concluded that it was unlikely that noise exposure early in life caused delayed onset of hearing loss years after the noise exposure ceased.12 Although in our studies we found cross-sectional associations between occupational noise exposure and hearing,1,3,6 our longitudinal study following subjects without hearing impairment at baseline has shown no association between occupational noise exposure and the 10-year risk of developing hearing impairment.2 Therefore, it seems unlikely that changes in noise exposure during working years impact the decline in hearing at later ages.

AGE-RELATED HEARING IMPAIRMENT, CVD AND ITS RISK FACTORS

Early epidemiological studies demonstrated that hearing thresholds were lower (better) in older rural Africans compared to Caucasian people in the United States.18 Rosen et al.18 reported that the Mabaans not only lived in a quieter environment, but ate diets high in fruits and fiber, did not smoke, had low rates of hypertension, were physically active and lean. These authors speculated that lower cardiovascular risk factors in the Mabaans contributed to better hearing with aging. In addition, Rosen and colleagues conducted a series of ecological studies that showed that the prevalence of hearing impairment was higher in countries or regions with high rates of CVD compared with countries/regions with low rates of CVD.19,20 They also conducted a hearing study ancillary to a clinical trial designed to evaluate the effects of lowering dietary cholesterol on serum cholesterol levels.21 Rosen et al.21 tested participants’ hearing at the end of a dietary trial and 4 years after the diets were switched (the hospital that had been on the low atherogenic diet was returned to the usual Finnish diet and the “control” hospital was changed to the low atherogenic diet). They reported that patients who had been on the low atherogenic diets during the first phase of the trial had better hearing thresholds than patients at the hospital receiving the typical Finnish diet. Four years after the diets were switched, the patients who changed to the atherogenic diet had a greater decline in hearing than patients placed on the lower fat/lower cholesterol diet (who experienced a small improvement in thresholds).21 These early studies provide intriguing suggestions that cardiovascular risk factors may be involved in age-related damage to the auditory system, but stronger evidence is needed.
In the Framingham Heart Study, Gates and colleagues demonstrated a strong association between hearing impairment and the 30-year risk of CVD. Women with hearing impairments were three times as likely to have a CVD event during the 30-year period as women with normal hearing; among men, the OR was 1.75.

In the Epidemiology of Hearing Loss Study (EHLS) cohort, women with a history of myocardial infarction were twice as likely to have cochlear dysfunction as measured by distortion product otoacoustic emissions. More recently, in the Beaver Dam Offspring Study, we found that retinal venular caliber (a marker of inflammation, cardiovascular risk factors, and white matter lesions in the brain) was associated with hearing impairment. In addition, intima-medial thickness of the carotid artery (a measure of atherosclerosis) and use of statin medications (a marker of CVD risk) were associated with poorer performance on a test of word recognition in competing message in this young cohort.

The Health ABC study also reported sex-specific cross-sectional associations between heart rate, body mass index, pulse wave velocity (a measure of arterial stiffness), smoking, and hearing sensitivity. Cigarette smoking was not associated with hearing impairment in the Framingham Heart Study or the Baltimore Longitudinal Study of Aging (BLSA). However, in the EHLS, current smokers were more likely to have a hearing impairment than nonsmokers. A recent multicenter study in Europe and the NHANES also reported associations between smoking and hearing impairment.

Cochlear and neural function are highly dependent on adequate blood supply, so it seems likely that age-associated changes in the blood vessels, similar to the processes that occur in CVDs, may contribute to the decline in hearing in aging. It is possible that cardioprotective measures such as reducing smoking and obesity, controlling blood pressure and hypercholesterolemia, and increasing exercise may contribute to sustaining good hearing into older ages. Longitudinal studies and clinical trials are needed to elucidate these associations and to assess the opportunity for prevention.

AGE-RELATED HEARING IMPAIRMENT AND DIABETES

Many cross-sectional studies reported that the prevalence of hearing impairment is higher among participants with diabetes than those without diabetes. However, not all studies have found a diabetes-associated excess of hearing loss. In the Health ABC study, diabetes was associated with greater prevalence of hearing loss among white participants only, but neither fasting insulin nor fasting glucose level were associated with hearing loss. In the NHANES, the prevalence of high-frequency hearing impairment was highest among those with diabetes, followed by those with impaired fasting glucose, and lowest among adults with normal glucose levels (age-adjusted prevalence: 48.4%, 40.5%, and 30.4%, respectively). Neither duration of diabetes nor glycemic control have been found to be associated with hearing impairment. Because type 2 diabetes is the most common form of diabetes, and onset is often at older ages, it is possible that the onset of diabetes occurs later than the onset of hearing impairment; for these individuals, diabetes does not increase the risk of hearing impairment. Because diabetes is known to affect both the vascular and neural systems, resulting in increased risk of retinopathy, nephropathy, neuropathy, and CVD, it seems likely that diabetes may cause damage to the auditory system as well. Longitudinal studies are needed to investigate the temporality of the diabetes-hearing impairment association.

