Noise Exposure to Young Ears: When Things Go From Bad To Worse

Sharon G. Kujawa, PhD
Massachusetts Eye and Ear Infirmary
Harvard Medical School

Noise-Induced Hearing Loss
In Children At Work And Play
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Characterizing Noise – Age Interactions

When and How?

The crux of the problem: NIHL and AHL often co-exist in the same ear; consequences vary widely among individuals.

85 yr male; Hx noise, WWII pilot, machine shop 20 yrs
Study of noise-age interactions in the human is complicated by:

Variability in NIHL
- *apparent* differences in vulnerability vs. *actual* differences in exposures
- inability to quantify lifetime noise ‘dose’
- identifying/quantifying/controlling variables
- genetic heterogeneity; true NIHL susceptibility differences

Variability in AHL
- heterogeneity in underlying pathology
- variable contribution of other insults….noise
- genetic heterogeneity; true AHL susceptibility differences
Small NIHL Variability *Within* Inbred Strains of Mice

12 identically exposed
Guinea Pigs

12 identically exposed
CBA/CaJ mice

Yoshida and Liberman 2000
Large NIHL Variability *Between* Inbred Strains of Mice

8-16 kHz OBN, 2 hr, 103 dB SPL

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**CB-ABR**

**MOLF-ABR**
Genetic Controls Allow Investigation of Other Sources of Variability

With less variability introduced by genetic heterogeneity, it is now easier to observe that, *within strains*, NIHL magnitude also is influenced by: *age-at-exposure, post-exposure time*

**Post-Exposure Time**

PTSs often quantified at relatively short post-exposure times (~2 wk – 2 mo)

Do such threshold changes associated with the original insult remain stable for many months or even years?
Age-At-Exposure
Noise – Age Interactions

**Mice:** CBA exposed at various ages; held various post exposure times

**Exposure:** 8 to 16 kHz, 100 dB SPL, 2hr

**Physiology:** PTSs quantified by ABR and DPOAE (5.6 to 45.2 kHz)

**Histopathology:** Cochlear tissues retrieved from subsets of animals

**Controls:** Age matched, non-exposed cagemates served as "pure" aging controls.

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Kujawa and Liberman 2006
Age-Related NIHL Vulnerability Shifts *Within* Inbred CBA/CaJ

2 Weeks Post-Exposure: 

*Things are bad:* Young-exposed ears show 40 dB PTS

Kujawa and Liberman 2006
Age-Related NIHL Vulnerability Shifts *Within* Inbred CBA/CaJ

Now, look at animals exposed at different ages, but all held for the same 2 weeks post-exposure:

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Kujawa and Liberman 2006

[Graph showing ABR with 16 kHz shift]
Age-Related NIHL Vulnerability Shifts Within Inbred CBA/CaJ

2 Weeks Post-Exposure:

Large vulnerability shift for 8 vs. 16 wk exposed animals
Cannot be accounted for by changes in hearing or middle ear function

Kujawa and Liberman 2006
Noise-Induced Histopathology at a Short Post-Exposure Time

Exposure: 8-16 kHz OBN, 2 hr 100 dB SPL

Noise exposure often produces lateral wall pathology.

For this exposure, the primary finding 2 wk after exposure, young or old, is Type IV fibrocyte loss in the base of the cochlea.

Kujawa et al
The Aging of Young-Exposed Ears

\[ dB + \int_{A}^{\Omega} dt = PTS - dB \]

Modified from Hawkins, 1973
Conventional Wisdom Holds: Post-Exposure Stability of NIHL

Medical-legal hearing loss assignment formulae use models in which NIHL and AHL add simply to form the aggregate hearing loss recorded in a noise-exposed, aging ear.

However…. 
Conventional Wisdom Holds:
Post-Exposure Stability of NIHL

‘Longitudinal threshold changes in older men with audiometric notches’
(Gates et al, 2000)

Subjects: 203 men, Framingham Heart Study cohort

Audiometric Data: Pure tone thresholds from biennial exam E15 (~65 yr) to E22 (~80 yr)

Question: Do male ears with audiometric evidence of noise damage change over time to the same degree as those without?
Noise-Induced and Age-Related Hearing Loss Interactions

In regions with large, pre-existing NIHL, there are small, additional shifts. In contrast, there is greater involvement of more apical cochlear regions.
So: Do threshold changes induced by noise in younger ears remain stable? Or, does noise exposure in early adulthood lead to a degenerative condition, such that hearing continues to decline?

Does it increase vulnerability to AHL or other challenges?

Do previously noise-exposed ears age *differently* from ‘unexposed’ ears as suggested by Gates et al??
Aggregate Hearing Loss in Early-Exposed, Long-Held Animals

Kujawa and Liberman 2006

Things get worse: Early exposure exacerbates AHL
Exaggerated AHL Correlates with Primary Neural Degeneration

Young-exposed ears held for long post-exposure times show widespread (~50%) SGC loss.

Never seen in age only, or in young- or old-exposed ears held for short post-exposure times.

Kujawa and Liberman 2006
Noise – Age Interactions: Evidence of a Misspent Youth

Kujawa and Liberman 2006
Characterizing Noise – Age Interactions: Summary

**Short Post-Exposure Time:**

- NIHL vulnerability in CBA/CaJ is a rapidly-changing function of age-at-exposure. Mice 4-8 wk are substantially more vulnerable than mice 16 wk or older.

- ABRs and DPOAEs yielded similar findings re: overall magnitude and frequency extent of noise-induced shifts.

- The exposure does not result in HC loss. Type IV fibrocyte loss was evident in basilar crest region of spiral ligament.
Long Post-Exposure Time:

- Early Previous NIHL in CBA/CaJ renders ears more vulnerable to AHL. Final shifts were greater than simple NIHL + AHL.

- Greater noise - age interaction was observed in ABRs than DPOAEs, suggesting inner hair cell/auditory nerve SOL.

- Histologic analyses revealed significant, primary neural degeneration: i.e. widespread loss of SGCs without loss of inner hair cells.
Collaborators

Support from: NIDCD

Boston

Charlie Liberman
John Rosowskki
George Gates
Bruce Tempel
Valerie Street
Noah Seixas

Seattle

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