Hearing loss can begin at any age.

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Prevalence of Hearing Loss in the United States, 2001-2008

Hearing loss defined as a better-ear PTA of 0.5-4kHz tones > 25 dB

Lin et al., Arch Int Med. 2011
Prevalence of Hearing Loss in the United States, 2001-2008

Hearing loss defined as a better-ear PTA of 0.5-4kHz tones > 25 dB

Lin et al., Arch Int Med. 2011
Global Prevalence Estimates

Prevalence of Tinnitus

Impact of Hearing Loss in Adults

• Primarily determined by its effects on speech understanding and communication
• A variety of environmental and personal factors
  – Physical and Mental Health
  – Relationships
  – Economics
  – Living situation (independent, assistive living, nursing home, palliative care)
Not what is the person’s hearing loss –

Who is the person with the hearing loss

- Robyn Cox
Hearing Loss in Adults

- More likely to be unemployed
- More likely to earn significantly lower wages

Hearing Loss in Adults

- Communication
- Frustration
  - Associated with
    - Sadness and depression
    - Worry and anxiety
    - Paranoia
    - Emotional turmoil and insecurity
- Reduced QoL
Hearing Loss in Older Adults

• An increased likelihood of depression:
  – Odds Ratio = 1.8 (95% Confidence Interval: 1.1-2.7)

• Decreased self-sufficiency in Activities of Daily Living:
  – Odds Ratio = 2.1 (95% Confidence Interval: 1.4-3.2)

• (Carabellese, Appollonio, Rozzini et al., 1993)
Hearing Loss in Older Adults

- Reduced walking speed

(Li et al., Gait & Posture 2012)
Hearing Loss in Older Adults

• Increased risk of falls

(Lin et al. Arch Int Med 2012)
Hearing Loss in Older Adults

- > 10 days of self-reported poor mental health
  - Odds Ratio = 1.57 (95% CI: 1.20 - 2.06)

- > 10 days of self-reported poor physical health
  - Odds Ratio = 1.36 (95% CI: 1.06 – 1.74)

- (Genther et al, JAMA, 2013)
Hearing Loss in Older Adults

• Increased likelihood of a hospitalization within the past year
  – Odds Ratio = 1.32 (95% CI: 1.07 – 1.63)

• Number of hospitalizations within the past year
  – Odds Ratio = 1.35 (95% CI: = 1.09 – 1.68)

  (Genther et al, JAMA, 2013)
Hearing Loss & Incident Dementia

Lin et al., Arch Neuro., 2011

Hazard ratio of incident all-cause dementia (compared to normal hearing)\(^a\)

<table>
<thead>
<tr>
<th></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>

\(^a\) Adjusted for age, sex, race, education, DM, smoking, & hypertension

Dementia incidence in 639 adults followed for >10 years in the Baltimore Longitudinal Study
Effect of Tinnitus
Global Burden of Disease (WHO)
Effect of Tinnitus
Global Burden of Disease (WHO)

Courtesy of A. Davis, 2015
Effect of Tinnitus
Global Burden of Disease (WHO)

Weights derived for GBD from first experimental derived weight across all sequelae
Hearing alone in blue and with tinnitus in red

Courtesy of A. Davis, 2015
Effect of Tinnitus
Global Burden of Disease (WHO)

Courtesy of A. Davis, 2015
Factors Related to the Effects of Hearing Loss on Speech Understanding

Secondary Effects Associated with Hearing Loss in Adults
Degree of Hearing Loss
The audiogram tells us how sensitive the individual’s hearing is to different sounds that range from low pitch to high pitch.
Degree of Hearing Loss

- Degree of hearing loss from mild to profound
- Pure Tone Average (PTA)
- Calculated by averaging sensitivity thresholds at specific frequencies (Hz)

*An example presbyacusis (sloping high-frequency hearing loss) synonymous with the ageing process.*
Degree of Hearing Loss

**AUDIOGRAM**

- **Left Ear** ×
- **Right Ear** ○

- Normal Hearing
- Mild Hearing Loss
- Moderate Hearing Loss
- Severe Hearing Loss
- Profound Hearing Loss

**Hearing Level in Decibels (dB)**

- 0 dB
- 20 dB
- 40 dB
- 60 dB
- 80 dB
- 100 dB
- 120 dB

**Frequency in Hertz (Hz)**

- 125 Hz
- 250 Hz
- 500 Hz
- 1000 Hz
- 2000 Hz
- 4000 Hz
- 8000 Hz

*An example presbycusis (sloping high-frequency hearing loss) synonymous with the ageing process.*
Degree of Hearing Loss

- Degree of hearing loss from mild to profound
  - Pure Tone Average (PTA)
    - Calculated by averaging sensitivity thresholds at specific frequencies (Hz)

Effects of HL Not as Simple

* An example presbyacusis (sloping high-frequency hearing loss) synonymous with the ageing process.
Degree of hearing loss (PTA) alone does not account for the classic complaint....

