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Feature Article

Associations among hearing loss, hospitalization, readmission and mortality in older adults: A systematic review☆

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ABSTRACT

Objective: Older adults with hearing loss face many challenges impacting health outcomes. The objective of this review was to evaluate current evidence for associations among hearing loss, hospitalizations, readmissions and mortality in older adults living with hearing loss.
Methods: A systematic search, of PubMed, CINAHL and Embase was performed in October 2018. Studies that were included consisted of populations aged 50 and older, publications after 2004, clearly defined hearing loss measurements, and non-aggregated, appropriate outcome variables. We excluded deafness, specified hearing losses, and cochlear implant users.
Results: Fifteen mortality studies, four hospitalization studies, and one readmission study were identified. After adjustments, three mortality, three hospitalization, and the one readmission study found significant associations.
Discussion: Hearing loss was associated with an increased risk of hospitalizations, readmission and mortality. However, there is insufficient evidence to support that hearing loss is independently associated to increased risk of these outcomes.

Introduction

Hearing loss is a major public health concern with over 5% of the world population or approximately 360 million people having disabling hearing loss (NCID, 2017). A study using the National Health and Nutritional Examination Surveys (NHANES) demonstrated that the hearing loss prevalence increased from 44.9% for those between ages 60–69 to 89.1% for people ages 80 and older[2] (NCID, 2017; WHO, 2018). With an estimated population of over 80 million Americans over the age of 65 by 2030, there is a strong imperative to increase healthcare and service research among individuals with hearing loss.[48]

Hearing loss, currently the third most common chronic condition in elderly Americans, negatively affects individuals' physical, emotional, behavioral, and social functioning.[5,35,61,76,79,80] Hearing loss and its link to depression and dementia- independent of socioeconomic status, demographics and age, is well documented.[5,54,55] Research demonstrated relationships between hearing loss and multiple negative outcomes including social isolation/loneliness, depression, dementia, falls, cardiac disorders, arthritis, diabetes, and lower self-rated health.[7,17,29,37,39,54,55,62,68,83,84] Moreover, McKee and colleagues found that individuals with hearing loss are more likely to have one or more comorbidities (e.g., arthritis, cancer, diabetes, cardiovascular disease, emphysema, high blood pressure and stroke) compared to their hearing peers.[61] Previous research also determined that those with, compared to those without multiple comorbidities and chronic conditions are more likely to be readmitted to the hospital within 30 days and are found to have longer and costlier hospitalizations.[18,81]

Multiple factors commonly seen among those with a hearing loss were found to be associated with hospitalization, readmission, and mortality in previous studies. Diabetes, dementia, cancer, heart disease, chronic kidney disease and chronic obstructive pulmonary disease all increased the risk for and number of hospitalizations.[23,45,66,72] Those

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with hypertension, heart disease, diabetes, dementia, chronic kidney disease and chronic obstructive pulmonary disease struggled with longer hospitalizations.[23,31,45] Moreover, patients with comorbidities injured in falls were found to be hospitalized 6 times longer than patients without comorbidities.[36] Aliyu and colleagues also found that older adults with poorer self-rated health status were three times more likely to be admitted to the hospital compared to those who reported good or excellent health status.[3] Additionally, Aliyu and colleagues established a direct relationship between inability to perform activities of daily living (ADL) and admission to the hospital for older adults.[3]

Previous research demonstrates that patients with cardiovascular disorders (hypertension, heart failure, coronary artery disease, cardiac arrhythmias), kidney disease and diabetes have higher readmission rates.[18,23,67] Research also demonstrates that hospital readmission is linked to higher patient morbidity and mortality rates.[89] Increased readmission rates are found to be correlated to an increase in comorbidities which has also been found to be an independent indicator of mortality.[70]

Hearing loss not only affects health outcomes, but also inpatient and outpatient healthcare experiences. Compared to their hearing peers, patients with any hearing loss have double the risk of nonadherence, a potential risk factor for hospital readmission. Furthermore, ten percent of all hospital readmissions are related to patient nonadherence.[6,9,69] Studies found that patients with any hearing loss have 33% higher healthcare costs and 10% lower satisfaction regarding the quality of provider-patient communications compared to their hearing peers.[9,10,64,80] This highlights the importance of investigating healthcare experiences and outcomes in older adults with hearing loss.

Purpose

Hearing loss is associated with a wide range of health conditions and poorer health outcomes. Yet, it is not as well understood how hearing loss may affect hospital-based outcomes and mortality in older adults. An evaluation and synthesis of studies examining relationships among hearing loss, hospitalizations, readmission and mortality may help to identify potential interventions to improve health outcomes in adults aged 50 and older with hearing loss. Therefore, the purpose of this review is to systematically evaluate the current research about readmissions, hospitalizations, and mortality in older adults with hearing loss.

Methods

This systematic review was conducted following the guidelines suggested in Research Synthesis and Meta-Analysis.[15] The review incorporated studies that included factors associated with hearing loss, hospitalization, readmission, and mortality. The PRISMA flow diagram is presented in Fig. 1 and the search terms are presented in Table 1.

Literature search

As of October 2018, there are no published review protocol to study associations among hospitalization, readmission and mortality in older adults with hearing loss. Studies were identified by using search terms in the following search engine databases: Pubmed, Embase and CINAHL in October 2018. An experienced medical research librarian with expertise in systematic reviews assisted with the creation of the search strings used for each of the three database. Two co-authors screened the articles and specifically sought studies that evaluated all three topics. Two authors screened all studies for eligibility at both the title/abstract and full text review stage using endnote. Disagreements in screening were resolved by a third author.

