Hearing Loss & Dementia in Older Adults

Alison R. Huang, PhD MPH
Senior Research Associate
Department of Epidemiology | Cochlear Center for Hearing and Public Health
Johns Hopkins Bloomberg School of Public Health
Outline

- Background, general definitions/principles
- Hearing loss and dementia: current evidence
- Mechanistic pathways
- Future directions
Poll Question 1
Normal Aging: Everyone experiences slight cognitive changes during aging.

Preclinical:
- Silent phase: brain changes without measurable symptoms
- Individual may notice changes, but not detectable on tests
- "A stage where the patient knows, but the doctor doesn't"

MCI:
- Cognitive changes are of concern to individual and/or family
- One or more cognitive domains impaired significantly
- Preserved activities of daily living

Dementia:
- Cognitive impairment severe enough to interfere with everyday abilities

Cognitive Decline

Time (Years)
Dementia is a public health priority

- Dementia affects quality of life
  - 2nd most feared condition among adults
  - Loss of communication, independence

- Dementia is costly
  - Global cost of dementia ($818 B in 2015) will increase as prevalence increases
  - “A family disease”

Alzheimer’s and Related Dementia Research Funding at the NIH

Source: NIA (National Institute on Aging) and Alzheimer’s Association

Harvard School of Public Health/Alzheimer Europe Five Country Alzheimer’s Disease Survey, 2011
https://alzimpact.org/research
Critical Public Health Questions

Lack of accessible and effective treatments

Focus on prevention

- What are the modifiable risk factors for dementia?
- What are the mechanistic pathways?
- What interventions can modify the mechanistic pathways to reduce risk of dementia?
Critical Public Health Questions

Lack of accessible and effective treatments

- What are the modifiable risk factors for dementia?
- What are the mechanistic pathways?
- What interventions can modify the mechanistic pathways to reduce risk of dementia?
Hearing loss in mid & late life identified as the single largest modifiable risk factor for dementia
Percentage of Individuals with Hearing Loss by Age & Severity

38.2 Million (14.3%) Americans aged 12 years or older have hearing loss

- 0.2% 12 - 19
- 0.4% 20 - 29
- 1.6% 30 - 39
- 6.5% 40 - 49
- 13.3% 50 - 59
- 26.8% 60 - 69
- 54.6% 70 - 79
- 81.5% ≥ 80

Hearing depends on peripheral auditory encoding and central auditory decoding.

Peripheral auditory transduction (encoding)

Central auditory processing (decoding)
Peripheral cochlear function

Central Cortical Functioning

Subjective Hearing & Communicative Function

Central Auditory Measures (Speech in Noise, Dichotic Listening Tasks)

Word Recognition in Quiet

Pure Tone Audiometry

Levels of Auditory Processing

Otoacoustic Emissions (OAE)

Peripheral cochlear function
Age-Related Hearing Loss

- Results from multiple etiologic processes that can progressively damage the cochlea
- Status of the cochlea is most commonly measured with pure tone audiometry

Pure tone average (PTA) of 0.5, 1, 2, & 4 kHz tones in the better-hearing ear
Hearing Loss and Dementia: Current Evidence
Lancet Commission on Dementia Prevention, Intervention & Care

**Figure 3:** Forest plot of the effect of hearing loss on incidence of dementia 9–17 years later in cognitively healthy people

Hearing loss was measured by pure-tone audiometry. RR=risk ratio.

---

**Table:**

<table>
<thead>
<tr>
<th>Study</th>
<th>RR (95% CI)</th>
<th>Weight % (random)</th>
<th>Risk ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lin et al (2011)(^66)</td>
<td>2.32 (1.32–4.07)</td>
<td>27.3%</td>
<td></td>
</tr>
<tr>
<td>Gallacher et al (2012)(^67)</td>
<td>2.67 (1.38–5.17)</td>
<td>21.3%</td>
<td></td>
</tr>
<tr>
<td>Deal et al (2016)(^68)</td>
<td>1.55 (1.10–2.19)</td>
<td>51.4%</td>
<td></td>
</tr>
<tr>
<td><strong>Random effects model</strong></td>
<td><strong>1.94 (1.38–2.73)</strong></td>
<td><strong>100%</strong></td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: \(P=0.29\), \(\tau^2=0.0278\), \(p=0.2445\)
Hearing Loss & Incident Dementia

