Ear Disease Potpourri: Tinnitus Treatments and the Association of Hearing Loss with Dementia & Cardiovascular Disease

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Indicators of Target Organ Damage

• Left ventricular hypertrophy (EKG/Echocardiogram)*
• Carotid wall thickening (Ultrasound)*
• Microalbuminuria (Urinalysis)*
Hypertensive Organ Damage*

- Heart
- Arteries
- Brain
- Kidneys
- Eyes
- Ear? (Audiogram)

*Sierra C., 2008
Audiometric Pattern as a Predictor of Cardiovascular Status: Development of a Model for Assessment of Risk

David R. Friedland, MD, PhD; Christopher Cederberg, MD; Sergey Tarima, PhD

- Age: 34 – 98
- 499M/669F
- 316 patients: Cardiovascular disease: Coronary, Cerebral, Peripheral
The presence of an association between cardiovascular variables and audiometric patterns was tested with a chi-square test based on a $2 \times 2$ contingency table. In the presence of small cell counts (i.e., < 5), the chi-square test was substituted by the Fisher exact test. Results were considered significant at $P < 0.05$. Odds ratios and confidence intervals were calculated for significant associations.

Associations between the strial audiometric pattern and cardiovascular variables were further tested with the Mantel-Haenszel statistic controlling for age and, in a separate analysis, for gender. Adjusted odds ratios for age and gender were calculated.

After the above exploratory analyses, which lacked a focus on controlling for family-wide false discovery rates, attention was turned toward building a multipredictor model. Logistic regressions were performed incorporating risk factors of AGE $> 75$, HTN, DM, LIPIDS, and SMOKING. The optimal cut-off of 75 years was found to define the highest (among other cutoff ages) likelihood in the logistic regression model. Audiogram pattern was defined as a variable AUDIOGRAM and forced into the logistic regression model. Thus, effects of different audiogram patterns on cardiovascular variables could be compared with the normal hearing pattern, and among themselves, controlling for age, hypertension, diabetes, hyperlipidemia, and smoking status.

A second logistic regression model was generated in which we looked solely at the contribution of low-frequency hearing loss (LFHL) to cardiovascular risk. Two analyses were performed in which a threshold of $> 25$ dB nHL at frequencies 250 Hz to 1 kHz and 500 Hz to 2 kHz in either ear was considered a low-frequency loss. All other subjects, regardless of other hearing loss pattern, were placed in the null category. Variables of AGE $> 75$, HTN, DM, LIPIDS, and SMOKING were included.

Both regression models were applied to the cardiovascular categories of MI, CAD, CVA, TIA, CABG, PTCA, and...
Audiometric Pattern & Cardiovascular Status

Cohort (N = 1,168)

- Low sloping
- Normal
- High sloping
- Mid sloping
- Strial

Friedland, et al., 2009
Audiometric Pattern & Cardiovascular Status

Coronary Vascular Disease N = 237

Friedland, et al., 2009
Cerebrovascular Disease (N = 137)

Audiometric Pattern & Cardiovascular Status

Friedland, et al., 2009
Audiometric Pattern & Cardiovascular Status

Peripheral Vascular Disease (N = 42)

- Low sloping
- Normal
- High sloping
- Mid sloping
- Strial

Friedland, et al., 2009
Association of Hearing Loss & CVD

• The strongest relation of hearing and CVD was for the low-frequency thresholds\textsuperscript{1,2}.

1. Friedland, et al., 2009
2. Gates, et al., 1993
Association of Hearing Loss & CVD

• “Hearing loss may be an early marker of vascular compromise by showing initial molecular deficits before the onset of morphological damage” (Friedland).