Inclusion/Exclusion criteria

We included studies with participants aged 50 and older as the prevalence of hearing loss has been shown to increase after the age of

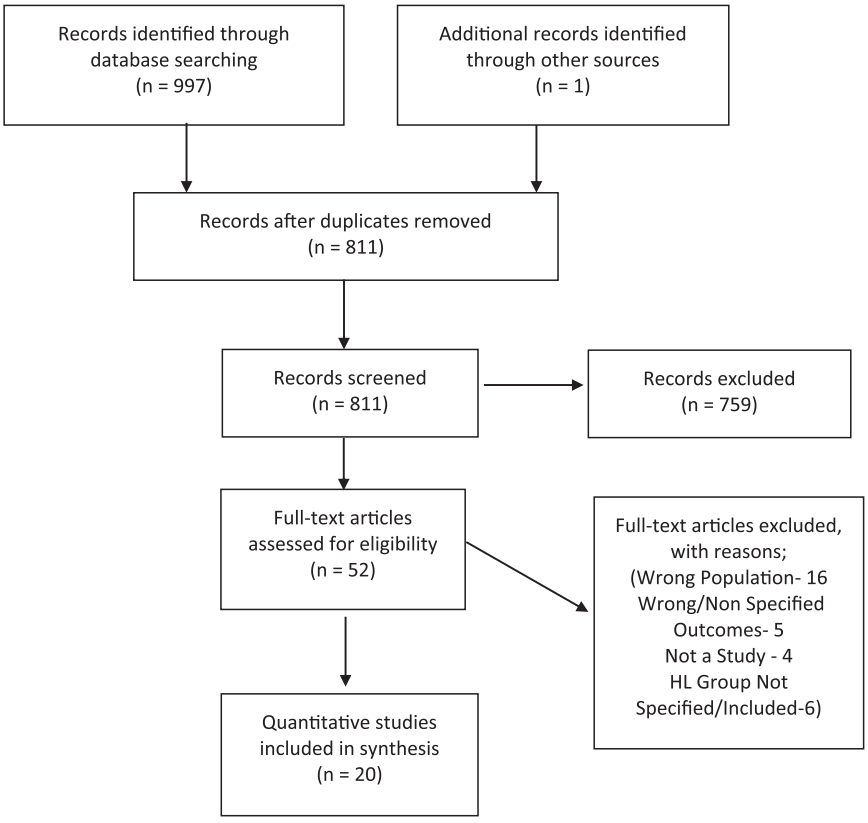

Fig. 1. PRISMA.

Table 1
Search terms.

Database	Search String	Restrictions
PubMed	(Presbycusis[tw] OR Hearing loss*[tw] OR Hearing impair*[tw] OR Hard of hearing [*tw*]) AND (Elderly[tw] OR Geriatric[tw] OR Older adult*[tw] OR Aged[*mesh*]) AND (Mortality[mesh] OR mortalit*[tw] OR readmission*[tw] OR hospitalization* [tw])	
CINAHL	(Presbycusis OR "Hearing loss" OR "Hearing impairment" OR "Hard of hearing") AND (Elderly OR Geriatric OR "Older adult" OR "Older adults" OR (MH "Aged+")) AND ((MH "Mortality+") OR mortalit* OR readmission* OR hospitalization*)	English, Publications after 2004 Peer Reviewed
Embase	presbycusis:de,ti,ab OR "hearing loss":de,ti,ab OR "hearing impairment":de,ti,ab OR "hard of hearing":de,ti,ab AND (elderly:de,ti,ab OR geriatric:de,ti,ab OR "older adult":de,ti,ab OR "older adults":de,ti,ab OR "aged"/exp) AND ("mortality"/exp OR mortalit*:de,ti,ab OR readmission*:de,ti,ab OR hospitalization*:de,ti,ab)	English only, Publications after 2004

50.[11,21,88] Further, the American Speech-Language Hearing Association (ASHA) recommends hearing screening at least every 10 years, then every 3 years after the age of 50, thus potentially prompting earlier identification and intervention for this age group.[91] We also included studies that clearly stated methods of hearing measurement, hearing and hearing loss groups for comparison and clearly defined, non-aggregated outcomes.

We excluded studies with populations that consisted of the deaf, participants with specified hearing loss criteria, and those who used cochlear implants. Our rationale for exclusion is that the deaf population's knowledge of disability resources, ability to advocate for themselves, and their access to information tends to differ from those who sustain hearing loss later in life.[40,50] Further, the focus of our review is age-related hearing loss, not specified hearing losses such as occupational noise induced hearing loss or use of cochlear implants. We also excluded studies published before 2004 as the American Disability Act (ADA) amendment changes required all general assembly facilities to provide hearing accommodations such as assistive listening devices (ADA Board, 2004). Exposure to assistive listening devices in public settings could result in a phenomenon called the mere exposure effect, which could increase public awareness of hearing health, potentially increasing identification and intervention.[44,47] Moreover, use of assistive listening technologies, including hearing aids, has been shown to improve healthcare outcomes.[60]

Our decision to exclude studies focused on long term, outpatient, and inpatient care settings was based on previous research which found mortality, readmission and hospitalization outcomes vary based on settings. For example, one study found that individuals discharged to long term settings are at higher risk for readmission and mortality, compared to those discharged to home.[63] Further, studies that recruited participants from inpatient settings were not included as hospitalization, readmission and mortality outcome would be less comparable across studies.[63] We also excluded studies that did not address our research questions or outcomes of interest, did not include subjects age 50 and older, did not specify the hard of hearing group, were not written in English, or were reviews, opinion pieces, and animal studies.

Data extraction & quality assessment

A standardized data extraction table was used to collect data; purpose, sample size, sample demographics, study setting, hearing aid usage, outcome measures, hearing loss screening method, hearing loss definition, and time to follow up. Two authors independently extracted 20% of the included articles to reach consensus on types and depth of information extracted. Two authors independently assessed the quality of study of 20% of the articles included in the review. One single author extracted data and assessed the quality of the remaining studies independently. Disagreements were resolved by a third author.