Dementia incidence in 639 adults followed for >10 years in the BLSA

Risk of incident all-cause dementia (compared to normal hearing)\textsuperscript{a}

<table>
<thead>
<tr>
<th>Severity</th>
<th>HR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>1.89</td>
<td>1.00 – 3.58</td>
<td>0.05</td>
</tr>
<tr>
<td>Moderate</td>
<td>3.00</td>
<td>1.43 – 6.30</td>
<td>0.004</td>
</tr>
<tr>
<td>Severe</td>
<td>4.94</td>
<td>1.09 – 22.4</td>
<td>0.04</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Adjusted for age, sex, race, education, DM, smoking, & hypertension

### Hearing Loss & Incident Dementia

**Dementia Incidence in 1057 Men Followed for 17 years in the Caerphilly Prospective Study (U.K.)**

<table>
<thead>
<tr>
<th>Cognitive Impairment</th>
<th>Model 1: adjusted for age, OR(^a) (95% CI), p value</th>
<th>Model 2: adjusted for age, social class, anxiety, OR(^a) (95% CI), p value</th>
<th>Model 3: adjusted for age, social class, anxiety, premorbid intelligence, OR(^a) (95% CI), p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All dementia (n = 79)</td>
<td>4.07 (2.21-7.50), &lt;0.001</td>
<td>3.26 (1.71-6.21), &lt;0.001</td>
<td><strong>2.67 (1.38-5.18), 0.004</strong></td>
</tr>
<tr>
<td>Vascular dementia (n = 38)</td>
<td>3.83 (1.69-8.65), 0.001</td>
<td>2.93 (1.24-6.94), 0.015</td>
<td><strong>2.40 (0.99-5.83), 0.05</strong></td>
</tr>
<tr>
<td>Nonvascular dementia (n = 41)</td>
<td>4.20 (1.84-9.55), 0.001</td>
<td>3.58 (1.50-8.51), 0.004</td>
<td><strong>2.96 (1.21-7.22), 0.017</strong></td>
</tr>
<tr>
<td>CIND (n = 146)</td>
<td>2.32 (1.50-3.59), &lt;0.001</td>
<td>1.72 (1.09-2.74), 0.021</td>
<td>1.24 (0.77-2.01), 0.38</td>
</tr>
<tr>
<td>All dementia (n = 46), omitting men with evidence of early cognitive decline</td>
<td>2.23 (1.04-4.77), 0.039</td>
<td>1.64 (0.72-3.73), 0.24</td>
<td>1.32 (0.57-3.12), 0.52</td>
</tr>
</tbody>
</table>

Abbreviations: CI = confidence interval; CIND = cognitive impairment no dementia; OR = odds ratio; PTA = pure-tone average (threshold).
\(^a\) Odds ratio is the effect per 10-dB\(_A\) rise in usual PTA.

Neurology 79  October 9, 2012
Hearing Loss & Incident Dementia

Dementia risk in 1,889 older adults followed for 9 years in the HealthABC Study


Figure 2. Multivariable-adjusted association between PTA and incident dementia, Health ABC Study, N = 1,889, 1999–2008. HR of incident dementia associated with PTA (in dBHL) when modeled continuously using penalized splines (used to allow for smooth, nonlinear effects in regression models). Adjusted for age (year), sex, race, education (less than high school/highs school/postsecondary), study site (Memphis or Pittsburgh), smoking status (never/former/current), hypertension, diabetes, and history of stroke. dBHL = decibels hearing level; Health ABC = Health, Aging and Body Composition; HI = hearing impairment; HR: hazard ratio; PTA, pure-tone average.
Estimates from more representative samples needed

- Potentially limited generalizability given:
  - Specific samples
    - Healthy older adults, volunteer cohort (BLSA)
    - From specific areas of the U.S.
    - Limited to men (Gallacher et al., 2012)
  - Clinic-based data collection
Research Letter

January 10, 2023

Hearing Loss and Dementia Prevalence in Older Adults in the US

Alison R. Huang, PhD; Kening Jiang, MHS; Frank R. Lin, MD, PhD; et al

» Author Affiliations


Strength: Representativeness
National Health and Aging Trends Study (NHATS)

Nationally representative cohort study
  Community dwelling, Medicare beneficiaries (65 + years) in the U.S.
  Annual data collection since 2011

