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Association of Hearing Impairment with Risk of Hospitalization in Older Adults

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Abstract

OBJECTIVES—To determine the association of hearing impairment (HI) with risk and duration of hospitalization in community-dwelling older adults in the United States.

DESIGN—Prospective observational study.

SETTING—Health, Aging and Body Composition study.

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PARTICIPANTS—Well-functioning community-dwelling White and Black Medicare beneficiaries aged 70–79 years at study enrollment in 1997–1998 were followed for a median of 12 years.

MEASUREMENTS—Incidence, annual rate, and duration of hospitalization were the primary outcomes. Hearing was defined as the pure-tone average of hearing thresholds in decibels re: Hearing Level (dB HL) at octave frequencies from 0.5–4 kHz. Mild HI was defined as PTA >25–40 dB HL, and moderate-or-greater HI was defined as PTA >40 dB HL.

RESULTS—Of the 2,148 participants included in the analysis, 1,801 (83.5%) experienced one or more hospitalizations, with 7,007 adjudicated hospitalization events occurring during the study period. A total of 882 (41.1%) participants had normal hearing, 818 (38.1%) had mild HI, and 448 (20.9%) had moderate-or-greater HI. After adjusting for demographics and cardiovascular comorbidities, persons with mild and moderate-or-greater HI, respectively, experienced a 16% (Hazard Ratio [HR]: 1.16, 95% CI: 1.04–1.29) and 21% (HR: 1.21, 95% CI: 1.06–1.38) greater risk of incident hospitalization and a 17% (Incidence Rate Ratio [IRR]: 1.17, 95% CI: 1.04–1.32) and 19% (IRR: 1.19, 95% CI: 1.04–1.38) greater annual rate of hospitalization compared to persons with normal hearing. There was no significant association of HI with mean duration of hospitalization.

CONCLUSION—Hearing-impaired older adults experience a greater incidence and annual rate of hospitalization than those with normal hearing. Investigating whether hearing rehabilitative therapies could affect the risk of hospitalization in older adults requires further study.

Keywords

hearing impairment; hospitalization; older adults; epidemiology

INTRODUCTION

Inpatient hospital admissions consume a significant and increasing portion of the United States healthcare budget, and demand for these services persistently exceeds supply.[1,2] Hospital admissions increased 15% from 34.3 million in 1993 to 39.5 million in 2006,[3] and since 2000, hospitalization-related costs have increased 4.2% per year, making it the second largest driver of increasing healthcare costs.[4] A substantial share of these costs comprise preventable hospitalizations, which unfortunately are common, numbering 1,395 per 100,000 adults in 2009.[5] Although, the rate of preventable hospitalizations decreased from 2001 to 2009,[5] owing to improved management and prevention of chronic disease,[6,7] the rate remains high, placing a burden on the U.S. healthcare infrastructure.[5] Reducing hospitalizations, particularly preventable admissions, is important to reducing healthcare costs,[5] and a necessary first step in this process is to identify potentially modifiable factors that contribute to this high rate of hospitalization.

Patient education programs that teach self-management of chronic conditions, particularly diabetes mellitus and cardiovascular disease, have been found to decrease healthcare costs and reduce unnecessary use of inpatient hospital services.[5,6] However, little attention has been given to other chronic conditions that may impact healthcare management, such as hearing impairment (HI), the third most prevalent chronic condition in older adults in the

US.[8] Hearing impairment affects nearly two-thirds of adults aged 70 years or older in the US and is treatable, but less than one-fifth of older adults with HI obtain treatment.[9] The estimated healthcare costs attributed to HI in 2010 exceed $3 billion,[10] and a recently published cross-sectional study, which was undertaken to build on previous studies that demonstrated associations between HI and various negative health outcomes, found that HI is independently associated with hospitalization in older adults, after controlling for demographic characteristics and cardiovascular risk factors.[11]

Given the importance of cost containment in the current healthcare environment, we sought to further investigate these cross-sectional findings and explore the association of HI with hospitalization in older adults using a longitudinal cohort of community-dwelling older adults followed in the Health, Aging and Body Composition study. We hypothesized that greater HI is associated with an increased risk and duration of hospitalization in older adults.