The Newcastle – Ottawa Quality Assessment Scale, a tool widely used for assessing non-randomized studies, was used to assess each study in this review.[58] Each of the studies were analyzed on eight items, categorized into three groups: study group selection, comparability of groups, and ascertainment of outcomes. The comparability section was further revised to fit the quality assessment needs of our review. For example, a star was awarded if studies accounted for age and sex and second star (hat) was awarded if they accounted for cognitive function in their adjustments, and/or predictor/outcome measures. Stars are awarded with the highest quality studies assigned nine stars and the lowest quality studies assigned zero stars. Studies were considered higher quality if they used an objective hearing screening method such as the gold standard audiometry, accounted for cognitive function, and did not have self-reported outcome measures. Studies were considered lower quality if they used self-report for hearing screening, did not account for cognitive function, and had self-reported outcome measures. The quality assessment of each study is noted in Table 3.

Results

This search identified 15 studies that investigated the association between hearing loss and mortality, four studies that investigated the association between hearing loss, and hospitalization and one study investigating the association between hearing loss and readmission. As described in Table 2, nine studies were conducted in the United States of America, four were performed in Australia, and one each completed in Japan, India, Britain, Canada, Germany, Iceland and Taiwan. Six mortality studies, two hospitalization studies and one readmission study examined hearing loss alone as the primary risk factor of interest. In addition to hearing loss, seven mortality and two hospitalization studies also included other potential predictors as primary risk factors of interest. The other two mortality studies considered hearing loss as a potential predictor of another association of interest.[19,87]

Fourteen mortality, four hospitalization and one readmission study included both males and females. One study focused solely on males,[53] and one study did not specify the sex included.[38] In all but four studies, females dominated the larger portion of the sample when both sexes were included.[13,27,85,87] One study did not provide female and male ratios for their final sample size.[12] Moreover, in seven studies where females dominated the overall sample size, more males had hearing loss compared to females.[4,22,25,26,43,59,90]

Multiple studies reported significant demographic differences between their hearing and hearing loss groups. Eight studies that provided characteristic comparisons between these two groups found that those with hearing loss tend to be significantly older, white and male with smoking, cardiac, stroke and depression history, as well as poorer cognitive function, poorer self-rated health, and lower education and income levels.[4,10,13,22,25,26,38,43] One study indicated differences in race as well as average age, smoking history, myocardial infarction history and education level; however, they did not provide *p* values to indicate if these differences were significant.[57] The rest of the studies did not provide clear characteristic comparisons between hearing loss and non-hearing loss groups.[2,11,19,30,38,53,59,77,85,87,90]

Out of all 20 studies, only one study reported that a power analysis was conducted, and that same study was completed with an adequate sample size.[2] Nineteen studies had a sample size that well exceeded one thousand participants with an exception of one study.[85]

Table 2
Study findings.

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (italic confounders accounted for in study HR & OR model)	Hearing Loss Association to Hospitalization &/or Mortality Outcomes HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Mortality Hazard Ratio							
Agrawal et al.[2]	Prospective community-based cohort Primary + blindness	Rural north India – Ballabgargh Block, Haryana. N: 1422 Age: 60 + M: *N* = 683 F: *N* = 739 HL (*n* = 210) UI (*n* = 1078) Rural community dwelling Participation rate: 100%	3 days to 567 days Median: 518 days Local death registrars	Whisper, Webber and Rhine Does not state clear definition	*Age, sex, literacy, hypertension, diabetes, coronary artery disease, stroke, orthopedic impairment, dressing, feeding and self-rated health.*	**Crude:** 2.4 (1.55 – 3.7) **(S)** **Hypertension, diabetes, coronary artery disease, stroke, orthopedic impairment, dressing, feeding and self-rated health only:** 2.38 (1.53- 3.69) **(S)** **All adjustments:** >70 years: 2.13 (1.29–3.54) **(S)**	8
Amieva et al.[4]	Prospective community-based cohort Primary	Bordeaux, France *N* = 3588 Age: 65+ M: *N* = 1507 F: *N* = 2081 HL: 1289 UI: 2290 Mean age: 75.3 Mean age of HL: 77–79 Hearing aid users: 176 Community dwelling Participation rate: 95%	25 years 12 follow up visits total with reassessments of cognitive and hearing function Family, physicians and civil state records	Self-Report "do you have trouble hearing?" (1)No trouble (2)Trouble in background noise (3) Major trouble (4) Use HA? Not clear which answers were considered to be HL	*Age, sex, educational level, and number of comorbidities (hypertension, myocardial infarction, angor, diabetes, dyspnea, history of stroke and smoking)*	No crudeHR HL: 0.99 (0.92 - 1.07) HL with no HA: 0.99 (0.92 - 1.07) HL with HA: 1.03 (0.87 - 1.21)	7
Contrera et al.[13]	Retrospective cohort Primary	USA – National Database N: 1666 Age: 70 + M: *N* = 847 F: *N* = 819 HL (mild (*n* = 589) mod/sev (*n* = 550)) UI (*n* = 527)	NHANES (2005- 2006 & 2009–2010) (Mortality 2011) Death certificates	Audiometry UI: (<25 dB) Mild: (>25-<40) Mod/Sev: (> 40 dB) PTA Database entry	*Age*, sex, education, race, hypertension, diabetes, cardiovascular disease, smoking, and stroke	**Base:** Mild: 1.54 (1.06 – 2.25) **(S)** Mod/severe: 2.30 (1.64 – 3.27) **(S)** **Age only:** Mod/sev: 1.54 (1.08 – 2.18) **(S)**	8
Feeny et al.[19]	Retrospective population-based cohort Secondary + vision, speech, ambulation, dexterity, emotion, cognition and pain.	Canada N: 3575 (60+) Age: 60 + M: (*n* = 1446) F: (*n* = 2129) Community dwelling	12 years Interviewed every 2 years with HUI3 Canadian Vital Statistics Database	Health Utilities Index Mark 3 (HUI3) {Interclass Corr Coeff 0.88) Normal (level 1) to most severe (level 6) Any HL (levels 2–6)	Age, sex, house hold income, education, marital status, hypertension, diabetes, coronary artery disease, cancer, stroke, cancer, bronchitis, heart disease, asthma, allergies, BMI, smoking, alcohol use, physical activity, self-rated health, mental health, perceived social support and cognitive function including alzheimers and dementia.	Sex (male): 1.9 (1.06 - 2.27) **(S)** Age (70–79): 1.89 (1.55 – 2.29) **(S)** (80 +) 4.58 (3.55 – 5.9) **(S)** Single: 1.43 (1.06–1.91) **(S)** <High School: 1.27 (1.06–1.52) **(S)** Infrequent physical activity: 1.34 (1.12–1.60) **(S)** Underweight: 2.12 (1.44–3.11) **(S)**	7
Fisher et al.[22]	Prospective population-based cohort Primary + vision and dual sensory	Reykjavik, Iceland N: 4926 Age: 67–98 Mean age: 76.4 Mean age HL: 78.9 M: (*n* = 2121) F: (*n* = 2805) UI (*n* = 2878), HL only (*n* = 1250) HA use in HL only	3 - 7 years Median: 5.3 Iceland death registrar	Audiometry Mod/sev: (> 35 dB) in better ear PTA Aggregated none and mild SI for reference Pure tone air conduction audiometry in sound treated booth.	*Age, sex, BMI, hypertension, diabetes, self-rated health, falls history, angina history, cardiovascular history, total cholesterol, hearing aid use, and cognitive function.*	**All adjustments;** Overall CVD: 1.70 (1.27–2.27) **(S)** Men CVDM: 1.93 (1.3 – 2.87) **(S)** Women CVD: 1.44 (0.93–2.22)	9

