Adding Insult to Injury: Progressive Cochlear Nerve Degeneration after “Temporary” Noise-Induced Hearing Loss

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Convention 2011, Washington, DC
-Or-
Noise is More Dangerous Than We Thought!

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Normal Structure and Function
Normal Inner Ear: Structure
Normal Inner Ear: Function

To brain…
Exquisite Architecture Supports Excellent Sensitivity

The normal ear is sensitive to very small motions
Loud sound produces very large motions
Hazardous Noise: What Does it Do to Ears and Hearing?
Noise-Induced Threshold Shifts (Hearing Loss)

Miller, Watson & Covell, 1963
Noise-Induced Threshold Shifts
(Hearing Loss)
Hair Cell Loss & Stereocilia Damage

Ears with PTS often have hair cell loss. Damage evident soon after exposure

Wang et al, 2002
Even if hair cells survive, stereocilia are often damaged.

Hair Cell Loss & Stereocilia Damage

(normal)  

(noise exposed)
Sugawara, et al. 2005

**Neural Degeneration Secondary to IHC Loss**

*Nerve loss often occurs as a secondary consequence of the hair cell loss; a slow process*

Sugawara, et al. 2005
Noise-Induced Neurodegeneration in “Recovered” Ears
Not all Hazardous Noises cause Permanent Hearing Loss

Miller, Watson & Covell, 1963
Noise-Induced Threshold Shifts (Temporary)
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

Thresholds recover from initial 30-40 dB shift

Kujawa & Liberman, 2009
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

Neural response amplitudes do not recover…why?

Kujawa & Liberman, 2009
Too Much of a Good Thing!

Swelling of cochlear nerve terminals at their hair-cell synapses

Dendritic swelling appears minutes after exposure

Wang et al, 2002
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

Use immunolabeling to see cochlear nerve terminals and synapses

Hair cells
Nerve Terminals
Synaptic Ribbons

Kujawa & Liberman, 2009
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

Cochlear nerve synapses disappear within hours – hair cells remain intact

Kujawa & Liberman, 2009
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

Kujawa & Liberman, 2009
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

What do we know about the nerve cells that die?
Primary Neural Degeneration after Temporary Noise-Induced Hearing Loss

Noise appears to target high threshold, low-med spontaneous rate fibers

Kujawa & Liberman, 2009; Lin et al 2011
Neural loss: What’s the Consequence to Hearing Function?
Thresholds

Thresholds for pure tones represent the gold standard for quantifying noise damage in humans

Measurement protocols are standardized and validated.

NIHL risk models, upon which every existing noise exposure standard is based, utilize audiometric threshold data and are aimed at preventing PTS.

Seixas, N.

But in some ears, thresholds recover after noise...implication is that the exposure was benign
Loss of cochlear neurons, especially low SR neurons, should decrease the robustness and fidelity of stimulus coding in low signal-to-noise conditions, for example speech in noise.

Hearing in Noise

Donald Schum 2001
“I expected to lose my hearing… but I thought it would be quiet.”

Peripheral neurodegeneration can lead to central reorganization.

May contribute to perceptual anomalies including tinnitus and hyperacusis, common consequences of loud sound exposure that can occur with or without threshold elevation.
Conclusions

Much permanent hearing loss after noise is from hair cell damage and loss; temporary hearing loss after noise can occur with hair bundle changes, synaptic changes, etc.

Noise causes rapid synaptic loss and slow degeneration of cochlear nerve fibers, even if hair cells recover.

Diffuse neural degeneration does not raise thresholds, but does decrease neural response amplitudes.

Neural degeneration may contribute to difficulties hearing in noise and other abnormal auditory perceptions like tinnitus.

Damage risk criteria assume threshold recovery = benign exposure; since that is not true, noise is more dangerous than we thought.
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