Department of Veterans Affai

Veterans Health Initiative

Hearing Impairment

Independent Study Course
Released: March 2002

Sponsored by
Department of Veterans Affairs
Employee Education System

Employee Education System

This is a Veterans Health Administration System-wide Training program, sponsored by the Employee Education System and Veterans Health Administration National Audiology and Speech Pathology Service. It is produced by the Employee Education System.

We dedicate this module to America's veterans who have defended the nation for two hundred and twenty five years and by their dedication, courage, and sacrifice have secured the blessings of freedom, the greatness of the nation, and the lasting gratitude of its people.

DEPARTMENT OF VETERANS AFFAIRS
UNDER SECRETARY FOR HEALTH
WASHINGTON DC 20420

Message from the Under Secretary for Health

I commend you for choosing to take advantage of this self-study program, "Hearing Impairment." Your commitment to continuing professional development benefits veterans who have unique needs related to their military service and reflects well on you as a dedicated health care provider.

VA health care providers need to understand the effects of hearing impairment, one of the most common service-related injuries. Veterans from all periods of service suffer from noise-induced hearing loss, a condition that significantly impairs communication and restricts their participation in employment, family, social, and recreational activities. More importantly, hearing impairment can limit a patient's active participation in his or her health care and can have, if left untreated, serious psychological consequences. Veterans are also at high risk for hearing loss due to aging. Thirty percent of Americans aged 65-74 years have hearing loss. In the 75-and-older age group, half of all Americans have significant hearing loss. Because many veterans are older or have suffered noise injuries, hearing loss is likely to be a frequent complaint among veteran patients.

The Department of Veterans Affairs is committed to providing all veterans with health problems, especially those related to military service, the highest quality health care. The information in this module will be helpful to you in your daily practice.

Thank you for participating in the Veterans Health Initiative.

Thomas L. Garthwaite, M.D.

DEPARTMENT OF VETERANS AFFAIRS
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MESSAGE FROM THE DIRECTOR, AUDIOLOGY AND SPEECH PATHOLOGY SERVICE

Hearing loss is one of the most common service-related injuries. Because of their history of noise exposure and advancing age, veterans are likely to complain of hearing loss. However, hearing loss is not only a problem among veterans; it is a significant public health problem. Over 35 million Americans have hearing loss. Hearing loss is the most common occupational injury and the second most common self-reported occupational disease. Hearing loss is insidious in its presentation but devastating in its personal, family, and social impact. However, a veteran need not be severely hearing impaired to suffer from the effects of hearing loss. A veteran with a high-frequency hearing loss, the most common type of hearing loss resulting from noise exposure, may have difficulty understanding speech in noisy environments, including those found in health care settings. Even mild hearing loss can have a significant effect on quality of life if left untreated.

There have been significant developments in the diagnosis and treatment of hearing loss. As a health care provider, you are the patient's most important resource for health information. This module is designed to introduce you to the problems experienced by veterans with hearing loss, the magnitude of hearing loss as a public health problem, the diagnosis and prevention of hearing loss, and treatment options.

I am pleased that you are taking the opportunity to educate yourself on hearing impairment. The knowledge you gain from this module will help you treat your patients, regardless of health care setting.

Lucille B. Beck, Ph.D.
Director, Audiology and Speech Pathology Service

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Independent Study Outline

Background On September 20, 1999, the Acting Under Secretary of Health requested that a working group be established to develop the Veterans Health Initiative (VHI). He envisioned this as a comprehensive program to recognize the connection between certain health effects and military service, to allow military history to be better documented, to prepare health care providers to better serve their veteran patients, and to establish a data base for further study. This was first discussed by the Acting Under Secretary in relation to the health of former prisoners of war. Development was really begun by the former Chief Academic Affairs Officer, Dr. David Stevens, with the Military Service History project. This involves a pocket card for medical residents detailing the important components of a military service history targeting the health risks associated with various periods of service and more generic issues of concern and a website containing references relevant to the issues.

Educational modules in the Veterans Health Initiative will assist health care providers in recognizing the connection between certain health effects and military service, prepare health care providers to better serve veteran patients, and will provide a data base for further study.

Purpose This independent study is designed to provide an introduction to issues regarding the long-term health consequences of hearing loss as a result of military experience:

- Enhance clinicians' abilities to assess and manage hearing loss in veteran patients
- Assist practitioners in making appropriate referrals to audiologists
- Provide veterans with the evaluations, guidance, and treatment they need and deserve.

Objectives After completing this independent study, participants should be able to:

- Describe primary care clinicians' roles in the prevention, identification, evaluation, and treatment of hearing loss
- Describe the basic anatomy and physiology of the auditory system
- Describe the primary care clinician's role in identifying, screening, and making appropriate referrals for hearing loss, tinnitus, and balance disorders
- Monitor patients' medication use

- Counsel patients on ways to avoid noise exposure
- Describe the primary care practitioner's role in assisting veterans in establishing well-grounded claims for disability-related hearing loss and ear disease
- Describe basic audiological assessment procedures and their role in the management of patients with hearing loss.

Outcome

The expected outcomes of this self study are: improved sensitivity to the effect of military experiences and exposures on veteran patients' health and attitudes, improved patient satisfaction, increased awareness of the occupational risks in a patient's history, and a data base for future research activities.

Target Audience

This independent study is designed for primary care providers.

Content Materials

Lesson 1
- Statistics on the Incidence of Hearing Loss
- History of Audiology in the VA

Lesson 2
- Anatomy and Physiology of the Auditory System
- Measuring Hearing Loss and Reporting Results

Lesson 3
- Preventive Medicine
- Guidelines for Audiological Screening in Primary Care
- Hearing Handicap Inventory for the Elderly — Screening Version

Lesson 4
- Preventing Ototoxic Hearing Loss

Lesson 5
- Preventing Noise-induced Hearing Loss

Lesson 6
- Treatment of Hearing Loss

Lesson 7

Content Materials

- Compensation and Pension

Lesson 8

- Tinnitus

Appendices

APPENDIX A

1. NIOSH Hearing Loss Publications

2. Work-Related Hearing Loss

3. *Noise and Hearing Loss, National Institutes of Health Consensus Development Conference Statement*, January 22-24, 1990

4. *NIDCD Fact Sheet — Noise-Induced Hearing Loss*, National Institute on Deafness and Other Communication Disorders, 1999

APPENDIX B

The Consequences of Untreated Hearing Loss in Older Persons, The National Council on the Aging, 1999.

Independent Study Questions for CME Credit

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LESSON 1 STATISTICS ON HEARING LOSS, HISTORY OF AUDIOLOGY IN THE VA

Kyle C. Dennis, Ph.D. (Editor)

OBJECTIVES:

- Describe the scope of hearing loss as a public health issue
- Define the role of the Department of Veterans Affairs in the prevention, identification, evaluation, and treatment of hearing loss

TAKE HOME MESSAGE

Hearing loss is a significant healthcare problem. Veterans are more likely to suffer hearing loss because of their military experience, employment, socioeconomic status, lack of access to health care, and age than other groups in the population. The Department of Veterans Affairs, as one of the nation's largest healthcare providers, is a leader in the management of hearing loss.

Hearing loss is a common medical problem. **Among veterans, the incidence of hearing loss is higher, often due to their military experience.**

Incidence of Hearing Loss in America

- Incidence of hearing loss in the general population: **35 million** Americans have hearing loss, or about **10%** of the population (Source: National Organization for Hearing Research Foundation).
- **30%** of Americans aged 65-74 have hearing loss.
- **50%** of Americans 75 years or older have hearing loss.

A Short History of Audiology in the Department of Veterans Affairs

The field of Audiology was developed during World War II as veterans with war injuries returned home for treatment. Thousands of these veterans suffered noise-induced hearing loss. At the time, there was no specialty devoted to the assessment and treatment of hearing loss. The field of Audiology grew out of the fields of acoustics, speech pathology, psychology, and otology. Military aural rehabilitation programs, such as the program at Walter Reed Army Medical Center, processed about 15,000 veterans between 1945 and 1947. The VA had identified 45,000 veterans with service-related hearing loss by 1949. By 1957, the VA had identified 71,000.

In 1945, Dr. Norton Canfield at Yale University was appointed as a consultant in Otolaryngology to the VA Chief Medical Director. The following year, Dr. Edward Truex, another otolaryngologist, was appointed to manage the newly created Audiology and Speech Correction Program. In 1947, Dr. Adam Glorig was appointed as the first Chief of the Audiology and Speech Correction Program. In 1948, the first two Audiology programs were established in Washington, DC and Philadelphia.

The VA hearing aid program began in the late 1950's, well before hearing aid fitting was considered within the scope of practice of audiologists. The VA became a leader in the development of evaluation and treatment methods and electro-acoustic evaluation of hearing aids.

Today, as in the immediate post-war years, the VA remains the nation's largest employer of audiologists and premier provider for the rehabilitation of hearing loss. There are more than 280,000 veterans with service-related hearing loss, one of the most common service-related injuries. VA audiologists treated over 316,000 patients and issued 241,458 hearing aids in FY2001.

The health problems of these veterans are the subject of this program. Hearing loss is not only a significant healthcare issue for the Department of Veterans Affairs; it is a major public health problem for the nation. Healthcare professionals in the VA, as well as in every health-care organization, have a duty to identify, to refer, and to manage patients suffering from the devastating effects of hearing impairment.

America's veterans, because of their military experience and because of their sacrifice to the nation, deserve special attention to their needs.

Source:

Allen Boysen, Ph.D.: *History of the Audiology and Speech Pathology Program*, Department of Veterans Affairs (1992)

Robert McLaughlin, Ph.D. "Audiologists in the United States". In David Lipscomb (Ed.*) Noise and Audiology*. Baltimore: University Park Press, 1978

Statistics on Hearing Loss and Treatment Services in the VA

- Number of veterans (1999): **24.8 million**
- Number of veterans treated in VA facilities (FY00): **3.6 million**
- Hearing loss is the most common service-related disability among veterans.
- Number of veterans receiving compensation or pension payments: **2.7 million**
- Compensation and pension payments to veterans (projected FY02): **$24.1 billion**
- Number of veterans **with hearing loss** as a service-connected disability (FY01): **296,759**
- Annual compensation payments to veterans **with hearing loss** as a service-connected disability (FY01): **$338,283,456**
- Hearing loss is the **ninth most common** service-connected disability among Gulf War veterans.
- Number of patient visits in VA Audiology Clinics (FY01): **627,197**
- Number of unique patients seen in VA Audiology Clinics (FY01): **316,389**
- Number of hearing aids issued by the VA (FY01): **241,458**
- Cost of VA hearing aids (FY01): **$80,774,030**
- Number of hearing aids issued by the VA per day (FY01): **943**
- Average cost of VA hearing aid (FY01): **$334.53**
- 132 Audiology Clinics, 123 dispensing hearing aids

LESSON 2 ANATOMY AND PHYSIOLOGY OF THE AUDITORY SYSTEM MEASURING HEARING LOSS AND REPORTING RESULTS

Lucille B. Beck, Ph.D. and Judy Schafer, Ph.D.

OBJECTIVES:

- Define basic anatomy and physiology of the auditory system
- Describe basic hearing loss measurement
- List the classifications of hearing loss

TAKE HOME MESSAGE

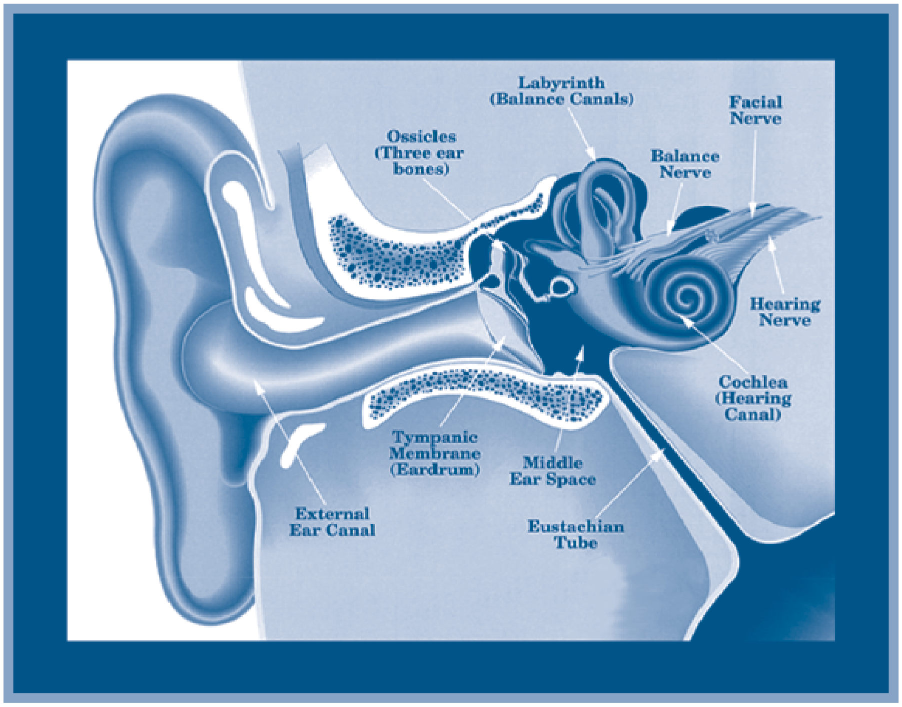
The **audiologist** provides critical information for the diagnosis of hearing loss. Specifically, the audiologist provides diagnostic information on etiology, degree, communicative effects, and treatment options for hearing loss, balance disorders, and tinnitus.

Supplemental Readings

The Audiology Primer for Students and Health Care Professionals, Department of Veterans Affairs, 1997
http://www.va.gov/621quillen/clinics/asp/products/PRIMER

Diagnosis and Treatment of Hearing Disorders, CD-ROM, Department of Veterans Affairs, 1999

ANATOMY AND PHYSIOLOGY OF THE EAR

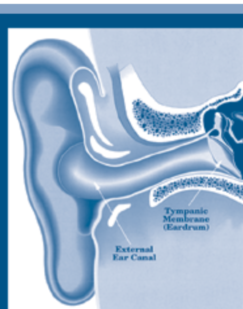


The ear consists of three divisions: the outer ear, the middle ear, and the inner ear.

Division	Mode of Operation	Function
Outer ear	air vibration	protection, amplification, localization
Middle ear	mechanical vibration	impedance matching, mechanical advantage (amplification), pressure equalization
Inner ear	mechanical, hydrodynamic electromechanical	transduction, frequency selectivity, active biomechanics, balance (vestibular portion)

The outer ear consists of the **pinna (auricle)** and the **external auditory meatus (ear canal)**. The middle ear consists of the **tympanic membrane, the ossicles, the middle-ear space, associated muscles and ligaments, and the Eustachian tube**. The auditory portion of the inner ear consists of the **cochlea and its attendant structures**. The vestibular portion of the inner ear consists of the **semicircular canals, the utricle,** and the **saccule**. **Cranial Nerve VIII** innervates the inner ear.

External Ear



External Ear

- Pinna (Auricle)
  - made up of skin and cartilage
  - helps collect and localize sound
- Ear Canal
  - about 1 inch long
  - part cartilage, part bone
  - protective (s-shape, cerumen)
  - self-cleaning (epithelial migration)

The **pinna** forms the most visible part of the ear. Composed of skin and cartilage, the pinna amplifies sounds and contributes to the localization of sounds in space. The ear canal is about one inch long in adults and has a cartilaginous section and a bony section. The ear canal performs primarily **a protective function, but also plays a role in amplifying certain sound**s. Cerumen (earwax) is a normal product of glands in the lining of the ear canal. Cerumen serves in a protective role, but may partially or totally occlude the lumen of the ear canal.

Pathologies of the External Ear

Some typical pathologies of the external ear are:

- Cerumen impaction
- Foreign bodies (insects or debris)
- Infections and inflammations (otitis externa, cellulitis, chondritis, dermatitis, herpes zoster oticus, otomycosis)
- Congenital malformations (atresia, stenosis, microtia, nodes)
- Bony growths (osteomas, exostoses)
- Tumors and other lesions (keratosis obturans, polyps, hypertrophic scarring)
- Carcinomas
- Necrotizing otitis externa

Middle Ear

The middle ear consists of the **tympanic membrane, the middle-ear space, the three ossicular bones (malleus, incus, and stapes), associated muscles, ligaments and tendons, and the Eustachian tube**. The middle ear is frequently the site of pathology.

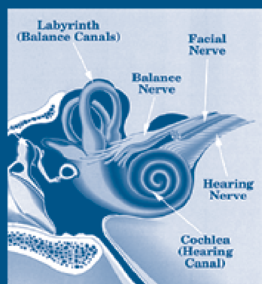
Middle Ear

- Normally air-filled
- Structures include:
  - Tympanic Membrane
  - 3 ossicles (malleus, incus, stapes)
- Sound is amplified via lever action of ossicles and transmitted to inner ear
- Pressure-equalization via Eustachian tube

Pathologies of the Middle Ear

- Tympanic membrane pathologies such as perforations and tympanosclerosis
- Infections of the middle ear (otitis media) and mastoid (mastoiditis)
- Tumors such as cholesteatoma and glomus tumors
- Ossicular trauma (disarticulation)
- Otosclerosis
- Patulous Eustachian tube

Inner Ear

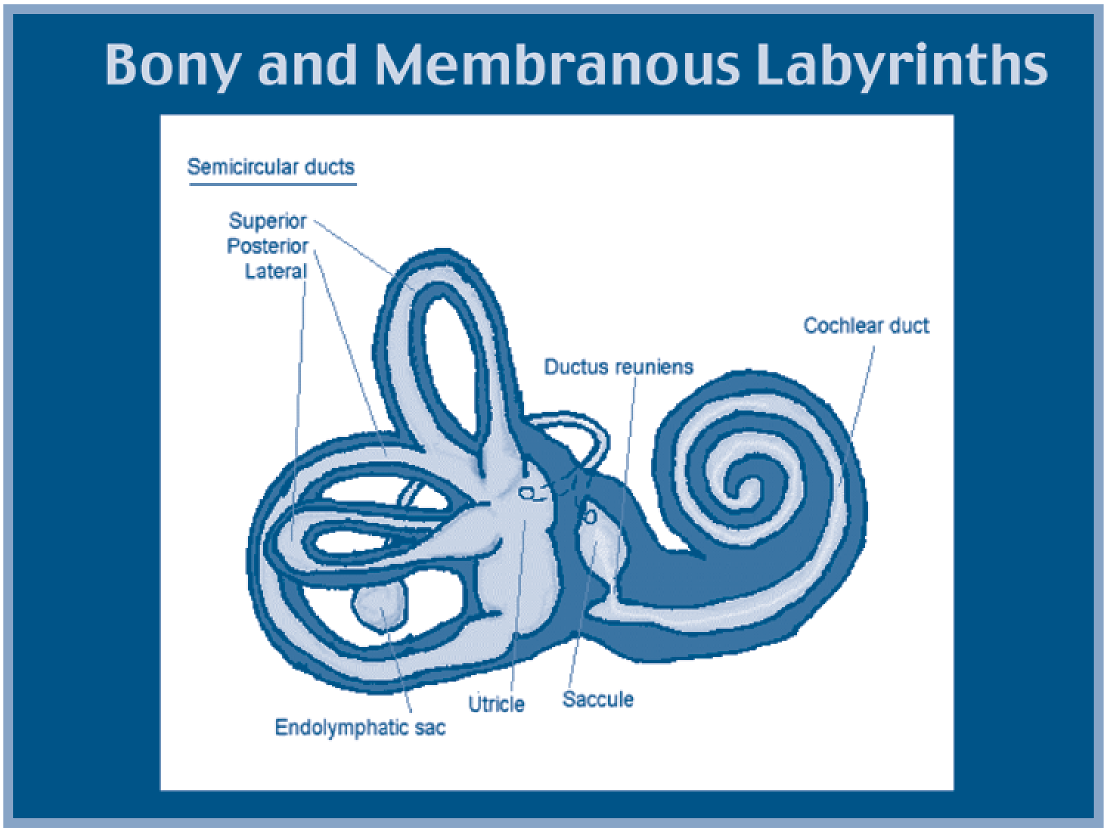


Inner Ear

- Encased in the temporal bone
- Consists of fluid-filled membranous sacs and ducts within a bony labyrinth
- 2 major structures:
  - Cochlea (hearing)
  - Semicircular canals (balance)
- Sensory and supporting hair cells
- Sound is transmitted via a “traveling wave” through the cochlea, which causes excitation of hair cells and stimulation of the auditory nerve

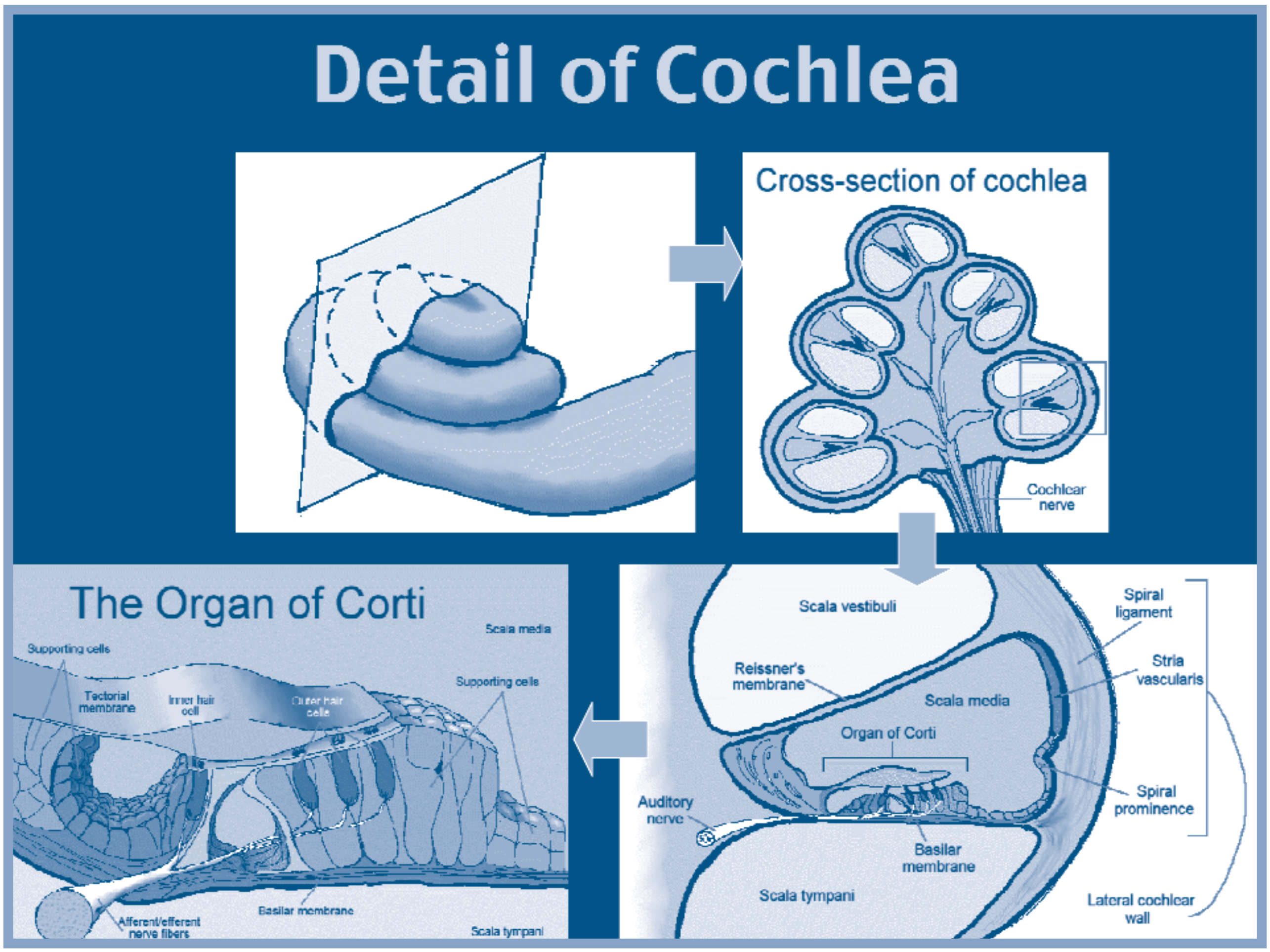
The dense bone of the **petrous pyramid of the temporal bone**, the hardest bone in the body, protects the delicate sensory structures of hearing and balance.

