Can Hearing Aids Delay Time to Diagnosis of Dementia, Depression, or Falls in Older Adults?

Elham Mahmoudi, PhD,[*†] *Tanima Basu, MS,*[†] *Kenneth Langa, MD, PhD,*[†‡§¶] *Michael M. McKee, MD, MPH,*[*†] *Philip Zazove, MD,*[*] *Neil Alexander, MD,*[§||] *and Neil Kamdar, MA*[†**††‡‡]

OBJECTIVE: To examine the association between hearing aids (HAs) and time to diagnosis of Alzheimer disease (AD) or dementia, anxiety or depression, and injurious falls among adults, aged 66 years and older, within 3 years of hearing loss (HL) diagnosis.

DESIGN: Retrospective cohort study.

SETTING: We used 2008 to 2016 national longitudinal claims data (based on office visit, inpatient, or outpatient healthcare encounters) from a large private payer. We used Kaplan-Meier curves to examine unadjusted disease-free survival and crude and adjusted Cox regression models to examine associations between HAs and time to diagnosis of three age-related/HL-associated conditions within 3 years of HL diagnosis. All models were adjusted for age, sex, race/ethnicity, census divisions, and prior diagnosis of cardiovascular conditions, hypertension, hypercholesterolemia, obesity, and diabetes.

PARTICIPANTS: The participants included 114 862 adults, aged 66 years and older, diagnosed with HL.

MEASUREMENT: Diagnosis of (1) AD or dementia; (2) depression or anxiety; and (3) injurious falls.

INTERVENTION: Use of HAs.

RESULTS: Large sex and racial/ethnic differences exist in HA use. Approximately 11.3% of women vs 13.3% of men used HAs (95% confidence interval [CI] difference = −0.024 to −0.016). Approximately 13.6% of whites (95% CI = 0.13-0.14) vs 9.8% of blacks (95% CI = 0.09-0.11) and 6.5% of Hispanics (95% CI = 0.06-0.07) used HAs. The risk-adjusted hazard ratios of being diagnosed with AD/dementia, anxiety/depression, and injurious falls within 3 years after HL diagnosis, for those who used HAs vs those who did not, were 0.82 (95% CI = 0.76-0.89), 0.89 (95% CI = 0.86-0.93), and 0.87 (95% CI = 0.80-0.95), respectively.

CONCLUSIONS: Use of HAs is associated with delayed diagnosis of AD, dementia, depression, anxiety, and injurious falls among older adults with HL. Although we have shown an association between use of HAs and reduced risk of physical and mental decline, randomized trials are needed to determine whether, and to what extent, the relationship is causal. **J Am Geriatr Soc 67:2362-2369, 2019.**

Key words: Alzheimer's disease; dementia; depression; fall; hearing loss; hearing aids

From the *Department of Family Medicine, University of Michigan Medical School, Ann Arbor, Michigan; †Institute for Healthcare Policy and Innovation, University of Michigan, Ann Arbor, Michigan; ‡Department of Internal Medicine, University of Michigan Medical School, Ann Arbor, Michigan; §Institute for Social Research, University of Michigan, Ann Arbor, Michigan; ¶Veteran Affairs (VA) Center for Clinical Management Policy Research, Ann Arbor, Michigan; ||Institute of Gerontology, University of Michigan, Ann Arbor, Michigan; **Department of Obstetrics and Gynecology, University of Michigan Medical School, Ann Arbor, Michigan; ††Department of Surgery, University of Michigan Medical School, Ann Arbor, Michigan; and the ‡‡Department of Emergency Medicine, University of Michigan Medical School, Ann Arbor, Michigan.