Greater inclusion of older adults typically underrepresented in epidemiologic studies
  Home visit data collection
  Oversampling of oldest old (90+ years), Black older adults

Objectively measured hearing (pure tone average) and dementia
## Hearing Loss and Prevalent Dementia

National Health and Aging Trends Study, 2021, N=2,413

### Table 2. Multivariable-Adjusted Association Between Hearing Loss, Hearing Aid Use, and Dementia, National Health and Aging Trends Study, Round 11, 2021

<table>
<thead>
<tr>
<th>Audiometric hearing</th>
<th>Unweighted No.</th>
<th>Weighted prevalence of dementia (95% CI)</th>
<th>Prevalence ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>674</td>
<td>6.19 (4.31-8.80)</td>
<td>[Reference]</td>
<td></td>
</tr>
<tr>
<td>Mild hearing loss</td>
<td>886</td>
<td>8.93 (6.99-11.34)</td>
<td>1.08 (0.72-1.63)</td>
<td>.71</td>
</tr>
<tr>
<td>Moderate to severe hearing loss</td>
<td>853</td>
<td>16.52 (13.81-19.64)</td>
<td>1.61 (1.09-2.38)</td>
<td>.02</td>
</tr>
<tr>
<td>P value for trend</td>
<td></td>
<td></td>
<td></td>
<td>.01</td>
</tr>
<tr>
<td>Per 10-dB worse hearing</td>
<td></td>
<td>1.16 (1.07-1.26)</td>
<td>&lt;.001</td>
<td></td>
</tr>
</tbody>
</table>

### Every 10 dB worse hearing associated with 16% greater prevalence of dementia

Meta-analysis, N=9 cohort studies
Does hearing loss impact cognitive measurement?
Assessing bias in cognitive testing for older adults with sensory impairment: an analysis of differential item functioning in the Baltimore Longitudinal Study on Aging (BLSA) and the Atherosclerosis Risk in Communities Neurocognitive Study (ARIC-NCS)

E. Nichols1, J.A. Deal1,2, B.K. Swenor1,3, A.G. Abraham1,4, N.M. Armstrong6, M.C. Carlson6, M. Grieswold7, F.R. Lin1,2,8, T.H. Mosley7, P.Y. Ramulu3, N.S. Reed1,2, S.M. Resnick9, A.R. Sharrett1, A.L. Gross1

“…..no instances of [differential item functioning] which resulted in bias of greater than 1 standard error of measurement in estimated cognitive scores in participants with and without vision and hearing impairment...”
“….HL affects performance on the MoCA. Furthermore, the effect of HL on MoCA scores can be compounded by the effect of vision impairment. Neglecting to take sensory impairments into account when conducting cognitive screening may, at least in some cases, lead to cognitive impairment being overestimated...”
What can we do?

• No standardized guidelines for testing cognition in older adults with sensory loss

• Provide optimal conditions, remind participants to bring sensory aids

• Measure hearing, modified administration (HI-MoCA), sensitivity analyses

• Ensuring Speech Understanding (ESU) test
  • Confirms participant can hear spoken instructions and testing items
  • Determine if accommodations needed
What can we do?

- No standardized guidelines for testing cognition in older adults with sensory loss

- Provide optimal conditions, remind participants to bring sensory aids

- Modified administration (HI-MoCA), sensitivity analyses

- Ensuring Speech Understanding (ESU) test
  - Confirms participant can hear spoken instructions and testing items
  - Determine if accommodations needed

Exclude older adults with hearing loss from study participation
Critical Public Health Questions

Lack of accessible and effective treatments

Focus on Prevention

- What are the modifiable risk factors for dementia?
- What are the mechanistic pathways?
- What interventions can modify the mechanistic pathways to reduce risk of dementia?
Hearing Loss and Dementia
Common Cause or Modifiable Risk Factor?

Hearing Loss and Dementia
Common Cause or Modifiable Risk Factor?


Cognitive Load

Information degradation hypothesis

• With hearing loss, speech is heard as garbled ---> “effortful listening”

• Greater cognitive resources allocated to auditory processing

• Fewer resources for other cognitive tasks

Hearing Loss & Cognitive Load

Poorer hearing is associated with:

- Reduced language-driven activity in primary auditory pathways
- Increased compensatory language-driven activity in pre-frontal cortical areas


Hearing Loss and Dementia
Common Cause or Modifiable Risk Factor?