Bony and Membranous Labyrinths



The temporal bone contains an intricate system of bony channels and fluid-filled membranous structures. The membranous structures include the cochlea, the ductus reuniens, the saccule, the utricle, the semicircular canals, and the endolymphatic sac. These structures form the sensory organs of hearing and balance.

Cochlear Structures



The cochlea has three fluid-filled **ducts: scala tympani, scala vestibuli, and the scala media**. The scala media contains the sensory structure of hearing, the **Organ of Corti**. The Organ of Corti rests on a thin membrane (basilar membrane) that vibrates in a characteristic traveling wave motion that is essential to the ear's ability to sense frequency (pitch). The traveling wave selectively stimulates two types of sensory cells, the **outer and inner hair cells**. Outer hair cells are highly susceptible to damage from loud noise and ototoxic medications, but inner hair cells can be damaged as well.

Pathologies of the Inner Ear

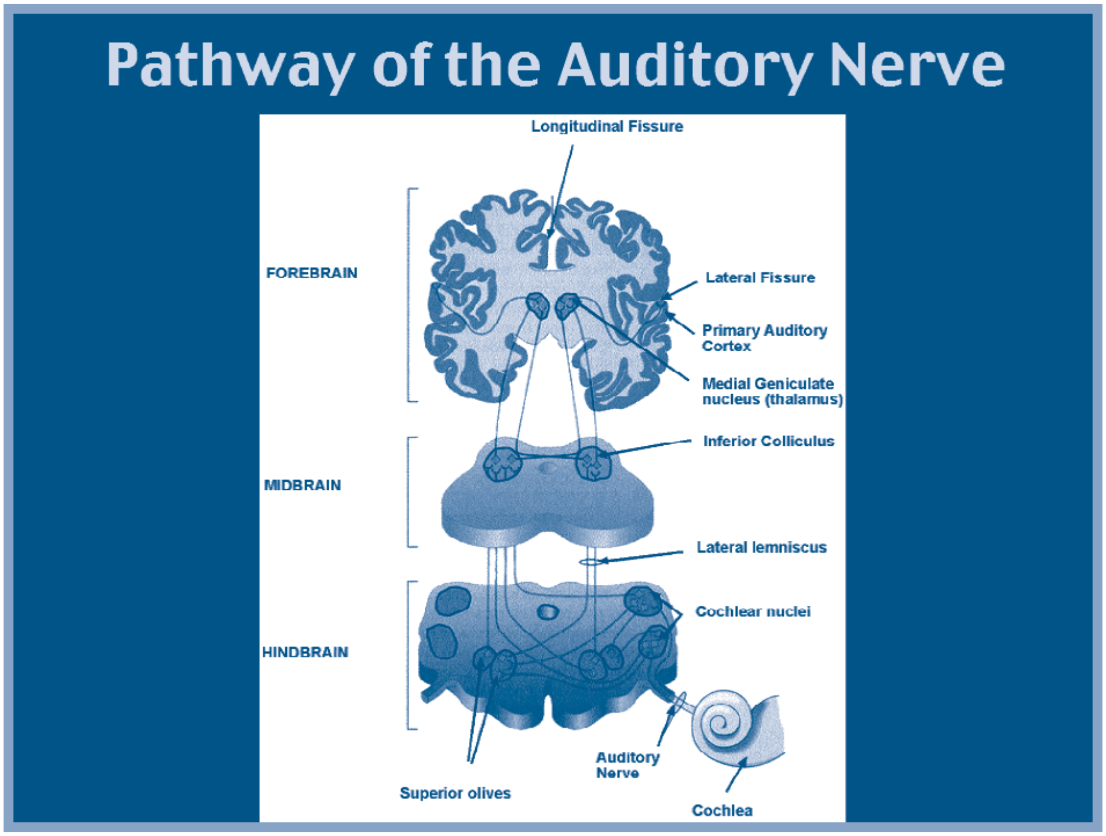
The inner ear is highly susceptible to injury and disease. Damage to the inner ear may result in temporary or permanent hearing loss. Common inner ear disorders are:

- Noise-induced hearing loss
- Ototoxicity
- Labyrinthitis
- Meniere's Disease
- Presbycusis
- Sudden idiopathic hearing loss
- Perilymph fistula
- Temporal bone fractures
- Viral infections
- Autoimmune disorders
- Vascular disease

Auditory Nerve

The **VIIIth cranial nerve** carries neural information from the sensory epithelium to the brainstem. The auditory nerve consists of two branches, the **auditory branch** and the **vestibular branch**. The two branches merge before entering the brainstem at the level of the cerebellopontine angle. The VIIIth cranial nerve also contains efferent neurons that pass information from higher auditory centers to peripheral sensory structures.

Auditory Pathways



After entering the brainstem at the level of the cochlear nuclei, auditory pathways follow a complex route through the brainstem, midbrain, and eventually to the auditory cortex.

Pathologies of the Central Auditory System

- Vestibular Schwannoma and neurofibromatosis (acoustic neuroma)
- Auditory neuropathy
- Neoplasms
- Multiple sclerosis and other demylenating disease
- Degenerative brain diseases
- Cerebrovascular disease
- Encephalitis
- Meningitis
- Cerebrovascular infarcts (stroke)
- Closed head injuries

Types of Hearing Loss

There are four types of hearing loss:

- conductive hearing loss
- sensorineural hearing loss
- mixed hearing loss
- central hearing loss

Conductive Hearing Loss (CHL)

Conductive hearing loss results from pathologies of the **external and middle ear**. This type of hearing loss typically results in a loss of sensitivity to **air-conducted sound**. Conductive hearing losses are usually correctable by medication or surgery. The audiologist performs tests to differentiate site of lesion.

Sensorineural Hearing Loss (SNHL)

- Sensory and sensorineural type hearing losses result from pathologies in the **inner ear** and higher auditory structures.
- These hearing losses are typically seen as decreased sensitivity to both air- and bone-conducted sound.
- Speech recognition may be affected, even when speech material is presented at audible levels.
- Patients with sensorineural hearing losses may complain of **difficulty hearing in noisy situations and sensitivity to loud sounds**.
- Some patients may experience an abnormal loudness perception called **recruitment.**
- **Sensorineural loss responds well to amplification (hearing aids) and, for the most severe cases, bioelectrical (cochlear) implants**.
- Sensorineural loss due to space-occupying lesions of the cerebellopontine angle is sometimes relieved by surgery, but more often the surgery results in complete loss of hearing in the affected ear. The audiologist performs tests to differentiate diseases of the inner ear from disease of more central structures (**retrocochlear disease**), but magnetic resonance imaging (MRI) is usually ordered when auditory nerve lesions are suspected.

Mixed Hearing Loss

Mixed hearing losses result from lesions that affect the outer or middle ear and the inner ear. The conductive component may be correctable.

Central Auditory Disorders

Pathologies in the central auditory system from brainstem to cortex may cause central auditory disorders.

- **These disorders typically cannot be detected with routine audiological tests**.
- Special auditory tests are used to determine site of lesion.

MEASURING HEARING LOSS AND REPORTING RESULTS

Audiogram

The audiogram is a plot of hearing threshold as a function of frequency. Hearing thresholds are measured in units called **decibels** (dB), named after Alexander Graham Bell, the famous American inventor. Frequency is measured in units called **Hertz** (Hz), named after Heinrich Hertz, a German physicist. The zero decibel (0 dB HL) line is the **threshold of hearing** for young, otologically normal listeners. The greater the number on the ordinate, the louder the sound must be before the patient hears the sound. The **audiogram** is a map of the hearing sensitivity of the patient. Hearing loss may affect speech recognition because speech sounds have characteristic frequency content.

Classification of Hearing Loss

[Adapted with permission from the American Academy of Audiology]

Mild hearing losses occur at 25-40 dB HL. This degree of hearing loss can affect audibility of soft sounds and speech sounds, especially in the presence of noise or competing sounds. **Moderate** hearing losses occur at 41-55 dB HL. This degree of loss may produce significant difficulty in most listening situations. **Moderately severe** losses occur at 56-70 dB HL. Patients with moderately severe hearing losses may have marked difficulty hearing in all listening situations. **Severe** losses occur at 71-90 dB HL. These losses make hearing and understanding almost impossible without amplification. **Profound** hearing losses occur above 90 dB HL. Patients with this degree of hearing loss hear only with the greatest difficulty and require amplification even in the best listening situations. Patients with any degree of hearing loss may benefit from amplification, but the severe and profound hearing losses may also benefit from cochlear implants. **Note that even mild hearing losses may cause some speech sounds to be inaudible.**

Effect of Hearing Loss

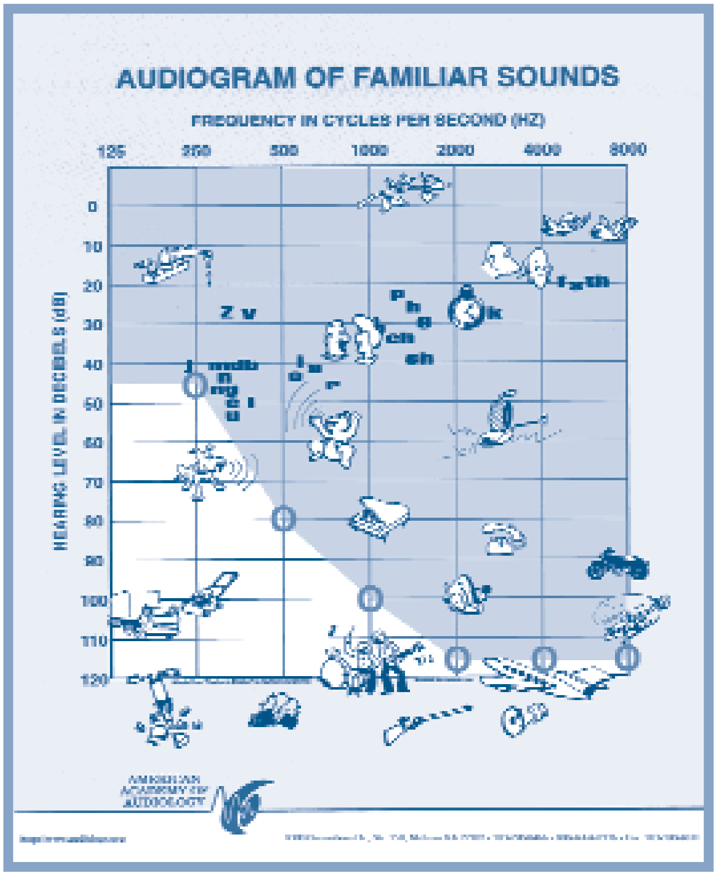
[Adapted with permission from the American Academy of Audiology]

High frequency hearing losses, which may result from noise exposure, limit the audibility of high frequency components of speech such as **consonants**. This patient might complain that he or she could not hear a watch tick, conversational speech in noisy situations, or telephone conversations. (The shaded area on the graph is inaudible to the patient.)

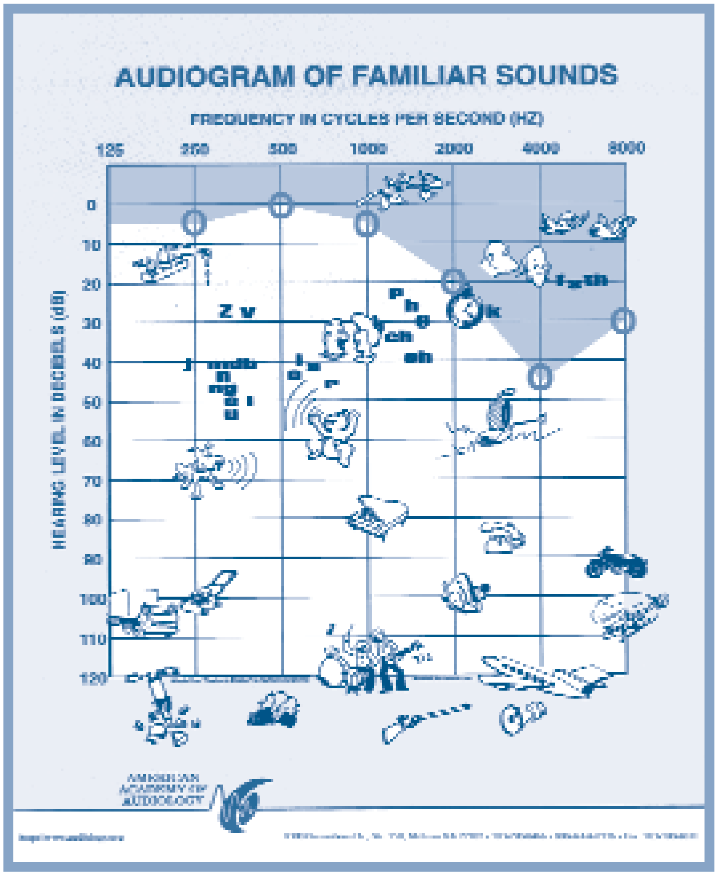
Symbols are used to indicate hearing thresholds. An “o” is used to indicate air conduction thresholds in the right ear. An “x” is used to indicate the air conduction thresholds in the left ear. Brackets (</>) are used to indicate bone conduction thresholds. Different symbols are used when masking is introduced. Masking is used to prevent the non-test ear from participating in the test. Symbols may be colored. Right ear responses are colored in red. Left ear responses are colored in blue.

[Adapted with permission from the American Academy of Audiology]

A more severe hearing loss, as in this example, renders most speech and environmental sounds inaudible. This patient would experience extreme difficulty hearing even in the best



listening situations.



[Adapted with permission from the American Academy of Audiology]

Even mild to moderate hearing losses, as in this example, may cause **significant communication problems** for the patient. Studies have shown that even very mild hearing losses may cause significant communication, family, social, occupational, and educational problems.

Quality Hearing Tests

Licensed or certified audiologists have the training and experience to perform hearing tests, differentiate pathology, and manage hearing impairment. Audiologists have a masters or doctoral degree in Audiology, must complete a clinical internship, and pass a national examination. Hearing tests must be performed in sound-treated rooms that control unwanted ambient sounds. Hearing tests require the use of highly specialized equipment.

Definitions

Air conduction — tests hearing sensitivity using earphones and evaluates the sensitivity of the entire auditory system.

Bone conduction — tests hearing sensitivity using bone vibration and evaluates the status of the inner ear and structures medial to the inner ear.

Crossover or cross hearing — the reception of sound by the non-test ear (via bone conduction). Usually occurs when the level in one ear is 40-70 dB above the threshold in the non-test ear for air conduction and 0 dB above the threshold in the non-test ear for bone conduction.

Threshold — the level at which a stimulus is just noticeable 50% of the time.

Masking — introduction of noise into the non-test ear to prevent crossover hearing. Usually applied during air conduction tests using circumaural earphones when the level in one ear is 40-70 dB above the bone conduction threshold in the non-test ear. Usually applied during bone conduction tests whenever there is a 10 dB or greater difference between the air conduction and bone conduction thresholds in the test ear.

Pure Tone Audiometry

Audiometric tests are used by audiologists to establish the type of hearing loss

Air conduction thresholds in right and left ear at 250, 500, 1,000, 2,000, 3,000, 4,000, 6,000, and 8,000 Hz

Bone conduction thresholds in right and left ear at 250, 500, 1,000, 2,000, 3,000, and 4,000 Hz

Speech Audiometry

Speech Reception Threshold (SRT) — threshold for spondaic words (two-syllable words with equal emphasis on both syllables, e.g. baseball, toothbrush)

Speech Recognition Test — percent of words presented at supra-threshold levels that are repeated correctly. Word lists are phonetically balanced for their occurrence in human speech.

Acoustic Immittance

Acoustic immittance tests are also known as **admittance**, **impedance**, or "**tympanometry**".

Static acoustic immittance — measurement of middle-ear mobility at a single pressure (usually best operating pressure)

Dynamic acoustic immittance — measurement of middle-ear mobility as air pressure is varied in the external canal. (Also known as tympanometry)

Immittance patterns are used to determine middle-ear pathology and middle ear pressure. Immittance can also be used to evaluate Eustachian tube function.

Acoustic reflex tests — change in immittance at the tympanic membrane caused by contraction of the stapedius muscle in response to sound. Test can also evaluate status of the auditory nerve (reflex decay).

Electrophysiological Tests

Auditory brainstem response (ABR) — measure of event-related EEG in response to sound. Evaluates pathways up to the level of the inferior colliculus.

Middle Latency Response (MLR) — measure of event-related EEG. Evaluates pathways from collicular to sub-cortical and perhaps cortical levels.

Late Response — measure of event-related EEG. Evaluates activity at the cortical level.

Otoacoustic emissions (OAE) — measure of energy generated by the cochlea. Objective test of outer hair cell function. These tests consist of spontaneous emissions (rarely done clinically), transient otoacoustic emissions (TOAE), and distortion product otoacoustic emissions (DPOAE).

LESSON 3 PREVENTIVE MEDICINE

Kyle C. Dennis, Ph.D. (Editor)

OBJECTIVES:

- Define the issues and trends related to hearing loss
- Identify recommended clinical interventions for hearing loss
- Identify the basic elements of hearing screening tools

TAKE HOME MESSAGE

Hearing loss is a significant public health problem. About 35 million Americans have hearing loss. Hearing loss results from outer and middle-ear pathologies, noise exposure, and aging. The primary care physician plays a critical role in identifying, screening, and making appropriate referrals for hearing loss, tinnitus, and balance disorders.

Supplemental Readings:

Vision and Hearing, Healthy People 2010, Department of Health and Human Services.

Screening for Hearing Impairment, National Library of Medicine, 2000.

Clinical Intervention for Hearing Impairment, National Library of Medicine, 2000.

Websites:

www.health.gov/healthypeople/document/html/volume2/28vision.htm

www.ahcpr.gov/clinic/cpsix.htm

Hearing Impairment

Hearing Loss as a Public Health Problem

The Department of Health and Human Services identified hearing loss as a significant public health problem in its **Healthy People 2010** initiative. Hearing is necessary for people to remain oriented to their environment. **More importantly, hearing is essential to understanding of spoken language**. Hearing is fundamental to quality of life. Prevention of hearing loss is a high priority for the nation as well as for the VA.

According to National Institutes of Health (NIH), more than 10 million persons in the United States **have permanent, irreversible hearing loss due to noise exposure**. More than 30 million Americans are exposed to **hazardous levels of noise** each day. Noise-induced hearing loss is the most common occupational disease and the second most self-reported occupational illness.

Americans are losing their hearing earlier in life, mainly due to noise exposure from occupational, military, and recreational causes. Men are more likely to suffer hearing loss because of **employment patterns, hazardous recreational activities**, and **military service**.

According to Healthy People 2010 projections, the work environment in the 21st century will require intense use of communication technologies and information skills. **Persons with hearing loss will be deeply disadvantaged in the workplace.** Hearing loss poses a significant barrier to accessing basic human services such as health care.

The incidence of **presbycusis**, changes in hearing related to aging, is expected to increase as people live longer.

Healthy People 2010 Objectives

Objective 28-11 Increase the proportion of newborns who are screened for hearing loss by age 1 month, have audiologic evaluation by age 3 months, and are enrolled in appropriate intervention services by 6 months.

Objective 28-12 Reduce otitis media in children and adolescents.

Objective 28-13 Increase access by persons who have hearing impairments to hearing rehabilitation services and adaptive devices, including hearing aids, cochlear implants, or tactile or other assistive or augmentative devices.

Objective 28-14	Increase the proportion of persons who have had a hearing examination on schedule. [In the adult population, both impairment and disability screening should occur every decade after age 18 years until age 50 years, with more frequent monitoring after age 50 years.]
Objective 28-15	Increase the number of persons who are referred by their primary care physician for hearing evaluation and treatment.
Objective 28-16	Increase the proportion of use of appropriate ear protection devices, equipment, and practices.
Objective 28-17	Reduce noise-induced hearing loss in children and adolescents aged 17 and under.
Objective 28-18	Reduce adult hearing loss in the noise-exposed public.

Source: *Vision and Hearing*, Healthy People 2010, Department of Health and Human Services

The Role of the Primary Care Physician

A study by the American Academy of Audiology indicated that 63% of persons with hearing loss considered their primary care physician as their most important source of information on hearing healthcare services.

Unfortunately, only 18% of primary care physicians routinely screen their patient's hearing and make appropriate referrals to hearing healthcare professionals.

Screening for Hearing and Balance Problems

1. This lesson includes screening forms and recommendations for screening in Primary Care in VA health care facilities. Primary Care physicians should meet with their Audiology counterparts to review screening needs and resources in each setting and to discuss the screening protocol best suited to a particular setting.

2. Screening should be conducted under the supervision of a licensed or certified audiologist. The screening itself may be done by audiologists, audiology or speech pathology trainees, health technicians, or other health care staff in the Primary Care clinic.

3. ***Justification for Screening***: The Healthy People 2010 initiatives of the U.S. Department of Health and Human Services recommends hearing tests every decade after age 18 until age 50 and more frequently after age 50. The U.S. Preventive Services Task Force recommends "screening older adults for hearing impairment by periodically questioning them about their hearing, counseling them about the availability of hearing aid devices, and making referrals for abnormalities when appropriate… The optimal frequency of such screening has not been determined and is left to clinical discretion. An otoscopic examination and audiometric testing should be performed on all persons with evidence of impaired hearing by patient inquiry."

