BOOK REVIEWS

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Noise-Induced Hearing Loss: Scientific Advances, Springer Handbook of Auditory Research, Vol. 40

Edited by C. G. Le Prell, D. Henderson, R. R. Fay A. N. Popper

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Synthetic Literature reviews are valuable for specialists to get "caught-up" and for students and non-specialists to learn about recent research. The Springer Handbook of Auditory Research has provided a forum for synthetic reviews for more than 20 yrs spanning 50 volumes. It would be difficult to find an auditory researcher who does not have at least one of the "green books" in their professional libraries. And many have contributed a review to the series.

The 2012 Le Prell *et al*. edition contains synthetic reviews focused on noise-induced hearing loss (NIHL). The volume consists of 14 chapters authored by 21 researchers. The editors divide the book into four parts: (1) "Noise-Induced Hearing Loss: Scope of the Problem," (2) "Relationship Between Noise Exposure and Resulting Anatomical, Physiological, and Perceptual Changes in Hearing," (3) "Susceptibility and Factors Contributing to NIHL," and (4) "Protection and Repair." The preface and first chapter provide a road map for the reader.

The first chapter of the "Scope" section is titled "The Public Health Significance of Noise-Induced Hearing Loss." Peter Rabinowitz lays out the problems associated with identifying NIHL as a public health factor. This is an excellent overview of the problem. He demonstrates that NIHL is not a new problem presenting literary evidence dating back to 1713. Among the issues he highlights are the difficulties of estimating the public health impact of NIHL, of differentiating NIHL from aging, number of people affected, prevalence of occupational NIHL, prevalence of non-occupational NIHL, and the severity of NIHL. Seemingly simple issues like defining what is hearing loss are discussed. This chapter is highly recommended to anyone interested in doing epidemiological research on NIHL.

Marjorie Grantham's chapter "Noise-Induce Hearing Loss and Tinnitus: Challenges to the Military" (the second in the "Scope" section) lays out the military concerns. Hearing is often vital to the safe and efficient operation of troops, but often the side with the most powerful (i.e., noisy) weapons wins. Hearing loss can significantly impact the efficiency of battle operations. Understanding speech in noise is vital but so is being able to localize and locate friendly and enemy noises. The number one disability of returning Gulf War veterans is tinnitus. It interferes with sleep and focus. Hearing loss and tinnitus are extremely costly to the taxpayer as well as the service member. Grantham lays out some of the costs in the chapter. The latter part of the chapter highlights military hearing conservation programs. Although hearing protectors are supposed to be the last solution—behind noise reduction and administrative changes—they are often the only practical solution. She emphasizes the cons of hearing protection—loss of low level communication and situational awareness. Troops sometimes weigh the risk of hearing loss as less than the risk of missing critical communication calls.

The first chapter in the "Dose Response" section is entitled "The Use of Kurtosis Measurement in the Assessment of Potential Noise Trauma" by Don Henderson and Roger Hamernik. The chapter describes characterizing impulsive noise by the kurtosis statistic. The chapter begins with a tutorial on the current U.S. noise exposure regulations which assume equal risk for the product of equal time and energy. A number of epidemiological and research studies have shown that the trading relation breaks down for non-Gaussian (impulsive) noise exposures. Complex non-Gaussian noises (impulses embedded in continuous noise) are more damaging than Gaussian continuous noise. They discuss the idea of a dynamic "critical level" for impulsive noise beyond which the cochlea begins to suffer mechanical damage. The chapter provides a good overview of the kurtosis metric but is not necessarily a primer on kurtosis.

Bohua Hu's almost 30 page chapter on noise-induced structural damage *is* a tutorial, including the only color photos in the book. His chapter "Noise-Induced Structural Damage to the Cochlea" is very hair-cell-centric. He begins by discussing normal hair cell loss in the cochlea. He describes the anatomy of a hair cell lesion (cochlear region with at least 50% hair cell loss), their distribution, their severity, and growth. He does a very thorough job describing damage and recovery to hair cell stereocillia. He outlines the death of the hair cell quite well. The last few pages of the chapter are concerned with repair processes.