Hearing Loss & Brain Structural Atrophy

In **animals**, hearing loss associated in *longitudinal studies* with:

- Tonotopic reorganization of auditory cortex (Kakigi 2000, Audiology; Cheung 2009, J. Neurosci)
- Morphologic changes in central neuronal structures (Groschel 2010, Neurotrauma)

In **prospective human studies** (i.e., hearing measured at baseline followed by serial MRI scans over years):

- Accelerated atrophy over the temporal lobe over 7 years of follow-up (Lin, Neuroimage 2014)
- Mid-life hearing loss associated with accelerated late-life volume atrophy in temporal lobe and hippocampus (Armstrong 2019, JAMA Oto)
Hearing Loss and Dementia
Common Cause or Modifiable Risk Factor?


Hearing Loss, Loneliness, and Social Isolation: A Systematic Review

Aishwarya Shukla, MPH¹,², Michael Harper¹, Emily Pedersen, MPH², Adele Goman, PhD²,³, Jonathan J. Suen, AuD²,⁴, Carrie Price, MLS⁵, Jeremy Applebaum¹, Matthew Hoyer¹, Frank R. Lin, MD, PhD²,³,⁶, and Nicholas S. Reed, AuD²,³,⁶

Abstract

Objective. Social isolation and loneliness are associated with increased mortality and higher health care spending in older adults. Hearing loss is a common condition in older adults and impairs communication and social interactions. The objective of this review is to summarize the current state of the literature exploring the association between hearing loss and social isolation and/or loneliness.

Data Sources. PubMed, Embase, CINAHL Plus, PsycINFO, and the Cochrane Library.

Review Methods. Articles were screened for inclusion by 2 independent reviewers, with a third reviewer for adjudication. English-language studies of older adults with hearing loss that used a validated measure of social isolation or loneliness were included. A modified Newcastle-Ottawa Scale was used to assess the quality of the studies included in the review.

Results. Of the 2495 identified studies, 14 were included in the review. Most of the studies (12/14) were cross-sectional. Despite the heterogeneity of assessment methods for hearing status (self-report or objective audiometry), loneliness, and social isolation, most multivariable-adjusted studies found that hearing loss was associated with higher risk of loneliness and social isolation. Several studies found an effect modification of gender such that among women, hearing loss was more strongly associated with loneliness and social isolation than among men.

Conclusions. Our findings that hearing loss is associated with loneliness and social isolation have important implications for the cognitive and psychosocial health of older adults. Future studies should investigate whether treating hearing loss can decrease loneliness and social isolation in older adults.
Social isolation is a modifiable risk factor for dementia

Social isolation associated with 28% higher risk of dementia
Social isolation is associated with upregulation of pro-inflammatory genes & increased inflammation.

Critical Public Health Questions

Lack of accessible and effective treatments

Focus on Prevention

- What are the modifiable risk factors for dementia?
- What are the mechanistic pathways?
- What interventions can modify the mechanistic pathways to reduce risk of dementia?
Hearing loss intervention could:

- Reduce the cognitive load of processing degraded sound
- Provide increased brain stimulation
- Improve social engagement
Poll Question 3
Can hearing treatment delay cognitive decline and reduce dementia risk?
Short answer: We don’t know yet
Observational studies

National Health and Aging Trends Study, 2011, N=2,413

<table>
<thead>
<tr>
<th>Table 2. Multivariable-Adjusted Association Between Hearing Loss, Hearing Aid Use, and Dementia, National Health and Aging Trends Study, Round 11, 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unweighted No.</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Audiometric hearing</td>
</tr>
<tr>
<td>Normal hearing</td>
</tr>
<tr>
<td>Mild hearing loss</td>
</tr>
<tr>
<td>Moderate to severe hearing loss</td>
</tr>
<tr>
<td><strong>P value for trend</strong></td>
</tr>
<tr>
<td>Per 10-dB worse hearing</td>
</tr>
<tr>
<td>Hearing aid use</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Yes</td>
</tr>
</tbody>
</table>