4. Guidelines for Screening:

   a. Case History should address hearing loss, tinnitus, middle-ear problems and dizziness. Answers to these questions will direct the need for further screening in particular areas.

   b. Otoscopy should include inspection of the outer ear, ear canal, and eardrum for obvious abnormalities, such as, foreign bodies or cerumen, needing referral to a physician. Any abnormality constitutes an automatic "FAIL".

   c. Pure-tone Screening: Absence of a response in either ear at 40 dB HL (or 25 dB HL in a sound-treated room) at 1,000 or 2,000 Hz is a "FAIL". Unilateral failure is an automatic referral. Pure tone screening in combination with a hearing handicap scale such as the *Hearing Handicap Inventory for the Elderly, Screening Version* (Criteria derived from Ventry, I. and Weinstein, B., *Asha* 25:37-42, 1983 and validated by Lichtenstein, M., *et al.*, *Journal of American Academy of Audiology*, 1: 11-22, 1990). Screening at 4,000 Hz may substantially increase the referral rate and should only be used in combination with a handicap scale.

   d. Additional Tests: If there is a question of a possible conductive component, then tympanometry or tuning fork tests may be performed.

   e. Dizziness Screening: If dizziness of unknown origin is reported in the case history, then further questions regarding the dizziness may be warranted. The goal is to determine which patients need further evaluation of their symptoms by differentiating between those with orthostatic symptoms and those with possible vestibular and/or vestibulo-ocular etiologies. Only the latter would be referred for further evaluation.

   f. Tinnitus Screening: If tinnitus is noted, further tinnitus questions are warranted to determine the need for referral.

AUDIOLOGICAL SCREENING

History

1. Do you have any trouble hearing?	YES	NO
2. Do you hear better in one ear than the other?	YES**	NO
3. Have you ever used a hearing aid?	YES	NO
4. Do you have difficulty understanding on the telephone?	YES	NO
5. Have you had recent earaches or drainage?	YES***	NO
6. Do you experience dizziness?	YES*	NO
7. Do you have any ringing or other noises in your ears?	YES*	NO

***Ask additional questions on next page** ****Automatic referral to Audiology**

***** Automatic referral to ENT**

[Other YES answers warrant further screening (Pure tone and/or HHIE-S)]

Otoscopy/Visual Inspection: **Left ear:** PASS FAIL **Right ear:** PASS FAIL

Pure-tone Screening @ 40 dB HL: (Indicate Pass or Fail, and instrument used)

	1,000 Hz	2,000 Hz	(4,000 Hz)	Handheld screener/Audiometer
Right ear:	________	________	________	Unilateral Loss-**REFER**
Left ear:	________	________	________	Bilateral-**Administer HHIE-S**

[Passes 1,000 Hz and 2,000 Hz but complains of difficulty hearing — Administer HHIE-S]

Hearing Handicap Inventory for the Elderly—Screening Version:

HHIE-S Score ___________

REFER if score is 10-22 and FAIL pure tones

REFER if score is 22-40 and PASS pure tones

Additional Tests and Questions:

Tympanometry:	Left ear: PASS FAIL	Right ear: PASS FAIL
Weber:	Left ear	Right ear Midline
Rinne:	Left ear: Positive Negative	Right ear: Positive Negative
Tinnitus:	PASS FAIL	
Dizziness:	PASS FAIL	

Results:

Pass Hearing, Tinnitus, Dizziness Screening **No referral**

Fail Hearing Screening	**Refer:** Audiology	ENT	Other________________________
Fail Hearing Screening	**No Referral**	Comments: _________________________	
Fail Tinnitus Screening	**Refer:** Audiology	ENT	Other________________________
Fail Dizziness Screening	**Refer:** Audiology	ENT	Other________________________

Comments:

Name ____

SSN______________________ **Examiner** ________________________ **Date** _______________

HEARING HANDICAP INVENTORY FOR THE ELDERLY — SCREENING VERSION (HHIE-S)*

1. Does a hearing problem cause you to feel embarrassed when meeting new people?	YES	NO	SOMETIMES
2. Does a hearing problem cause you to feel frustrated when talking to members of your family?	YES	NO	SOMETIMES
3. Do you have difficulty hearing when someone speaks in a whisper?	YES	NO	SOMETIMES
4. Do you feel handicapped by a hearing problem?	YES	NO	SOMETIMES
5. Does a hearing problem cause you difficulty when visiting friends, relatives or neighbors?	YES	NO	SOMETIMES
6. Does a hearing problem cause you to attend religious services less often than you would like?	YES	NO	SOMETIMES
7. Does a hearing problem cause you to have arguments with family members?	YES	NO	SOMETIMES
8. Does a hearing problem cause you difficulty when listening to TV or a radio?	YES	NO	SOMETIMES
9. Do you feel that any difficulty with your hearing limits or hampers your personal or social life?	YES	NO	SOMETIMES
10. Does a hearing problem cause you difficulty when in a restaurant with relatives or friends?	YES	NO	SOMETIMES
	______ (x4)	______ (x0)	______ (x2)
Subtotal	______	______	______
HHIE Score	__________		

No Handicap (0-8) **Mild (10-22)** **Severe Handicap (24-40)**

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* *"Hearing Handicap Inventory for the Elderly — Screening Version" used with permission of the author, Dr. Barbara Weinstein.*

TINNITUS SCREENING

1.	Is the tinnitus in only one ear, or louder in one ear?	YES	NO
2.	Does the tinnitus keep you from sleeping?	YES	NO
3.	Does the tinnitus affect your ability to concentrate?	YES	NO
4.	Do you want to see someone for help with your tinnitus?	YES	NO

[“YES” to <u>any</u> of the above questions constitutes a “FAIL” and needs referral]

DIZZINESS SCREENING

1.	Is your dizziness brought on by movements or position changes ***<u>other than</u> standing up quickly or bending over***?	YES	NO
2.	Are you unsteady when standing or walking?	YES	NO
3.	Do you have difficulty walking in the dark?	YES	NO
4.	Do you have a history of migraine headaches?	YES	NO
5.	Do you avoid certain movements or activities because of your dizziness?	YES	NO
6.	Would you like to have your dizziness evaluated?	YES	NO

[“YES” to <u>any</u> of the above questions constitutes a “FAIL” and needs referral]

LESSON 4 PREVENTING OTOTOXIC HEARING LOSS

Kathleen C.M. Campbell, Ph.D.

OBJECTIVES:

- Identify ototoxic medications, chemotherapeutic agents, environmental toxins, and recreational drugs
- Identify potential risks associated with ototoxic medications and their inter-relationships
- Describe the physician's role in an effective ototoxicity prevention program

TAKE HOME MESSAGE

Hearing loss can be caused by a variety of medications, chemotherapeutic agents, and environmental toxins. **The primary care physician plays a critical role in the prevention of ototoxic hearing loss and monitoring medication use and environmental hazards in their patients**.

Ototoxicity

The term "ototoxic hearing loss" commonly refers to drug-induced and sometimes radiation-induced hearing loss. These drugs may be medications (e.g. chemotherapeutics, aminoglycoside antibiotics), industrial chemicals or metals, or recreational drugs.

Several classes of medications are known to frequently cause hearing loss in patients, but the benefits exceed the known risk of ototoxicity. Other medications rarely cause hearing loss, but the physician needs to recognize ototoxicity when it occurs.

Chemotherapeutics

- **The most ototoxic drug in common clinical use is cisplatin**. The degree of ototoxicity is related to the cumulative dose. For patients receiving relatively high dose long term cisplatin chemotherapy, as in stage IV ovarian cancer patients, approximately 50% of the survivors may have permanent, clinically significant, sensorineural hearing loss. For patients receiving only short term and/or low dose cisplatin chemotherapy (e.g. early stage testicular cancer), the risk is substantially less. The plasma level, the administration rate, and both the single and cumulative dosing levels can all influence the risk of ototoxicity. **The strongest correlation for cisplatin-induced hearing loss appears to be with the cumulative cisplatin dose.**

Although a clear dose response relationship between cisplatin dosing and ototoxicity exists, inter-subject variability is high. Some patients may experience a significant permanent threshold shift after a single dose, and other seemingly similar patients, may exhibit no hearing loss after several months of chemotherapy. During chemotherapy, some patients may have a gradual deterioration, while others may show a sudden, marked drop in sensitivity. Further, some patients may experience delayed hearing loss onset, or progression within a few months following chemotherapy cessation. **Once cisplatin-induced hearing loss occurs, it is almost always irreversible.**

Several factors may exacerbate the risk of cisplatin ototoxicity. Concomitant use of **other ototoxic drugs** including aminoglycoside antibiotics and loop diuretics, may not only additively, but also synergistically, increase the risk of ototoxicity. **Radiation** for head and neck cancer alone can cause permanent hearing loss, but greatly enhances the risk of ototoxicity in combination with cisplatin chemotherapy.

Concomitant **noise exposure** during, or in the months following, cisplatin exposure may increase the patient's risk of permanent hearing loss. **Patients should be advised against noise exposure during this time, including personal headsets for listening to loud music, lawn mowers, power tools, or any other noise exposure above conversational level.**

A **low serum albumin level** increases the risk of cisplatin ototoxicity, a particular problem if the patient has poor nutrition secondary to nausea and/or vomiting. As for noise-induced hearing loss, (NIHL), the patient's **oxidative status** may play a role. A wide variety of research currently focuses on the role of the oxidative pathways, including the glutathione pathway, in protecting hearing from drug-induced and noise-induced hearing loss. In a sense, NIHL may be considered a form of ototoxicity because of some similar mechanisms for damage.

Whether or not **pre-existent otologic problems and/or hearing loss** protect against or predispose to further ototoxic hearing loss is not resolved. The conclusions vary from study to study and may be sample specific. Similarly, the role of **pigmentation** in ototoxicity is not resolved. Some studies have suggested that blue-eyed individuals are more susceptible than brown-eyed individuals, but again more research will be needed.

As with most types of drug-induced hearing loss, **poor renal clearance** exacerbates the risk of cisplatin-induced ototoxicity by reducing renal clearance of the drug.

Tinnitus is also a common side effect, but because it is frequently only reported anecdotally, solid data regarding the severity and incidence are difficult to obtain. Tinnitus does appear to be highly variable and, unlike cisplatin-induced hearing loss, is frequently reported to be reversible when chemotherapy is discontinued.

- **Carboplatin is ototoxic, but generally less ototoxic than cisplatin**. Many of the early animal studies used equal dosing of cisplatin and carboplatin to compare ototoxicity and reported that carboplatin was not ototoxic. **However, for equivalent therapeutic efficacy, carboplatin is used in higher doses than cisplatin and ototoxic hearing loss can occur**. Nonetheless, for equivalent therapeutic efficacy, the risk of carboplatin ototoxicity is less than for cisplatin. **When carboplatin is used in conjunction with blood brain barrier disruption for brain cancers, however, the incidence of ototoxicity can be 80%.**
- Although the platinum-based chemotherapeutics carry the highest risk of ototoxicity, other chemotherapy agents can be ototoxic. **Vincristine and vinblastine sulfate** rarely cause hearing loss, but can occasionally cause sudden and severe hearing loss. Nitrogen mustard can also be ototoxic. When hearing loss occurs in those patients, the possibility of ototoxicity should be considered.

Aminoglycosides

- Aminoglycoside antibiotics have long been known to cause ototoxic hearing loss. The risk of permanent hearing loss can vary widely by the specific agent used. **Kanamycin**, now only rarely used, sometimes caused profound hearing loss in patients during the 1950s. **Neomycin** is generally limited to topical application because of its severe ototoxicity when administered systemically. Some physicians even recommend against neomycin eardrops in the presence of a perforated tympanic membrane, to avoid any possible transmission to the cochlea via the round window. **Gentamicin** can cause hearing loss, but more commonly causes vestibulotoxicity. **Tobramycin and amikacin** can cause permanent hearing loss, but the risk is lower than with kanamycin or systemic neomycin. **Netilmycin** carries a very low risk of ototoxicity, but appears to be rarely used clinically.
- Whether or not some glycopeptides, such as **vancomycin**, are ototoxic has been questioned. However, a clear relationship between glycopeptide administration and ototoxic hearing loss, in the absence of other ototoxins (e.g. aminoglycosides), has never been clearly established.

- **Aminoglycoside-induced hearing loss may be permanent or reversible. As with the platinum compounds, hearing loss may occur or progress for several months after discontinuation of aminoglycosides. Aminoglycosides may be retained in the cochlea for at least 6 months after treatment completion.**
- Several factors enhance the risk of aminoglycoside ototoxicity. **The longer the treatment, the higher the dose, the greater the risk of hearing loss.** Previous aminoglycoside use may also increase the risk of hearing loss, possibly due to prior subclinical cochlear damage. As with the platinum compounds, inter-subject variability for ototoxicity is high. Much of current research is focusing on the role of the oxidative pathways in susceptibility and eventual protection against aminoglycoside ototoxicity.
- The risk of permanent severe hearing loss is less for aminoglycosides than for platinum compounds. However, even with appropriate pharmacologic monitoring, **the incidence of aminoglycoside-induced ototoxic change has been reported as 30%.**
- **Concomitant use of loop diuretics** synergistically increases the risk of permanent severe hearing loss. Many animal models of deafness use simultaneous aminoglycoside and loop diuretic administration. **As with cisplatin, reduced renal clearance or noise exposure during or within 6 months after aminoglycoside administration increases the risk of ototoxicity.** Unlike cisplatin, geriatric patients rather than pediatric patients, appear to be more susceptible.

Loop diuretics

Loop diuretics can cause ototoxic hearing loss. In adults, the hearing loss is usually, but not always, reversible when the loop diuretics are discontinued. Delayed onset or progressive hearing loss is not characteristic for loop diuretics as it is for platinum compounds and aminoglycosides. Some evidence exists that neonates may be at higher risk of permanent hearing loss secondary to loop diuretics, but more research is needed.

- **Ethacrynic acid** is the most ototoxic loop diuretic, although uncommonly used in the United States. **Furosemide** is less ototoxic, but more commonly used. **Bumetanide** is a markedly more potent diuretic than furosemide, but not necessarily more ototoxic.
- **Loop diuretics can cause permanent severe hearing loss when administered in conjunction with platinum-based chemotherapeutics or aminoglycosides.** Although less information is available regarding noise exposure and loop diuretics, counseling these patients against noise exposure is probably advisable.

Salicylates

Salicylates, particularly **aspirin**, are widely used, but can be ototoxic. Generally aspirin causes only mild to moderate hearing loss, which is almost always reversible, usually within a few days. **Tinnitus is a more common side effect and can occur even in the absence of hearing loss.** Aspirin-induced hearing loss may be predominantly high frequency, as is typical for platinum compounds and aminoglycosides, or may be flat. The incidence of aspirin-induced hearing loss is low, approximately 11 per 1,000 patients, and usually occurs only at high dosing, either physician recommended or self-administered. Long-acting aspirin appears to increase the risk of ototoxicity. **Geriatric patients appear to be particularly susceptible.** Unlike platinum compounds and aminoglycosides, noise exposure does not appear to have a synergistic reaction with aspirin-induced ototoxicity.

Quinine

Quinine can be ototoxic, particularly in the dosing that was historically used for malaria. Typically, quinine-induced ototoxicity is predominant in the high frequencies. However, unlike platinum-induced and aminoglycoside-induced hearing loss, quinine-induced hearing loss may not become progressively worse at frequencies above 4,000 Hz, but may have a notch at 4,000 Hz. Thus, the audiometric configuration can be similar to noise-induced hearing loss (NIHL). Unlike NIHL, quinine-induced hearing loss is **frequently reversible**, particularly if therapy is discontinued before the mid-frequency range is affected. Tinnitus is common in conjunction with quinine-induced ototoxicity. **Vestibular effects** can occur even in the absence of other ototoxic changes.

Current clinical use of quinine in the United States is generally low dose, as for the **treatment of leg cramps**, and is rarely ototoxic. However, the physician may wish to be aware that anecdotal reports of reversible hearing loss with low dose therapeutic quinine administration exist and consider that possibility if hearing loss occurs in one of those patients. Even ingestion of **tonic water** can cause vestibular effects.

Industrial ototoxins

A variety of industrial chemicals are ototoxic. It is also quite possible that many ototoxic compounds have not yet been identified as such. While most ototoxic medications have predominantly peripheral effects of cochleotoxicity or vestibulotoxicity, many industrial chemicals have central effects. However, the ototoxic mechanisms of these agents have generally not been as well studied as the aforementioned ototoxic medications.

- **Trichloroethylene**, present in many spot removers, rug cleaners, degreasers, and used in paint, wax, pesticide, adhesive, and lubricant manufacturing, can cause hearing loss and balance disorders. Occasional, appropriate, consumer use of these products in a well-ventilated area, will rarely cause ototoxicity. However, chronically-exposed industrial workers are at higher risk.
- **Styrene and Xylene** can both cause hearing loss. Styrene is used in the production of synthetic rubbers, resins, plastics, and various insulating materials. Xylene is present in many paints, varnishes and thinners, and used in some laboratories. Their primary effect may be difficulty understanding speech in adverse listening conditions.
- **Hexane** is a neurotoxin. It is used as a solvent in a wide variety of industries such as shoe manufacturing. As a neurotoxin, it may cause some atypical auditory deficits such as difficulty hearing continuous tones. **Carbon disulfide** is also a neurotoxin, but may also cause more typical hearing loss and balance disorders.
- **Toluene** is present in motor vehicle emissions and some industrial emissions. It is also present in some home products. Thus, it is fairly ubiquitous. Industrial uses of toluene include manufacturing paints, lacquers, adhesives, rubber, various chemicals, leather tanning, and some printing. Toluene itself may cause hearing loss. More commonly, toluene appears to exacerbate the amount of hearing loss secondary to noise exposure. Therefore, toluene-exposed workers may need even more careful monitoring for noise exposure and greater hearing protection. Toluene may also adversely affect the central auditory pathway, causing difficulty processing and understanding speech.
- **Carbon monoxide** poisoning can cause hearing loss that is frequently, but not invariably, reversible. Some of the effects may be central, causing difficulty in sound processing.
- **Heavy metal exposure** can cause hearing loss, including central auditory involvement, as well as a host of other symptoms. Heavy metals affecting the auditory system include **mercury, arsenic, tin, manganese, and lead**. Outbreaks of heavy metal poisoning, including hearing disorders, have occurred, not only in industrial workers, but also in populations consuming contaminated fish, shellfish, or grain. Lead poisoning continues to be a problem in many populations.

Substance abuse

Substance abusers are a difficult group to study. They are frequently poor historians and difficult to prospectively monitor. A brief review of some considerations in this population is as follows:

- **Alcohol**: Chronic alcohol abuse can permanently damage the central auditory system. Fetal alcohol syndrome can include hearing loss.
- **Cocaine**: Cocaine can damage the central auditory system, particularly in fetuses.
- **Marijuana**: Although not well studied, marijuana has been reported to exacerbate **tinnitus** in some patients.
- **Nicotine and caffeine**: Although not well studied, caffeine and nicotine have been reported to exacerbate **tinnitus**. Nicotine has been reported to exacerbate **noise-induced hearing loss**.
- **Inhalants**: Inhalant abuse can involve a variety of ototoxins including **xylene**, **hexane**, **toluene**, and **butyl nitrate** (present in some air fresheners). The auditory effects are as described in the section on industrial chemicals.

Audiologic Monitoring for Ototoxicity

As previously described, a variety of agents are ototoxic. However, the most common agents prospectively monitored for ototoxicity are the **platinum-based chemotherapeutics and aminoglycoside antibiotics** because of their relatively high incidence of ototoxicity. For both platinum-based chemotherapeutics and aminoglycoside antibiotics, ototoxic hearing loss generally starts in the high frequencies, above the range required for speech understanding (10,000 to 20,000 Hz), and then progresses into the lower frequency ranges (250 to 8,000 Hz) which are critical for speech understanding.

Consequently, careful audiologic monitoring with sensitive test techniques can many times alert the physician to ototoxic changes before communicative function is impaired.

Even if the therapeutic regimen cannot be changed if ototoxicity develops, prospective audiologic monitoring allows the audiologist to assist the patient and family in maintaining communication if hearing loss develops. Maintaining communicative function during and after the major illnesses treated with these medications is an important **quality of life** issue.

Ototoxic hearing loss is generally symmetric, but asymmetry does not rule out an ototoxic etiology. Therefore, monitoring must consistently be performed for both ears.

Patient report is not an adequate method of monitoring for ototoxicity. Patients will generally not notice a change in the high frequencies above 8,000 Hz. Even when the frequencies of 3,000 to 8,000 Hz are affected, the patients may not report the change. Hearing loss in the 3,000 Hz and above regions will predominantly impair speech understanding in noise. Seriously ill patients may not be exposed to those difficult listening environments during their treatment. However, the ability to listen in background noise is critical for many of the social and work environments the patients will encounter after treatment. Even when the frequencies of 2,000 Hz and below are affected, many patients will not report a change to their physician, even when asked. **Patients frequently attribute their inability to understand a conversation to an inability to concentrate, malaise, stress, or even cognitive decline. Consequently, patients may hide their communication problem.**

Monitoring protocols

- **Baseline Assessment** — The baseline audiologic assessment is critical for ototoxicity monitoring. Because over 10% of the U.S. population is hearing impaired, without a baseline evaluation, subsequent hearing tests cannot determine if a change in hearing has occurred. All too often, the patient is referred only after a self-report of a change in hearing. However, without a baseline evaluation, possible ototoxic change cannot be determined. **The baseline evaluation also protects the physician from the patient blaming treatment for a hearing loss that was actually pre-existent.** Even if the patient will be receiving a relatively low risk ototoxic agent, a baseline audiologic assessment may be advisable. Then, if a change does occur, a reference will be available.

For an adult patient, the baseline evaluation for ototoxicity monitoring should include pure-tone air conduction testing in the conventional frequency range of 250 Hz - 8,000 Hz and high frequency audiometry for 10,000 Hz and above. Usually high frequency audiometry extends up to 16,000 or 20,000 Hz. For pediatric patients, other monitoring techniques may be used. For patients too ill to provide reliable behavioral responses, OAEs and/or auditory brainstem response (ABR) testing can be used. However, the techniques and interpretation of those tests for ototoxicity monitoring are not standardized.

If a hearing loss is present in the 250 to 4,000 Hz range, bone conduction testing should also be performed. Tympanometry, to assess middle ear function, is also recommended, particularly if a conductive component to the hearing loss is discovered. An unidentified fluctuant **conductive component** can confound interpretation of ototoxicity monitoring test results. Patients on aminoglycosides for systemic infections and immuno-suppressed chemotherapy patients may be particularly prone to **otitis media**.