Eric Young's chapter "Neural Coding of Sound with Cochlear Damage" encompasses almost 50 pages. The title of the chapter undersells it. It actually is a nice synthesis of cochlear electrophysiology beginning with cochlear potentials, hair cell physiology, and cochlear mechanics. The chapter has a clinical flavor which might find value in a graduate audiology program. It is very clearly written. The downside to the chapter is the grouping of multiple graphs into whole page presentations. The text relies heavily on the figures. I found myself trying to locate the various figures, usually a couple of pages back.

Mini Shrivastav's chapter on "Suprathreshold Auditory Processing in Noise-Induced Hearing Loss" is clinically oriented. She begins by discussing temporary threshold shift (TTS), permanent threshold shift (PTS), and asymptotic threshold shift. She discusses the difficulties that NIHL poses for speech understanding. She first reviews the effects of NIHL on basic aspects of auditory processing such as frequency resolution, temporal resolution, and loudness perception. She then discusses changes in more complex auditory processing abilities. These processes impact the ability to understand speech, even when amplified.

The final chapter in the second section is James Kaltenbach and Ryan Manz's "The Neurobiology of Noise-Induced Tinnitus." They begin by laying out the burden of tinnitus at both a population and individual level. They then examine the hypothetical mechanisms of noise-induced tinnitus. They provide evidence that although noise-induced tinnitus may be triggered by a cochlear hair cell injury, the actual generators are located centrally. They discuss interesting phenomena such as pitch instability and residual inhibition. They also examine animal data providing insights into the mechanisms of noise-induced tinnitus and attempt to correlate it with human perception. They present convincing evidence that noise-induced tinnitus may be caused by the plastic imbalance of inhibitory and excitatory neurotransmitters in the brain stem centers of the auditory system. They examine the clinical implications for dealing with these dynamic changes in the brain stem. The good news is there appears to be a range of tinnitus treatments either available or in development.

The third section of the book "Susceptibility and Factors Contributing to NIHL" begins with a chapter "Genes That Influence Susceptibility to Noise-Induced Hearing Loss" by Tzy-Wen Gong and Margaret Lomax. They discuss the role of the genes encoding cadherin 23 and protocadherin 15 in susceptibility to NIHL. Mutations to these genes were initially identified in mice and have been implicated in human NIHL. The authors discuss the importance of ionic pumps for the proper protection of the cochlea from noise. Included are discussions of $Ca^{2+}$and K^{+} pumps as well as connexins. The next part of the chapter is concerned with oxidative stress. This is a very concise review of the catalase, super-oxide dismutase, paraoxonase, and glutathione systems. The next two sections talk about Heat Shock Protein, glucocorticoids, and glutamate metabolism. The chapter concludes with discussions about future perspectives in identifying genes and challenges to identifying genetic susceptibility to NIHL.

Eric Bielefeld contributes a chapter "Effects of Early Noise Exposure on Subsequent Age-Related Changes in Hearing." The author makes the case that age-related hearing loss is inherent and not a phenomenon of lifetime accumulated noise exposures. The author poses the question whether age-related and NIHL are additive, synergistic, or antagonistic. The answer is important for the medico-legal system. The lack of controlled noise exposures in humans makes it impossible to answer the question. Bielefeld presents human epidemiological data showing that age and noise are

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antagonistic within the noise notch but synergistic in the audiometric frequencies surrounding the noise notch. He presents other evidence that point to no interaction and other studies having additive effects. Certainly animal models will clear this up. Well, the animal research is not as simple as additive, synergistic, or antagonistic. The interaction seems to be dependent upon the mechanism of the age-related hearing loss. The chapter is a head scratcher but gives a good orientation to the state of the science.