Address correspondence to Elham Mahmoudi, PhD, MS, University of Michigan, North Campus Research Complex, 2800 Plymouth Rd, Building 14, Room G234, Ann Arbor, MI 48109. E-mail: mahmoudi@med.umich.edu

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More than 27 million Americans, aged 65 years and older, live with hearing loss (HL).[1] Prevalence of HL is estimated to grow due to our growing geriatric population.[2] Prior literature indicates strong associations between HL and adverse conditions, such as social isolation, depression,[3,4] cognitive decline,[5-7] injuries associated with falls,[8] and reduced quality of life.[9,10] Despite these findings, use of hearing aids (HAs) as a potential treatment intervention for those with HL remains low.[1] This has been attributed to multiple factors, including lack of perceived need, limited apparent benefit,[1] uncomfortable fit, a complex system of hearing care with multiple points of contact,[11] stigma,[12] and cost[13] (exacerbated by no or low insurance coverage in the United States).[14]

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There is a paucity of research on the impact of HAs on medical outcomes. Further, the results of these studies are often inconsistent. For example, Dawes et al found no significant differences in cognitive and mental health outcomes between HA users and nonusers.[15] A cross-sectional analysis of 164 770 adults, aged 40 to 69 years, with HL in the United Kingdom found better cognitive function among those who used HAs compared with those who did not.[16] A recent review of the literature[17] by Hubbard et al showed that hearing interventions have been successful in slowing the progression of cognitive decline among aging adults without dementia.[18-20] Despite contradictory findings and lack of literature studying this population, evidence-based research on hearing interventions among older adults with HL is gaining momentum.[17] More longitudinal research on this topic is warranted.

Although routine HL examinations and HA-related expenditures are not covered by Medicare fee-for-service plans, many managed care plans cover a portion of HA costs. Thus, we used nationwide claims data from a private managed care payer to examine the association between HA use and time to diagnosis of three common conditions among adults, aged 66 years and older, who were diagnosed with HL: (1) Alzheimer disease (AD) or dementia[7,21]; (2) depression or anxiety[3,22]; and (3) injuries related to falls.[8,23] We hypothesized that HAs are associated with a delay in diagnosis of the above age-related conditions.

METHODS

Data Source

This retrospective cohort study of adults with HL diagnoses defined in any patient care setting used a national, private insurance claims database, Clinformatics DataMart Database (OptumInsight). This deidentified claims database captures all emergency department, outpatient, and inpatient encounters of over 79 million adults and children who were commercially insured by a single, large US private payer and who had both medical and pharmacy coverage throughout their enrollment. The study was deemed exempt by the Institutional Review Board at the researchers' institution.

Patient Selection

The study period covered 2008 to 2016. Using all private payer claims data between January 1, 2008, and December 31, 2013, adults aged 66 years and older with *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*), diagnosis codes for HL were identified (Supplementary Table S1). Diagnosis of HL is usually done by an audiologist. To identify patients with incident HL, those with HL diagnoses or HA procedure codes within 1 year prior to the incident HL were excluded (Supplementary Table S2). Additional exclusion criteria included (1) fewer than 12 months of continuous enrollment prior to index HL diagnosis; (2) preexisting diagnosis of dementia, AD, anxiety, depression, and a fall leading to injury within 12 months prior to the index HL diagnosis (Supplementary Table S3)[24,25]; and (3) not having at least 3 years of continuous enrollment after the index HL. Figure 1 depicts the final sample size.

Dependent and Explanatory Variables

Outcomes included being diagnosed with AD or dementia, depression or anxiety, and injurious fall, as determined by *ICD-9* and *ICD-10* codes. The difference in days for the time to the outcome was calculated by identifying the first claim service date with any diagnosis of the three outcome conditions in the 3-year period following the index HL. Baseline demographic characteristics included age, sex, race and ethnicity, and US census division (New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific) at the time of HL diagnosis. Comorbidities for risk adjustment included hypertension (nongestational), diabetes (nongestational), obesity, cardiovascular conditions, and hypercholesterolemia in the 12 months prior to