Speech recognition testing should also be conducted at the baseline evaluation as a reference if a change in hearing occurs later during the monitoring period.

Counseling at the baseline evaluation should include telling the patient to avoid noise exposure during and for several months after ototoxic drug administration. The patient should also be advised to immediately notify the physician or audiologist if a change in hearing, balance, or tinnitus occurs.

While no standards for prospective tinnitus or vestibular ototoxicity monitoring exist, the patient should be aware that the onset of these symptoms **could be related to their medication and be advised to report them immediately.**

- **Monitoring assessments and interpretation** — Subsequent evaluations will generally only include pure-tone air-conduction thresholds in the conventional and high frequency ranges. If a significant change is noted, testing should be repeated within 24 hours to determine if the change replicates.

Significant change criteria have been established by the American Speech Language Hearing Association (1994). **These criteria are (a) ≥ 20 dB decrease at any one test frequency; (b) ≥ 10 dB at any two adjacent test frequencies; or (c) loss of response at any three consecutive test frequencies where responses were previously obtained.** The latter criterion specifically refers to the highest frequencies tested. Although these criteria were written for the conventional frequency range of 250 Hz- 8,000 Hz, they can also be applied to high frequency audiometry.

If a significant change is found and replicates within 24 hours, bone conduction thresholds and tympanometry should immediately be tested to determine if the change is sensorineural or conductive. If the change is conductive, it is not considered ototoxic, but the physician is notified. If the change is sensorineural, then speech recognition should also be tested to obtain more complete information on the impact of the hearing loss on communicative function.

Whenever a replicable significant sensorineural change is found, the patient's physician is immediately notified. At that point, the physician can discuss with the patient any possible **changes in medication** to reduce the chance of further ototoxic change. The physician should also discuss with the patient whether there has been **any noise exposure or use of any other medications, including over-the-counter medications, or substance abuse** that may have contributed to the change in hearing. If there are seemingly no other contributing factors and medications cannot be changed, **the patient should be counseled that further hearing loss may occur. Rehabilitation options including hearing aids and/or assistive listening devices should be discussed**.

- **Scheduling** — Appropriate patient scheduling is important for ototoxicity monitoring. As previously discussed, a baseline evaluation is critical for interpretation of later results. For aminoglycosides, patients are generally scheduled for monitoring once or twice per week, depending on the risk factors. For platinum-based chemotherapeutic agents, testing is generally conducted **just prior to each round** of chemotherapy. Because patients receiving aminoglycosides and/or platinum-based chemotherapy are frequently quite ill, and because monitoring requires careful listening by the patient, ototoxicity monitoring should be scheduled when the patient is **most alert**.

Environmental factors also play a role. While bedside testing can be performed, testing will be more accurate and comprehensive in the audiology clinic. Ambient noise and electrical noise outside of a sound-treated booth can adversely affect test results. Fluctuant noise levels can yield poor test reliability and replicability. Many times, if patients are too ill to be transported to the audiology clinic, they may be too ill to provide reliable responses. Again, while OAEs and ABRs can be used, their procedures are not standardized for monitoring.

For infectious disease patients, the physician must be aware that audiologic monitoring equipment is not disposable. Although disposable eartips can be used, the equipment itself cannot be autoclaved, or otherwise completely sterilized before or after the patient assessment.

If the patient is transported to the audiology clinic, any other monitoring or treatment devices should be as quiet as possible. If possible, those devices should be turned off during the evaluation.

Tips for Preventing Ototoxic Hearing Loss

- Counsel patients to **avoid any noise exposure** during and for several months after exposure to ototoxic drugs.
- Always obtain a **baseline audiologic assessment** before the patient begins ototoxic drug exposure.
- **Prospectively schedule the ototoxicity monitoring appointments as recommended.**
- Counsel patients regarding the importance of **attending all appointments** for ototoxicity monitoring.
- For patients with hearing aids, work with the audiologist to ensure that the **maximum power output of the hearing aid is carefully controlled** to avoid possible noise damage before and during chemotherapy.
- Advise patients to keep the physician informed of all **other medications** they use, including **over-the-counter medications**.
- **Advise patients to inform the physician and/or audiologist immediately of any changes in hearing, balance, or tinnitus.**
- **Advise patients to use chemicals, cleaners and solvents in well-ventilated areas only.**
- Advise industrial workers that some **industrial chemicals** may cause hearing loss and/or exacerbate NIHL. Therefore, they need to be careful about **avoiding exposure when possible** and to be conscientious about **wearing hearing protectors**.
- As appropriate, advise patients that some **recreational drugs** can cause or exacerbate hearing loss.
- If any patient experiences unexplained hearing loss, obtain a **complete history** of possible ototoxic drug exposure, including industrial chemicals and metals, prescribed and over-the-counter medications, and any recreational drugs.

The Future

- **<u>Test techniques</u>** — Many researchers, particularly those within the Department of Veterans Affairs, are working to develop new techniques for ototoxicity monitoring. These new techniques include: 1) methodologies for testing fewer frequencies in the conventional and high frequency ranges by selecting them for each patient's individual hearing thresholds, for quicker more efficient monitoring; 2) developing new test protocols and interpretation paradigms for various types of OAEs; and 3) developing new test protocols and interpretation paradigms for ABRs.
- **<u>Pharmacologic prevention of noise-induced and ototoxic hearing loss</u>** — Researchers are developing new pharmacologic agents that can prevent chemotherapy-induced, aminoglycoside-induced, and noise-induced hearing loss. For example, researchers have found in a variety of animal studies that **D-methionine**, an amino acid, can prevent all three types of hearing loss. Fortunately, studies suggest that it may not interfere with cisplatin's antitumor activity, or the antimicrobial action of aminoglycosides.

However, D-methionine is not the only protective agent. A number of other animal studies have also shown at least partial otoprotection for at least one type of these hearing losses with a variety of agents including: **lipoic acid, N-acetylcysteine, salicylates, sodium thiosulfate, glutathione, and glutathione ester**.

> Preventing noise-induced hearing loss and ototoxic hearing loss by administering a concomitant or prophylactic drug is an exciting and very real possibility.

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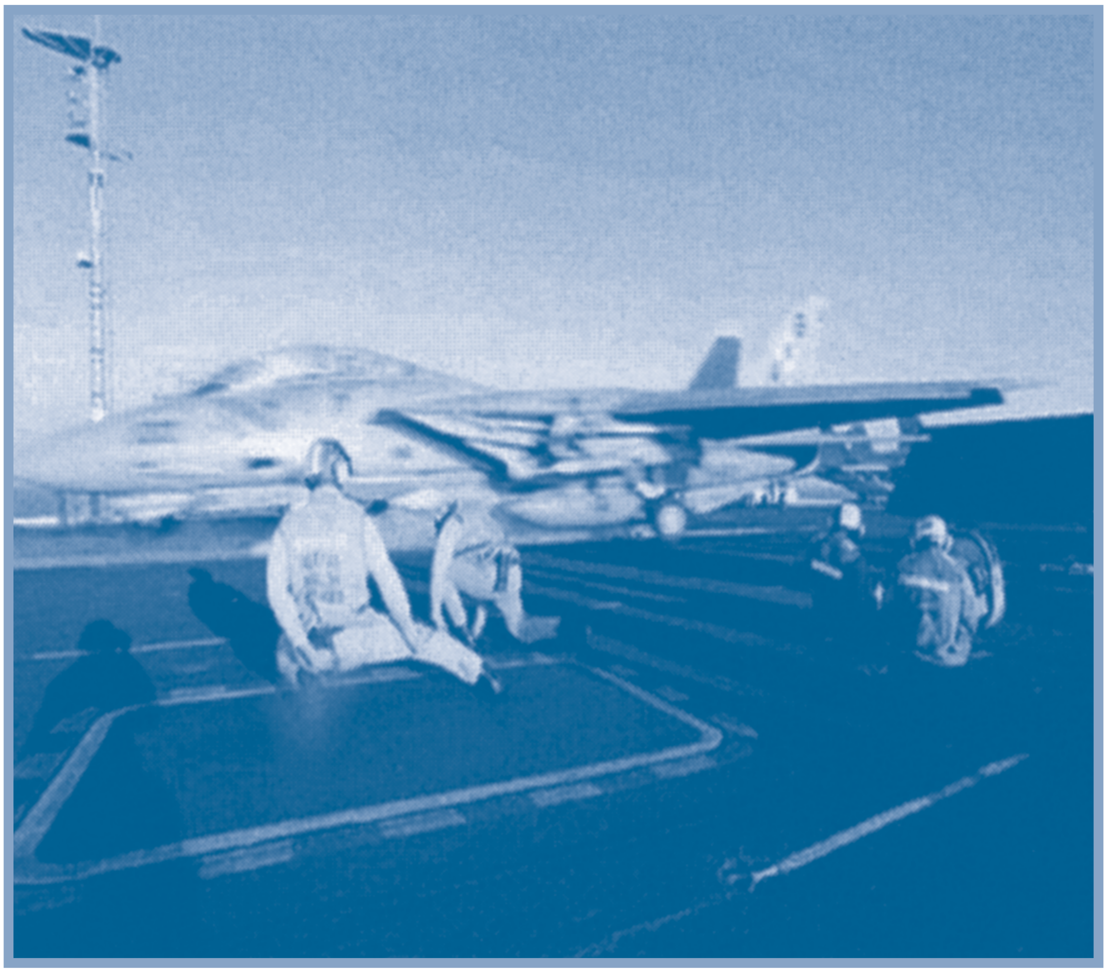
Noise-induced Hearing Loss



LESSON 5 PREVENTING NOISE-INDUCED HEARING LOSS

Kathleen C.M. Campbell, Ph.D., David W. Chandler, Ph.D., and Kyle C. Dennis, Ph.D.

OBJECTIVES:

- Identify potential risks of noise exposure
- Identify methods for preventing noise exposure
- Describe the physical, emotional, and quality of life effects of noise exposure in the military experience

TAKE HOME MESSAGE

Because of their unique military experience, veterans are at high risk for noise-induced hearing loss. Noise-induced hearing loss is the #1 occupational injury in the workplace, including the military. Noise-induced hearing loss is generally avoidable in occupational settings, but may be an unavoidable risk in combat situations. **The primary care physician plays a critical role in counseling patients to avoid noise exposure and assisting patients in effective treatment strategies for noise-induced hearing loss.**

Supplemental Readings in This Lesson:

Consensus Statement on Noise and Hearing Loss, National Institutes of Health, 1990. [Appendix A]

Noise-induced Hearing Loss, National Institute on Deafness and Other Communication Disorders, 1999. [Appendix A]

A Call for Hearing Protection in Rural America. NIH News Advisory, September 21, 2000. [Appendix A]

Exercise
Go to **www.cdc.gov/niosh**. Look at the listing of common workplace noises.

Websites:

www.cdc.gov/niosh/noise.html

www.nidcd.nih.gov/health/hb.htm

NOISE-INDUCED HEARING LOSS

Noise-induced hearing loss is by far the most common work-related injury and the second most common self-reported occupational illness. Noise-induced hearing loss is, in most cases, completely avoidable and preventable.

According to the National Institute on Deafness and Other Communication Disorders (NIDCD), more than 30 million Americans are exposed to hazardous levels of noise each day. **Noise exposure occurs in the workplace, in the military services, at home, and during hazardous recreational activities**. According to NIH, more than 10 million persons in the United States have permanent, irreversible hearing loss due to noise exposure. Industry studies indicate that 44% of carpenters and 48% of plumbers report hearing loss. Studies show that 90% of coal miners have hearing loss by age 52 years and 70% of sheet metal and non-metal miners have hearing loss by age 60 years. Nearly 50% of farmers report hearing loss by age 17 years.

Hearing loss threatens firefighters, police officers, military personnel, construction and factory workers, musicians, farmers, and truck drivers, to name a few. Recreational hazards include **shooting and hunting, vehicles, lawn care equipment, woodworking tools, household appliances, and chain saws**.

The cost of noise-induced hearing loss is enormous. Compensation for occupational hearing loss in private industry exceeds $242 million. This cost does not include the cost of hearing aids and other treatment services. Annual compensation payments for hearing loss to military veterans exceed $292 million (see Figure 1). In the past 20 years, the VA spent over $4.4 billion compensating veterans for service-related noise exposure. The Army saved $504 million over the past 20 years through its hearing conservation programs. The VA spent over $88 million on hearing aids and related services in FY01.

Cost of Hearing Loss for All Veterans 1977-1999

Total = $4,386,986,916

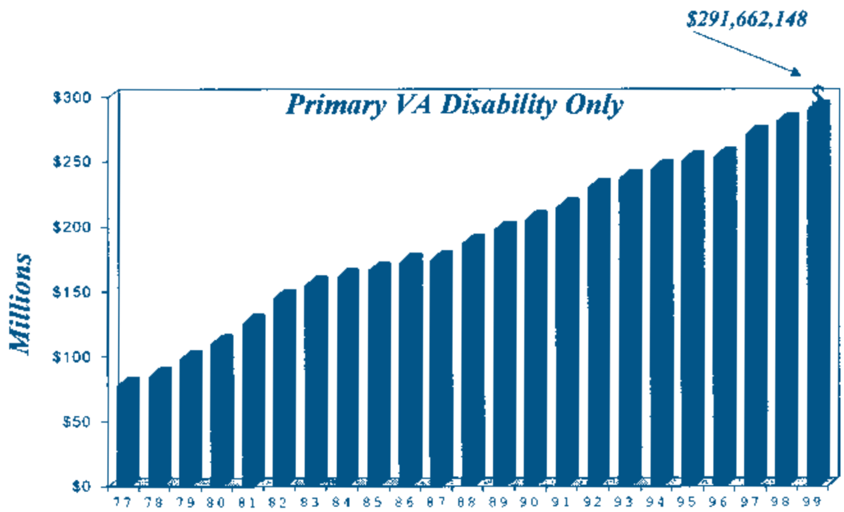


Figure 1

Noise-induced hearing loss has significant effects on daily life, especially in poor listening environments such as in crowds. **Noise causes loss of hearing sensitivity, loss of speech recognition, fatigue, stress, anxiety, and depression**. Noise-induced hearing loss may lead to loss of employment and disruption of family and social life. Tinnitus can be a significant and debilitating complication.

The Occupational Safety and Health Administration (OSHA) requires that hearing conservation measures be implemented when workers are exposed to hazardous levels of noise. Some sounds, such as impulse noise and gunshots, may **cause instantaneous and permanent hearing loss** even after a single unprotected exposure.

Both industry and military hearing conservation programs consider the overall exposure to noise during an eight-hour day. All hearing conservation programs in industry and government limit an unprotected eight-hour noise exposure, require monitoring of personnel at risk for noise exposure, and require the use of hearing protection devices when hazardous levels of noise are present. **Even with such protections in place, noise trauma occurs. In the military experience, use of hearing protection may not be feasible in combat or field situations.** It should also be noted that hearing conservation programs were not widely effective until after 1969 in industry and the 1980's for the military. Thus, significant numbers of veterans suffered noise-induced hearing loss.

Susceptibility

A number of factors can influence susceptibility to noise-induced hearing loss (NIHL), the primary cause of hearing loss in military populations. The primary risk factor, of course, is the noise exposure itself. Basically, the greater the duration and intensity level of noise, the greater the risk of permanent hearing loss. Risk is not related directly to the sound level that the individual personally finds objectionable. Individuals vary widely in their ability to psychologically tolerate noise.

> In counseling patients, a good rule of thumb is "If you have to raise your voice to carry on a conversation, not just get a few words across, you should be wearing hearing protection in work or recreational environments."

Subjects can vary widely in their susceptibility to NIHL. Clearly, not all the factors are fully understood. It is known that **smokers** are more susceptible to NIHL. In human and animal studies, a **high fat diet** in conjunction with noise exposure exacerbates NIHL. There is also a correlation between **cardiovascular disease and/or lipid disorders** and hearing loss. The individual's **oxidative state** may play a role.

Noise-induced hearing loss is frequently subcategorized as **Temporary Threshold Shift (TTS)** and **Permanent Threshold Shift (PTS)**. TTS is the hearing threshold shift that occurs after noise exposure, but reverses afterwards, usually within 16 hours. PTS is the non-reversible component. TTS is misleading to many patients because they believe that their hearing "always comes back". However, TTS gradually introduces permanent cochlear hair cell loss, rendering them more susceptible to PTS as the redundancy of the system is lost. **Eventually TTS leads to PTS**. PTS is associated with irreversible damage to hair cells, and loss of hair cells and neural attachments. Once lost, hair cells cannot regenerate. (Figures 2 & 3)

Normal Cochlea

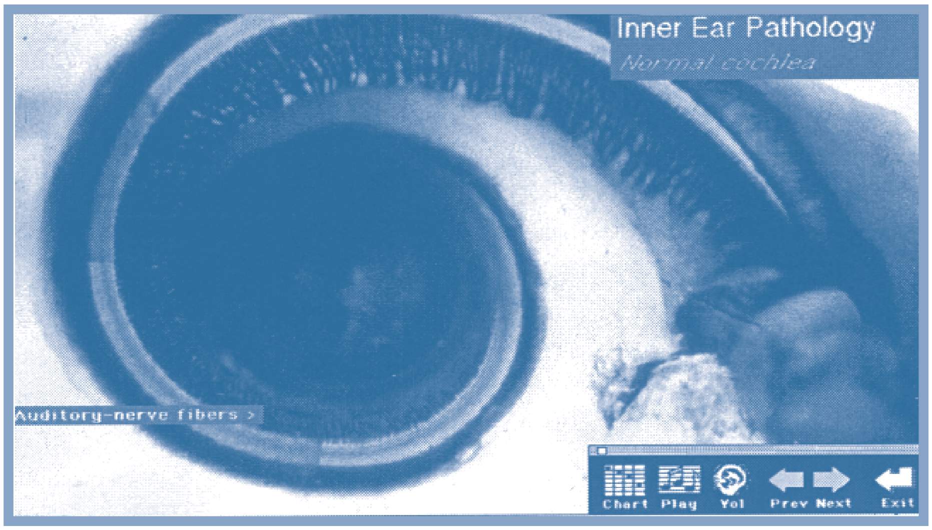


Figure 2

Noise-damaged Cochlea

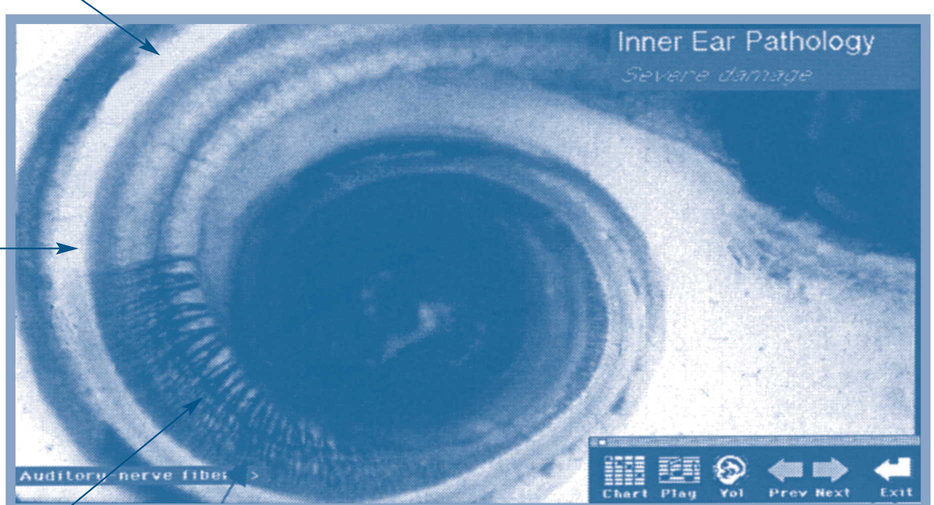


Figure 3

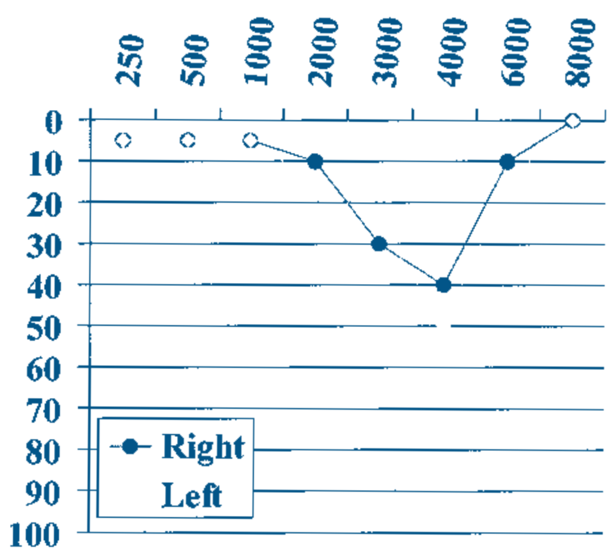
Noise-induced hearing loss is frequently associated with tinnitus.

A sensorineural dip in hearing sensitivity at around 4,000 Hz is frequently considered an "early warning sign" for noise-induced hearing loss. (Figure 4)

Clinical Findings

- Decreased hearing at 3,000-6,000 Hz
- As noise exposure increases, the notch deepens and widens
- Hearing loss is bilateral, sensorineural, seldom greater than 70 dB
- Difficulty understanding speech in noisy environments
- Tinnitus

Audiometric Configuration



Speech Recognition:
R: 92% at 50 dB
L: 88% at 50 dB

SRT: R: 10 dB
L: 5 dB

Figure 4

Audiologic testing for noise-exposed patients should include, not only octave band frequency thresholds, but also the half octaves of 3,000 Hz and 6,000 Hz to check for these early shifts. Some audiologists use otoacoustic emissions (OAEs), a non-invasive, but sensitive, measure of cochlear hair cell function, to monitor for early evidence of noise or music-induced damage. OAEs can frequently detect early damage even before any threshold shifts occur.

Curiously, several studies have demonstrated that individuals who like certain types of music at high levels may incur a slightly lesser degree of hearing loss. However, hearing loss has been estimated to occur in **approximately 70% of professional musicians**. Hunters or other shooters have a similar incidence of hearing loss, with the hearing loss usually being worse on the side opposite the hunter's dominant hand.