Friedland, et al., 2009
Early Markers for Cardiovascular Risk

- Elevated C-reactive protein*
- Abdominal obesity/metabolic syndrome*
- Hyperlipidemia*

- Hearing Loss

*Sierra C., 2008
Hearing Loss, Diabetes, HTN

N = 80
Age > 60

Rolim, et al., 2015
(Duck, et al., 1997)
Take Home Points

• Consider audiometric evaluation
  – Early marker for CVD
  – Assessment of end organ damage

• HTN + DM patients: audiogram
Hearing Loss and Cognitive Decline in Older Adults

Frank R. Lin, MD, PhD; Kristine Yaffe, MD; Jin Xia, MS; Qian-Li Xue, PhD; Tamara B. Harris, MD, MS; Elizabeth Purchase-Helzner, PhD; Suzanne Satterfield, MD, DrPH; Hilsa N. Ayonayon, PhD; Luigi Ferrucci, MD, PhD; Eleanor M. Simonsick, PhD; for the Health ABC Study Group

• 2013
• N = 1,162
• Audiometric/Cognitive testing over 6 years
Hearing loss is defined as a pure-tone average exceeding 25 dB. Normal hearing is defined as a pure-tone average of 25 dB or less.

Table 3. Cox Proportional Hazards Regression Models for Incident Cognitive Impairment by Baseline Hearing Status in 1626 Individuals With at Least 1 Follow-up Visit

<table>
<thead>
<tr>
<th>Hearing Status</th>
<th>Hazard Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>1.00 (0.82-1.22)</td>
<td>0.98</td>
</tr>
<tr>
<td>Hearing loss</td>
<td>1.24 (1.05-1.48)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The interaction term is between hearing loss and time. Study year 5 is 2001-2002, study year 11 is 2007-2008.

Figure. Multivariate mixed-effects models for adjusted mean scores by study year and by baseline hearing status. A, Modified Mini-Mental State Examination (3MS). B, Digit Symbol Substitution (DSS) test. Error bars indicate 95% CIs. All models are adjusted for age, sex, race/ethnicity, education, study site, smoking status, hypertension, diabetes mellitus, and stroke history.

3MS: global test for orientation, concentration, language, praxis, memory

Our results demonstrate that hearing loss is independently associated with accelerated cognitive decline and a 24% increased risk for incident cognitive impairment during a 6-year period compared with individuals having normal hearing. On average, individuals with hearing loss would require 7.7 years to decline by 3-5 points, compared with 10.9 years in those having normal hearing. In total, 609 cases of incident cognitive impairment were recorded during the 6-year period.

We also examined whether hearing aid use among individuals with hearing loss was more common and whether hearing aid use was associated with lower risk for incident cognitive impairment. Hearing aids had higher baseline cognitive scores on the 3MS in individuals using hearing aids compared with 218 individuals not using hearing aids (on the 3MS, hazard ratio, 1.22; 95% CI, 1.05-1.48; P = .01) increased risk for incident cognitive impairment. The magnitude of this association was linearly associated with the severity of an individual's hearing loss at baseline. The interaction term was not statistically significant, with individuals having hearing loss demonstrating a 30% to 40% accelerated rate of cognitive decline compared with individuals having normal hearing. The magnitude of these associations is clinically significant, with individuals having hearing loss demonstrating a 30% to 40% accelerated rate of cognitive decline compared with individuals having normal hearing.
Figure.

The graph shows the mean DSS scores (95% CI) over the study years for individuals with normal hearing and those with hearing loss. The y-axis represents the DSS score mean, and the x-axis represents the study years.

- **Normal hearing**: 817 participants
- **Hearing loss**: 1149 participants

The graph indicates a decline in DSS scores over the study years for both groups, with the hearing loss group showing a steeper decline compared to normal hearing.

- **Model Status in 1626 Individuals With at Least 1 Follow-up Visit for Incident Cognitive Impairment by Baseline Hearing**: The model is adjusted for age, sex, race/ethnicity, education, study site, smoking status, hypertension, diabetes mellitus, and stroke history.

<table>
<thead>
<tr>
<th>Hearing Status</th>
<th>No. of Participants</th>
<th>3MS Score Mean (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>1149</td>
<td>818 (530, 534)</td>
</tr>
<tr>
<td>Hearing loss</td>
<td>817</td>
<td>876 (530, 534)</td>
</tr>
</tbody>
</table>

- **Table 3. Cox Proportional Hazards Regression Models**: The table shows the hazard ratios (HR) and 95% confidence intervals (CI) for incident cognitive impairment associated with hearing loss.