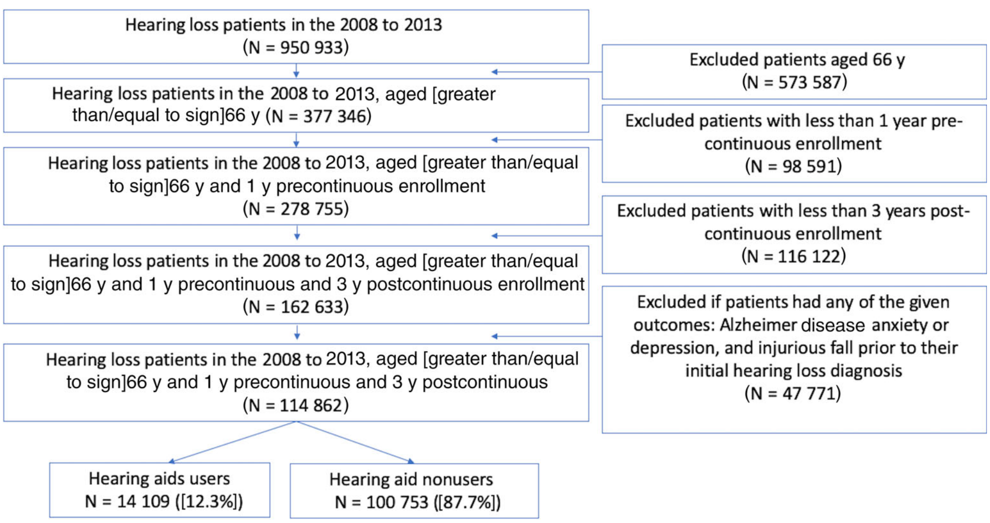

Figure 1. Schematic flow diagram of the sample size. The study period covered 2008 to 2016. We identified adults, aged 66 years or older, with *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*), diagnosis codes for hearing loss between January 1, 2008, and December 31, 2013. [Color figure can be viewed at wileyonlinelibrary.com]

HL diagnosis. These conditions were chosen because of their higher prevalence among people with HL.[26]

Statistical Analysis

Bivariate analyses of baseline demographic characteristics and comorbid conditions at the time of HL diagnosis were conducted for HA users and nonusers. For categorical variables, bivariate analysis was conducted using χ^2 testing, and 95% confidence intervals (CIs) for differences in proportions were calculated. For continuous variables, means and SDs were calculated and their distributions were examined to ensure robustness of parametric *t*-tests.

To examine disease-free survival of HA users vs nonusers, Kaplan-Meier product-limit survival curves were constructed for each outcome. Log-rank tests were applied to examine the proportional hazards assumption and to test for differences in survival curves. Patients were right censored if they did not experience the outcome in the 3-year follow-up period. Cox proportional hazards regression models were developed to calculate unadjusted and risk-adjusted hazard ratios to measure the effect of HA use on each outcome.

Additionally, state-level variation in incidence rates of outcomes was assessed by calculating the state-specific unadjusted rates over the entire time frame of 2008 to 2016. All states were ranked and split into tertiles based on their unadjusted incident rates of HA use and the three outcomes. To examine the hypothesized effect of state-specific HA utilization on each outcome, a Pearson correlation coefficient was calculated. To assess geographic variation, state-level heat maps were developed and divided into tertiles. The strength of the association of HA utilization and outcomes was measured via Pearson correlation coefficients (Supplementary Figure and Supplementary Table S4). All analyses were conducted using SAS 9.4 (SAS Institute Inc). Statistical testing was two tailed, with a 0.05 significance level.

Sensitivity Analysis

The effect of selection bias was examined by performing propensity score matching using multivariable logistic regression adjusting for the following observable confounders: age, sex, US census division, and clinically relevant medical conditions. We used a caliper matching algorithm with caliper size of 0.001 and a 1:1 ratio of HA users (cases) to controls (HA nonusers) without replacement. After propensity score matching, Cox regression models were fit with HA as the main effect to estimate hazard ratios for each outcome. The results did not appreciably change (Supplementary Table S5). Therefore, main results are presented without propensity matching.

RESULTS

In a sample of 114 862 adults, aged 66 years or older, diagnosed with HL, 14 109 (12.3%) used HAs (Table 1). The mean (SD) age was 75.8 (5.8) years, with no significant difference between those with and without HAs. Approximately 11.3% of females vs 13.3% of males (difference = 2.0%; 95% CI = −0.0237 to −0.0161) had HAs, along with 13.6% of whites vs 9.8% of blacks (difference = 3.8%; 95% CI = 0.0300-0.0451) and 6.5% of Hispanics (difference = 7.1%; 95% CI = 0.0653-0.0760) ($P < .0001$ for all). Among the nine US census divisions, the highest level of HA use (36.9%) was in the West North Central division (Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota). The lowest (5.9%) was in the Mountain division (Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico) ($P < .0001$). On average, the prevalence rates of hypertension (24.4% vs 21.6%; $P < .0001$), hypercholesterolemia (47.9% vs 44.4%; $P < .0001$), and diabetes (17.9% vs 15.5% ($P < .0001$) were higher among patients without HAs compared with those with HAs.