HEARING IMPAIRMENT AND OTHER SENSORY DISORDERS

In the EHLS, 48% of the people with hearing impairments also had vision impairments and/or olfaction impairments. This sensory comorbidity was greater than what would be expected by chance alone. Similar sensory comorbidity has been reported in the Blue Mountains Eye Study and in a study by Schneck et al. Thus, not only are older adults with hearing impairments more likely to have other chronic diseases such as diabetes and CVD, it is likely they have other sensory impairments as well.

Recent studies have reported an intriguing association between hearing impairment and...
risk of cognitive impairment or dementia. Gates et al.\textsuperscript{42} reported an association between very poor performance on a measure of central auditory dysfunction and subsequent development of dementia in a subset of the Framingham Heart Study. More recently, in a study of 274 volunteers followed for an average of 26 months, poorer performance on the Dichotic Sentence identification task was associated with increased risk of developing dementia.\textsuperscript{43} In the BLSA, hearing impairment was associated with risk of dementia; however, the effect was small (HR = 1.20 per 10 dB of hearing loss).\textsuperscript{44} These studies are limited by the small number of cases of dementia observed in the study populations. Whether these associations reflect direct effects of poor auditory signals to the brain, social isolation from hearing impairment, or shared etiologic factors (damage to the auditory system and central damage from the same causes) remains to be determined.

**IMPLICATIONS AND FUTURE DIRECTIONS**

For the practicing clinician, it is important to recognize that older patients presenting with hearing impairments are likely to have complex medical histories. As shown in Table 1, in the EHLS cohort, the average person with hearing impairment had two other health conditions (diabetes, CVD, cancer, arthritis, and/or hypertension) and took more than five prescription medications. Thus, it is important to consider how hearing impairment may be affecting the patient’s understanding of the clinicians’ recommendations and how these medical conditions and medications may be impacting his or her hearing. It is well known that some medications have ototoxic effects, and it is highly likely that long-term use of other medications also has subtle effects on hearing that have gone unrecognized. In some cases, consulting with primary care physicians may identify alternatives or modifications of medications that may reduce the potential impact on the auditory system. For medications with known ototoxic effects, regular monitoring of hearing is warranted to assess the need for hearing aids, adjust hearing aids, or recommend other changes to minimize the impact of declining hearing and maximize communication abilities. Educating patients about the links between other health conditions (or medications) and hearing health might encourage them to adhere to treatment recommendations and improve their management of serious medical conditions—efforts that may reduce or slow damage to hearing.

For researchers, it is critical to learn more about the underlying processes that damage the auditory system and to move beyond the old concept of hearing loss in aging as “normal.” The declining prevalence in hearing impairment noted by Zhan and colleagues is strong evidence that hearing impairment in older adults is at least partially preventable.\textsuperscript{5,6} Given the strong similarities to CVD patterns and the growing evidence that vascular and neural damage—perhaps by inflammation—contribute to hearing impairment in aging, it is possible that improved prevention and

<table>
<thead>
<tr>
<th>Age Group (y)</th>
<th>Number of Participants (n)\textsuperscript{a}</th>
<th>History of Diabetes or CVD, n (%)</th>
<th>History of Cancer, Arthritis, or Hypertension, n (%)</th>
<th>Number of Medical Conditions (of 5), Mean (SD)</th>
<th>Number of Prescription Medications, Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>63–69</td>
<td>185</td>
<td>61 (33)</td>
<td>163 (88)</td>
<td>1.8 (1.0)</td>
<td>4.6 (3.3)</td>
</tr>
<tr>
<td>70–79</td>
<td>465</td>
<td>184 (40)</td>
<td>421 (92)</td>
<td>2.2 (1.1)</td>
<td>5.2 (3.6)</td>
</tr>
<tr>
<td>80–89</td>
<td>346</td>
<td>126 (38)</td>
<td>301 (89)</td>
<td>2.0 (1.2)</td>
<td>6.0 (3.7)</td>
</tr>
<tr>
<td>90–100</td>
<td>81</td>
<td>29 (38)</td>
<td>66 (88)</td>
<td>2.2 (2.2)</td>
<td>7.1 (3.8)</td>
</tr>
<tr>
<td>All</td>
<td>1077</td>
<td>400 (38)</td>
<td>951 (90)</td>
<td>2.1 (1.1)</td>
<td>5.5 (3.6)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Denominators for each cell vary due to missing data.

CVD, cardiovascular disease; SD, standard deviation; PTA, pure-tone threshold average.
treatment of CVD is contributing to the lower risk of hearing impairment. However, most of the cited studies were cross-sectional by design and therefore do not provide strong evidence that vascular risk factors cause declines in hearing; it is possible these are chance findings or the result of changes in behaviors/exposures subsequent to the onset of hearing impairment. Nonetheless, when treating patients with hearing impairments, clinicians should consider how other systemic disorders may be impacting hearing health.

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