“I can hear people talking but I can’t understand what they are saying when it’s noisy”
Configuration of Hearing Loss
Configuration of Hearing Loss

SLOPING

RISING

FLAT

UNILATERAL
Unilateral Hearing Loss

• Affect people at any age
• Acute or progressive
• Mild to Profound
• Unknown etiology,
  – but need to r/o infections, neoplasms, stroke,
    demyelinating and autoimmune disease, perilymphatic
    fistula, and Ménière’s disease

• Functional Impact
  – Difficulty with localization
  – Difficulty following, taking part in a conversation
Configuration of Hearing Loss
PTA and configuration together do not fully explain the classic complaint....

“I can hear people talking but I can’t understand what they are saying when it’s noisy”
Two Components of Hearing Loss

- Audibility
- Distortion
Two Components of Hearing Loss

Audibility

Distortion

No matter how loud we make the sounds, there can still be problems with the clarity or the clearness.
Making sound louder is necessary, but not sufficient.
Audibility & Distortion are determined by the “type of hearing loss”
Audibility & Distortion determined by the “type of hearing loss”
Hearing Loss
Hearing Loss
Hearing Loss
Hearing Loss

The diagram illustrates the auditory pathway, including the outer ear, middle ear, and inner ear. Key structures labeled include:

- Eardrum (Tympanic membrane)
- Auditory bones
- Semicircular canals
- Cochlea
- Ear canal
- Eustachian tube
- Mastoid process

The auditory pathway continues through the brain to the primary auditory cortex.
Hearing Loss

Conductive Hearing Loss

Audibility

Audibility

Audibility

Audibility

Audibility

Audibility

Audibility

Audibility

Conductive Hearing Loss
Treatment for Conductive Hearing Loss

Medically

Surgically
Treatment for Conductive Hearing Loss

Technological Interventions

- Bone Conduction Hearing Aid
- BAHA
- Middle Ear Implants
- SoundBite
- Air Conduction Hearing Aids
The Auditory System

Conductive Hearing Loss
Hearing Loss
Hearing Loss

Sensorineural Hearing Loss
Causes of SNHL

- Idiopathic sudden hearing loss
- Perilymph fistula
- Autoimmune Disorders
- Infections (e.g., encephalitis, meningitis, etc.)
- Trauma (temporal bone fractures)
- Diabetes
- Multiple Sclerosis
- Noise-induced hearing loss (NIHL)
- Age-related hearing loss (Presbycusis)
Cross-section of the normal cochlea
Cross-section of the normal cochlea

Outer Hair Cells
Cross-section of the normal cochlea

Inner Hair Cells
Cross-section of the damaged cochlea
Cross-section of the damaged cochlea

- Sound becomes softer due to loss of OHCs
- Signal to the brain becomes less robust creating distortion due to loss of the IHCs
What happens when the hair cells are damaged?

- Processing of sound in the cochlear
- Effects neural input to our brains
- Progressive loss of cochlear neurons
- Decrease in fiber density in IHCs
  - IHC sensory fibers constitute 95% of cochlear nerve
- We hear with our brain and not our ears
- Information from ears to temporal lobe is decreased
- Lose robustness of the signal
- Creating distortion

- Processing of sound in the cochlear
- Effects neural input to our brains
- Progressive loss of cochlear neurons
- Decrease in fiber density in IHCs
  - IHC sensory fibers constitute 95% of cochlear nerve
Distortion Component

Audiological Evaluation

- Signal-to-noise ratio needed to recognize 50% of the message
• Normal hearing person needs speech to be 2 dB > noise for 50% correct recognition
  – $SNR-50 = +2$ dB

• Person with hearing loss might need the speech to be 12 dB > than the noise for 50% correct recognition
  – $SNR-50 = +12$ dB
SNR-50 cannot be predicted by the audiogram!

Patient 1
67 y/o
SNR-50 = 15.2 dB

Patient 2
77 y/o
SNR-50 = 26.0 dB
External Noise Exacerbates Peripheral Distortions

- Obscures speech sounds that are weaker than itself
- Distracts the listener
Special Type of Noise

- Visual Analogy

The following is a list of Farmer's markets to be held in the surrounding areas.

Slide from permission from A. Boothroyd
The level of the direct speech signal falls by 6 dB for every doubling of distance.
Combined Negative Effects

• Make listening & communicating difficult for all
• Exacerbated by effects of:
  – Hearing Loss
  – Aging-related processing declines
## Sequelae definitions

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**World Health Organization – Global Burden of Disease**

A. Davis, Personal Communication
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**World Health Organization – Global Burden of Disease**

A. Davis, Personal Communication
Hearing impaired at 20-34 dB HL can't hear this

Normal can hear this message

Can you hear this in noise
Can you hear this in noise
Can you hear this in noise
Can you hear this in noise
Can you hear this in noise
Can you hear this in noise
Can you hear this in noise