Figure 2 shows the unadjusted hazard ratios for diagnosis of each outcome within a 3-year period. For all three outcomes, HA users had lower hazard ratios than non-HA users: AD or dementia (0.83; 95% CI = 0.77-0.89), depression or anxiety (0.86; 95% CI = 0.83-0.90), and injurious fall (0.87; 95% CI = 0.80-0.93).

Kaplan-Meier curves in Figure 3 also indicate delays in diagnosis of the three outcomes among adults with HL who used HAs compared with those who did not. Within 3 years of HL diagnosis, a higher percentage remained free of a diagnosis of AD or dementia (96.6% vs 96.1%), depression or anxiety (83.5% vs 81.6%), or a fall (94.9% vs 94.2%).

The risk-adjusted hazard ratio for developing AD or dementia within 3 years of being diagnosed with HL was lower by 0.82 (95% CI = 0.76-0.89) among those who used HAs than those who did not. For depression or anxiety, it was lower by 0.89 (95% CI = 0.86-0.93). For injurious falls, it was lower by 0.87 (95% CI = 0.80-0.95) (Table 2). The estimated models and corresponding hazard ratios are reported in supplemental materials (Supplementary Table S6-S9).

Correlations between HA use and the three outcomes were also examined at the state level. The heat maps in Supplementary Figure depict substantial geographic clustering among the 52 states in incidence rates of HA use and the three outcomes. For example, the incidence of HA use in most Pacific division states (ie, Oregon, Washington, California) was lower than in West North Central states (ie, Minnesota, Iowa, Missouri). Conversely, the incidence rates of AD and dementia and anxiety and depression were higher in Pacific states compared with West North Central states. State-level Pearson correlation coefficients did not indicate significant correlation between HA use and the three outcomes (Supplementary Table S4).

DISCUSSION

In a large national database of insurance claims, use of HAs among adults with HL was associated with a significantly lower risk of being diagnosed with AD or dementia, depression or anxiety, and injurious falls. We also found significant racial/ethnic and sex disparities in use of HAs.

By providing enhanced hearing input, HAs may facilitate greater social engagement, lower levels of effort to recognize sounds and speech, lower levels of depression or anxiety symptoms, higher levels of physical balance, and greater feelings of independence and self-efficacy.[27-30] Believing in one's physical and cognitive ability to socially engage and accomplish a task or participate in social events has been shown to advance cognitive measurements. In contrast, isolation and depression are independently associated with AD and dementia-related illnesses.[31,32] Despite evidence related to the positive association

Table 1. Descriptive Characteristics of People, Aged 66 Years or Older, With Hearing Loss With and Without Hearing Aids

Variables	Total (N = 114 862)	Without hearing aids (N = 100 753)	With hearing aids (N = 14 109)	*P* value[a]
Age, y				<.0001
66-70	28 685 (25.0)	25 248 (88.0)	3437 (12.0)	
71-75	27 126 (23.6)	23 897 (88.1)	3229 (11.9)	
76-80	24 553 (21.4)	21 615 (88.0)	2938 (12.0)	
80+	34 498 (30.0)	29 993 (86.9)	4505 (13.1)	
Sex				<.0001
Female	57 885 (50.4)	51 338 (88.7)	6547 (11.3)	
Male	56 958 (49.6)	49 397 (86.7)	7561 (13.3)	
Unknown	19 (0.02)	18 (94.7)	1 (5.0)	
Race				<.0001
White	83 185 (72.4)	71 887 (86.4)	11 298 (13.6)	
Black	6688 (5.8)	6031 (90.2)	657 (9.8)	
Hispanic	10 236 (8.9)	9570 (93.5)	666 (6.5)	
Asian	3741 (3.3)	3429 (91.6)	312 (8.3)	
Unknown/missing	11 012 (10)	9836 (89.3)	1176 (10.7)	
Census divisions[b]				<.0001
New England	4843 (4.2)	4472 (92.3)	371 (7.7)	
Middle Atlantic	6803 (5.9)	6330 (93.1)	473 (6.9)	
East North Central	10 011 (8.7)	9015 (90.1)	996 (9.9)	
West North Central	15 810 (13.8)	9980 (63.1)	5830 (36.9)	
South Atlantic	20 718 (18.0)	18 474 (89.2)	2244 (10.8)	
East South Central	2650 (2.3)	2498 (94.3)	152 (5.7)	
West South Central	11 512 (10.0)	10 633 (92.4)	879 (7.6)	
Mountain	14 590 (12.7)	13 734 (94.1)	856 (5.9)	
Pacific	26 236 (22.8)	24 046 (91.7)	2190 (8.3)	
Unknown or Puerto Rico	1689 (1.5)	1571 (93.0)	118 (7.0)	
Chronic conditions				<.0001
Cardiovascular	39 518 (34.4)	34 690 (34.4)	4828 (34.2)	
Hypertension (complicated)	27 602 (24.0)	24 558 (24.4)	3044 (21.6)	
Hypercholesterolemia	54 544 (47.5)	48 284 (47.9)	6260 (44.4)	
Obesity	16 703 (14.5)	14 714 (14.6)	1989 (14.1)	
Diabetes (complicated)	20 197 (17.6)	18 016 (17.9)	2181 (15.5)	