METHODS

Study population

We obtained data from the Health, Aging and Body Composition (Health ABC) study, a prospective observational study that enrolled 3,075 well-functioning community-dwelling older adults aged 70–79 years in 1997–1998.[12,13] Study participants were recruited from a random sample of White and Black Medicare beneficiaries living in zip codes in Pittsburgh, Pennsylvania and Memphis, Tennessee within a one-hour drive of the examination site. Only White and Black individuals were recruited because an original study objective was to examine race-related differences in body composition parameters, and there were insufficient resources to include other races. To be eligible, participants had to report no difficulty walking a quarter of a mile, climbing ten steps without resting, or performing basic activities of daily living.

Audiometric testing was administered in Year 5 (2001–2002) of the study. Various causes (missed clinical visit in Year 5 [n=508], inability to complete audiometry [n=88], death prior to Year 5 [n=263], withdrawal from study prior to Year 5 [n=8]) prevented all participants from undergoing audiometric testing. Those excluded from the analysis were less likely to have postsecondary education and more likely to be older, African American, from the Memphis study site. Additionally, they were more likely to have a baseline history of hypertension, CV disease, and current smoking status ($p<0.05$ for all comparisons). In total, 2,208 participants underwent audiometric testing. Sixty (2.7%) participants were excluded for missing covariate data. The remaining 2,148 individuals comprise our analytic cohort. All participants provided informed consent, and the institutional review boards of all sites approved this study.

Audiometry

Audiometric assessments were performed with participants seated in a sound-treated booth. Air-conduction thresholds for each ear were obtained for pure tones at octave frequencies from 0.25 to 8 kHz presented via an audiometer (Maico MA40) configured with supra-aural earphones (TDH 39). A handheld otoscope was used to examine the ear canalThe

audiometer and examiner were located outside the booth during testing, and the booth and audiometer met current American National Standards Institute standards (ANSI S3.1-1979; ANSI S3.6-1996). All thresholds were measured in decibels re: hearing level (dB HL). A pure-tone average (PTA) of hearing thresholds at 0.5, 1, 2, and 4 kHz was calculated for the better hearing ear. In accordance with WHO definitions,[14] mild HI was defined as PTA >25–40 dB HL, and moderate-or-greater HI was defined as PTA >40 dB HL.

Hospitalization Outcome Variables

Every 6 months, participants were asked to report any hospitalizations since their last visit and were asked directed questions to elicit such information. A hospitalization was defined as an illness episode resulting in overnight admission to an acute care hospital. Health ABC staff adjudicated the details of each hospitalization using medical records and supporting documents. These data include primary and secondary admission diagnoses and dates of admission and discharge. All data were adjudicated through 5/30/2010 for the Pittsburgh site and 04/30/2010 for the Memphis site.

Time to incident hospitalization was defined as the date of study enrollment to the date of the first hospital admission. Rate of hospitalization was defined as the number of hospitalizations per year of enrollment. Duration of hospitalization was defined as the date of hospital admission to the date of discharge. Hospitalizations resulting in death and same-day hospitalizations were excluded from duration of hospitalization analyses.

Covariates

At enrollment, participants reported their age, sex, race, and educational history. Pre-specified algorithms based on self-reported and physician diagnoses, recorded medications, and laboratory data were used to define the presence of hypertension (clinic measure, medications, or self-report), diabetes mellitus (fasting blood glucose level, medications, or self-report), and cardiovascular (CV) disease (ECG findings, medications, or self- report).[15] Self-reported smoking status (current/former/never) and hearing aid use were based on interviewer-administered questionnaires. At the time of audiometry, the Modified Mini-Mental State (3MS) Examination was administered. Scores for the 3MS range from 0–100 with a score <80 considered indicative of cognitive impairment.[16]

Cardiovascular Hospitalization Classification

For sensitivity analyses, hospitalizations were secondarily categorized as CV or non-CV in nature. A hospitalization was classified as being CV if the primary admission diagnosis was myocardial infarction, angina, ischemic heart disease, congestive heart failure, cardiomyopathy, carotid artery disease, peripheral artery disease, cerebrovascular accident, or transient ischemic attack.