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Table 2 (*Continued*)

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (italic confounders accounted for in study HR & OR model)	Hearing Loss Association to Hospitalization &/or Mortality Outcomes HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		(*n* = 624) Community dwelling Participation rate: 99.6%					
Genther et al.	Prospective cohort Primary	Pittsburgh, Pennsylvania & Memphis, Tennessee, USA *N* = 1958 Age 70–79 M: (*n* = 936) F: (*n* = 1022) UI (*n* = 812) HL (*n* = 1146) HA use (*n* = 250) Urban community dwelling/ Medicare beneficiaries	8 years Death certificate confirmation	Audiometry Any HL: (>25 dB) PTA Pure tone air conduction audiometry in sound treated booth by audiometer "?r and examiner.	*Age, sex, race, education, hypertension, stroke, smoker, diabetes, depression, gait speed and cognitive function*	**Any HL:** Demographic + cardiovascular factors: 1.20 (1.03 – 1.41) **(S)** Full model + depression: 1.20 (1.03 – 1.41) **(S)**	9
Gopinath et al.[30]	Retrospective population-based cohort Secondary Dual sensory impairment	Australia N: 2812 Age: 55+ Mean age DSI: 74 UI: 64 M: (*n* = 1216) F: (*n* = 1596) UI: (*n* = 1865) DSI: (*n* = 947) Community dwelling	10 years Australia National Death Index	Audiometry Any HL: (>25 dB) Mild: (>25–40 dB) Mod/severe: (>40 dB) Pure tone air conduction audiometry in sound treated booth	*Age, sex, BMI, systolic blood pressure, smoking, self rated health, walking disability, hypertension, diabetes, hx of cancer, angina, stroke, myocardial infarction, and cognitive function.*	**(Table 2 – presenting vision loss)** Mild HL: 1.27 (1.01–1.61) **(S)** **(Table 3- best corrected vision loss)** mild HL: 1.32 (1.06–1.66) **(S)** any HL: 1.29 (1.04–1.59) **(S)**	9
Karpa et al. (2010)	Retrospective population-based cohort Primary	Australia N: 2965 Age 50 + Mean age: 66.6 HL mean age: 73 M: (*n* = 1218) F: (*n* = 1747) UI: (*n* = 1886) Mild: (*n* = 635) Mod/Sev: (*n* = 294) Community dwelling	8 years Australia National Death Index	Audiometry & Self-Report (56%) UI: (<25 dB) Mild: (>25–45 dB) Mod/sev: (>45 dB) PTA "Do you feel you have hearing loss" Pure tone air and bone conduction audiometry in sound treated booth by audiologist	*Age, sex, smoking, alcohol use, hypertension, BMI, angina, acute myocardial infarction, stroke, cancer, walking disability, self-rated health and cognitive function.*	**Age and sex:** Mild HL: CVD: 1.44 (1.04–1.90) **(S)** All Cause: 1.39 (1.09–1.77) **(S)** Mod/Sev HL: All Cause: 1.41 (1.06–1.88) **(S)** **SEM** Direct: 1.09 (0.84–1.41) Indirect: 2.37 (1.58–3.54) **(S)** Total: 2.58 (1.65–4.05) **(S)**	9
Liljas et al.[53]	Prospective cohort Primary	Britain N: 3981 Age: 63 – 85 Mean age: 72 HL mean age: 73.5 Male only UI: (*n* = 2907) Not hear/no aid: (*n* = 424) Could hear/used aid: (*n* = 482) Not hear/used aid: (*n* = 168)	10 years National Health Service register	Self-Report Unclear untested instrument No clear definition	*Age, sex, social class, smoking, physical activity, hypertension, diabetes, BMI and cardiovascular disease.*	**Age only:** Could not hear/ No HA 1.19 (1.01 - 1.40) **(S)** **All adjustments:** Could hear, Used HA: 1.01 (0.86–1.19) Could not hear, No HA: 1.12 (0.93 – 1.34) Could not hear, Used HA: 1.14 (0.89 – 1.45)	6

(*continued on next page*)

Table 2 (*Continued*)