Thais Morata and Ann-Christin Johnson present a chapter "Effects of Exposures to Chemicals on Noise-Induced Hearing Loss." (Disclosure: Morata is a co-worker.) An interesting feature of the chapter are two tables—one extending over eight pages, the other four pages. The chapter begins with a discussion of solvents and carbon monoxide—agents which have been shown to be ototoxic alone. These agents cause hearing loss in the mid-frequency audiogram; different from ototoxic antibiotics causing changes in the high frequencies. The focus of the chapter involves ototoxicity of solvents, asphyxiants, and metals in which noise has been identified as a co-factor. Each section begins with a review of the animal literature and then discusses occupational studies. Not surprisingly, while there often are animal studies on a noise-chemical combination, there may not be corresponding human studies.

Part four of the book is entitled "Protection and Repair." The first chapter by John Casali is entitled "Hearing Protection Devices: Regulation, Current Trends and Emerging Technologies." He begins his chapter with a history of hearing protection devices (HPDs). He then discusses the use of HPDs as an adjunct to noise controls. Casali then does a thorough review of the U.S. Occupational Safety and Health Administration regulations. He then discusses HPD labeled attenuation versus the actual field performance. For those interested in the details of the American National Standards Institute HPD standards and Environmental Protection Agency HPD regulations, it is all in this chapter. A short description of the effects of passive HPDs on signal and speech audibility is then provided. The last half or so of the chapter is concerned with advanced technologies. This section is very interesting in summarizing some of the HPD shortcomings and the technological solutions to those shortcomings. For the general reader, the cutting edge technologies are probably the most interesting.

Colleen Le Prell and Jianxin Bao's contribution is "Prevention of Noise-Induced Hearing Loss: Potential Therapeutic Agents." This is an update of the review by Le Prell *et al.* (2007). Since TTS is used as a metric for protection, they begin by reviewing the relationship between TTS and PTS. They discuss the evidence for the oxidative stress role in NIHL. This evidence suggests that oxygen-free radicals produce the majority of damage to the cells of the organ of Corti. The authors review the normal processes that detoxify these free radicals. These protective processes become overwhelmed during noise exposure. They also discuss apoptosis. Le Prell and Bao review the current candidate agents for prevention of NIHL. The chapter includes three tables—two multi-page. They also discuss the possibility of using extended high frequency audiometry and distortion product otoacoustic emissions to detect early NIHL. The chapter contains 315 references!

The final chapter is "Frontiers in the Treatment of Hearing Loss" by Tatsuya Yamasoba, Josef Miller, Mats Ulfendahl, and Richard Altschuler. They identify a number of molecular steps where drug interventions could stop or reduce the pathology from noise. They detail three protective pathways: Antioxidants, neurotrophic factors, and heat shock proteins. In addition, they discuss blocking "bad" pathways: Apoptotic and excitotoxic pathways. They discuss the use of drugs promoting blood flow during noise exposure. One section is devoted to post-trauma rescue interventions. There is a lot that can be done pharmacologically to rescue hearing hours or days after a traumatic exposure. There is evidence that pre-trauma treatment with multiple agents can result in greater protection than the single agents given alone. They discuss a novel therapeutic tool: Hydrogen gas and water. Hydrogen gas is a targeted antioxidant which does not interfere with beneficial ROS (Reactive Oxygen Species) processes. The final third of the chapter is concerned with: Once damage has occurred how can it be treated? They divide treatments into maintenance (preventing further pathology) and restoration (repair, regeneration, replacement). Application of neurotrophic factors and electrical stimulation maintains cochlear afferent fibers. Several neurotrophic factors are candidates for promoting regrowth of peripheral processes of afferent neurons. The chapter provides a path through some of the exciting research on regeneration, and replacement. A more reasonable approach for humans might be to inject precursor cells. Perhaps it will be awhile before we can line up to have stem cells injected into our cochleae but the cochlear prosthesis exists today. Current technology is moving toward less traumatic implantation and hybrid devices which take advantage of residual hearing. In the future noise and chemical vulnerability may be modified by gene therapy.

I was surprised by the tidbits of information that I learned along the way. This volume earns its space on the bookshelf next to the other volumes of the Springer Handbook of Auditory Research.

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