Statistical Analyses

Baseline characteristics of study participants were compared using Kruskal-Wallis one-way analysis of variance for continuous variables and Fisher’s exact test for categorical variables. We used Cox proportional hazards models to investigate the association between HI and incident hospitalization, using time from enrollment to incident hospital admission as the

time scale. The assumption of proportional hazards was checked using the correlation between the scaled Schoenfeld residuals and transformed survival times. The nonparametric base hazard function was stratified by history of diabetes to achieve proportional hazards. We used hurdle negative binomial models to model the number of hospitalizations, using time on study as an offset to account for varying length of follow-up. We analyzed the association between HI and duration of hospitalization using parametric lognormal survival models, using robust standard errors to account for repeated hospitalizations within individuals. In addition to other covariates, we further adjusted the lognormal models for the number of concurrent diagnoses per admission. For all models, linearity of relationships was assessed using smoothed residual plots, and parametric assumptions were checked using plots of residuals or transformations of the survivor function where applicable. All analyses were conducted in R 3.0.2 (R Foundation for Statistical Computing, Vienna, Austria).[17] Hurdle negative binomial models were fitted using the pscl package.[18] All hypothesis tests were two-sided, with a significance level of 0.05.

RESULTS

Participant Characteristics

Our study population consists of 2,148 older adults with audiometric testing and complete demographic and clinical data. Of these, 1,801 (83.5%) experienced one or more hospitalizations, with a total of 7,007 adjudicated hospitalizations occurring during the study period. A total of 882 (41.1%) participants had normal hearing, 818 (38.1%) had mild HI, and 448 (20.9%) had moderate-or-greater HI. Individuals with HI were more likely to be older, male, White, less educated, from the Memphis site, have a history of smoking, use a hearing aid, and experience more hospitalizations (Table 1). There were no differences in prevalence of hypertension, diabetes, stroke, or CV disease according to hearing status.

Incident Hospitalization

We examined the association of HI (normal hearing, mild HI, moderate-or-greater HI) with time to first (incident) hospitalization using both unadjusted Kaplan-Meier estimates (Figure 1) and Cox proportional hazards models adjusted for demographics (age, sex, race, and educational history) and CV comorbidities (hypertension, diabetes mellitus, smoking history, and cardiovascular disease) (Table 2). In both models, HI was significantly associated with risk of incident hospitalization. In the Cox model, mild and moderate-or-greater HI, respectively, were associated with a 16% (Hazard ratio [HR]: 1.16, 95% CI: 1.04–1.29) and 21% (HR: 1.21, 95% CI: 1.06–1.38) increased risk of incident hospitalization compared to normal hearing (Table 2). In a confirmatory analysis treating HI as a continuous variable, HI was nonlinearly associated with an increased risk of incident hospitalization. The HR of incident hospitalization increased 11% for every 10 dB increase in hearing threshold up to 40 dB HL (HR: 1.11 per 10 dB, 95% CI: 1.05–1.19) and plateaued with no additional increase in risk after 40 dB HL (Figure 2).

Annual Rate of Hospitalization

We next explored the association of HI with annual rate of hospitalization using hurdle negative binomial regression, adjusting for demographics and CV comorbidities. In

individuals with at least one hospitalization, mild and moderate-or-greater HI, respectively, were associated with a 17% (Incident rate ratio [IRR]: 1.17, 95% CI: 1.04–1.32) and 19% (IRR: 1.19, 95% CI: 1.04–1.38) greater annual rate of hospitalization compared to normal hearing (Table 2). Treating HI as a continuous variable yielded similar results. In the fully adjusted model, every 10 dB increase in hearing threshold was associated with a 5% higher hospitalization rate (IRR: 1.05 per 10 dB, 95% CI: 1.01–1.10).

Duration of Hospitalization

To investigate the association of HI with mean duration of hospitalization, we used a lognormal model, adjusting for demographics and cardiovascular comorbidities. In this analysis, we excluded 283 (4.0%) admissions resulting in death and 20 (<0.1%) same-day admissions. After these exclusions, 6,724 (96.0%) hospitalization events were included. The mean duration of hospitalization was not significantly different between individuals with normal hearing and those with HI (mild HI factor change in mean duration of hospitalization: 1.04, 95% CI: 0.99–1.10; moderate-or-greater HI factor change: 1.06, 95% CI: 0.99–1.13). In a model treating HI as continuous, every 10 dB increase in hearing threshold was significantly associated with a 5% longer mean length of hospitalization up to 30 dB HL (factor change: 1.05 per 10 dB, 95% CI: 1.01–1.09). At thresholds greater than 30 dB HL, this association was attenuated (factor change: 1.00 per 10 dB, 95% CI: 0.97–1.03).