[a]Significance testing for age was performed using a *t*-test, and χ^2 tests at an $\alpha = .05$ were used for all categorical variables.
[b]Census divisions: New England (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut); Middle Atlantic (New York, Pennsylvania, New Jersey); East North Central (Wisconsin, Michigan, Illinois, Indianan, Ohio); West North Central (North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri); South Atlantic (Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida); East South Central (Kentucky, Tennessee, Mississippi, Alabama); West South Central (Oklahoma, Texas, Arkansas, Louisiana); Mountain (Idaho, Montana, Wyoming, Nevada, Utah, Colorado, Arizona, New Mexico); Pacific (Alaska, Washington, Oregon, California, Hawaii).

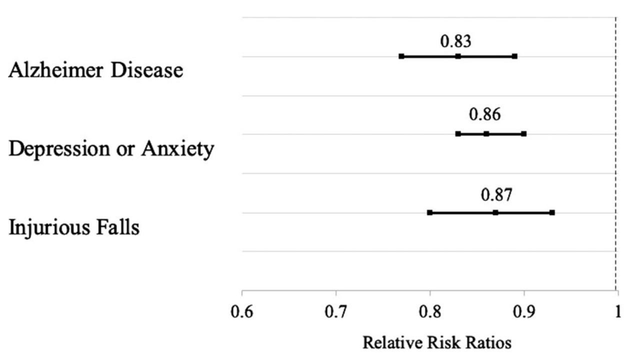

Figure 2. Unadjusted hazard ratios for developing age-related conditions among adults with hearing loss who used hearing aids compared with those who did not. Unadjusted hazard ratios and 95% confidence intervals were determined using Cox proportional hazards regression models with hearing aid use as the covariate.

between HA use and improvement in quality of life and well-being, prior studies have reported conflicting results regarding the preventative role of HAs in age-related conditions.[15,33-36]

The present findings support previous literature on substantial sex and racial/ethnic disparities in the use of HAs.[12,33,37] The underlying factors behind these disparities have been discussed extensively.[13,38] Our findings are unique because they underscore the importance of protective associations of HA with each of our conditions that are more common among females and minorities. For example, prevalence of AD or dementia[39,40] and anxiety or depression[40,41] is substantially higher among females than males as well as among African Americans compared to whites. It follows that reducing disparities in access and use of HAs is likely attributable to insurance coverage and affordability among these subpopulations. It is also conceivable that other salient factors, such as severity of HL, frailty, socioeconomic status, lifestyle, and behavior choices, are associated with diagnosis of age-related conditions.