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (italic confounders accounted for in study HR & OR model)	Hearing Loss Association to Hospitalization &/or Mortality Outcomes HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Liu et al.[57]	Retrospective cohort Primary + vision, cognition and dual sensory	North Carolina, USA *N* = 3871 Age: 65+ M: (*n* = 1355) F: (*n* = 2516) UI: (*n* = 2330) HL: (*n* = 564/ 55.3% female) Community dwelling	6 years National Death Index	Self-Report (a) Have you ever worn a hearing aid? (b) Can you hear and understand a person without seeing his or her face? (c) How often do you wear a hearing aid (1 = *never*, 2 = *occasionally*, 3 = *frequently*, 4 = *always*)? Interviewer: (d) Did respondent have difficulty hearing or was deaf (1 = *no*, 2 = *some*, 3 = *deaf*)? HL was considered present if at least one response indicated HL	*Age, sex, race, education, marital status, BMI, history of smoking, depression, and a health index score that reflects self-reported disease burden*	**All adjustments:** HL only: 1.11 (0.89–1.39)	7
Lopez et al.[59]	Retrospective cohort Primary + vision	Australia N: 5354 Age: 76–81 years. M: (*n* = 2340) F: (*n* = 3014) UI: (*n* = 4289) HI: (*n* = 1065) Community dwelling	Mean 6.36 years Australian National Death Index	Self-Report "Do you have difficulty hearing conversation even with HA?"	Age, sex, education, BMI, hypertension, diabetes, stroke, falls, chronic obstructive pulmonary disease, and cardiovascular disease.	**Crude:** Male: 0.95 (0.80–1.13) Female: 1.10 (0.87–1.40).	6
Schubert et al. (2016)	Retrospective population-based cohort Primary + vision and olfactory	Beaver Dam, WI N: 2418 Age: 53 – 97 Mean age: 69 M: (*n* = 1021) F: (*n* = 1397) HL: (*n* = 1209) UI: (*n* = 1209) Community dwelling	Mean 12.8 years Maximum of 17 years. Annual contact with participants and local obituaries	Audiometry HL: (>25 dB) PTA Every 5 years Pure tone air and bone conduction audiometry in sound treated booth	*Age, sex, education, hypertension, diabetes, CVD, cancer, smoking, BMI, frailty, alcohol use, cognitive function intima media thickness, C reactive protein, and interluken 6*	**Multiple sensory models: Adjusted for everything, but intima media thickness, C reactive protein and interluken 6:** 1.21 (1.01 – 1.45) **(S)** **Full model adjustment:** 1.17 (0.97 – 1.40).	8
Wang et al. (2017)	Retrospective cohort Secondary VES-13 scale	Taiwan *N* = 2184 Age: 65 + M: (*n* = 1192) F: (*n* = 992) HL: (*n* = 301) UI: (*n* = 1883) Community dwelling	4 years Taiwan Longitudinal Study on Aging (TLSA) database Year: 2003 Survival data collected in 2007 Department of Health death registry	Self-report "Respondents were inquired if they could hear clearly, either with or without hearing aids"	Sex, marital status, education, area of residence, number of chronic diseases, harmful behavior (smoking/drinking), dizziness, depression, incontinence, pain, falls, physical limitations, vision impairment, hearing impairment, low BMI, and cognitive function.	**Multivariate:** 1.323 (1.013 – 1.730) (**S**)	7
Odds Ratio							
Wahl et al.[85]	Prospective cohort Primary + vision and dual sensory	Two ENT clinics in Heidelberg and Mannheim, Germany *N* = 430 Age: 75 - 94 M: (*n* = 254) F: (*n* = 176) HL (*n* = 116) UI (*n* = 150) Community dwelling	4 years City registries & family members	Audiometry HL: (>35 dB) in better ear PTA 2 years HL prior to enrollment No specification – recruitment through ENT clinic	*Sex*, age, education, subjective health, living arraignments and activities of daily living.	**Sex only** Any HL; 3.381 (1.444–7.920) **(S)**	9

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Table 2 (*Continued*)

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (italic confounders accounted for in study HR & OR model)	Hearing Loss Association to Hospitalization &/or Mortality Outcomes HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
		Participation rate: HI: 96% UI: 97%					
Yamada et al.	Prospective cohort Primary	Kurabuchi, Japan *N* = 1250 Age: 65+ M: (*n* = 608) F: (*n* = 756) HL male (*n* = 121) HL Female (*n* = 120) UI: (*n* = 1123) HA use (*n* = 59/241) Community dwelling Participation rate: 99.4%	3 years Local government	Self-Reported "Do you have difficulty hearing and understanding what a person says to you in a quiet room if they speak normally to you (even with a hearing aid)? No difficulty/a little difficult/very difficult	*Age, sex, education, social support, marital status, vision, depression and self-rated well being*	**Crude:** Little difficult: 2.20 (1.34 - 3.60) **(S)** Very difficult: 9.61 (4.06 - 22.75) **(S)** **All adjustments:** Little difficult: 0.92 (0.52 – 1.64) Very difficult: 2.56 (0.93 – 7.09)	7
Hospitalization Hazard Ratio							
Genther et al.	Prospective cohort Primary	Pittsburgh, Pennsylvania & Memphis, Tennessee, USA *N* = 2148 Age 70–79 M: (*n* = 1033) F: (*n* = 1115) Mild HL (*n* = 818) Mod/Sev HL (*n* = 448) UI (*n* = 882) HA use (*n* = 196) Urban community dwelling/ Medicare beneficiaries	Median: 12 years Participant self-reported every 6 months	Audiometry Mild: (>25–40 dB) Mod/Sev: (>40 dB) PTA Pure tone air conduction audiometry in sound treated booth by audiometer and examiner	*Age, sex, race, hypertension, diabetes, stoke, smoking, CVD , education and income, cognitive function and hearing aid use.*	**Incident hospitalizations:** Mild HL: 1.16 (1.04 – 1.29) **(S)** Mod/Sev HL: 1.21 (1.06–1.38) **(S)** **Annual Hospitalization Rate:** Mild HL: 1.17 (1.04–1.32) **(S)** Mod/Sev HL: 1.19 (1.04–1.38) **(S)**	8
Odds Ratio							
Chia et al.[12]	Retrospective cross sectional Primary + vision, cognition and mobility	Australia *N* = 2873 Mean age: 66.7 years HL: (*n* = 949) (33.4%) UI: (*n* = 1551) (54%)	Blue Mountains Eye study Hospitalizations in a 12 month period Self-report	Audiometry Any HL: (>25) Pure tone air conduction	*Age and sex*	**Hospitalizations in 12-month period:** 1.1 (0.9–1.3)	7
Genther et al.[27]	Retrospective cross-sectional Primary	USA *N* = 1669 Age 70+ M: (*n* = 848) F: (*n* = 821) Mild HI (*n* = 590) Mod HL: (*n* = 446) sev HI: (*n* = 97) UI (*n* = 529)	NHANES (2005- 2006 & 2009–2010) Hospitalizations in a 12-month period. Computer assisted/ interviewer administered questionnaires – self-report	Audiometry HL: (>25 dB) PTA Database entry of pure tone air conduction audiometry	*Age, sex, race, education level, income, hypertension, diabetes, stroke, CVD, congestive heart failure and smoking.*	**Any Hospitalizations last 12 months:** 1.32 (1.07 – 1.63) **(S)** **Number of Hospitalizations last 12 months:** 1.35 (1.09–1.68) **(S)**	7
Huddle et al.[38]	Retrospective cross-sectional Primary + vision and dual sensory	USA *N* = 1669 Age 70+ Mild: (*n* = 436) Mod/sev: (*n* = 413) UI (*n* = 431)	NHANES (2005- 2006 & 2009–2010) Hospitalizations in a 12-month period. Computer assisted/ interviewer administered questionnaires – self-report	Audiometry UI: (<25 dB) Mild: (>25–39 dB) Mod/Sev: (>40 dB) PTA Database entry of pure tone air conduction audiometry	*Age, sex, race, education, income, self-rated health, hypertension, diabetes, stroke, smoking and CVD.*	**Any hospitalizations last 12 months:** Mod/sev: 1.69 (1.14–2.53) **(S)** **Number of hospitalizations last 12 months:** Mod/sev: 1.78 (1.19–2.65) **(S)**	7