Hearing Aid Use

We included hearing aid use as a covariate in fully adjusted models to determine if hearing aid use was associated with risk or duration of hospitalization. Hearing aid use was not associated with incident hospitalization in Cox models treating HI as a categorical (HR of hearing aid use: 1.02, 95% CI: 0.85–1.21) or continuous (HR: 1.03, 95% CI: 0.86–1.23) predictor variable. Hearing aid use was also not associated with annual rate of hospitalization in negative binomial models treating HI as categorical (IRR: 0.91, 95% CI: 0.75–1.10) or continuous (IRR: 0.88, 95% CI: 0.73–1.06). However, hearing aid use was associated with a shorter mean duration of hospitalization. In fully adjusted lognormal models, hearing aid use was associated with a 13% (factor change: 0.87, 95% CI: 0.80–0.94) and 14% (factor change: 0.86, 95% CI: 0.79–0.93) shorter the mean length of hospitalization when treating HI as categorical and continuous, respectively.

Sensitivity Analyses

We conducted a sensitivity analysis stratified by type of hospitalization (non-CV [n = 5,377] vs. CV [n = 1,651]) to investigate if the observed associations were stronger for CV than for non-CV hospitalizations (possibly suggesting that unmeasured CV risk factors may be confounding the observed associations). In these analyses, we observed that the magnitude of the association of HI with incidence of non-CV and CV hospitalizations did not substantively differ; however, only the association of HI with incidence of non-CV hospitalization was statistically significant (*non-CV hospitalizations, HR* - mild HI: 1.18, 95% CI: 1.06–1.32; moderate-or-greater HI: 1.24, 95% CI: 1.09–1.43; *CV hospitalization, HR* - mild HI: 1.09, 95% CI: 0.93–1.28; moderate-or-greater HI: 1.13, 95% CI: 0.93–1.37; compared to normal hearing). Hearing impairment remained associated with rate of non-CV

hospitalization (*IRR* - mild HI: 1.14, 95% CI: 1.01–1.29; moderate-or-greater HI: 1.20, 95% CI: 1.03–1.40), and mild HI remained associated with rate of CV hospitalization (*IRR* - mild HI: 1.39, 95% CI: 1.01–1.91; moderate-or-greater HI: 1.18, 95% CI: 0.80–1.74).

We also investigated whether our main results were robust to excluding individuals with cognitive impairment (3MS score <80 at time of audiometry, n = 149) In these analyses, our results remained substantively unchanged (*incident hospitalization, HR* - mild HI: 1.16, 95% CI 1.04–1.29; moderate-or-greater HI: 1.21, 95% CI: 1.06–1.38; *annual rate of hospitalization, IRR* - mild HI: 1.17, 95% CI: 1.04–1.32; moderate-or-greater HI: 1.19, 95% CI: 1.03–1.38; compared to normal hearing).

DISCUSSION

Our results demonstrate that hearing impairment in community-dwelling older adults in the United States is independently associated with higher incidence and annual rate of hospitalization. On average, we observed that individuals with mild and moderate-or-greater HI had a 16–21% greater incidence and a 17–19% higher annual rate of hospitalization compared to individuals with normal hearing. These associations were robust to adjustment for multiple confounders and sensitivity analyses. These findings suggest that HI in older adults, which is highly prevalent but undertreated, may be an unrecognized risk factor for increased risk of hospitalization.

Our findings are consistent with previous reports examining the association of HI with greater use of hospital resources. A recent study examining nationally representative data from the National Health and Nutrition Examination Survey found that HI was associated with a 32% higher odds of any hospitalization and a 35% higher odds of a greater number of hospitalizations for every 25 dB increase in hearing thresholds, after adjusting for demographics and cardiovascular comorbidities.[11] However, this study was cross-sectional and used self-reported hospitalization data, limiting the strength of its conclusions. Our study builds upon these findings by using data from a longitudinal cohort and adjudicated hospitalization data. Another study by Kurz and colleagues[19] found that individuals with HI were more likely to seek hospital care compared to normal hearing individuals. Previous research has also demonstrated that HI is associated with greater utilization of outpatient resources.[19–22]

Multiple possible mechanisms may underlie the observed associations of HI with risk of hospitalization. Shared risk factors or pathological processes such as inflammation[23] or microvascular disease[24,25] could potentially contribute to both poorer hearing and risk of hospitalization. These factors may not be fully accounted for in the demographics and CV comorbidities adjusted for in our models. However, our sensitivity analyses demonstrated that HI remained associated with both non-CV and CV hospitalizations, suggesting that substantial bias from unmeasured CV-related factors (residual confounding) is less likely.