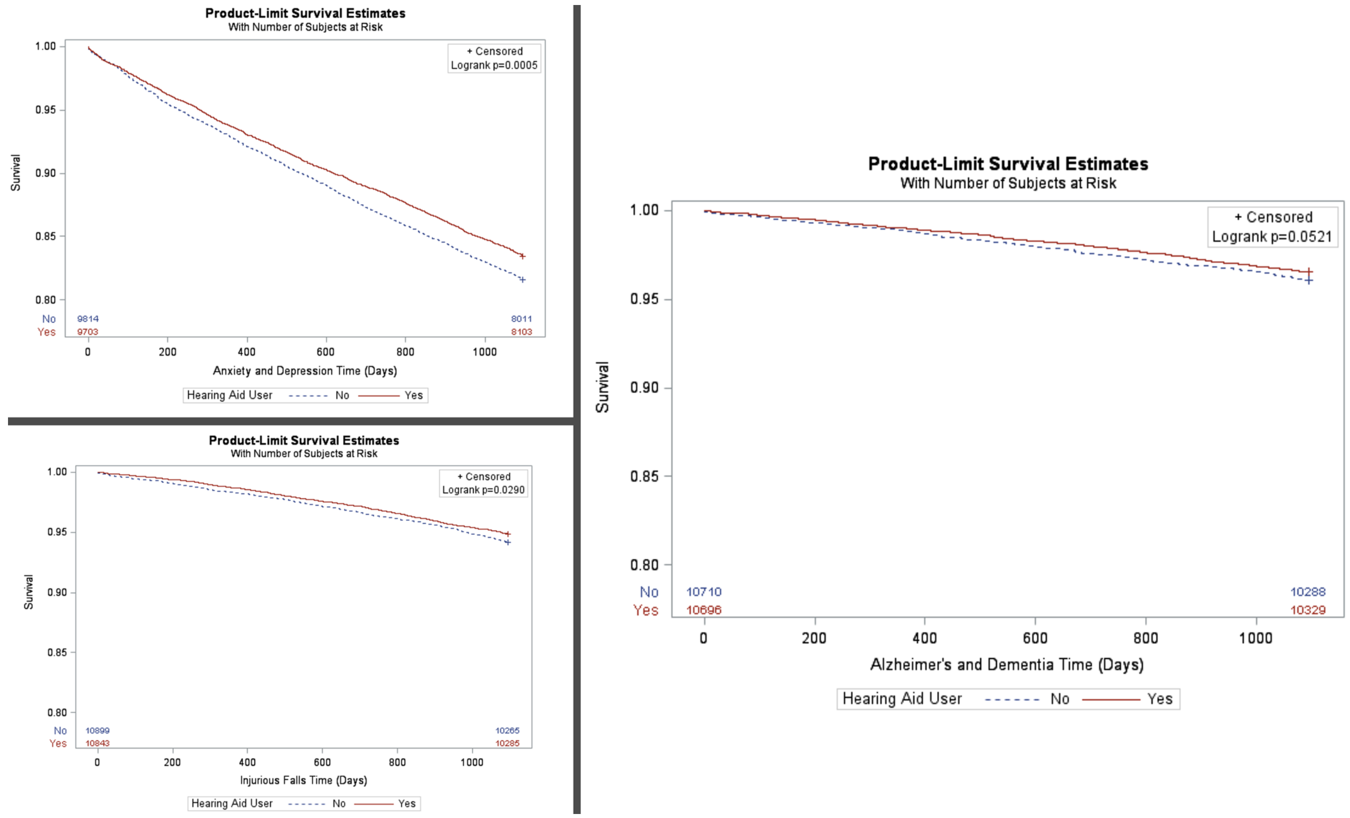

Figure 3. Kaplan-Meier curves: disease-free time in days to the diagnosis of three age-related conditions. (1) All adults in the cohort had no diagnosis of Alzheimer disease or dementia, anxiety or depression, or falls on a claim for 1 year prior to the index diagnosis of hearing loss. (2) All log-rank tests were significant at the .05 level.

Mounting evidence indicates strong associations between HL and cognitive decline and increased risk of falls among older adults.[5,9,15,42] Two main theories explain this association: (1) cascade theory and (2) common cause theory.[43,44] The cascade theory hypothesizes that extended periods of uncorrected HL cause more isolation and less stimulation, which may lead to cognitive decline among older adults.[44] The common cause theory hypothesizes that both HL and physical and cognitive decline are associated with aging changes in the nervous system, meaning that both are part of the normal aging process.[45]

Our findings corroborate existing literature asserting that use of HAs is associated with lower risk of being diagnosed with AD or dementia, anxiety or depression, and falls.[46] Recent studies found hearing interventions to be protective against further cognitive decline among older adults with dementia. For example, Maharani et al found reduced rates of decline in episodic memory scores among older adults with HL and dementia after they started using HAs.[47] Prolonged sensory deprivation due to hearing or vision loss has been linked to social isolation, delirium, and cognitive decline.[48] Our findings posit additional evidence that HL may be a modifiable risk factor (through HA intervention) for AD or dementia.