For individuals who are noise-exposed through their work, as in the military, and also have recreational noise exposure, the risk is, of course, increased. Formal studies correlating recreational noise exposure to hearing loss with or without exposure in the work place are, however, problematic. Recreational noise exposure is frequently poorly reported and monitored. **However, if patients have noise exposure at work, it is even more critical for them to consistently wear hearing protection during recreational exposure as well as in the work environment.**

Noise Exposure

Throughout the military, noise levels are monitored, and military personnel are counseled regarding appropriate hearing protection for their specific environment. However, each physician should be aware of Permissible Noise Exposure Levels (PELs) as defined by the Occupational Safety and Health Administration (OSHA). PELs are designed to protect hearing in the average worker from permanent hearing loss for 8 hours per day, 5 days per week, 50 weeks per year over 40 years. Individuals can vary widely in their susceptibility to noise-induced hearing loss; **therefore, these guidelines will not fully protect all workers.** These guidelines are also designed primarily for industrial environments where the noise exposure may be more steady state than in the military. However, these recommendations are based on the Time Weighted Average (TWA) of the noise. Recreational exposure is not included in these calculations.

OSHA Noise Standard: Permissible Exposure Level (PEL)

Duration per Work Shift (Hours)	Sound Level dBA*
32	80
16	85
8	90
4	95
2	100
1	105
0.5	110
0.25	115

(* dBA is a decibel reference largely used in industry that weights high frequencies more than low frequencies)

(Note that for every 5 dB noise decrement, the allowable exposure duration is doubled.)

Examples of Common Noise Levels:

Approximate Sound Level (dBA)

90	Battery-powered siren on toy ambulance, lawnmower
100	Blowdryer, snowmobile, chainsaw
110	Snowblower, automobile horn
120	Jackhammer, rock concert
130	Jet engine at 100 feet distance
140	Shotgun blast

(excerpted from Burtka and Yaremchuck (1997). For a more comprehensive listing refer to Dobie 1993)

Even a single exposure to high level impulse noise, like an explosion or firecracker, can cause permanent hearing loss. Although high level impulse noise may rupture the tympanic membrane and damage the middle ear, the permanent component is generally secondary to the cochlear damage. Although most TTS is secondary to cochlear damage, neurons of the VIIIth nerve can eventually deteriorate due to lack of stimulation.

Suggestions for Preventing or Reducing Hearing Loss in Noise-exposed Patients

- **Check fit of hearing protectors**. Even a pinhole leak can abrogate the protection. Individuals with glasses may need special fitting of earmuff style protectors. Some individuals will need custom fit earplugs for a good fit.
- **Ensure that patients are consistently using the hearing protectors recommended for their particular work environment.** If they are not, explore the reasons why. Some patients may need custom fit plugs or muffs to maintain comfort for a full day. Others may need a special acoustic fit for specific listening needs. For example, special hearing protectors are available that protect hearing, but preserve the fidelity of sound. These plugs are especially useful for musicians and music fans.
- **Counsel hearing aid patients that hearing protectors and hearing aids cannot be used simultaneously, and that a hearing aid, even when turned off, cannot substitute for hearing protection.**
- **Counsel hearing-impaired patients to obtain amplification in the relatively early stages of hearing loss**, before the VIIIth nerve fibers degenerate secondary to loss of cochlear stimulation. Patients should also obtain amplification while they can still easily recognize all speech sounds and before they forget how to ignore background noise.
- **Check noise-exposed patients for early warning signs of impending NIHL** through behavioral threshold measures and OAEs.
- Sometimes patients with NIHL feel that “the damage is already done” and ignore hearing protection. They need to be carefully counseled that the **hearing loss can still progress and hearing protection is essential for work and for recreational noise exposure.**
- **Counsel patients that a healthy lifestyle (e.g. healthy diet, cholesterol control, no smoking, exercise) may render them less susceptible to NIHL, but is not a substitute for noise avoidance or hearing protection.**

- **Many patients do not realize the impact that noise-induced hearing loss could eventually have on their lives.** It may be useful to let them listen to one of the many tapes available that simulate hearing loss. That experience will frequently change their minds about hearing protection.

Hearing Loss from Noise is:

- Permanent
- Progressive
- Painless
- Preventable

Figure 5

The important point is that noise-induced hearing loss is permanent, progressive, painless, and preventable.

The Future

- **Pharmacologic prevention of noise-induced hearing loss** — Researchers are developing new pharmacologic agents that can prevent chemotherapy-induced, aminoglycoside-induced, and noise-induced hearing loss. For example, researchers have found in a variety of animal studies that **D-methionine**, an amino acid, can prevent all three types of hearing loss.

However, D-methionine is not the only protective agent. A number of other animal studies have also shown at least partial otoprotection for at least one type of these hearing losses with a variety of agents including: **lipoic acid, N-acetylcysteine, salicylates, sodium thiosulfate, glutathione, and glutathione ester**.

Preventing noise-induced hearing loss by administering a concomitant or prophylactic drug is an exciting and very real possibility.

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A Call for Hearing Protection in Rural America. NIH News Advisory, September 21, 2000.

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LESSON 6 TREATMENT OF HEARING LOSS

Kyle C. Dennis, Ph.D. (Editor)

OBJECTIVES:

- Identify appropriate and effective treatment options for different types of hearing loss
- Define basic terminology, types, and applications of hearing aids
- Identify appropriate and effective use of alternatives to hearing aids such as assistive listening devices
- Define the appropriate use of specialized treatment options such as middle-ear implanted hearing aids, cochlear implants, and brainstem implants
- Identify the consequences of untreated hearing loss.

TAKE HOME MESSAGE

Hearing loss is treatable. No patient should ever be told that hearing loss cannot be treated, or that he or she must live with the condition. There is conclusive evidence that hearing aids are effective and that failure to provide appropriate and effective treatment of hearing loss can have neurological and psychological effects that might significantly diminish the patient's quality of life.

Supplemental Readings in This Lesson:

The Consequences of Untreated Hearing Loss in Older Persons, The National Council on the Aging, 1999 [Appendix B]

Website

www.ncoa.org

TREATMENT OF HEARING LOSS

About 95% of patients with hearing loss will not need medical or surgical management. Effective treatment strategies are available, however. **No patient should ever be told that hearing loss is not treatable**.

Available treatment options are:

- Amplification (hearing aids)
- Assistive listening devices
- Implantable devices (for some types of conductive hearing loss and severe to profound sensorineural hearing loss)
- Aural rehabilitation

Research studies have shown that failure to provide effective amplification for hearing loss can cause **sensory deprivation** in children and adults. Recent large-scale demographic studies have shown that users of hearing aids have significantly **better quality of life** than non-users. A large-scale clinical trial published by the National Institute on Deafness and Other Communication Disorders and the Department of Veterans Affairs in the October 11, 2000, issue of the *Journal of the American Medical Association* demonstrated conclusively that hearing aids are effective. Sadly, only 20% of patients who could benefit from hearing aids actually use them.

Guidelines for Referral

Certain medical conditions or symptoms warrant an appropriate referral to an otorhinolaryngology (ENT) specialist:

- History of active drainage from the ear(s) during the past 90 days
- History of sudden or rapidly progressive hearing loss
- Suspected hearing loss in one ear
- Tinnitus (head noise) in one ear
- Acute or chronic dizziness
- Pain or discomfort in the ear(s)
- Facial paralysis
- **Hearing loss appears to interfere with medical treatment or achievement of rehabilitative goals**

Behaviors Associated with Hearing Loss

Hearing loss should be suspected if you observe or the patient or patient's spouse complains of any of the following:

- The patient turns up the TV or radio.
- The patient asks frequently to have words repeated.
- The patient fails to respond to speech.
- The patient fails to respond to environmental sounds.
- The patient frequently asks others to speak louder.
- The patient complains that others mumble.
- The patient responds or behaves inappropriately.

- The patient favors one ear, leans forward, or cups the ear.
- The patient avoids conversational situations.
- The patient withdraws from social contact.
- The patient speaks too loudly or softly.

Strategies for Communicating with Persons with Hearing Loss

Persons with hearing loss may have significant limitations, especially in adverse listening situations. Visual cues are important. Shouting or raising the voice only complicates the problem. Consider keeping an assistive listening device such as a personal hardwire amplifier in your office.

Here are some other suggestions:

- Get the patient's attention first.
- Speak at close range (within 3 feet).
- Speak slowly and distinctly.
- Lower the pitch of your voice.
- Maintain good eye contact.
- Do not obscure your mouth or face.
- Use gestures and body language.
- Face the person and ensure that lighting is adequate.
- Don't stand in front of windows.
- If the patient has hearing aids or eyeglasses, make sure he/she uses them.
- Reduce or eliminate background noise.
- Avoid communication in large group settings.
- Ask what you can do to make communication easier.

- Avoid asking “yes” or “no” questions.
- Ask for repetition to insure understanding.
- If the patient does not understand, rephrase rather than repeat.
- Do not raise your voice.
- Use assistive listening devices.
- Use written instructions.

TREATMENT OPTIONS FOR HEARING LOSS

If a patient complains of hearing loss, difficulty understanding speech, balance problems, or tinnitus, the patient should be referred to **an audiologist** or **otolaryngologist**, as appropriate, in accordance with local policy.

When medical or surgical treatment options have been completed or ruled out (for example, in noise-induced hearing loss or presbycusis), the patient should be referred to an **audiologist** for management. A number of treatment options are available, depending on the nature and severity of loss, and the patient’s needs.

HEARING AIDS

Hearing aids have been widely available since the 1940’s. Over time, devices have become **smaller and more sophisticated** with advances in microcircuits, microphones, batteries, and advanced signal processing.

Some basic parts of a hearing aid:

- **Ear mold** — A custom-made plastic insert that connects the behind-the-ear, body worn, or eyeglass hearing aid to the ear.
- **Microphone** — The microphone picks up sound and sends a signal to an amplifier. Directional microphones may improve listening performance in noisy situations.

- **Amplifier circuit** — The amplifier circuit amplifies sound, but also performs sophisticated processing on the signal to protect the patient against loud sounds, to improve clarity, and to improve performance in noisy situations.
- **Receiver** — The receiver transforms the electrical signal in the hearing aid circuit back into audible sound.

In general, hearing aids fall into the following classes:

- **In-the-ear hearing aids** (ITE) — Custom-made devices that fit into the concha and ear canal. These devices include (in order of size from largest to smallest): full-shell, half-shell, canal, and mini-canal instruments. These devices are the most commonly used devices.
- **Completely-in-the-canal hearing aids** (CIC) — Custom-made devices that fit deeply into the ear canal within a few millimeters of the tympanic membrane.
- **Behind-the-ear hearing aids** (BTE) — These devices are off-the-shelf (stock) hearing aids used for patients whose hearing loss is too severe for ITE or CIC fittings, who prefer to wear a BTE instrument (e.g. dexterity reasons), or who for medical reasons cannot wear an in-the-ear type device. This device consists of an amplifier, microphone, and receiver worn behind the ear, and an ear mold that fits in the ear canal.
- **Body hearing aids** — Body aids are reserved for the most profound hearing losses. This device consists of a body worn amplifier, microphone, and a receiver button coupled to an ear mold and worn in the ear.
- **Eyeglass hearing aids** — Once a mainstay of the hearing aid industry, eyeglass fittings in which the hearing aid fits inside the eyeglass temples are now uncommon.
- **CROS/BICROS** — These hearing aids are specialized devices used to enhance localization for patients with complete loss of hearing on one side, or for patients with asymmetrical hearing losses. The contralateral routing of signal (CROS) device sends an amplified signal from the poor side to the better ear by wire or wireless means. The bi-directional contralateral routing of signal (BICROS) device amplifies the better ear and receives an amplified sound from the poor side. These circuits may be found in ITE hearing aids, hybrid hearing aids (one ITE and one BTE), BTE hearing aids, or in eyeglass fittings.
- **Bone conduction hearing aids** — These hearing aids use a vibrator on the mastoid process to send amplified sound to the inner ear via bone conduction. These devices are used when congenital pinna or ear canal defects or chronic middle-ear diseases prevent the use of conventional air conduction hearing aids.

- **Programmable hearing aids** — These hearing aids, technically known as digitally programmable analog hearing aids, can be programmed by computer to adjust hearing aid performance. Many of these hearing aids have multiple channels and memories. A multi-channel hearing aid divides the hearing range into two or more bands and allows the audiologist to adjust circuit settings in each channel. A multi-memory hearing aid allows the audiologist to program the instrument for different listening situations. The user controls the memory selection by a button or switch on the hearing aid, or by a remote control device.
- **Digital hearing aids** — True digital hearing aids convert sound into digital code, perform sophisticated mathematical processing, and convert the digital code back into audible sound. These devices have all of the multi-channel, multi-memory, and programming features of programmable analog devices, but offer more complex spectral and temporal signal processing algorithms to enhance speech signals, reduce background noise, and reduce feedback. These devices are the most advanced and expensive hearing aids available.

ASSISTIVE LISTENING DEVICES

Assistive listening devices (ALDs) are used in conjunction with, or as an alternative to personal hearing aid use. ALDs include a wide range of devices designed to facilitate communication under adverse listening conditions and to alert hearing-impaired patients to events that occur within their environment. Handheld hardwire devices can be used quite effectively in the primary care setting to enable the healthcare provider to communicate more effectively with the hearing-impaired patient.

Assistive listening devices are classified by function:

- **Amplifying devices** — Devices that transmit sounds directly from their source to the ear of the patient in an attempt to reduce the adverse effects of noise, reverberation and distance on the quality of the signal. They can be used for one-to-one communication, as well as wide-area amplification (e.g., theatres, places of worship, conference rooms). Examples include **personal hardwire**, **FM wireless**, **infrared** and **audio induction loop** devices and systems. Personal hearing aids equipped with a telecoil or direct audio input can be coupled directly to any of these amplifying ALDs.
- **Signaling/alerting devices** — Devices that use altered auditory, visual and/or vibrotactile signals to get the patient's attention. The devices can be used to alert the patient to the telephone ring, doorbell, smoke detector, alarm clock, baby cry, and turn signal indicator. The devices use flashing lights, vibrations and high-intensity sounds.

- **Telecommunications devices** — Devices that assist the patient in communicating over the telephone. These devices include handset, in-line and portable amplifiers; amplified telephones; speakerphones; visual display pagers; and **TTY's** (teletypewriters, also known as TDD's or TT's). The TTY enables the patient with a severe hearing and/or speech impairment to send and receive typewritten messages via the telephone.
- **Television devices** — Includes devices that directly transmit the signal from the television to the ear of the patient (such as hardwire and wireless devices and systems), and **closed caption decoders** that display the text of the television program on the screen while the program is in progress.

TAKE HOME MESSAGE

In the healthcare setting, it is the healthcare provider's responsibility to insure that their patients hear and understand them. Healthcare providers should have ready access to a handheld hardwire device for use as needed.

IMPLANTABLE HEARING AIDS

Implantable hearing aids are **surgically implanted amplification devices** used when conventional hearing aids cannot be worn because of congenital pinna defects or chronic middle-ear disease. The FDA has also approved implanted hearing aids for certain moderate to severe sensorineural type losses.

The **otolaryngologist** performs the medical and surgical evaluation of the patient, performs the surgery, and monitors the patient. The **audiologist** programs the device, trains the patient in its use, and monitors the patient.

Implantable hearing aids include **bone-anchored hearing aids (BAHA), middle-ear implanted hearing aids, and brainstem implants**. The latter group is restricted to patients with neurofibramatosis-Type 2 (NF-2) who suffer from bilateral vestibular schwannomas.

Bone-anchored hearing aids are attached to the mastoid bone using a titanium screw. After a period of osseo-integration, an amplifier assembly is attached to the screw. Amplified sound is transmitted to the inner ear via bone conduction.

The FDA recently approved **middle-ear implanted hearing aids**. These devices use an electromechanical driver to vibrate the ossicular chain (incus attachment). The driver is wired to an electromagnetic receiver implanted in a recess in the mastoid bone under the skin. The external transmitter assembly is coupled to the receiver by a magnet. When the device is not worn, there are no visible or protruding parts.

COCHLEAR IMPLANTS

A **cochlear implant** consists of a **receiver** implanted in a recess in the mastoid bone, an **external processor**, a **transmitter**, and an **electrode array** that is inserted into the cochlea. The electrode array sends coded electrical impulses directly into the auditory nerve fibers. The surgical process destroys the Organ of Corti. For this reason, cochlear implants are restricted to patients with the most severe hearing losses who do not benefit from conventional amplification.

FDA Criteria for Implantation:

- Severe to profound sensorineural hearing loss
- Post-lingually impaired
- Limited benefit from amplification (speech recognition on sentence test less than 30% in the aided condition)
- No medical or psychological contraindications

Recently, the FDA approved relaxed criteria that would make available implants to adults who have speech recognition of 50% in the aided condition on sentence tasks in the implant ear and as much as 60% in the non-implant ear. Implants are also available to children as young as 12 months.

LESSON 7 COMPENSATION AND PENSION

Caroll McBrine, M.D. and Kyle C. Dennis, Ph.D.

OBJECTIVES:

- Describe the primary care physician's role in the compensation and pension process
- Define how compensation and pension exams are performed

TAKE HOME MESSAGE:

Hearing loss is one of the most common service-related disabilities. Veterans are more likely to suffer hearing loss because of hazardous levels of noise in many military activities. Veterans are entitled to seek compensation for injuries caused or aggravated by military service. The primary care physician plays a key role in identifying possible service-related problems and counseling patients on the compensation process.

Because of their exposure to hazardous levels of noise during military service, veterans are very likely to suffer hearing loss. Combat veterans may suffer hearing loss because use of hearing protection is impossible. However, non-combat veterans may also suffer hearing loss. For example, veterans who served on aircraft carriers, in engine rooms, in artillery or mortar units, or even laundries or kitchen areas may suffer hearing loss.

Veterans who believe their hearing may have been damaged during military service may file a claim for disability with the local VA Regional Office. The VA Regional Office will assist the veteran in establishing a claim, gathering evidence to support the claim, and obtaining medical and other specialty exams. In some cases, the veteran or the VA Regional Office may request a medical opinion from a qualified physician or other expert. If a claim is denied, the veteran has extensive appellant rights.

A veteran who has been awarded a disability rating of any percentage is a ***service-connected (SC) veteran.*** A veteran without a service-connected disability is a ***non service-connected (NSC) veteran.***

While monetary compensation may be paid for service-related injuries, service connected status gives the veteran access to medical and other special services (such as hearing aids) that might not otherwise be available.

The primary care physician plays an important role in the claims process. You should always ask your patients about their military history. If the patient believes hearing loss occurred in service or you believe that the medical history points toward a possible service-related injury, you should determine if the patient has filed a claim for disability with the VA. If the veteran has never filed for disability, you should counsel the veteran to contact the nearest VA Regional Office, the Audiology Department at the medical center, a veterans' service organization,
the compensation or eligibility office, or the patient representative for assistance. Most VA medical centers have representatives from service organizations to assist veterans with compensation issues.

It is important to remember that most of your patients are more interested in access to health care services than monetary compensation. Because eligibility status often determines access to special services, the compensation process may be a necessary part of the care you need to provide your patients.

Eligibility Reform

As the veteran's primary care provider, you may be asked about eligibility for hearing aids. The primary care physician plays a critical role in identifying hearing impairment and referring patients for treatment services.

In 1996, Congress passed Public Law 104-262, the Veterans Health Care Eligibility Reform Act of 1996. This law significantly changed the rules that governed eligibility for prosthetic services. Congress required the VA to establish special rules for "sensori-neural devices" (eyeglasses and hearing aids). The rules for sensori-neural devices are contained in 38 CFR §17.149.

Under this rule, the VA will furnish hearing aids to veterans who receive VA health care services and who meet the eligibility criteria outlined below. A veteran will meet the health care provision of the law if they are enrolled for VA health care services and receive ongoing VA primary care medical services or other health care services.

Veterans will receive hearing aids if one or more of the following apply:

- they have a compensable service-connected disability or combination of disabilities. (Compensable means a disability rated at 10% or greater).
- they are former prisoners of war.
- they are receiving special benefits under 38 U.S.C. 1151 (tort claims).
- they receive increased pensions based on the need for aid and assistance or because they are permanently housebound.
- they have hearing impairment resulting from the existence of another medical condition for which the veteran is receiving VA care, or which results from the treatment of such condition (an example would be middle-ear disease or ear surgery).
- they have a significant functional or cognitive impairment evidenced by reduced activities of daily living, but not including normally occurring hearing impairment.
- they have a hearing impairment so severe that the provision of a hearing aid is necessary to permit active participation in their own medical treatment.
- they have a non-compensable service-connected disability (0%) for hearing loss and the hearing loss contributes to a loss of communication ability.

The Compensation Process — Evaluation of Hearing Impairment

You may be asked about disability ratings. The rules for rating ear and hearing disabilities are published in 38 CFR §§ 4.85, 4.86 and 4.87. The VA Regional Office provides this information to veterans.

Warning — VA ratings are determined only by qualified rating specialists. Healthcare providers should not use this information to rate conditions or counsel patients on disability compensation. Questions concerning compensation and pension issues should be addressed to the nearest VA Regional Office or Compensation and Pension (C&P) Office. Providers should exercise caution in discussing hearing loss in terms of percentage of impairment or handicap using American Academy of Otolaryngology (AAO) or American Medical Association (AMA) guidelines. VA disability ratings are described as percentages, but these percentages reflect disability of the whole person and are usually less than estimates of “hearing impairment” or “handicap” based on the AAO or AMA formulae.

(a) An examination for hearing impairment for VA purposes must be conducted by a **state-licensed audiologist** and must include a controlled speech discrimination test (Maryland CNC) and a pure tone audiometry test. Examinations will be conducted without the use of hearing aids.

(b) Table VI, “Numeric Designation of Hearing Impairment Based on Puretone Threshold Average and Speech Discrimination,” is used to determine a Roman numeral designation (I through XI) for hearing impairment based on a combination of the percent of speech discrimination (horizontal rows) and the pure tone threshold average (vertical columns). The Roman numeral designation is located at the point where the percentage of speech discrimination and pure tone threshold average intersect.

(c) Table VIa, “Numeric Designation of Hearing Impairment Based Only on Puretone Threshold Average,” is used to determine a Roman numeral designation (I through XI) for hearing impairment based only on the pure tone threshold average. Table VIa will be used when the examiner certifies that use of the speech discrimination test is not appropriate because of language difficulties, inconsistent speech discrimination scores, etc., or when indicated under the provisions of §4.86.

(d) “Puretone Threshold Average,” as used in Tables VI and VIa, is the sum of the pure tone thresholds at 1,000, 2,000, 3,000 and 4,000 Hertz, divided by four. This average is used in all cases (including those in §4.86) to determine the Roman numeral designation for hearing impairment from Table VI or VIa.

(e) Table VII, “Percentage Evaluations for Hearing Impairment,” is used to determine the percentage evaluation by combining the Roman numeral designations for hearing impairment of each ear. The horizontal rows represent the ear having the better hearing and the vertical columns the ear having the poorer hearing. The percentage evaluation is located at the point where the row and column intersect.

(f) If impaired hearing is service-connected in only one ear, in order to determine the percentage evaluation from Table VII, the non-service-connected ear will be assigned a Roman Numeral designation for hearing impairment of I, subject to the provisions of §3.383 of this chapter.