The association of HI with hospitalization risk may be mediated through social isolation, which can be an insidious sequela of HI in older adults.[26,27] Social networks and relationships influence health-promoting or risk-related behaviors, and, generally, social

connectedness is inversely related to negative health behaviors.[28] Additionally, impaired psychological mechanisms such as self-efficacy, coping skills, perceived self-worth, and depression have been associated with social isolation[28,29] and may contribute to poor personal health management and outcomes in persons with HI, given that social isolation is more common in these individuals.[26,27] Hearing impairment may also contribute to decreased health-related oral literacy (ability to engage in effective verbal communication with physicians and care providers).[30–33] Health-related oral literacy is a key component of overall health literacy (also comprised of print literacy and numeracy), which is a critical determinant of health outcomes in older adults.[34,35] Inadequate health literacy has been shown to be an independent risk factor for hospitalization, with reports demonstrating a 29–52% increased risk of hospitalization among individuals with inadequate health literacy.[34,35] Hearing impairment has also been found to be strongly associated with poor cognitive function,[36–38] which may contribute further to hospitalization risk.

We did not find a significant association of HI with duration of hospitalization, although there was a trend toward a longer mean duration. When examining the association of HI as a continuous variable, there was a 5% longer mean duration of hospitalization, but this association was attenuated beyond 30 dB HL and requires further confirmation. One possibility is that HI substantively affects only certain types of hospitalizations, such as those in which delirium is more likely to occur. Hearing impairment has been associated with an increased risk of delirium,[39,40] a key determinant of length of hospital stay.[39,41] Inpatient programs aimed at decreasing the onset of delirium that have included hearing loss treatment have demonstrated shorter hospital stays in older adults.[39,41]

In the present study, we found that self-reported hearing aid use was independently associated with a decreased mean length of hospitalization, but not risk of hospitalization. Interpreting this finding is difficult because key information on hearing aid use (e.g., use of hearing aids during hospitalization, hours worn per day, number of years used, use of other communicative strategies) that would affect the success of hearing rehabilitation and subsequently affect any observed associations was not available. Therefore, whether hearing rehabilitative treatments alone could affect risk and duration of hospitalization among older adults with HI remains uncertain and requires further study.

A key limitation of the current study is our inability to determine the mechanistic basis for the observed associations between HI and risk of hospitalization. Additionally, hearing impairment was only measured at one time point (Year 5), and information is not available on the duration and trajectory of HI before or after this assessment. Given that HI is a chronic, irreversible condition which generally progresses at a rate of 1–2 dB/year[42] and that the definition of hearing impairment used in this study is inherently conservative and based on the better hearing ear, we feel it is unlikely that including hearing impairment measured in Year 5 as a time-fixed predictor variable indicative of baseline hearing function would lead to a substantive bias in our results. However, we cannot exclude such a bias. Strengths of the current study are that the results are based on a cohort of community-dwelling older adults and that standardized audiometric assessments using definitions of HI adopted by the WHO[14] were used. Furthermore, hospitalization details were objectively adjudicated using hospital records and supporting documents, ensuring fidelity of this information

In summary, preventable hospitalizations are a significant driver of growing healthcare costs in the United States. Our results demonstrate that hearing impairment in older adults, which is highly prevalent but undertreated, is independently associated with an increased incidence and annual rate of hospitalization. Further study is required to determine if hearing rehabilitation could potentially mitigate the role of hearing impairment in risk of hospitalization in older adults.

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Dr. Lin serves as a consultant for Pfizer, Autifony, and Cochlear Americas and has been a speaker for Med El and Amplifon.