<table>
<thead>
<tr>
<th>Hearing Categories</th>
<th>HR (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hearing</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Mild hearing</td>
<td>1.19 (0.99-1.44)</td>
<td>.06</td>
</tr>
<tr>
<td>Moderate hearing</td>
<td>1.36 (1.08-1.70)</td>
<td>.008</td>
</tr>
<tr>
<td>Severe hearing</td>
<td>1.50 (1.16-1.94)</td>
<td>.002</td>
</tr>
</tbody>
</table>

- **Values P = .02 for interaction**: The interaction term is between hearing loss and time.

**COMMENT**: Our results demonstrate that hearing loss is independently associated with increased risk for incident cognitive impairment. The protective effect of hearing aid use was not significantly associated with lower risk compared to individuals using hearing aids.

**REFERENCES**: 3-5, 7-9, 22-26
Figure 1. Dual-task costs in secondary task tracking performance during word-list recall for four groups of participants (younger and older adults with good hearing and poor hearing), with cost calculated as \[(Single-task percent time-on-target) - (dual-task percent time-on-target)\]. (Error bars represent one standard error.)

Tun et al. Psychol Aging. Author manuscript; available in PMC 2010 September 1.
Of the participants with moderate or severe HI, 21% (n = 176) used a hearing aid at Year 5. In analyses restricted to this group, the estimated effect of hearing aid use was in the anticipated direction (ie, reduced dementia risk, HR: 0.84, 95% CI: 0.51, 1.39) but did not achieve statistical significance and inference is limited, given the wide CI.

Cognitive Decline

We conducted additional analyses to investigate the association between HI and specific cognitive domains (memory, perceptual speed, and processing speed). At baseline (Year 3), participants with HI had lower mean total recall scores on the Buschke SRT (p = 0.001, Table 1), but mean scores in psychomotor speed and perceptual speed did not differ by HI status (Table 1). The baseline difference in memory score persisted after full adjustment; participants with moderate or severe HI scored an average of −0.24 SD (p = 0.02) lower than participants with normal hearing. When PTA was modeled continuously, we estimated an average difference of −0.05 SD (p = 0.04) for every 10 dB decrease (Table 3). No differences in rates of cognitive change for any cognitive domains were observed by HI status (Table 3).

Discussion

In a biracial cohort of well-functioning older adults (mean age 76 years in 1999–2000), our results demonstrate that moderate/severe peripheral HI (>40 dBHL) is associated with greater risk of incident dementia over 9 years (HR: 1.55, 95% CI: 1.10, 2.19), compared with participants having normal hearing after adjustment for multiple demographic, health behavior, and disease covariates. Except for poorer baseline memory performance (difference of −0.24 SD, 95% CI: −0.44, −0.04), no associations were observed between HI and rates of 7-year cognitive change in the domains of memory, perceptual speed, or processing speed.

Our results are consistent with previous longitudinal studies of audiometric HI and dementia (1, 2) and global cognitive change (2, 6, 7) over time. In 639 participants aged 36–90 years, baseline HI was associated with increased risk of all-cause dementia over 12 years (HR: 1.27 per every 10-dB loss, 95% CI: 1.06, 1.50) (1). In 1,057 men (mean age 56 years), each 10-dB increase in hearing level at baseline was associated with an increased odds of all-cause dementia measured 17 years later (odds ratio: 2.7, 95% CI: 1.4, 5.2) (2).

Deal, JA., 2016
Relationship of HL & Impaired Cognition

Hearing Impairment → Cognitive Load

Changes in brain structure & function → Reduced Social Engagement

Reduced Social Engagement → Impaired Cognitive Functioning & Dementia

Common Etiology (e.g., aging, microvascular disease)

Lin, FR., 2014
Hearing Loss & Impaired Cognition

- EFFECT of impaired cognition??