(g) When evaluating any claim for impaired hearing, refer to §3.350 of this chapter to determine whether the veteran may be entitled to special monthly compensation due either to deafness, or to deafness in combination with other specified disabilities.

(h) Numeric tables VI, VIa*, and VII.

[52 FR 44119, Nov. 18, 1987, as amended at 64 FR 25206, May 11, 1999]

TABLE VI
NUMERIC DESIGNATION OF HEARING IMPAIRMENT BASED ON PURETONE THRESHOLD AVERAGE AND SPEECH DISCRIMINATION

% of discrim-ination	Puretone Threshold Average								
	0-41	42-49	50-57	58-65	66-73	74-81	82-89	90-97	98+
92-100	I	I	I	II	II	II	III	III	IV
84-90	II	II	II	III	III	III	IV	IV	IV
76-82	III	III	IV	IV	IV	V	V	V	V
68-74	IV	IV	V	V	VI	VI	VII	VII	VII
60-66	V	V	VI	VI	VII	VII	VIII	VIII	VIII
52-58	VI	VI	VII	VII	VIII	VIII	VIII	VIII	IX
44-50	VII	VII	VIII	VIII	VIII	IX	IX	IX	X
36-42	VIII	VIII	VIII	IX	IX	IX	X	X	X
0-34	IX	X	XI	XI	XI	XI	XI	XI	XI

TABLE VIa*
NUMERIC DESIGNATION OF HEARING IMPAIRMENT BASED ONLY ON PURETONE THRESHOLD AVERAGE

Puretone Threshold Average

0-41	42-48	49-55	56-62	63-69	70-76	77-83	84-90	91-97	98-104	105+
I	II	III	IV	V	VI	VII	VIII	IX	X	XI

*This table is for use only as specified in §§4.85 and 4.86.

TABLE VII
PERCENTAGE EVALUATION FOR HEARING IMPAIRMENT
(DIAGNOSTIC CODE 6100)

Poorer Ear

XI	100*										
X	90	80									
IX	80	70	60								
VIII	70	60	50	50							
VII	60	60	50	40	40						
VI	50	50	40	40	30	30					
V	40	40	40	30	30	20	20				
IV	30	30	30	20	20	20	10	10			
III	20	20	20	20	20	10	10	10	0		
II	10	10	10	10	10	10	10	0	0	0	
I	10	10	0	0	0	0	0	0	0	0	0
	XI	X	IX	VIII	VII	VI	V	IV	III	II	I

***Review for entitlement to special monthly compensation under §3.350 of this chapter.**

[41 FR 11298, Mar. 18, 1976, as amended at 52 FR 44119, Nov. 18, 1987; 64 FR 25208, May 11, 1999]

Exceptional Patterns of Hearing Impairment

(a) When the pure tone threshold at each of the four specified frequencies (1,000, 2,000, 3,000, and 4,000 Hertz) is 55 decibels or more, the rating specialist will determine the Roman numeral designation for hearing impairment from either Table VI or Table VIa, whichever results in the higher numeral. Each ear will be evaluated separately.

(b) When the pure tone threshold is 30 decibels or less at 1,000 Hertz, and 70 decibels or more at 2,000 Hertz, the rating specialist will determine the Roman numeral designation for hearing impairment from either Table VI or Table VIa, whichever results in the higher numeral. That numeral will then be elevated to the next higher Roman numeral. Each ear will be evaluated separately. (Authority: 38 U.S.C. 1155)

[29 FR 6718, May 22, 1964, as amended at 64 FR 25209, May 11, 1999]

Schedule of Ratings for Ear Conditions (38 CFR §4.87)

Diseases of the Ear

Rating

6200 Chronic suppurative otitis media, mastoiditis, or cholesteatoma (or any combination):

During suppuration, or with aural polyps 10%

Note: Evaluate hearing impairment, and complications such as labyrinthitis, tinnitus, facial nerve paralysis, or bone loss of skull, separately.

6201 Chronic nonsuppurative otitis media with effusion (serous otitis media):

Rate hearing impairment

6202 Otosclerosis:

Rate hearing impairment

6204 Peripheral vestibular disorders:

Dizziness and occasional staggering 30%

Occasional dizziness 10%

Note: Objective findings supporting the diagnosis of vestibular dysequilibrium are required before a compensable evaluation can be assigned under this code. Hearing impairment or suppuration shall be separately rated and combined.

6205 Meniere's syndrome (endolymphatic hydrops):

Hearing impairment with attacks of vertigo and cerebellar gait occurring more than once weekly, with or without tinnitus 100%

Hearing impairment with attacks of vertigo and cerebellar gait occurring from one to four times a month, with or without tinnitus 60%

Hearing impairment with vertigo less than once a month, with or without tinnitus 30%

Note: Evaluate Meniere's syndrome either under these criteria or by separately evaluating vertigo (as a peripheral vestibular disorder), hearing impairment, and tinnitus, whichever method results in a higher overall evaluation. But, do not combine an evaluation for hearing impairment, tinnitus, or vertigo with an evaluation under diagnostic code 6205.

6207 Loss of auricle:

Complete loss of both 50%

Complete loss of one 30%

Deformity of one, with loss of one-third or more of the substance 10%

6208 Malignant neoplasm of the ear (other than skin only) 100%

Note: A rating of 100 percent shall continue beyond the cessation of any surgical radiation treatment, antineoplastic chemotherapy or other therapeutic procedure. Six months after discontinuance of such treatment, the appropriate disability rating shall be determined by mandatory VA examination. Any change in evaluation based on that or any subsequent examination shall be subject to the provisions of §3.105(e) of this chapter. If there has been no local recurrence or metastasis, rate on residuals.

6209 Benign neoplasms of the ear (other than skin only):

Rate on impairment of function.

6210 Chronic otitis externa:

Swelling, dry and scaly or serous discharge, and itching requiring frequent and prolonged treatment 10%

6211 Tympanic membrane, perforation of 0%

6260 Tinnitus, recurrent 10%

Note: A separate evaluation for tinnitus may be combined with an evaluation under diagnostic codes 6100, 6200, 6204, or other diagnostic code, except when tinnitus supports an evaluation under one of those diagnostic codes. (Authority: 38 U.S.C. 1155)

[29 FR 6718, May 22, 1964, as amended at 64 FR 25209, May 11, 1999]

Descriptions of Disability Examinations

Primary care physicians may be called upon to write a medical opinion or counsel a patient on compensation exams. If you are unsure about an exam, contact your local compensation office.

What may be needed in an examination of the auricle, external canal, tympanic membrane, and mastoids?

- **Auricle**. Note deformities, cicatrices, ulcerations, or other dermatologic and cartilaginous abnormalities.
- **External Canal.** Note any abnormality in size or shape of canal. Note edema, erythema, or ulceration of the skin lining. If lumen obstructed, note whether the cause is cerumen, foreign body, or exudate. Record whether any exudate is serous, purulent, sanguinous, mucoid, odorous, profuse, scanty, or pulsating. If the external canal has a small diameter, a small speculum and adequate cleansing with a small cotton-tipped applicator or a suction tip may be necessary for adequate evaluation.
- **Tympanic Membrane**. Remove all exudate and debris from the canal for a satisfactory examination. The entire drum membrane should be visualized. Report any abnormality in the landmarks indicating scarring, retraction, bulging, or inflammation. Use a Siegel speculum to determine membrane mobility. Note and describe any perforations and their size and position (whether marginal or central).

- **The Tympanum.** With a perforation of the drum membrane, the status of the middle ear can often be ascertained. Particularly, reference should be made to hyperplastic tympanic mucosa, granulation tissue, cholesteatoma, and ossicle necrosis. With a cooperative patient and the gentle use of a silver probe or an attic hook, one may specifically diagnose an attic perforation. A detailed examination should allow evaluation of an infectious process in the middle ear; the type of treatment (medical or surgical) required; and often the prognosis re hearing.

- **The Mastoid**. Information regarding the condition of the mastoid can often be determined during the examination of the middle ear. Adjuvant procedures are helpful and on occasion may be specifically diagnostic.
  - Mastoid tenderness. This sign is elicited during acute disease by firm palpation over the mastoid process. Local erythema, induration, and a fluctuant mass may be present.
  - Mastoid X-rays. Correlate X-ray abnormalities with clinical findings. Polytomography may reveal cellular or cortical erosion not visible with conventional techniques.

What are the essentials of an audiological examination?

- **What is the significance of a hearing impairment?** The significance depends upon the type and degree of hearing loss. The participation restriction (handicap) a person experiences in everyday life is related both to loss of hearing sensitivity and loss of speech discrimination.

- **What are the methods of measuring hearing loss?** Although the more desirable methods of measuring hearing loss involve **quantitative** procedures such as calibrated audiometry, there may be instances where **qualitative** tests (such as whispered voice tests and tuning fork tests) have been used in classifying hearing loss. However, qualitative procedures do not substitute for calibrated audiometry as measures of hearing impairment or disability.

  Whispered or spoken voice tests were used extensively before calibrated audiometry was widely available in the military (before 1970). These tests involve a gross assessment of hearing impairment using spoken or whispered words without visual cues. These tests are inherently insensitive to high frequency hearing loss, the type of hearing loss most commonly caused by noise exposure.

  The most commonly used **tuning fork tests** are the Weber Test, the Rinne Test, and the Bing Test.

- **Weber Test.** The Weber Test involves the placement of a tuning fork on the forehead. The patient is asked to indicate where the tone is heard. If the tone is heard in the middle of the head, then one may infer that the patient has normal hearing, equal sensorineural loss in both ears, or equal conductive components in both ears. If the tone lateralizes to either ear, then one may infer that there is a conductive component or lesser sensorineural hearing loss in the lateralized ear.
- **Rinne Test.** The Rinne Test complements the Weber Test. The Rinne Test involves the presentation of tones by air conduction and bone conduction. For air conduction, the examiner presents a tone near the ear canal. For bone conduction, the tuning fork is moved to the mastoid process. The patient is asked to indicate if the tone is louder by air conduction or bone conduction. If the patient hears the tone louder by air conduction, the ear has a sensorineural hearing loss (a positive Rinne). If the patient hears the tone louder by bone conduction, the patient has a conductive component (a negative Rinne).
- **Bing Test.** The Bing Test is also used to differentiate conductive hearing loss. The test involves the presentation of a tone via bone conduction (Weber Test). The ear is occluded by plugging the ear with a fingertip. The patient is asked if the tone changes in loudness or lateralizes. If the tone increases in loudness or lateralizes to the occluded ear, the Bing Test is positive and indicates normal hearing or a sensorineural hearing loss. If the patient reports no change in loudness or the tone does not lateralize to the occluded ear, the patient has a conductive component (negative Bing).

Because of uncertainty as to which ear is responding to a test, tuning fork tests are difficult to interpret unless effective masking is used in the non-test ear.

How are audiometric tests conducted?

Audiometric examinations are quantitative and indicate the magnitude of the hearing impairment. The examination must be conducted without the use of hearing aids. Both ears must be examined for hearing impairment even if hearing loss in only one ear is at issue.

1. **Calibration**. Audiometers utilized in basic audiological procedures are calibrated to the American National Standards Institute *Specifications for Audiometers* (ANSI S3.6-1989). The ANSI standard was adopted by the VA in July 1975. Prior to that time, the American Standards Association specifications (ASA 224.5-1951) were used. When reviewing audiometric results, it is important to note the date of the examination. Audiometric test results based on the ASA standards will show better hearing sensitivity than tests results based on the ANSI standard.

2. **Approved rooms**. Tests must be conducted in approved sound-treated rooms that meet the American National Standards Institute *Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms* (ANSI S3.1-1991).
3. **Presentation of stimuli**. Most basic tests involve the presentation of pure tones or recorded speech material through circumaural or insert earphones. Bone conduction involves the presentation of stimuli through a bone vibrator located on the mastoid process or the forehead.
4. **Examiner requirement.** An examination of hearing impairment must be conducted by a state-licensed audiologist (38 CFR §4.85).
5. **Basic testing**. The basic evaluation includes a controlled speech recognition test using an approved recording of the Maryland CNC Test and pure tone audiometry.
6. **Air and bone conduction test frequencies.** Air conduction audiometry must include the following frequencies: 250, 500, 1,000, 2,000, 3,000, 4,000, 6,000, and 8,000 Hz. Bone conduction audiometry must include the following frequencies: 250, 500, 1,000, 2,000, 3,000, and 4,000 Hz.
7. **Other tests for assessment.** In addition, the basic audiometric assessment includes speech reception thresholds (SRT), tympanometry, and acoustic reflex tests.
8. **Tests for non-organicity.** When necessary, tests for non-organicity (such as the Stenger Test) and otoacoustic emissions (OAE) are obtained. Other more advanced tests such as auditory evoked potentials may be indicated.
9. **Details of testing**. Bone conduction tests are obtained when the air conduction thresholds are poorer than 15 dB HL. A modified Hughson-Westlake procedure is used to obtain thresholds. Appropriate masking is used. Stenger Tests are administered whenever pure tone air conduction thresholds at 500, 1,000, 2,000, 3,000, or 4,000 Hz differ by 20 dB HL or more between ears.
10. **Speech reception threshold.** The speech reception threshold (SRT) is defined as the level (in dB HL) at which the patient correctly identifies 50% of a set of two-syllable (spondee) words. The SRT should be in agreement with the average of pure tone thresholds from 500 to 2,000 Hz.
11. **Speech recognition tests**. Speech recognition tests involve the presentation of approved monosyllabic words. Speech recognition must be obtained with a VA-approved recording of the Maryland CNC Test. The audiologist presents word lists at increasing intensity levels until no further change in the speech recognition score occurs. However, presentation levels will not exceed the patient's level of discomfort or 105 dB HL, whichever is lower. This procedure is known as a Performance-Intensity function. The maximum speech recognition score for a 50-word list is reported.

12. Other tests. In addition to the basic audiometric test battery, other electrophysiological or behavioral tests may be reported to determine the degree of hearing loss or the site of lesion.

- Immittance testing (tympanometry) is a procedure that assesses middle-ear function by measuring the mobility of the tympanic membrane and middle-ear structures. Immittance equipment measures the flow of energy through the middle-ear in response to a tone introduced through a probe in the external auditory canal. A microphone in the probe records the amount of sound energy reflected from the tympanic membrane. Middle-ear pressure can be estimated by measuring the response to applied pressure variations. The results are compared to normal values and assist in differential diagnosis of middle ear disorders.
- Acoustic reflex tests involve the presentation of a loud tone intended to elicit a contraction of the stapedius muscle in the middle ear. The acoustic reflex test provides objective information on the status of the middle ear as well as the integrity of the auditory nerve.
- Otoacoustic emissions (OAEs) are another frequently used electrophysiological measure. Otoacoustic emissions are propagated from normal cochleae by outer hair cells and are measured in the ear canal by use of a tiny microphone probe placed in the ear canal. Transient OAEs are evoked by presenting a series of clicks to the ear and recording the amplitude and time and frequency spectra of the emission response. Distortion product OAEs involve the presentation of two tones and recording the amplitude and time and frequency spectra of distortion products created in the cochlea. OAEs are not usually observed in ears with hearing losses greater than 30 dB HL or with conductive involvement.
- Most other auditory tests contribute additional information about site of lesion. These tests are most effective when viewed as a battery of diagnostic tests. The selection of the appropriate audiometric tests or test batteries that should be incorporated in the assessment of the veteran's hearing impairment is predicated upon the results obtained from the basic audiometric assessment. The audiologist is best qualified to determine which tests are appropriate and to interpret such tests.

How are audiometric test results reported?

- **VA Forms 10-2364 or 10-2364a** may be used to report the majority of audiometric tests conducted within the VA. VBA Worksheet 1305 (AUDIO), or its electronic equivalent, is used to record audiometric thresholds and rating narratives.
- **History.** Under the Medical History section of Worksheet 1305, the audiologist reports the patient's chief complaint, the situations of greatest difficulty, pertinent medical, family, social, and military history, and history of military, occupational, and recreational noise exposure.
- **Physical Examination section.** Under the Physical Examination section, the audiologist reports the pure tone air conduction thresholds at 500, 1,000, 2,000, 3,000, and 4,000 Hz in each ear, the four-frequency pure tone average (1,000, 2,000, 3,000, and 4,000 Hz), and the maximum speech recognition score on the Maryland CNC Test in each ear.

  When only pure tone thresholds should be used to evaluate hearing loss, the audiologist will certify that language difficulties or other problems make the combined use of pure tone averages and speech recognition scores inappropriate.
- **Tinnitus.** If tinnitus is present, the audiologist should state date and circumstances of onset, whether it is unilateral, bilateral, or unlocalized, whether it is recurrent (if periodic indicate the frequency and duration), and the most likely etiology. If hearing loss is present at any frequency, the audiologist must state if the tinnitus is due to the same etiology or causative factor(s) as the hearing loss.
- **Diagnostic and Clinical Tests section.** In the Diagnostic and Clinical Tests section, the audiologist describes the results of all tests conducted during the examination. In cases where there is poor inter-test reliability and/or positive Stenger Test results, the audiologist obtains and reports estimates of hearing thresholds using a combination of behavioral techniques, Stenger interference levels, and electrophysiologic tests such otoacoustic emissions (OAEs) and auditory evoked potentials (ABRs).
- **Diagnosis section.** In the Diagnosis section, the audiologist summarizes the audiologic test results. The audiologist also notes if medical follow-up is needed for an ear, or hearing problem and whether there is a problem that, if treated, might change hearing thresholds.

When is hearing loss disabling for VA compensation and pension purposes?

For adjudication purposes, hearing impairment is disabling when pure tone thresholds at 500, 1,000, 2,000, 3,000, or 4,000 Hz are 40 dB HL or greater; or when pure tone thresholds for at least three of these frequencies are 26 dB HL or greater; or when speech recognition scores are less than 94%.

How is the degree of hearing impairment classified?

The degree of hearing impairment is classified in terms of the effect of the loss on the person's ability to understand speech in everyday situations. Hearing is considered to be normal when hearing thresholds are 25 dB HL or less.

- **Mild hearing loss** occurs when the four frequency (1,000, 2,000, 3,000, and 4,000 Hz) pure tone average (PTA) is 26-40 dB HL. A mild hearing loss may cause difficulty hearing faint speech or normal speech in the presence of background noise.
- **Moderate hearing loss** occurs when the PTA is 41-54 dB HL. A moderate hearing loss may cause difficulty with speech at normal conversational levels, especially when background noise is present.
- A **moderately-severe hearing loss** occurs when the PTA is 55-69 dB HL. A patient with a moderately-severe hearing loss may have difficulty hearing or understanding all but loud speech. Speech recognition may be nearly impossible in the presence of background noise.
- A **severe hearing loss** occurs when the PTA is 70-89 dB HL. A patient with a severe hearing loss may have extreme difficulty understanding spoken words, even in quiet situations.
- A **profound hearing loss** occurs when the PTA is 90 dB HL or worse. A patient with a profound hearing loss is functionally deaf and may not understand even amplified sounds.

How are the types of hearing loss classified and what are their causes?

The type of hearing loss may be described as conductive, mixed, sensorineural, or central. Conductive hearing losses are due to lesions that reduce transmission of sound through the external auditory canal, tympanic membrane, or middle ear. In purely conductive hearing losses, cochlear function is normal. Sensorineural hearing losses occur in lesions of the cochlea and auditory nerve. Mixed hearing losses involve both conductive and sensorineural components. Central hearing losses occur in lesions of the central nervous system from the brainstem to the auditory cortex. Audiologists are qualified to perform site of lesion tests to differentiate these types of hearing loss.

- **Conductive hearing loss** may result from congenital malformations of the auricle, external canal, and middle-ear. More commonly, conductive hearing loss results from otitis media, pathologies of the tympanic membrane, or pathologies involving the ossicles. Untreated middle-ear disease may be lead to erosion of the ossicles or cholesteatomas. This type of hearing loss also results from foreign bodies, cerumen, and inflammation of the external auditory canal. Neoplasms of the ear are relatively uncommon, with glomus tumors, middle-ear polyps, and carcinomas being the most common.

  Otosclerosis, a localized disease of the otic capsule sometimes affecting the stapes footplate, accounts for about one half of bilateral conductive deafness in adults.

  Other diseases of the otic capsule are osteogenesis imperfecta, Paget's Disease, lipoid dystrophies, and Wegener's granulomatosis.

- **Sensorineural hearing loss** may result from congenital hypoplasia of bony or membranous structures in the petrous pyramid, prenatal rubella, Rh incompatibility, anoxia, meningitis, and cytomegalovirus.

  The most common causes of sensorineural hearing loss are aging and traumatic noise exposure.

  Sensorineural loss may also result from drug-induced ototoxicity. The most common ototoxic factors are antibiotics such as streptomycin, neomycin, kanamycin, vancomycin, polymixin B, gentamicin, salicylates (aspirin), platinum-based anti-neoplastics such as cisplatin, and loop diuretics such as ethacrynic acid.

  Sensorineural loss may also result from temporal bone fracture or closed head injuries, labyrinthitis, syphilis, other viral and bacterial infections, vascular disease, meningitis, autoimmune disorders, tumors of the cerebellopontine angle, and endolymphatic hydrops (Meniere's Disease).

- **Central hearing loss** may be caused by congenital or developmental factors, trauma, space-occupying lesions, meningitis, autoimmune disorders, demyelinating diseases, and cerebrovascular disease.

What are the disabilities related to the vestibular system?

- With vestibular dysfunction, an individual usually complains of dizziness, but an attempt should be made to differentiate dysequilibrium and true vertigo.
- **Vertigo** is the illusion of motion, usually accompanied by a characteristic jerking motion of the eyes called nystagmus. If the symptoms occur in attacks, the examiner should ask the patient to describe the typical attack, premonitory signs, syncope, motion intolerance, associated nausea, vomiting, or sweating, changes in sensorium, direction of falling or spinning, duration, and after effects.
- The relationship to headaches or migraines, epilepsy, hearing or tinnitus should also be noted. Any association of symptoms with fatigue, excitement, medication or drug use, tobacco, or caffeine should be noted. Psychogenic disorders are often characterized by symptoms of weakness, faintness, nuchal or cranial pressure, malaise, or dyspnea.
- If symptoms are persistent or severe, a general medical examination with emphasis on myocardial infarction, hypertension, and diabetes is indicated. A neurological examination with evaluation of cranial nerve and cerebellar function, and an ophthalmologic examination of the vision and oculomotor nuclei should be performed. However, symptoms that persist for weeks or months are usually not of vestibular origin or may have a psychogenic overlay.
- **Oculomotor function and the presence of nystagmus** can be observed in the office using Frenzel lenses (20 diopter lenses) to eliminate visual fixation. If the eyes are directed 45° or more from central gaze, physiologic or endpoint nystagmus may be induced. However, observation in the office does not substitute for complete medical evaluation, including objective balance assessment using electronystagmography (ENG) or other electrophysiological techniques.