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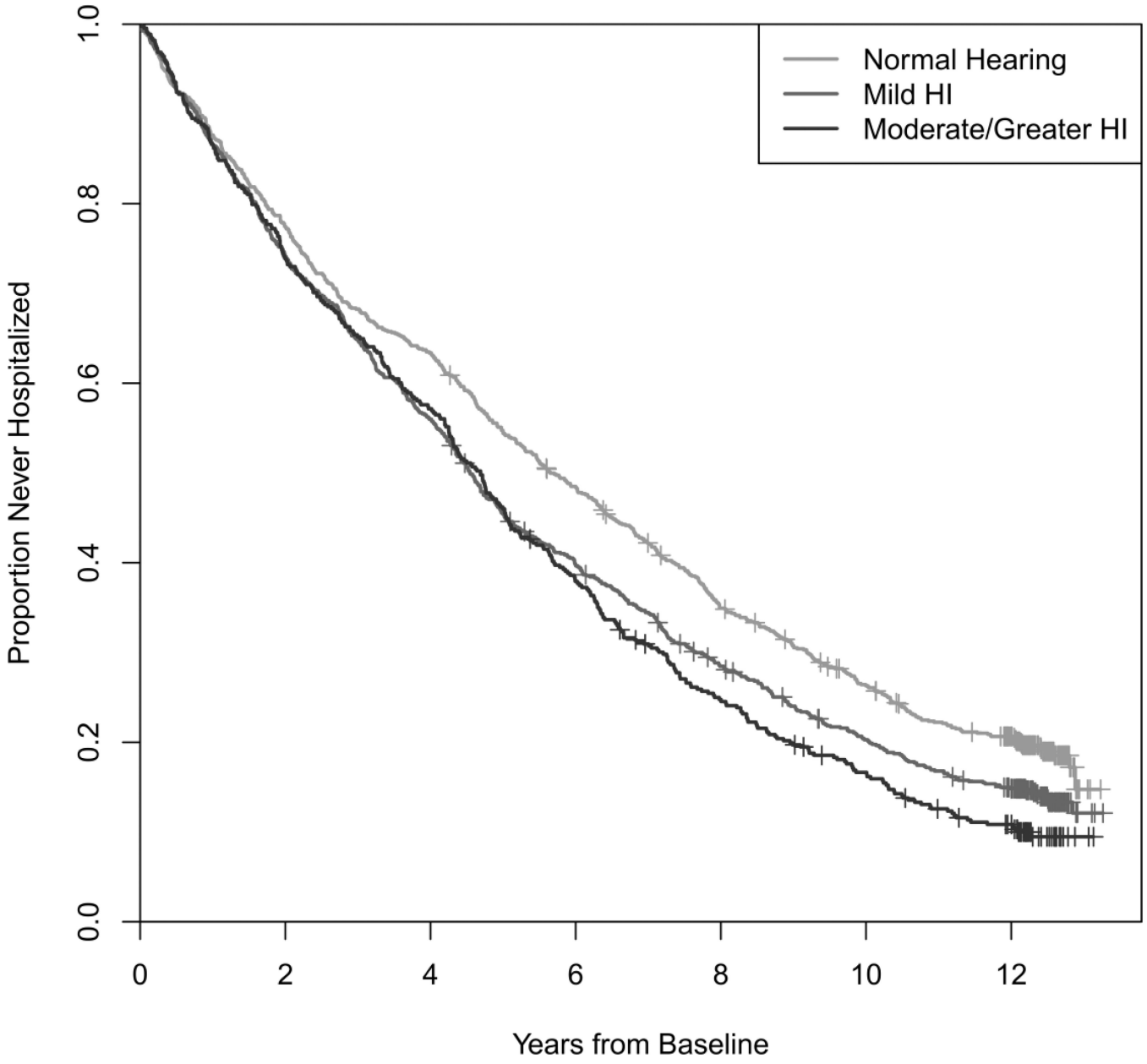

Figure 1. Kaplan-Meier survivor estimate for the proportion of participants remaining free of incident hospitalization by degree of hearing impairment

Mild and moderate/greater HI, respectively, are defined as a pure-tone average >25–40 dB HL and >40 dB HL of hearing thresholds at octave frequencies from 0.5–4 kHz in the better ear. HI, hearing impairment; dB HL, decibels re: Hearing Level.