- Audiogram: Screen

Ear Institute of Chicago & Hearing Aid Center
Hearing Loss & Impaired Cognition

- EFFECT of impaired cognition??
- Audiogram: Screen

- CAUSE of impaired cognition??
- Treatment: HA

Prevention
Hearing Loss In United States

- Hearing Loss is the **THIRD MOST PREVALENT CHRONIC CONDITION IN OLDER AMERICANS**
Mental Health and Hearing Loss

• Hearing loss results in social isolation. Adults with untreated hearing loss tend to withdrawal from engaging with family and friends.
Hearing Loss

- 90% of patients experience a significant improvement in their quality of life when their hearing improves.
THANK YOU!

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References


References


• Martinia, A. Aging, Cognitive Load, Dementia and Hearing Loss. Audiol Neurotol 2014;19(suppl 1):2-5

References


Tinnitus

- Tinnitus is the perception of sound without an actual external sound source
- About 50 million people experience tinnitus, according to the American Tinnitus Association (ATA)
- About one in four seeks medical attention
- About 5% suffer from chronic, severe tinnitus
Impact of Tinnitus

- Anxiety
- Social Isolation
- Depression
- Sleep
- Concentration
Causes of Tinnitus

• Tinnitus is not a disease, it is a SYMPTOM

• Often associated with hearing loss; however, tinnitus itself does not cause hearing loss

• Tinnitus often occurs in conjunction with an auditory impairment
Causes of Tinnitus

• Excessive noise exposure
• Side effects from medications (aminoglycosides, chemotherapy, Aspirin)
• Metabolic Conditions (Diabetes, vitamin or mineral deficiencies)
• Disorders of the Auditory nerve
• Unknown Causes
Tinnitus

• With long-term tinnitus, one or more of the causes above have led to an auditory malfunction

• The brain’s attempt to compensate for this malfunction is the start of a vicious tinnitus cycle
Tinnitus Mechanisms

• The auditory cortex is the part of the brain that is responsible for hearing

• The nerve cell assemblies in a specific area of the auditory cortex are 'tuned' to a certain frequency, similar to the arrangement of keys on a piano
Tinnitus

• No matter what triggers may be responsible for the tinnitus – noise, medication, presbycusis— they all lead to an interruption of the signal transmission from the ear to the auditory cortex

• To stay with the piano image: some of the piano's keys no longer work and cannot be struck by the pianist
Tinnitus

• These nerve cell assemblies do not react to the lack of stimulus by simply remaining 'silent'.

• Instead the nerve cells begin to 'chatter' spontaneously and become synchronously attuned to one another.
Tinnitus

• Once they have become hyperactive and synchronous in this way, the nerve cells simulate a tone that the brain 'hears' – the tinnitus tone

• In the piano analogy, the broken keys have created their own permanent tone even without the keys being struck by the pianist

• Over time, this pattern strengthens and the tinnitus becomes permanently anchored – the brain has learned a phantom sound
Tinnitus Cycle

- The brain compensates for the hearing loss by “turning up” the sensitivity of the hearing system, not only amplifying the tinnitus but also making ordinary sounds uncomfortably loud for some people.

- This intolerance to loud sounds further adds to the patient’s stress enhancing the disturbance level.
Tinnitus Cycle

• What seems to make tinnitus disturbing is how the brain responds to the sound

• The process of developing an increased sensitivity to sound always involves the limbic system, the emotional response center of the brain

• For some people, the presence of tinnitus is troubling, and so the brain treats it as important and focuses on it, increasing awareness
Tinnitus Cycle

• This “increased awareness” can lead to stress, resulting in further enhancement by the emotional centers of the brain, and further amplification of the tinnitus

• Patients seek medical attention
Tinnitus Protocol

• Medical Evaluation and Treatment

• Tinnitus Management Procedures
  • Sound Therapy
  • Amplification
  • Education/Counseling
Sound Therapy

• Sound therapy has shown a consistent success rate of 60-90% in treating tinnitus

• Uses external sounds to provide short and long term relief from tinnitus

• Can be used on an as needed basis for its immediate masking and distracting effects to provide instant relief and a sense of control

• Sound therapy, when used correctly, can facilitate habituation
Habituation

• Habituation allows the patient to learn to disregard tinnitus by altering the patient’s perception of the tinnitus, even when it is persistently present