(*continued on next page*)

Table 2 (*Continued*)

Studies	Design & HL primary or secondary focus	Setting, Sample & Participant Rate	Length of Follow Up/Dataset Dates & Outcome Measure	Hearing Screening & Definition	Confounding Variables (italic confounders accounted for in study HR & OR model)	Hearing Loss Association to Hospitalization &/or Mortality Outcomes HR & OR 95% CI	Newcastle – Ottawa Quality Assessment Scale
Readmission Odds Ratio							
Chang et al.	Retrospective observational Primary	USA *N* = 4426 Age: 65+ M: 1928 F: 2398 HL M: 251 HL F: 262	Medicare Current Benificiary Survey (MCBS) 2010 – 2013 30 day readmission	Self-Report No trouble communicating / little trouble communicating	*Age, sex, marital status, education, race, ethnicity, income) and health (Elixhauser comorbidities present during index admission self-rated health) factors.*	**Unadjusted:** 1.49 (1.26–1.76) **(S)** **Adjusted:** 1.32 (1.06–1.64) **(S)**	6

Key:
BMI: Body Mass Index.
CVD: Cardiovascular disease.
DSI: Dual Sensory Impairment.
F: Female.
HA: Hearing aid.
HL: Hearing Loss.
M: Male.
Mod/Sev: Moderate to severe.
UI: Unimpaired.

Hospitalization

Of the four hospitalization studies, three studies found that hearing loss was significantly associated with incident (first) hospitalizations and number of annual hospitalizations. This association was independent of demographic (age, sex, race, education, income), and cardiovascular factors (hypertension, stroke, cardiovascular disease (CVD) and smoking), as well as diabetes, and cognitive function.[26,27,38] Furthermore, Genther and colleagues also looked at hearing loss and its association to length of hospital stay, but this resulted in non-significant findings.[26] One study did not find significant associations between hearing loss and rate of annual hospitalizations after adjustments for age and sex, and this same study did not provide a crude odds ratio.[12]

Readmission

One study was identified investigating hearing loss and its association to readmission.[10] This study found an increased risk of readmission in those who reported trouble communicating with their providers, compared to those who reported no trouble, before and after all covariate adjustments. This study reported that those who had trouble communicating had an average of 32% greater odds of readmission compared to their hearing peers.

Mortality

Twelve of the fifteen studies provided the following hazard ratios (HR) or odds ratios (OR); crude, univariate, and minimal adjustments (age and/or sex), which indicated significant associations between hearing loss and mortality.[2,13,19,22,25,30,43,53,65,77,85,87,90] Two studies did not provide a crude or unadjusted HR or OR, and one study provided an insignificant crude HR.[4,57,59] Of these twelve studies, three studies demonstrated significant associations between hearing loss and mortality after adjusting for all covariates.[2,22,30]

Covariates

Many factors influenced the relationship between hearing loss and mortality. Common factors included, but were not limited to, age, sex, cognitive function, mobility, self-rated health, and comorbidities including cardiac factors.[2,4,13,22,25,43,77,90] Age and sex were considered to have large confounding effects in several studies. For example, in Agrawal et al., significance was only found in those aged 70 and older after adjustments for all covariates, whereas no statistical significance was found in other age groups.[2] Two other studies found similar results; Feeny et al. found significance in males and subjects over 70 years old, and Fisher et al. found significance in males only.[19,22]

Evidence suggests that the relationship between hearing loss and mortality can be attenuated with further adjustments, including cardiovascular factors. For example, one study, when adjusted for all covariates, excluding blood vessel thickening cardiac factors such as; interleuken, intermedia thickness, and C reactive protein, indicated a significant relationship between hearing loss and mortality.[77] When adjusting for all covariates, including the aforementioned cardiac covariates, this study demonstrated no significance, therefore indicating that some cardiac factors could have potential confounding effects.[77] Cardiovascular factors were also found to influence the association in three other studies. Fisher et al. found cardiovascular disease related mortality, but not all-cause mortality, to be significant in men with hearing loss.[22] In Contrera et al. the relationship between hearing loss and mortality was attenuated when sex, race, education and cardiovascular factors were adjusted. Furthermore, Feeny et al. also indicated significant associations between hearing loss and

Table 3
Newcastle–Ottawa quality assessment.