Additionally, HL has been linked with depression and anxiety.[31] People at greater risk of isolation because of functional or sensory impairments are prone to experience depression. Our results suggest that HAs may delay diagnosis of depression and anxiety among individuals with HL. While improvement in one-to-one and group conversations in various social and healthcare settings is important, HA use also confers improvements in independently accomplishing tasks, work productivity, self-awareness, self-confidence, and self-advocacy.

Table 2. Crude and Adjusted HRs With 95% CIs for Diagnosis of Age-Related Conditions Among Older Adults With Hearing Loss Who Used Hearing Aids Compared to those Without Hearing Aids

Aging-related morbidity	Crude HR (95% CI)	*P* value	Adjusted HR (95% CI)	*P* value
Alzheimer disease or dementia	0.826 (0.765-0.891)	<.001	0.824 (0.761-0.893)	<.001
Anxiety or depression	0.863 (0.827-0.900)	<.001	0.894 (0.856-0.934)	<.001
Falls	0.865 (0.801-0.934)	<.001	0.871 (0.804-0.945)	<.001

Abbreviations: CI, confidence interval; HR, hazard ratio.

Note: Crude HRs and 95% CIs were estimated with hearing aid use as the primary exposure variable. Adjusted HRs and 95% CIs were calculated using Cox proportional hazards regression models for age, sex, US census division, hypertension, diabetes, hypercholesterolemia, obesity, and cardiovascular conditions (see Supplementary Tables S6-S9).

Age-related HL is negatively associated with balance function and increases the risk of fall-related injuries.[49,50] Plausibly, this could be explained by poorer spatial awareness or cognitive overload resulting from auditory deprivation among adults with HL. A decline in the ability to notice auditory cues may lead to lower awareness of one's surroundings and thus to higher incidence of falls.[8]

Currently, there is no standard estimate of incidence or prevalence for each of the outcomes in our study. Depending on the data source, there can be vastly different prevalence and incidence estimates. For instance, the Health and Retirement Study linked to Medicare administrative claims data has shown that cognitive test results from survey data vs diagnoses from claims data can yield different incidence for dementia.[51] For example, among whites, incidence of dementia based on cognitive tests from surveys was lower than that using diagnosis codes from claims (3.2% vs 12.3%).[51] In contrast, among blacks, dementia incidence was higher using cognitive tests compared to that using diagnosis codes (15.2% vs 11.1%).[51]

Prior literature shows incidence for dementia, injurious falls, and depression in the general geriatric population is 12.2%,[51] 7.5%,[52] and 25.2%,[53] respectively. In support of previous literature, our findings indicate higher incidence of these conditions among HL patients. From 2008 to 2016, we found incidence of dementia, injurious falls, and depression for HL patients to be 13.9%, 12.7%, and 35.6%, respectively.

On average, HAs cost between $2000 and $7000 and are not covered (or are underinsured) by most health plans, which shifts the financial burden of HAs to patients.[13] Today, more than 27 million older Americans live with HL, but only approximately 14% of them use HAs.[1] While cost is a pertinent and plausible barrier to access to HAs, efforts have been made to improve access. The US president's council of advisors on science and technology[54] report asserts that the HA prescription process should be made similar to that for eyeglasses and contact lenses. Furthermore, the Over-the-Counter Hearing Aid Act[55] enables availability of HAs over the counter without a prescription. Although HAs are expensive, the medical costs of many conditions that could be prevented or delayed by using HAs are substantially more expensive. For example, in 2017, the annual incidence rate of AD among Americans aged 65 years or older was 480 000 patients; by 2050, this is expected to rise to approximately 1 million patients.[39] Average annual direct healthcare payments (in 2016 dollars) are $46 000 for each patient with AD alone (approximately $34 000 more than direct healthcare spending for those without AD).[39] Any delay in diagnosis of AD or dementia could not only lead to large cost savings, but also improve the health and well-being of older adults.