Hearing aid use associated with 32% lower prevalence of dementia

Observational studies

Meta-analysis, N=8 studies

Figure 2. Longitudinal Association of Hearing Aid Use and Any Cognitive Decline

<table>
<thead>
<tr>
<th>Source</th>
<th>TE</th>
<th>seTE</th>
<th>HR (95% CI)</th>
<th>Favor hearing aids</th>
<th>Favor no hearing aids</th>
<th>Weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lin et al, 2013</td>
<td>-0.20</td>
<td>0.1768</td>
<td>0.82 (0.58-1.16)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sugiura et al, 2022</td>
<td>-0.39</td>
<td>0.2326</td>
<td>0.68 (0.43-1.07)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tai et al, 2021</td>
<td>-0.20</td>
<td>0.1481</td>
<td>0.82 (0.61-1.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bucholc et al, 2021</td>
<td>-0.31</td>
<td>0.0964</td>
<td>0.73 (0.60-0.88)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amieva et al, 2018</td>
<td>-0.15</td>
<td>0.1936</td>
<td>0.86 (0.59-1.26)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mahmoudi et al, 2019</td>
<td>-0.19</td>
<td>0.0408</td>
<td>0.82 (0.76-0.89)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lin, 2011</td>
<td>-0.03</td>
<td>0.3703</td>
<td>0.97 (0.47-2.00)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Davies et al, 2017</td>
<td>-0.01</td>
<td>0.2156</td>
<td>0.99 (0.65-1.51)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Random-effects model</td>
<td></td>
<td></td>
<td>0.81 (0.76-0.87)</td>
<td></td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Heterogeneity: $\tau^2 = 0$ (P = .88); $I^2 = 0\%$
Findings from observational studies are encouraging, but...

• Cannot disentangle whether observed potential benefit of hearing aids is due to the device or other factors tied to hearing aid use (confounding by indication)

• Hearing aid users tend to have higher SES, health care access

Randomized controlled trials are needed
Aging & Cognitive Health Evaluation in Elders (ACHIEVE) Randomized Trial

2018/2019 – 2022, N=977

Intervention

Best-Practices Hearing Rehabilitative Treatment Vs. Successful Aging Control

Proximal/Mediating Outcomes

Audibility of speech & environmental sounds
Enhanced Verbal Communication & Social Engagement

Primary Outcome

Cognitive Functioning

Secondary Outcomes

Dementia
MRI brain
Social/Mental Health
Physical Functioning
Falls & Hospitalizations
Health care utilization

Co-PI's: Frank Lin, MD PhD, Josef Coresh, MD PhD
Johns Hopkins University
Supported by National Institute on Aging: R01AG055426, R01AG060502, R34AG046548
The ACHIEVE Study Interventions

**Hearing Intervention**
University of South Florida (Chisolm, Sanchez)

4 sessions with a study audiologist to receive hearing loss education & hearing devices

**Health Education Control**
University of Pittsburgh (Glynn)

4 sessions with a health educator to cover the 10 Keys™ program

Established program that helps promote understanding of key health topics (nutrition, etc.) important for healthy aging

Semiannual visits for 3 years to receive booster sessions

Supported by National Institute on Aging: R01AG055426, R01AG060502, R34AG046548
The ACHIEVE Study

• Results expected later this year

• Whether positive or null, findings will have implications for public health

• Stay tuned!
What are the modifiable risk factors for dementia?

*Risk factors for dementia are multi-factorial. Hearing loss is a prevalent and strong and modifiable risk factor.*

What are the mechanistic pathways between hearing loss and dementia?

*Increased cognitive load, direct changes to brain structure and function, social isolation, common cause (non-causal)*

What interventions can modify the mechanistic pathways to reduce risk of dementia?

*Hearing treatment, potentially, but no definitive evidence yet*
Thank You!

ahuang31@jhu.edu
Supplemental Slides
Know Your Hearing Number™

Introducing the Hearing Number—a sound metric that can help you engage with life.

www.hearingnumber.org
# Participants

<table>
<thead>
<tr>
<th>Inclusion Criteria</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Community dwelling</td>
<td>• Self-reported difficulty in two or more activities of daily living</td>
</tr>
<tr>
<td>• Aged 70-84 years</td>
<td>• Vision loss</td>
</tr>
<tr>
<td>• Untreated, audiometric hearing loss (PTA ≥30 and &lt;70 dB HL)</td>
<td>• Ineligible for the hearing treatment</td>
</tr>
<tr>
<td>• Without dementia</td>
<td></td>
</tr>
</tbody>
</table>
Participants

- Partially nested within the Atherosclerosis Risk in Communities Study (ARIC)
- From 4 US communities
- Recruited from the ARIC Study (24%) and *de novo* (76%)