	Mortality	Agrawal, 2011	Amieva, 2018	Contrera, 2015	Feeny, 2012	Fisher, 2014	Genther, 2015	Gopinath, 2013	Karpa, 2010	Lilijas, 2016	Liu, 2016	Lopez, 2011	Schubert, 2016	Wahl, 2013	Wang, 2017	Yamada, 2011	Hospitalization	Chia, 2006	Genther, 2015	Genther, 2013	Huddle, 2016	Readmission	Chang, 2018
Selection																						
Representativeness of the exposed cohort		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Selection of the non-exposed cohort		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Ascertainment of the exposure (hearing loss)		*		*		*	*	*	*				*	*				*	*	*	*		
Demonstration that outcome of interest was not present at start of study		*		*		*	*	*	*				*	*				*	*	*	*		
Comparability																							
Comparability of cohorts on the basis of design or analysis (accounts for age/sex* and cognitive function ^)		*	*^	*	*^	*^	*^	*^	*^	*	*^	*	*^	*^	*^	*		*	*^	*	*		*
Outcome																							
Assessment of outcome		*	*	*	*	*	*	*	*	*	*	*		*	*	*							*
Was follow-up long enough for outcomes to occur		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Adequacy of follow up of cohorts		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*	*		*
Total Score		8	7	8	7	9	9	9	9	6	7	6	8	9	7	6		7	8	7	7		6

mortality in those with chronic conditions associated with mortality, including hypertension, chronic bronchitis, diabetes, cancer, stroke, and heart disease.

Cognitive function, walking ability/mobility, and self-rated health were found to be potential mediators in two studies. For example, one study assessed whether hearing loss had a direct or indirect association to mortality by utilizing the structural equation modeling analysis.[43] This study indicated that hearing loss had an effect only if there was a mediating factor such as walking mobility, cognitive function, and self-rated health. Another study found similar results indicating that cognitive function and mobility were strong mediators.[25] Concurrent impairments also increased risk of negative outcomes in several studies. Six studies in our review suggest concurrent sensory impairments such as hearing loss/vision loss or hearing loss/cognitive impairment significantly increased mortality risk.[4,22,30,43,57,59] Cognitive function was also found to be a significant independent risk factor to mortality in two studies in our review.[19,57]

Hearing screening

The use of different assessment methods and definitions to measure hearing loss made comparisons among the reported findings difficult. All four studies investigating hospitalization, and seven out of 15 mortality studies utilized the gold standard audiometric screening.[2,13,22,25,30,43,77,85] In the remainder of the mortality studies, one study used whisper, Weber and Rinne tests, one study used the Health Utilities Index 3 instrument (HUI3), and six studies used self-report for assessing hearing loss.[4,19,53,57,59,87,90] The readmission study used self-report measures.[10] Further details regarding screening can be found in Table 2.

Hearing loss definition, even when using the same screening methods, also varied across studies making comparisons difficult. Eleven studies which assessed hearing loss using audiometry presented different definitions for hearing loss as seen in Table 2. Some studies aggregated hearing loss severity[11,22,25,27,77,85] and some studies stratified hearing loss severity.[13,26,29,38,43] Seven studies found that as the severity of the hearing loss increased, the risk of hospitalization and mortality increased. In other words, moderate to severe hearing loss had stronger associations to mortality and hospitalizations compared to mild and no hearing loss.[13,19,22,25,38,85,90] Interestingly, one study found significant associations in mild, but not moderate to severe hearing loss.[30]

Hearing aids

One of the four hospitalization and five of the 15 mortality studies included hearing aid use in their analyses. One study found that though hearing aid use had no significant association with incident or rate of annual hospitalization, the utilization of hearing aids was found to shorten the length of hospitalizations.[26] Two mortality studies found hearing aid use made a significant difference in mortality risk.[22,53] The remaining studies did not find significant differences in hearing aid use and mortality.[4,26,90] Though Amieva et al. did not find significant differences in mortality, they did find that hearing aid users fared better than non-users and were on par with hearing counterparts with respect to risk of depression, disability and dementia.[4]

Quality assessment

When evaluated by the Newcastle Ottawa Quality Assessment scale, five studies received 9 points, five studies received 8 points, seven studies received 7 points, and three studies received 6 points with higher points indicating higher quality. Details provided in Table 3. Newcastle–Ottawa Quality Assessment Scale.

Discussion

In this systematic review of twenty studies, there is support that hearing loss is potentially associated with increased risk of hospitalization, readmission, and mortality. However, there is insufficient evidence to indicate that hearing loss is an independent predictor due to limiting factors such as the minimal number of studies investigating hospitalization and readmission, inconsistent methods of hearing loss measurements, varied definitions for hearing loss, and conflicting findings in several studies. In the majority of the studies, factors such as age, sex, cognitive function, walking ability/mobility, self-rated health, and cardiac disorders had confounding effects on the relationship. Sample size also appeared to have an impact as one study which had a substantially smaller sample size compared to the others resulted in non-significant findings after minimal adjustments possibly due to power.[85] Several studies that indicated any significant associations shared characteristics such as an older sample population (70+), longer follow up periods, stratified by hearing loss severity, and conducted objective screening measures such as audiometry for hearing loss.[2,13,19,22,25,26,27,30,38,43,53,65,77,85,87,90]

Multiple studies suggest that those with hearing loss had higher hospitalization and mortality risk compared to hearing peers. However, these studies indicated that hearing loss may not independently increase risk, but the negative effects of hearing loss can. Two studies in our review indicated that cognitive function, walking ability/mobility and self-rated health were possible mediators.[26,43] *Several studies in our review also investigated these three potential mediators as predictors or outcomes and found significant associations.*[4,19,43,57,59] *For example, two studies indicated cognitive impairment to be significantly associated to mortality, and three studies found hearing loss to be significantly associated to cognitive impairment.*[4,19,43,57,59]