Decrease signal to noise

A. Davis, Personal Communication
It is important to consider both components of hearing loss:
- Audibility
- Distortion

Communication Environment
Sensorineural Hearing Loss

- Elevated thresholds (can’t hear soft sounds)
- Reduces speech understanding in noisy and reverberant (echoing) environments
- Interferes with the perception of rapid changes in speech
- Exacerbated due to effects of cognitive aging
- There is NO CURE.
- But there are efficacious interventions.
Technical Interventions

- Hearing Aids

* An example presbyacusis (sloping high-frequency hearing loss) synonymous with the ageing process.
Optimal Fitting of Hearing Aids

- Numerous evidence based decisions
  - Style
  - Features
  - Signal processing, etc

- Verification
  - Physical fit & comfort
  - Signal processing “Real ear testing”
Moderate Hearing Loss (30-60 dB)
Moderate Hearing Loss (30-60 dB)

- Frequency in Hertz: 125, 250, 500, 1000, 2000, 4000, 8000
- Sound level in dBHL:
  - 0
  - 20
  - 40
  - 60
  - 80
  - 100

Aided
Efficacy of Hearing Aid Intervention

- Randomized Controlled Trial
  - Mulrow et al., 1990
- Improvements
  - Emotional function
  - Social function
  - Communication function
  - Cognitive function
- Lessening of depression
- Sustained for up to 1 year of hearing aid use
HUI QoL measure as a function of hearing level in new referrals before and after (3m) hearing aid fitting MHAS  N= 589

Davis et al., 2007
HUI QoL measure as a function of hearing level in new referrals before and after (3m) hearing aid fitting MHAS  N= 589

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Davis et al., 2007
Hearing Difficulty & Hearing Aid Rates by Age Group

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<th>Age Group</th>
<th>Hearing Difficulty</th>
<th>Hearing Aids</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18 years</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>18-24 years</td>
<td>3%</td>
<td>1%</td>
</tr>
<tr>
<td>25-34 years</td>
<td>5%</td>
<td>1%</td>
</tr>
<tr>
<td>35-44 years</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>45-54 years</td>
<td>11%</td>
<td>2%</td>
</tr>
<tr>
<td>55-64 years</td>
<td>17%</td>
<td>3%</td>
</tr>
<tr>
<td>65-74 years</td>
<td>22%</td>
<td>9%</td>
</tr>
<tr>
<td>75-84 years</td>
<td>34%</td>
<td>14%</td>
</tr>
<tr>
<td>85+</td>
<td>62%</td>
<td>26%</td>
</tr>
</tbody>
</table>

MT9, Hearing Industries Association, 2015
Technical Intervention

• Cochlear Implants

Lin et al 2013
Cochlear Implants

- Medically and surgically appropriate candidate
- Selection of devices
  - Internal surgically implanted electrode arrays
  - External signal processors
- Surgery
- Mapping (adjusting the T- and C-levels) for optimal comfort and understanding

- Improvements
  - Speech perception
  - QoL

  - *e.g.*, Klop et al 2007
  - *Laryngoscope*
We live in a very noisy world!
Hearing Assistive Technologies

• Assistive Listening Devices (ALDs)
  – Used alone or combined with hearing aids and/or cochlear implants
  – To supplement performance in difficult listening conditions.
Sound is picked up and transmitted directly to the listener, thus overcoming deterioration due to noise, reverberation and distance.

Hardwired or Wireless (FM, Induction, Infrared, Bluetooth) Link between sound source and listener

With permission C. Compton-Connelly, 2014
Hearing Assistive Technologies

- Alerting Devices
  - Visual or Tactile
Systematic Device Orientation & Instruction

• Device use and care
• Individually or in Groups
• At least one, but sometimes several sessions
• Only about 50% of medical information in general, and HAO information too! (Reese & Chisolm, 2004)
Technology Solutions

• Hearing Aids, Cochlear Implants, ALDs
  – Can minimize the impact on speech understanding
  – Technology is not a panacea

• Many individuals need and benefit from “non-technological” interventions
Aural Rehabilitation

- Chisolm & Arnold (2012)
  - Evidence About the Effectiveness of Aural Rehabilitation Programs for Adults
Group or Individual Sessions

- Communication strategies
- Problem solving
- Assistive listening devices
- Information & advices to spouses
- Applied relaxation
Many Commercially Available Computer-Based Speech Perception Training Programs
Progressive Audiological Rehabilitation Management (PARM)

- Hearing aids and/or Cochlear Implants
- Educational/Counseling Based AR
- Auditory and/or Auditory-Visual Perceptual Training (PT)
- Assistive Listening Devices
- Hearing aids and/or Cochlear Implants
- Education and/or PSAPs

Abrams & Chisolm, Seminars in Hearing, 2013
ONE SIZE DOES NOT FIT ALL.
ONE SIZE DOES NOT FIT ALL.
KEEP TRYING...
ONE SIZE DOES NOT FIT ALL.
KEEP TRYING...

AND EVENTUALLY YOU WILL FIND THE PERFECT FIT.