• Most people habituate, but some do not

• Habituation is effective 60-90% of the time (ATA)

• Many of those who do not habituate still benefit from sound therapy as part of tinnitus management
Sound Therapies

- Desyncra Neuromodulation
- Neuromonics
- Serenade
Neuromodulation for Tinnitus

• Recent developments in neuroscience have led to a clearer understanding of the neuronal activity behind tinnitus

• Neurons in the auditory cortex become hyperactive and synchronized, which is perceived by patients as tinnitus
Changed Neural Behavior

• Desyncra for Tinnitus applies Neuromodulation to disrupt or “desynchronize” the pathological, neuronal behavior

• The proprietary pitch-matching procedure makes use of this to target the therapy to the hyperactive region in the auditory cortex
Changed Neural Behavior

- Improved symptoms are reflected in EEG imaging, showing reduced delta wave activity across tinnitus neural networks.
Neurotherapy

• Therapy delivered using therapeutic tones via an iPod and special earphones over 36 weeks

• Therapy is tailored to the patient’s tinnitus profile and is adjusted throughout the therapy to ensure it remains optimized

• Patients report improved symptoms, including decrease in loudness and annoyance
Neuromononics

- Stimulates the auditory system where it is deprived
- Positively engages the limbic system
- Relies on neuro-plasticity of the brain
- Allows for intermittent, momentary tinnitus perception within a pleasant and relaxing stimulus, facilitating desensitization to the tinnitus signal
Treatment Stage 1

High level of interaction

Maximum stimulation

Relief and reduction of tinnitus awareness during listening sessions
Treatment: Stage 2

- Gradual reduction in intensity
- Intermittent interaction with tinnitus
- Continued tinnitus desensitization
- Retrain brain
Neuromononics Advantage

• Rapid relief & sense of control
• Improved relaxation and sleep
• Reduced awareness and disturbance
• Improved tolerance of loud sounds
• Long-term benefit
Sound Cure Serenade

• Approach is to introduce cortically interesting sounds to positively alter abnormal neural activities for the purpose of tinnitus suppression (S-Tones)
Tinnitus Management: Addresses 2 Key Components

Acute / Short-term

Longer-term

S-Tone / NB / BB

Habituation / Sound Therapy

Neurophysiological

Neural component

Perceptual

Focus, reaction, interaction, limbic system
Goal of Serenade

• The goal of any long term program is to provide habituation

• S - Tones facilitate habituation

• Habituation reduces hyper monitoring, the inappropriate over perception of sound, causes an inappropriately perceived stimulus (loud tinnitus) to return to normal (soft tinnitus)
Why Hearing Aids Help

• Increased stimulation sent to the auditory cortex
• Ambient noise can partially mask tinnitus
• The amplified signal can reduce the contrast between tinnitus and silence
• Fatigue and stress is reduced
• Sound therapy stimulus can be activated in hearing aids
Factors Influencing Patient's Ability to Habituate

- Stress levels of patient
- Support system of patient
- Coping abilities of patient
- Patient's insight into symptom
- Interactions among above
- Education/Counseling
Education

• For the tinnitus patient…
  “KNOWLEDGE IS POWER”

• Educating patients on what we understand about tinnitus, and what we do not understand gives patients a sense of power
Counseling

• Both instructional and adjustment based

• Educate patient and assist the limbic system to alter or re-classify the negative interpretation of the tinnitus

• For patients with high distress, the use of cognitive behavioral intervention is recommended
Summary

• Each patient is unique in terms of the cause of tinnitus, psychological profile, auditory profile and response to treatments

• Management of tinnitus needs to be customized for each patient based on careful assessment of the patient’s needs

• Management of chronic severe tinnitus often requires a combination of treatment measures and a multi-disciplinary approach
Thank You!

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References


• Hanley & Davis. Treatment of Tinnitus With a Customized, Dynamic Acoustic Neural Stimulus. Trends Amplification. 2008; 0


• Published: “Counteracting Tinnitus by Acoustic Coordinated Reset Neuromodulation”, Restorative Neurology and Neuroscience (2012)