What does a vestibular examination include?

A vestibular examination includes:

- **Observation of gaze nystagmus.** Spontaneous nystagmus occurs in the absence of a stimulus and may indicate acute or uncompensated disease. Gaze nystagmus that is strongest for gaze in the direction of the fast phase is usually caused by peripheral lesions. According to Alexander's Law, first degree nystagmus is strongest with lateral gaze in the direction of the fast phase. Second degree nystagmus occurs when gaze nystagmus is noted in the primary position and with lateral gaze in the direction of the fast phase. Third degree nystagmus occurs when gaze nystagmus is also noted with lateral gaze in the direction of the slow phase.

- Congenital nystagmus is usually characterized by pendular or jerk nystagmus, but the nystagmus is usually distorted with eyes open. Congenital nystagmus may have a null point at which the nystagmus decreases or disappears. Congenital nystagmus is rarely vertical. During upward gaze, the nystagmus is usually horizontal, not vertical. Congenital nystagmus also tends to decrease or disappear with convergence of the eyes on a target.

- **Tests of positional nystagmus**. Positions include, sitting, supine, lying lateral on the right side, lying lateral on the left side, and supine with head hanging. Positional nystagmus is abnormal if the direction changes in any one position, it is present in three or more positions, it is intermittent in four or more positions, or it is greater than 6° per second. Positional nystagmus is abnormal if it is enhanced with eyes open.

- Direction-fixed nystagmus is usually caused by peripheral lesions. Direction-changing, particularly with eyes open, usually signifies a CNS lesion. However, the examiner needs to rule out positional alcohol nystagmus (PAN).

- Positioning nystagmus is evaluated using the Hallpike maneuver in which the patient in sitting position is moved suddenly to a supine position with head hanging with right ear or left ear down. The eyes are observed for evidence of jerk or rotary nystagmus. The presence of brief, intense, delayed, fatigable nystagmus is characteristic of benign paroxysmal positioning vertigo (BPPV), a very common condition thought to be caused by dislodged otoconia in the cristae of the semicircular canals.

- Some examiners define direction-fixed positional nystagmus as spontaneous nystagmus. Spontaneous nystagmus is differentiated from positional nystagmus by the fact that positional nystagmus is characterized by differences in intensity between head positions, whereas spontaneous nystagmus is constant in all positions.

- **Other examinations.** Head-shaking nystagmus may be evoked by having the patient shake his/her head vigorously for 15-20 seconds. Eye movements are observed by Frenzel lenses. If the patient has nystagmus and did not have spontaneous nystagmus, an uncompensated lesion is noted. Normally, the nystagmus beats away from the lesion side.

- **Tests for postural vertigo.** Tests such as the Romberg, Past-pointing, tandem walking, or the Fukuda Stepping Test are useful in grossly assessing vestibular function.

  The **Romberg Test** involves having the patient stand with feet together and arms folded at the chest, eyes closed. Patients with unilateral peripheral lesions will sway or fall, usually toward the lesion side.

  Past-pointing involves having the patient place an index finger on the examiner's finger, extend the arm to vertical position, and return the index finger to the examiner's finger. Deviation is noted. Patients with peripheral lesions tend to past point toward the lesion side.

  Tandem walking involves having the patient walk heel to toe with eyes closed and open. In the eyes closed condition, swaying or deviation may indicate a peripheral vestibular lesion. In the eyes open condition, swaying or deviations may indicate a cerebellar disturbance.

  The Fukuda Test involves having the patient march in place (50 steps) with eyes closed. The amount of rotation is noted. Usually, the patient rotates toward the lesion side. However, the direction of deviation or rotation in these tests is a poor indicator of the side of the lesion.

- **Caloric stimulation.** This test should be performed only on those patients with normal external auditory canals and intact tympanic membranes. Using 2 ml of ice water in a syringe with a 14 or 16 gauge needle, the examiner injects the water slowly into the ear canal. The head is hyper-extended by 60° from the vertical axis if the patient is in the sitting position. If the patient is in supine position, the head is flexed 30° to bring the lateral semi-circular canal into the vertical plane. The latency and duration of the nystagmus are measured with a stopwatch. Nystagmus should be observed with the patient wearing Frenzel lenses. The opposite ear is tested after a five minute rest period. The normal duration is 80-120 seconds. If a 30-second or greater difference exists between ears, the side with the reduced duration has a hypo-reactive response.

- **Electronystagmography**. Non-electrical recordings must be considered to be qualitative. Electronystagmography (ENG) is an electrophysiologic test battery that provides a quantitative measure of oculomotor and vestibular function and is usually performed by audiologists.

  ENG is usually obtained measuring eye position using the corneal-retinal potential with electrodes or infrared video recordings. Eye movements are displayed graphically on a strip chart or a video display.

  The typical ENG battery consists of oculomotor tests (saccades, smooth pursuit or pendular tracking, and optokinetic tests), positional and positioning tests as described above, and caloric stimulation using cool and warm water or air.

  Oculomotor tests evaluate the oculomotor nuclei and/or brainstem-cerebellar systems. Saccade tests involve having the patient track a light target that jumps right, left, up and down. CNS lesions may produce ocular dysmetria, saccadic slowing, or disconjugate eye movements. Tracking or pursuit tests involve having the patient track a light target moving across the visual field. Disorganized or saccadic pursuit usually indicates a CNS lesion.

  Positional tests evaluate the effect of movement or gravity on vestibular responses. The diagnostic significance is the same for the observation tests described above.

  Caloric tests evaluate peripheral vestibular function. Failure to suppress nystagmus with visual fixation is usually indicative of CNS disease.

- **Other objective measures** useful in the diagnosis of balance disorders are sinusoidal vertical axis rotation testing (rotary chair), and computerized dynamic posturography. The latter test provides detailed analysis of vestibular, visual, and somatosensory integration.

LESSON 8 TINNITUS

Kyle C. Dennis, Ph.D.

OBJECTIVES:

- Describe the causes of tinnitus
- Explain the treatment options for tinnitus

TAKE HOME MESSAGE:

Tinnitus is often a debilitating condition that may interfere with a patient's concentration, sleep, or sense of well being. In some cases, tinnitus can cause a sense of hopelessness, stress, anxiety, or depression. While the cause of tinnitus is elusive, tinnitus can be treated by a variety of medical, audiological, and psychological methods.

What is Tinnitus?

Tinnitus refers to a group of auditory sensations that are not related to external stimuli. In many respects, tinnitus is similar in its presentation and effect to **chronic pain**.

True tinnitus (**phantom auditory perception**) must be differentiated from externally generated auditory perceptions, body sounds, auditory memories, or auditory hallucinations related to psychosis. Body sounds (**somatosounds**) can be generated in the inner ear (spontaneous otoacoustic emissions), or outside the inner ear (muscular, vascular, joint crepitus, and respiratory sounds). **Auditory memories** (e.g. a recurring music refrain) must be differentiated from **auditory hallucinations** that may occur in schizophrenia. Patients with psychoses may "re-interpret" true tinnitus as auditory hallucinations (e.g. voices). **True tinnitus, unlike somatosounds and auditory images, may be persistent, annoying, intrusive, and sometimes debilitating.**

Only the patient experiences subjective tinnitus. Subjective tinnitus is also known as **idiopathic tinnitus**. **Objective tinnitus** is usually caused by an internal vibratory source and may be perceived by both patient and examiner. Objective tinnitus is also known as **vibratory, extrinsic, or pseudo-tinnitus**. Objective tinnitus usually has an overt underlying otologic or vascular cause such as vascular pathology, myoclonic activity in the middle-ear muscles or palate, or a patulous Eustachian tube.

Subjective tinnitus may be perceived as ringing (tonal), rushing, whistling, hissing, humming, buzzing, or "crickets". Some patients describe tinnitus as pulsing, pounding, roaring or clicking. In general, the former group is more associated with auditory disease, while the latter group has overt middle ear, vascular or myoclonic disease. About 80% of patients complain of tonal tinnitus. About 80% of patients complain that tinnitus comes from their ears.

Prevalence of Tinnitus

- About 36 million Americans suffer from tinnitus.
- About 7 million Americans complain of severe, disabling tinnitus.
- About 7% of patients complain of tinnitus to their physician.
- About 70% of persons with hearing loss also have tinnitus.
- **The most common factor associated with tinnitus is hearing loss**.
- Age and exposure to noise are also significant factors.
- Although less common, tinnitus does occur in the absence of hearing loss.

However, the presence of hearing loss does not necessarily mean that the condition that caused the hearing loss also caused the tinnitus. Indeed, tinnitus appears to be less of a problem for persons with severe hearing loss. Studies have shown that only 30-40% of patients with very severe hearing loss ever complained of tinnitus. While noise exposure is a common cause for both hearing loss and tinnitus, only about 25% of patients with noise exposure complain of tinnitus.

Classification of Subjective Tinnitus

Adapted from Shulman, A. (1991). *Clinical Types of Tinnitus*. In Shulman, A. et al. (Eds) Tinnitus: Diagnosis and Treatment. Philadelphia: Lea and Febiger, pp. 323-341.

In most cases, the cause of tinnitus is not known. However, subjective tinnitus can be classified and associated with known diseases.

- **Auditory** — classic tinnitus of middle-ear, cochlear, vestibular, neural or central origin
- **Non-auditory** — tinnitus associated with non-auditory causes such as cervical injuries (whiplash), cardiovascular disease, temporomandibular joint syndrome (TMJ), central nervous system disease (e.g. multiple sclerosis)
- **Sub-clinical** — tinnitus that is present, but is not manifest or worrisome
- **Middle-ear** — tinnitus associated with middle-ear, tympanic membrane, Eustachian tube, or ossicles
- **Cochlear** — tinnitus associated with cochlear damage (e.g. noise trauma)
- **Vestibular** — tinnitus associated with vestibular or combined cochlear and vestibular disease (e.g. Meniere's Disease)
- **Cervical** — tinnitus associated with neck movements and degenerative changes in the cervical spine or basilar artery disease
- **Central** — tinnitus of central auditory or vestibular origin (e.g. stroke, head trauma, concussion, degenerative neural disease, demyelinating diseases)

What Causes Tinnitus?

In most cases, the cause of subjective tinnitus is not known. The fact that most tinnitus appears to be coming from the ear led to a belief that tinnitus was generated in the inner ear. This is not the case. **Damage in the inner ear may be a precursor for subjective tinnitus, but subjective tinnitus is generated in the central auditory pathways and is perceived as a sound.**

Current research suggests that tinnitus is similar to **phantom limb syndrome** (causalgia or reflex sympathetic disorder). Phantom limb syndrome occurs when patients feel pain or other sensations from an amputated limb. Some research suggests that the subcortical auditory nervous system generates auditory sensations to replace inputs missing from the damaged cochlea. Spontaneous neural activity may be processed through the normal auditory pathways to be perceived as sound. Aberrant neural activity leads to tinnitus and an aberrant perception of loudness (**hyperacusis**).

The key point is that aberrant neural activity is processed in normal auditory pathways and is perceived as sound.

Tinnitus is frequently triggered by **psychological factors**. Eighty percent of patients related the emergence of tinnitus to changes in psychological state (bereavement, stress, and anxiety). There is a high correlation between the ability to cope with stress and perceived severity of tinnitus.

While the physiology of tinnitus is not well understood, some conditions and treatments are known to cause tinnitus. For example, **exposure to noise** frequently causes tinnitus. **Ototoxic medications** (see Lesson 4) such as aminoglycoside antibiotics, salicylates, non-steroidal anti-inflammatories, cisplatin, loop diuretics, and quinine are known to cause tinnitus. A wide variety of diseases are known to cause tinnitus.

The most common causes are:

- External and middle-ear infections
- Autoimmune ear disease
- Meniere's Disease
- Otosclerosis
- Vestibular schwannoma
- Viral and bacterial inflammatory ear disease
- Temporomandibular joint syndrome (TMJ)
- Cerebrovascular disease
- Concussion and head trauma
- Multiple sclerosis
- Sudden idiopathic hearing loss
- Renal disease

Treatment for Tinnitus

There is no single effective treatment for tinnitus. In most cases, the object of treatment is to alleviate the **psychological manifestations** of tinnitus and to assist the patient in coping with the intrusive effects of the condition.

Surgical — Surgical section of the VIIIth cranial nerve has been used with mixed success. Since subjective tinnitus does not originate in the cochlea at all, tinnitus may persist after nerve section.

Instrumental — Tinnitus instruments, tinnitus maskers and hearing aids may help to make tinnitus less annoying by introducing a masking sound into the ear. Tinnitus instruments are essentially hearing aids that provide masking sounds in addition to amplification. Tinnitus maskers are external devices that produce masking noises. A study by Hazell et al., (1985) indicated that 41-61% of patients reported relief from tinnitus maskers, 17-52% from tinnitus instruments, and 19-22% from conventional hearing aids.

Electrical Suppression — Transcutaneous, transtympanic, or intracochlear electrical stimulation provides relief in about 20% of patients. Electrical stimulation is most effective with cochlear tinnitus. Only the intracochlear device (cochlear implant) is approved for use by the FDA.

Pharmacological — No medication has been found to relieve tinnitus completely or consistently. Medications may be used to control anxiety, stress, or depression. Medications known to affect tinnitus include local anesthetics, anti-depressant drugs, anti-psychotic and anti-anxiety drugs (barbiturates, benzodiazepines), anti-convulsant drugs, Niacin, Vitamin B, sodium fluoride, zinc, anti-histamines, vasodilators, muscle relaxants, beta-blockers (propanolol), calcium channel blockers, diuretics, and antibiotics (streptomycin).

Behavior Modification — Behavior modification uses cognitive therapy methods to modify maladaptive thoughts, fears, and behaviors. The therapy involves defining problems and fears, identifying negative reactions and behaviors, and developing coping strategies.

Stress Management — Stress therapy assists patients to cope with stressors such as tinnitus. The therapy is based on the relationship between coping skills and stress levels.

Biofeedback — Biofeedback assists the patient to relax and deal with stress. Classic biofeedback emphasizes muscular relaxation. Biofeedback may be combined with other techniques.

Desensitization — Desensitization assists patients in habituating to a broad band noise. In effect, the technique teaches the brain to recognize tinnitus as non-threatening and to ignore it.

Acupuncture — While it is used frequently in other countries, acupuncture has not been used widely as a tinnitus treatment in this country.

Support Groups — Support groups such as the American Tinnitus Association can be very helpful to patients in providing contacts with other tinnitus sufferers, organizing self-help and support groups, publishing literature, sponsoring research, and fostering professional dialogue.

Diet — Control of tobacco, caffeine, soft drinks, and alcohol is an important part of treatment. A holistic approach to tinnitus management focuses on nutritional deficiencies, metabolic imbalances, and allergies. Physicians should pay attention to their patient's sugar intake, cholesterol, and triglycerides. Diet should avoid the intake of foods or drink naturally high in caffeine, sodium or salicylates. There is no conclusive evidence that herbal supplements (gingko biloba) are effective.

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APPENDIX A

APPENDIX A

NIOSH Hearing Loss Publications

Work-Related Hearing Loss, National Institute for Occupational Safety and Health

76. Noise and Hearing Loss
National Institutes of Health Consensus Development Conference Statement January 22-24, 1990

NIDCD Fact Sheet — Noise-Induced Hearing Loss, National Institute on Deafness and Other Communication Disorders, 1999

NIOSH Hearing Loss Publications

Preventing Occupational Hearing Loss: A Practical Guide
NIOSH Publication No. 96-110

This guide, developed by experienced hearing conservation professionals, presents some of the important attributes of successful hearing loss prevention programs. Concepts and action items are presented in terms of the responsibilities of three groups of personnel: those representing management, those who implement the hearing loss prevention programs, and those who are affected by exposure to noise or ototoxic chemicals. Checklists are provided in the appendices to assist in evaluating hearing loss prevention programs on a step-by-step basis.

Criteria for a Recommended Standard: Occupational Noise Exposure.
Revised Criteria 1998
NIOSH Publication No. 98-126

This criteria document reevaluates and reaffirms the recommended exposure limit (REL) for occupational noise exposure established by NIOSH in 1972. The recommendations in this document go beyond attempts to conserve hearing by focusing on prevention of occupational NIHL. For workers whose noise exposures equal or exceed 85 dBA, NIOSH recommends a hearing loss prevention program (HLPP) that includes exposure assessment, engineering and administrative controls, proper use of hearing protectors, audiometric evaluation, education and motivation, recordkeeping, and program audits and evaluations.

The NIOSH Compendium of Hearing Protection Devices
NIOSH Publication No. 95-105

This compendium was put together to allow those who select hearing protectors to do so in a more informed manner. The compendium profiles three hundred and sixty devices. Tables in the compendium show listings for protector type, composition, features, and compatibility. The test laboratories that performed the attenuation testing and manufacturer-provided comments about special features are also listed. Full data sets on each protector are included in an appendix, rather than in the body of the compendium.

Health Hazard Evaluations: Noise and Hearing Loss: 1986-1997
NIOSH Publication No. 99-106

Through the Health Hazard Evaluation (HHE) Program, NIOSH staff evaluate noise exposures in many workplaces. From 1986-1997, NIOSH conducted 27 HHE's that addressed noise as a hazard in industries such as agriculture, construction, manufacturing, transportation, and service. This publication presents summaries of these 27 HHE's organized by industry, including the type of facility, the purpose of the HHE, keywords associated with it, and an abstract of the findings. Information on obtaining full copies of individual HHE reports is provided.

National Occupational Research Agenda
NIOSH Publication No. 96-115

Hearing loss was identified by NIOSH and the occupational safety and health community as one of the 21 priority areas in the National Occupational Research Agenda. This publication summarizes the NORA process, and details the importance of hearing loss research and the occupational hearing loss research opportunities which exist.

Noise and Mining
NIOSH Pittsburgh Research Laboratory Publications

Researchers at NIOSH's Pittsburgh Research Laboratory (part of the former Bureau of Mines), have produced a series of documents of noise in the mining environment. These documents include: *Measurement and Control of Drill Noise*, *Preparation and Processing Plant Noise*, *Personal Hearing Protectors*, *Surface Mine Noise*, and *Underground Coal Mine Noise*. Copies of these documents are available by contacting the NIOSH 800 number

For copies of the documents described here or for more information on occupational hearing loss or other work-related injuries or illnesses, contact NIOSH at 1-800-35-NIOSH or visit the NIOSH website at **http://www.cdc.gov/niosh**

Work-Related Hearing Loss

Work-related hearing loss continues to be a critical workplace safety and health issue. The National Institute for Occupational Safety and Health (NIOSH) and the occupational safety and health community named hearing loss one of the 21 priority areas for research in the next century. Noise-induced hearing loss is 100 percent preventable, but once acquired, hearing loss is permanent and irreversible. Therefore, prevention measures must be taken by employers and workers to ensure the protection of workers' hearing.

MAGNITUDE

Approximately 30 million workers are exposed to hazardous noise on the job and an additional nine million are at risk for hearing loss from other agents such as solvents and metals.

Noise-induced hearing loss is one of the most common occupational diseases and the second most self-reported occupational illness or injury. Industry specific studies reveal:

- 44% of carpenters and 48% of plumbers reported that they had a perceived hearing loss.
- 90% of coal miners will have a hearing impairment by age 52 (compared to 9% of the general population); 70% of male, metal/nonmetal miners will experience a hearing impairment by age 60.

While any worker can be at risk for noise-induced hearing loss in the workplace, workers in many industries have higher exposures to dangerous levels of noise. Industries with high numbers of exposed workers include: agriculture; mining; construction; manufacturing and utilities; transportation; and military.

COSTS

There is no national surveillance or injury reporting system for hearing loss. As such, comprehensive data on the economic impact of hearing loss are not available. Some estimates find that occupational hearing loss compensation costs alone are in the hundreds of millions of dollars per year. The following examples provide an indication of the economic burden of occupational hearing loss. In Washington State, workers' compensation disability settlements for hearing-related conditions cost $4.8 million in 1991. This figure does not include medical costs or personal costs which can include approximately $1500 for a hearing aid and around $300 per year for batteries. Moreover, workers' compensation data are an underestimate of the true frequency of occupational illness, representing only the tip of the iceberg.

In British Columbia, in the five-year period from 1994 to 1998, the workers' compensation board paid $18 million in permanent disability awards to 3,207 workers suffering hearing loss. An additional $36 million was paid out for hearing aids.

Through their hearing conservation program, the U.S. Army **saved** $504.3 million by reducing hearing loss among combat arms personnel between 1974 and 1994. Between 1987 and 1997, as a result of military efforts to reduce civilian hearing loss, the Department of Veterans Affairs saved $220.8 million and the Army an additional $149 million.

PREVENTION

Removing hazardous noise from the workplace through engineering controls (e.g. installing a muffler or building an acoustic barrier) is the most effective way to prevent noise-induced hearing loss. Hearing protectors such as ear plugs and ear muffs should be used when it is not feasible to otherwise reduce noise to a safe level. NIOSH recommends hearing loss prevention programs for all workplaces with hazardous levels of noise. These programs should include noise assessments, engineering controls, audiometric monitoring of workers' hearing, appropriate use of hearing protectors, worker education, recordkeeping, and program evaluation.

For more information on occupational hearing loss or other work-related injuries or illnesses, contact NIOSH at 1-800-35-NIOSH or visit the NIOSH website at http://www.cdc.gov/niosh

76. NOISE AND HEARING LOSS

National Institutes of Health Consensus Development Conference Statement

January 22-24, 1990

This statement was originally published as:

Noise and Hearing Loss. NIH Consens Statement 1990 Jan 22-24;8(1):1-24.

For making bibliographic reference to the statement in the electronic form displayed here, it is recommended that the following format be used:

Noise and Hearing Loss. NIH Consens Statement Online 1990 Jan 22-24 [cited year month day];8(1):1-24.

ABSTRACT

The National Institutes of Health Consensus Development Conference on Noise and Hearing Loss brought together biomedical and behavioral scientists, health care providers, and the public to address the characteristics of noise-induced hearing loss, acoustic parameters of hazardous noise exposure, individual and age-specific susceptibility, and prevention strategies. Following a day and a half of presentations by experts and discussion by the audience, a consensus panel weighed the evidence and prepared a consensus statement.

Among their findings, the panel concluded that sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent hearing loss at any age. Sound levels of less than 75 dB(A) are unlikely to cause permanent hearing loss, while sound levels above 85 dB(A) with exposures of 8 hours per day will produce permanent hearing loss after many years. Current scientific knowledge is inadequate to predict that any particular individual will be safe when exposed to a hazardous noise. Strategies to prevent damage from sound exposure should include the use of individual hearing protection devices, education programs beginning with school-age children, consumer guidance, increased product noise labeling, and hearing conservation programs for occupational settings.