Studies that accounted for impairments, including but not limited to; cognition, mobility, vision, and olfaction were less likely to result in significant findings compared to studies that did not report how these covariates were accounted.[2,10,27,38] It is important to report how variables such as these are accounted for as significant relationships among these variables and the outcomes under study has been well established.[1,8,20,24,28,32–34,42,46,51,56,71,78,82]

Due to several studies finding significant differences in age and sex, special attention should be paid to these variables of the sample. For example, in few studies, the results of samples with older adults and males when aggregated yielded different results than when stratified.[2,19,22] In one study, males and combined sexes were found to be significantly associated to CVD mortality.[22] However, females individually did not reach statistical significance. Males inflated the overall result indicating that all sexes with hearing loss have higher CVD mortality when that was not the case for this study. Similarly, Agrawal et al., and Feeny et al. also indicated significance after stratification for age and sex. These findings are not surprising as previous research has established strong associations among hearing loss, aging, and sex.[41,52,86]

Though the use of different assessment methods to measure hearing loss made comparisons among the reported findings difficult, this review can shed some light on this matter. Five out of seven studies using self-report screening methods found statistical significance compared to ten out of eleven audiometry, one Weber/Rhine/whisper tests, and one HUI3 screening study, with none or minimal adjustments (age and/or sex). Research indicates that hearing loss is often underestimated and underreported by older adults.[75] As a consequence, their self-reported screening results did not match with their audiometric testing.[75] Moreover, self-reported screenings heavily rely on the patients' knowledge, candor, and acceptance of hearing status which can impact identification.[5] Relying on subjective screening tools such as self-report may not be ideal, as it could result in predictor contamination in the control/reference group.

Evidence in our review suggests that the more severe the loss of hearing, the higher risk of hospitalization and mortality. Seven of the twenty studies that stratified by hearing severity indicated that moderate to severe hearing loss had stronger associations to these negative outcomes compared to those with mild or no hearing loss.[13,19,22,26,38,85,90] Two studies that found mild hearing loss had stronger associations to hospitalizations and mortality could be due to a larger mild hearing loss sample size and broader definition of mild hearing loss (Karpa et al; 25dB-45dB).[30,43] Studies that aggregated hearing loss severity to any hearing loss >25 dB could have resulted in less accurate findings compared to if they had stratified by severity.[11,25,27,77] Research suggests that aggregation can result in loss of valuable information, therefore aggregation of hearing loss severity could result in missing pertinent associations or inflating findings depending on sample and design.[74]

There is strong evidence to suggest that technological accommodations such as hearing aids may be an important quality improvement intervention, as their use has been associated with improved healthcare experiences and outcomes.[14,47,49,60,73] Studies in our review suggest that hearing aid use may be associated with decreased risk of depression, length of hospitalizations, ADL deficiency and mortality.[4,22,26,53] It is important to note that the two studies that found significance in the relationship between hearing aid use and mortality adjusted for minimal to no socioeconomic factors (income, education, occupation).[22,53] Hearing aids and hearing healthcare services being cost prohibitive for older adults may result in hearing accommodation disuse, and may highlight the importance for future studies to put more emphasis on socioeconomic status in adjustments for more accurate results.[16]

Future research

Hearing loss and its association with various morbidities, hospitalization and mortality has been well studied. Although the associations among hearing loss, hospitalization and readmission is not as heavily studied as morbidities and mortality, the four hospitalization and one readmission study in this review do give valuable insight on the phenomenon. Due to the minimal number as well as the retrospective and cross-sectional nature of the majority of the hospitalization and readmission studies, it is recommended that future research prioritize to further investigate this phenomenon using prospective longitudinal cohort design. Future research should also prioritize investigating if early identification and effective management of age-related hearing loss, whether through screening, hearing aids, assistive listening devices or other methods, could decrease adverse health outcomes such as hospitalizations, readmission and mortality. It is recommended that future studies screen for hearing loss using audiometry, adhere to established audiometric definitions of hearing loss (i.e., World Health Organization classification of hearing loss), accurately measure and control for common confounders, abstain from aggregating hearing loss severity, and stratify for age and sex to optimize results.

Limitations

Several limitations in this review should be considered. Only 20 studies met the inclusion criteria, and of those, only four looked at hospitalization and one looked at readmission as an outcome. We observed several variations across all studies making comparisons of study findings difficult. Variations occurred in the populations studied, how hearing loss was screened and defined, how hospitalization and mortality were assessed, and whether other common confounding factors were considered in the inclusion/exclusion criteria or analyses. Several studies which provided characteristic comparisons between hearing loss and non-hearing loss groups indicated significant differences between the two groups. Eleven studies did not provide characteristic comparisons between hearing loss and non-hearing loss groups. Only 11 of the 20 studies used gold-standard audiometry to identify and define hearing loss. Any error in the classification of hearing loss status may result in predictor contamination in the control group, and subsequently bias observations toward the null hypothesis. Lastly, there was only one study in our review that looked at hearing loss and readmission which did not account for patient disposition (patient discharge location). This is important as patients whom are discharged to long term care facilities have higher risk of readmission compared to those discharged to home.[63] Since only one study was found looking at readmission, more studies are necessary to assist with better understanding of this phenomenon.

Conclusion

This systematic review provides evidence that hearing loss appears to be associated with statistically significant increased risk of hospitalization, readmission, and mortality. Investigating specific predictors and the relationships among hospitalizations, readmission, and mortality will help to inform us of how to better care for and educate patients with hearing loss in healthcare settings. Accomplishing this could help to inform which morbidities or interventions need to be prioritized for better patient outcomes.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.gerinurse.2018.12.013.

Appendix

Quality Assessment

https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

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