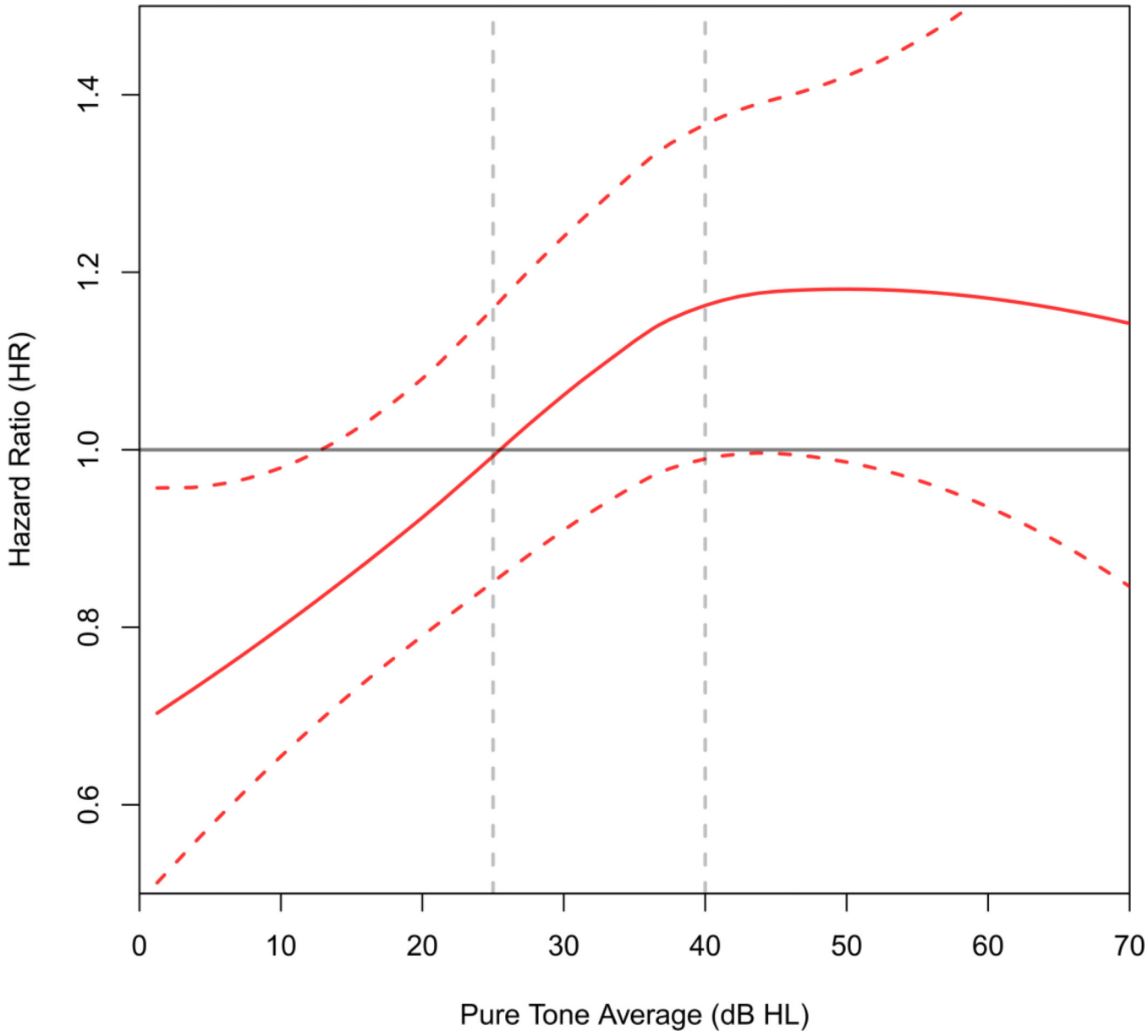

Figure 2. Hazard ratio of incident hospitalization by degree of hearing impairment

Hearing is defined as the pure-tone average of hearing thresholds at octave frequencies from 0.5–4 kHz in the better ear. The solid line indicates the hazard ratio, and the dotted lines represent the 95%CI. dB HL, decibels re: Hearing Level.

Table 1

Demographic and clinical characteristics of study population[a,b]

Characteristic	Normal Hearing (n=882)	Mild Hearing Impairment (n=818)	Moderate-or-greater Impairment (n=448)	P-value
Age, mean (SD), years	73.3 (2.7)	74.1 (2.8)	74.9 (2.9)	<.0001
Sex				<.0001
Male	342 (38.8)	402 (49.1)	289 (64.5)	
Female	540 (61.2)	416 (50.9)	159 (35.5)	
Race				<.0001
White	478 (54.2)	545 (66.6)	335 (74.8)	
Black	404 (45.8)	273 (33.4)	113 (25.2)	
Education				.026
Some high school	182 (20.6)	166 (20.3)	124 (27.7)	
High school graduate	287 (32.5)	277 (33.9)	134 (29.9)	
Some college or greater	413 (46.8)	375 (45.8)	190 (42.4)	
Study Site				.011
Pittsburgh	490 (55.6)	418 (51.1)	211 (47.1)	
Memphis	392 (44.4)	400 (48.9)	237 (52.9)	
Hypertension	557 (63.2)	501 (61.2)	272 (60.7)	.604
Diabetes Mellitus	142 (16.1)	141 (17.2)	89 (19.9)	.232
CV Disease	181 (20.5)	193 (23.6)	110 (24.6)	.159
Smoking				<.0001
History				
Never	444 (50.3)	365 (44.6)	167 (37.3)	
Former	363 (41.2)	398 (48.7)	237 (52.9)	
Current	75 (8.5)	55 (6.7)	44 (9.8)	
Years at risk, median [IQR]	12.3 [11.3, 12.6]	12.2 [10.3, 12.5]	12.1 [9.4, 12.4]	<.0001
At least one hospitalization	706 (80.0)	696 (85.1)	399 (89.1)	.0001
At least one CV hospitalization	312 (35.4)	315 (38.5)	184 (41.1)	.109
At least one non-CV hospitalization	650 (73.7)	654 (80.0)	375 (83.7)	<.0001
No. of hospitalizations, median [IQR]	2 [1, 4]	3 [1, 5]	3 [1, 5]	<.0001
No. of CV hospitalizations, median [IQR]	0 [0, 1]	0 [0, 1]	0 [0, 1]	.089
No. of non-CV hospitalizations, median [IQR]	2 [0, 3]	2 [1, 4]	2 [1, 4]	<.0001
Pure tone average, mean (SD), dB HL	18.2 (5.0)	32.5 (4.4)	50.4 (9.1)	<.0001
Hearing aid use	5 (0.6)	43 (5.3)	148 (33.0)	<.0001