LIMITATIONS

Our study has several potential limitations. First, inherent limitations of using claims data include a lack of information about patients' socioeconomic status, lifestyle choices, educational attainment, and other salient factors. While appropriate use of HAs might delay the diagnosis of age-related conditions, HA users could have different lifestyle choices and resources available to them that could also contribute to a delayed diagnosis of these conditions. Second, since we use claims and diagnostic codes to define HL, we may be unable to identify all patients with HL. HL patients without official diagnoses may not be included; others may have been incorrectly included as new patients if their diagnosis preceded the 12-month look-back period. Furthermore, claims data do not include direct audiometric measurements of HL. We were able to identify those who were diagnosed with HL but could not determine HL severity. We assumed that most adults, aged 66 years and older, who were diagnosed with HL had moderate to severe HL, and thus were in need of HAs. Third, we did not have any way to measure frequency and duration of HA use, if any, among individuals who purchased HAs. Often, HAs are not fitted properly, and people do not use their HAs consistently.[14] There are also cultural taboos among many subpopulations, such as minorities and females, regarding the use of HAs. Individuals with HL may purchase HAs on the advice of physicians or family members, but rarely use them. Fourth, analysis of falls is complex. Using claims data, we controlled for no history of fall-related injuries during the 12-month period before index hearing loss diagnosis but were not able to control for other fall-related factors. Finally, our data came from a private insurance database that might introduce biases into our findings associated with the health status and higher functioning of Medicare managed care patients. Furthermore, state-level market penetration from a single large private payer varies; therefore, in the absence of sampling weights, national prevalence is not estimable at this time.

The study's strengths include having a large sample size due to using claims data, which contain large sample sizes and longitudinal follow-up of health services and provide a broad clinical perspective on health outcomes over time. Since HAs are not covered by Medicare fee-for-service plans, this covers an important segment of the population that likely has at least some coverage for HAs. Therefore, we examined a reasonably exhaustive snapshot of their service utilization.

To ensure the absence of prior diagnosis of our outcomes, a 1-year clean period was used as a sufficient amount of time to ensure no preexisting diagnoses. This enabled us to measure the association between HAs and time to diagnosis of three conditions within 3 years of HL diagnosis, controlling for confounding demographics and comorbidities.

CONCLUSION

Use of HAs among adults with HL was associated with delay or prevention of three common and important age-related conditions: AD or dementia, depression or anxiety, and fall-related injuries. Timely diagnosis of HL and early use of HAs may delay the diagnosis of cognitive decline and reduce the risk of injurious falls.

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Conflict of Interest: No conflict of interest to report.

Author Contributions: Dr. Mahmoudi had full access to all of the data in the study and takes responsibility for

the integrity of the data and the accuracy of the data analysis. Study concept and design: Mahmoudi Acquisition, analysis, or interpretation of data: Mahmoudi, Kamdar Drafting of the manuscript: All authors Critical revision of the manuscript for important intellectual content: All authors Statistical analysis: Kamdar, Basu.

Sponsor's Role: N/A.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article.

Supplementary Table S1. *ICD-9* and *ICD-10* diagnosis codes for hearing loss.

Supplementary Table S2. Procedure codes for hearing aids.

Supplementary Table S3. *ICD-9* and *ICD-10* diagnosis codes for Alzheimer disease and dementia, anxiety and depression, alcohol and drug disorders, and fall.

Supplementary Table S4. Summary statistics of the state-specific proportions of the outcomes of interest.

Supplementary Table S5. Propensity-matched adjusted hazard ratios for diagnosis of age-related morbidities among patients with hearing loss who used hearing aids compared with those who did not.*

Supplementary Table S6. Cox regression results for Alzheimer disease or dementia.

Supplementary Table S7. Cox regression results for anxiety or depression.

Supplementary Table S8. Cox regression results for injurious fals.

Supplementary Figure S1. Heat maps of incidence rates of hearing aid use, Alzheimer disease and/or dementia, anxiety and/or depression, and injurious fall within 52 states.