Abbreviations: SD, standard deviation; CV, cardiovascular; IQR, interquartile range; dB HL, decibels re: Hearing Level

[a] Population includes all study subjects who participated in audiometric testing in Year 5 and have no missing data on demographic characteristics or cardiovascular risk factors (N=2,148).

[b] All values are expressed as number (%) of participants unless otherwise indicated. Hearing is defined as a pure-tone average (PTA) of hearing thresholds at 0.5, 1, 2, and 4 kHz in the better hearing ear in units of dB HL (decibels re: Hearing Level). Mild hearing impairment is defined as a PTA >25–40 dB HL, and moderate-or-greater hearing impairment is defined as a PTA >40 dB HL.

Table 2

Association of hearing impairment with incident hospitalization, annual rate of hospitalization, and mean duration of hospitalization in multivariate models for all hospitalizations

	Model					
	Incident Hospitalization[a]		Annual Rate of Hospitalization[b]		Mean Duration of Hospitalization[c]	
Independent Variable	**Hazard Ratio (95% CI)**	**P-value**	**Incidence Rate Ratio (95% CI)**	**P-value**	**Factor Change (95% CI)**	**P-value**
Hearing Status[d]						
Normal hearing	Reference		Reference		Reference	
Mild impairment	1.16 (1.04 – 1.29)	.006	1.17 (1.04 – 1.32)	.008	1.04 (0.99 – 1.10)	.133
Moderate-or-greater impairment	1.21 (1.06 – 1.38)	.005	1.19 (1.04 – 1.38)	.015	1.05 (0.99 – 1.13)	.082

Abbreviations: CI, confidence interval; dB HL, decibels re: Hearing Level

[a] Time to first (incident) hospitalization was determined by Cox proportional hazards regression, controlling for demographic characteristics (age, sex, race, and educational history) and cardiovascular comorbidities (hypertension, diabetes mellitus, smoking history, and cardiovascular disease). Included in the analysis were 2,148 participants with a total of 7,007 hospitalizations.

[b] Annual rate of hospitalization among participants with *at least one hospitalization* was determined by hurdle negative binomial regression, controlling for demographic characteristics (age, sex, race, and educational history) and cardiovascular comorbidities (hypertension, diabetes mellitus, smoking history, and cardiovascular disease). Included in the analysis were 1,801 (83.5%) participants with a total of 7,007 hospitalizations.

[c] Mean length of hospitalization was determined using lognormal regression, controlling for demographic characteristics (age, sex, race, and educational history) and cardiovascular comorbidities (hypertension, diabetes mellitus, smoking history, and cardiovascular disease). Included in the analysis were 1,771 participants with a total of 6,724 *eligible* hospitalizations. Hospitalizations resulting in death (283 [4.0%]) and same day admissions (20 [<0.1%]) were excluded from the total of 7,007 hospitalization events.

[d] Hearing is defined as a pure-tone average (PTA) of hearing thresholds at 0.5, 1, 2, and 4 kHz in the better hearing ear in units of dB HL (decibels re: Hearing Level). Mild hearing impairment is defined as a PTA >25-40 dB HL, and moderate-or-greater hearing impairment is defined as a PTA >40 dB HL.