The full text of the consensus panel's statement follows.

INTRODUCTION

Hearing loss afflicts approximately 28 million people in the United States. Approximately 10 million of these impairments are at least partially attributable to damage from exposure to loud sounds. Sounds that are sufficiently loud to damage sensitive inner ear structures can produce hearing loss that is not reversible by any presently available medical or surgical treatment. Hearing impairment associated with noise exposure can occur at any age, including early infancy, and is often characterized by difficulty in understanding speech and the potentially troublesome symptom, tinnitus (i.e., ringing in the ears). Very loud sounds of short duration, such as an explosion or gunfire, can produce immediate, severe, and permanent loss of hearing. Longer exposure to less intense but still hazardous sounds, commonly encountered in the workplace or in certain leisure time activities, exacts a gradual toll on hearing sensitivity, initially without the victim's awareness. More than 20 million Americans are exposed on a regular basis to hazardous noise levels that could result in hearing loss. Occupational noise exposure, the most common cause of noise-induced hearing loss (NIHL), threatens the hearing of firefighters, police officers, military personnel, construction and factory workers, musicians, farmers, and truck drivers, to name a few. Live or recorded high-volume music, recreational vehicles, airplanes, lawn-care equipment, woodworking tools, some household appliances, and chain saws are examples of nonoccupational sources of potentially hazardous noise. One important feature of NIHL is that it is preventable in all but certain cases of accidental exposure. Legislation and regulations have been enacted that spell out guidelines for protecting workers from hazardous noise levels in the workplace and consumers from hazardous noise during leisure time pursuits. Inconsistent compliance and spotty enforcement of existing governmental regulations have been the underlying cause for their relative ineffectiveness in achieving prevention of NIHL. A particularly unfortunate occurrence was the elimination of the Office of Noise Abatement and Control within the Environmental Protection Agency in 1982.

On January 22-24, 1990, the National Institute on Deafness and Other Communication Disorders, together with the Office of Medical Applications of Research of the National Institutes of Health, convened a Consensus Development Conference on Noise and Hearing Loss. Co-sponsors of the conference were the National Institute of Child Health and Human Development, the National Institute on Aging, and the National Institute for Occupational Safety and Health of the Centers for Disease Control. The effects of environmental sounds on human listeners may include:

- Interference with speech communication and other auditory signals.
- Annoyance and aversion.
- Noise-induced hearing loss.

- Changes in various body systems.
- Interference with sleep.

This conference was entirely centered on NIHL. The panel focused on five questions related to noise and hearing loss:

- What is noise-induced hearing loss?
- What sounds can damage hearing?
- What factors, including age, determine an individual’s susceptibility to noise-induced hearing loss?
- What can be done to prevent noise-induced hearing loss?
- What are the directions for future research?

Following a day and a half of presentations by experts in the relevant fields and discussion from the audience, a consensus panel comprising specialists and generalists from the medical and other related scientific disciplines, together with public representatives, considered the evidence and formulated a consensus statement in response to the five previously stated questions.

WHAT IS NOISE-INDUCED HEARING LOSS?

Sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent hearing loss. The hearing loss may range from mild to profound and may also result in tinnitus. The effect of repeated sound overstimulation is cumulative over a lifetime and is not currently treatable. Hearing impairment has a major impact on one’s communication ability and even mild impairment may adversely affect the quality of life. Unfortunately, although NIHL is preventable, our increasingly noisy environment places more and more people at risk.

Studies of NIHL

Most studies of the association between sound exposure and hearing loss in humans are retrospective measurements of the hearing sensitivities of numerous individuals correlated with their noise exposures. The variability within these studies is usually large; thus, it is difficult to predict the precise magnitude of hearing loss that will result from a specific sound exposure. Prospective studies of selected workers’ hearing levels over a long time while their sound exposures are carefully monitored are costly and time-consuming and, due to attrition, require a large number of subjects. When significant hearing loss is found, for ethical reasons, exposures must be reduced, interfering with the relationships under study. Although studies of NIHL in humans are difficult, they provide valuable information not available from animal studies and should be continued.

In prospective animal studies, sound exposures can be carefully controlled, and the anatomic and physiologic correlates of NIHL can be precisely defined. Although there may be interspecies differences with respect to the absolute sound exposure that will injure the ear, the basic mechanisms that lead to damage appear to be similar in all mammalian ears.

Anatomic and Physiologic Correlates of NIHL

Two types of injury are recognized: acoustic trauma and NIHL. Short-duration sound of sufficient intensity (e.g., a gunshot or explosion) may result in an immediate, severe, and permanent hearing loss, which is termed acoustic trauma. Virtually all of the structures of the ear can be damaged, in particular the organ of Corti, the delicate sensory structure of the auditory portion of the inner ear (cochlea), which may be torn apart.

Moderate exposure may initially cause temporary hearing loss, termed temporary threshold shift (TTS). Structural changes associated with TTS have not been fully established but may include subtle intracellular changes in the sensory cells (hair cells) and swelling of the auditory nerve endings. Other potentially reversible effects include vascular changes, metabolic exhaustion, and chemical changes within the hair cells. There is also evidence of a regional decrease in the stiffness of the stereocilia (the hair bundles at the top of the hair cells), which may recover. This decrease in stereocilia stiffness may lead to a decrease in the coupling of sound energy to the hair cells, which thereby alters hearing sensitivity.

Repeated exposure to sounds that cause TTS may gradually cause permanent NIHL in experimental animals. In this type of injury, cochlear blood flow may be impaired, and a few scattered hair cells are damaged with each exposure. With continued exposure, the number of damaged hair cells increases. Although most structures in the inner ear can be harmed by excessive sound exposure, the sensory cells are the most vulnerable. Damage to the stereocilia is often the first change, specifically, alteration of the rootlet structures that normally anchor the stereocilia into the top of the hair cell. Once destroyed, the sensory cells are not replaced. During the recovery period between some sound exposures, damaged regions of the organ of Corti heal by scar formation. This process is very important because it reestablishes the barrier between the two fluids of the inner ear (perilymph and endolymph). If this barrier is not reestablished, degeneration of hair cells may continue. Further, once a sufficient number of hair cells are lost, the nerve fibers to that region also degenerate. With degeneration of the cochlear nerve fibers, there is corresponding degeneration within the central nervous system. The extent to which these neural changes contribute to NIHL is not clear.

With moderate periods of exposure to potentially hazardous high-frequency sound, the damage is usually confined to a restricted area in the high-frequency region of the cochlea. With a comparable exposure to low-frequency noise, hair cell damage is not confined to the low-frequency region but may also affect the high-frequency regions. The predominance of damage in different cochlear regions with different frequency exposures reflects factors such as the resonance of the ear canal, the middle-ear transfer characteristics, and the mechanical characteristics of the organ of Corti and basilar membrane.

Assessment of NIHL

Hearing loss is measured by determining auditory thresholds (sensitivity) at various frequencies (pure-tone audiometry). Complete assessment should also include measures of speech understanding and middle-ear status (immittance audiometry). Pure-tone audiometry is also used in industrial hearing conservation programs to determine whether adequate protection against hazardous sound levels is provided.

The first audiometric sign of NIHL resulting from broadband noise is usually a loss of sensitivity in the higher frequencies from 3,000 through 6,000 Hertz (Hz) (i.e., cycles per second), resulting in a characteristic audiometric “notch.” With additional hearing loss from noise or aging, the threshold at 8,000 Hz may worsen and eliminate this characteristic audiometric pattern. Thus, the presence or absence of NIHL cannot be established on the basis of audiometric shape, per se. The hearing loss is usually bilateral, but some degree of asymmetry is not unusual, especially with lateralized noise sources such as rifles. After moderate sound exposure, TTS may occur, and, during a period of relative quiet, thresholds will return to normal levels. If the exposure continues on a regular basis, permanent threshold shifts (PTS) will result, increasing in magnitude and extending to lower and higher frequencies. If the exposures continue, NIHL increases, more rapidly in the early years. After many years of exposure, NIHL levels off in the high frequencies, but continues to worsen in the low frequencies. Although TTS and PTS are correlated, the relation is not strong enough to use TTS to predict the magnitude of permanent hearing loss.

An important consequence of the sensitivity loss associated with NIHL is difficulty in understanding speech. Whereas a large proportion of the *energy* in speech is contained within the low-frequency range, much of the *information* required to differentiate one speech sound from another is contained within the higher frequencies. With significant hearing loss in the high frequencies, important speech information is often inaudible or unusable. Other interfering sounds such as background noise, competing voices, or room reverberation may reduce even further the hearing-impaired listener’s receptive communication ability. The presence of tinnitus may be an additional debilitating condition.

NIHL may interfere with daily life, especially those social activities that occur in noisy settings. Increased effort is required for understanding speech in these situations, which leads to fatigue, anxiety, and stress. Decreased participation in these activities often results, affecting not only hearing-impaired individuals but also friends and family members. Hearing loss is associated with depression in the elderly and may be related to dementia and cognitive dysfunction. Systematic study of the effects of hearing loss on the quality of life have only lately focused specifically on individuals with NIHL; therefore, continued studies of this kind are desirable.

The impairment in hearing ability resulting from NIHL may vary from mild to severe. An individual's ability to communicate and function in daily life varies with the degree of loss and the individual's communication needs although these relationships are complex. The magnitude of the effect on communication ability may be estimated by a variety of scales, which are often used in disability determinations. These scales, which vary substantially in the frequencies used, the upper and lower limits of impairment, age correction, and adjustment for asymmetric hearing loss, attempt to predict the degree of communication impairment (understanding of speech) on the basis of pure-tone thresholds. There is no consensus about the validity or utility of the scales, which scale should be used, whether measures of speech understanding should be included, or whether self-assessment ratings should be incorporated into either impairment rating scales or disability determinations.

WHAT SOUNDS CAN DAMAGE HEARING?

Some sounds are so weak physically that they are not heard. Some sounds are audible but do not have any temporary or permanent after-effects. Some sounds are strong enough to produce a temporary hearing loss from which there may appear to be complete recovery. Damaging sounds are those that are sufficiently strong, sufficiently long-lasting, and involve appropriate frequencies so that permanent hearing loss will ensue.

Most of the sounds in the environment that produce such permanent effects occur over a very long time (for example, about 8 hours per workday over a period of 10 or more years). On the other hand, there are some particularly abrupt or explosive sounds that can cause damage even with a single exposure.

The line between these categories of sounds cannot be stated simply because not all persons respond to sound in the same manner. Thus, if a sound of given frequency bandwidth, level, and duration is considered hazardous, one must specify for what proportion of the population it will be hazardous and, within that proportion, by what criterion of damage (whether anatomical, audiometric, speech understanding) it is hazardous.

The most widely used measure of a sound's strength or amplitude is called "sound level," measured by a sound-level meter in units called "decibels" (dB). For example, the sound level of speech at typical conversational distances is between 65 and 70 dB. There are weaker sounds, still audible, and of course much stronger sounds. Those above 85 dB are potentially hazardous.

Sounds must also be specified in terms of frequency or bandwidth, roughly like the span of keys on a piano. The range of audible frequencies extends from about 20 Hz, below the lowest notes on a piano, to at least 16,000 or 20,000 Hz, well above the highest notes on a piccolo. Most environmental noises include a wide band of frequencies and, by convention, are measured through the "A" filter in the sound-level meter and thus are designated in dB(A) units. It is not clear what effect, if any, sound outside the frequency range covered in dB(A) measurements may have on hearing. At this time, it is not known whether ultrasonic vibration will damage hearing.

To define what sounds can damage hearing, sound level, whether across all frequency bands or taken band by band, is not enough. The duration of exposure — typical for a day and accumulated over many years — is critical. Sound levels associated with particular sources such as snowmobiles, rock music, and chain saws, are often cited, but predicting the likelihood of NIHL from such sources also requires knowledge of typical durations and the number of exposures.

There appears to be reasonable agreement that sound levels below 75 dB(A) will not engender a permanent hearing loss, even at 4,000 Hz. At higher levels, the amount of hearing loss is directly related to sound level for comparable durations.

According to some existing rules and regulations, a noise level of 85 dB(A) for an 8-hour daily exposure is potentially damaging. If total sound energy were the important predictor, an equivalent exposure could be as high as 88 dB(A) if restricted to 4 hours. (A 3-dB increase is equivalent to doubling the sound intensity.) This relation, enshrined in some standards and regulations, is a theory based on a dose or exposure defined by total energy.

In spite of the physical simplicity of a total-energy concept, other principles have been invoked to define equivalent exposures of different sound levels and durations. Early research suggested that NIHL after 10 years could be predicted from temporary threshold shifts (TTS) measured 2 minutes after a comparable single-day exposure. Those results, however, were taken to indicate that a halving of duration could be offset by a 5-dB change in sound level rather than a 3-dB change. This 5-dB rule is implemented in the Walsh-Healey Act of 1969 and subsequent Occupational Safety and Health Administration regulations for the purpose of requiring preventive efforts for noise-exposed workers. The 3-dB trading rule is agreed to in International Standards Organization (ISO) Standard 1999.2 (1989) for the purpose of predicting the amount of noise-induced hearing loss resulting from different exposures. There is no consensus concerning a single rule to be used for all purposes in the United States.

Generally, for sound levels below about 140 dB, different temporal forms of sound, whether impulse (gunshot), impact (drop forge) or steady state (turbine), when specified with respect to their level and duration, produce the same hearing loss. This does not appear to follow at levels above 140 dB, where impulse noise creates more damage than would be predicted. This may imply that impulse noise above a certain critical level results in acoustic trauma from which the ear cannot recover.

Although sound exposures that are potentially hazardous to hearing are usually defined in terms of sound level, frequency bandwidths, and duration, there are several simple approximations that indicate that a sound exposure may be suspected as hazardous. These include the following: If the sound is appreciably louder than conversational level, it is potentially harmful, provided that the sound is present for a sufficient period of time. Hazardous noise may also be suspected if the listener experiences: (a) difficulty in communication while in the sound, (b) ringing in the ear (tinnitus) after exposure to the sound, and/or (c) the experience that sounds seem muffled after leaving the sound-exposure area.

In the consideration of sounds that can damage hearing, one point is clear: it is the acoustic energy of the sound reaching the ear, not its source, which is important. That is, it does not matter if the hazardous sound is generated by a machine in the workplace, by an amplifier/loudspeaker at a rock concert, or by a snowmobile ridden by the listener. Significant amounts of acoustic energy reaching the ear will create damage — at work, at school, at home, or during leisure activities. Although there has been a tendency to concentrate on the more significant occupational and transportation noise, the same rules apply to all potential noise hazards.

WHAT FACTORS, INCLUDING AGE, DETERMINE AN INDIVIDUAL'S SUSCEPTIBILITY TO NOISE-INDUCED HEARING LOSS?

One thoroughly established characteristic of NIHL is that, on the average, more intense and longer-duration noise exposures cause more severe hearing loss. A second is that there is a remarkably broad range of individual differences in sensitivity to any given noise exposure. Several factors have been proposed to explain differences in NIHL among individuals; others may be associated with differences over time within the same individual. It is important to distinguish those factors whose roles in determining susceptibility are supported by a consistent body of theory and empirical evidence from other factors whose roles have been proposed but for which theory, data, or both are less conclusive.

Differences Among Individuals

Both temporary threshold shift (TTS) and permanent threshold shift (PTS) in response to a given intense noise may differ as much as 30 to 50 dB among individuals. Both animal research and retrospective studies of humans exposed to industrial noise have demonstrated this remarkable variation in susceptibility. The biological bases for these differences are unknown. A number of extrinsic factors (e.g., characteristics of the ear canal and middle ear, drugs, and prior exposure to noise) may influence an individual's susceptibility to NIHL. However, animal studies that have controlled these variables suggest that individual differences in inner ear anatomy and physiology also may be significant. Additional research is necessary to determine whether vascular, neural feedback (efferent system), or other mechanisms can account for and predict such individual variation.

One factor that may be associated with decreased susceptibility to NIHL is conductive hearing loss; the cochlear structures may be protected by any form of acoustic attenuation. For similar reasons, middle ear muscles, which normally serve a protective function by contracting in response to intense sound, when inoperative, can result in increased susceptibility. Among the other factors that are *theoretically* associated with differences in susceptibility are (a) unusually efficient acoustic transfer through the external and middle ear, as a determinant of the amount of energy coupled to the inner ear structures, and (b) preexisting hearing loss, which could imply that less additional loss would occur if the sensitive structures have already been damaged. Support for these hypotheses has been modest, in the case of the transfer function, because little empirical work has been done to test that hypothesis, and, in the case of reduced sensitivity, because several studies disagree. In general, when there is a difference in average loss to a given noise exposure, those ears with previous PTS or TTS have shown somewhat less additional loss than those not previously exposed.

Findings have sometimes implicated degree of pigmentation, both of the receptor structures (melanization) and of the eye and skin, as related to susceptibility. However, these results too are equivocal.

Gender

There is little difference in hearing thresholds between young male and female children. Between ages 10 and 20, males begin to show reduced high-frequency auditory sensitivity relative to females. Women continue to demonstrate better hearing than men into advanced age. These gender differences are probably due to greater exposure of males to noise rather than to their inherent susceptibility to its effects.

Differences Within Individuals

Ototoxic drugs

Among the causes of differences of susceptibility to noise exposure *within* individuals are ototoxic drugs and other chemicals. In animal research, certain antibiotics (aminoglycosides) appear to exacerbate the damaging effects of noise exposure. Clinical evidence of corresponding effects in human patients has not been established, but precautions should be taken with regard to noise exposures of individual patients treated with these medications. Although high doses of aspirin are widely known to cause TTS and tinnitus, aspirin has *not* been shown to increase susceptibility to NIHL.

Age

In certain animal models there is evidence of heightened susceptibility to noise exposure shortly after birth — a “critical period” (possibly following the time when fluids fill the middle ear but before complete development of the cochlear structures). However, it is *not* clear that data from such animal models can be generalized to full-term normal human infants. Premature infants in noisy environments (e.g. neonatal intensive care units), however, may be at risk.

At the other extreme, increasing age has been hypothesized to be associated with decreasing susceptibility. This contention is based on the existence of presbycusis, hearing loss that increases with age and that is *not* known to be attributable to excessive noise exposure or other known etiology. The typical levels of presbycusis at various ages have recently been incorporated as Annex A in International Standards Organization Standard 1999.2 (1989). That standard may be used to estimate the portion of overall hearing loss that is attributable to exposure to excessive noise.

In summary, scientific knowledge is currently inadequate to predict that any individual will be safe in noise that exceeds established damage-risk criteria, nor that specific individuals will show greater-than-average loss following a given exposure. Among the many proposed explanations, the hypothesis that the resonant and transmission properties of the external and middle ear affect individual susceptibility deserves further attention. Empirical support for this hypothesis should not be difficult to obtain, but very few data have been collected on this question, both for TTS (experimentally) and PTS (retrospectively). Differences in susceptibility of the cochlear structures to NIHL may exist, but no practical approach to predicting them is yet available. Identification of susceptible humans will almost certainly be delayed until a successful animal model is available.

WHAT CAN BE DONE TO PREVENT NOISE-INDUCED HEARING LOSS?

Noise-induced hearing loss occurs every day — in both occupational and nonoccupational settings. The crucial questions for prevention are as follows: (1) What can individuals do to protect themselves from NIHL? (2) What role should others, such as educators, employers, or the Government, play in preventing NIHL? (3) What general strategies should be employed to prevent NIHL? Answers to these questions have long been known, but solutions have not been effectively implemented in many cases. As a result, many people have needlessly suffered hearing loss.

Individual Protection Strategies

Hearing conservation must begin by providing each individual with basic information. NIHL is insidious, permanent, and irreparable, causing communication interference that can substantially affect the quality of life. Ringing in the ears and muffling of sounds after sound exposure are indicators of potential hazard. Dangerous sound exposures can cause significant damage without pain, and hearing aids do not restore normal hearing. Individuals should become aware of loud noise situations and avoid them if possible or properly use hearing protection. It is important to recognize that both the level of the noise and its duration (i.e., exposure) contribute to the overall risk. Certain noises, such as explosions, may cause immediate permanent damage.

Many sources, such as guns, power tools, chain saws, small airplanes, farm vehicles, firecrackers, some types of toys, and some medical and dental instruments may produce dangerous exposures. Music concerts, car and motorcycle races, and other spectator events often produce sound levels that warrant hearing protection. Similarly, some stereo headphones and loudspeakers are capable of producing hazardous exposures. Parents should exercise special care in supervising the use of personal headset listening devices, and adults and children alike should learn to operate them at safe volume settings.

Nonoccupational Strategies

Hearing loss from nonoccupational noise is common, but public awareness of the hazard is low. Educational programs should be targeted toward children, parents, hobby groups, public role models, and professionals in influential positions such as teachers, physicians, audiologists and other health care professionals, engineers, architects, and legislators. In particular, primary health care physicians and educators who deal with young people should be targeted through their professional organizations. Consumers need guidance and product noise labeling to assist them in purchasing quieter devices and in implementing exposure reduction strategies. The public should be made aware of the availability of affordable, effective hearing protectors (ear plugs, ear muffs, and canal caps). Hearing protection manufacturers should supply comprehensive instructions concerning proper protector use and also be encouraged to increase device availability to the public sector. Newborn nurseries, including neonatal intensive care units, should be made quieter. Medical and dental personnel should be trained to educate their patients about NIHL.

Individuals with significant noise exposure need counseling. Basic audiometric evaluations should be widely available. The goal is to detect early noise-induced damage and interrupt its progression *before* hearing thresholds exceed the normal range.

Occupational Strategies

Hearing conservation programs for occupational settings must include the following interactive components: sound surveys to assess the degree of hazardous noise exposure, engineering and administrative noise controls to reduce exposures, education to inform at-risk individuals why and how to prevent hearing loss, hearing protection devices (earplugs, earmuffs, and canal caps) to reduce the sound reaching the ear, and audiometric evaluations to detect hearing changes. Governmental regulations that currently apply to most noisy industries should be revised to encompass *all* industries and all employees, strengthened in certain requirements, and strictly enforced with more inspections and more severe penalties for violations.

Many existing hearing conservation programs remain ineffective due to poor organization and inadequately trained program staff. Senior management must use available noise controls, purchase quieter equipment, and incorporate noise reduction in planning new facilities. Noise exposures must be measured accurately and the degree of hazard communicated to employees. Hearing protection devices must be available that are comfortable, practical for the demands of work tasks, and provide adequate attenuation. Labeled ratings of hearing protector attenuation must be more realistic so that the degree of protection achieved in the workplace can be properly estimated. Each employee must be individually fitted with protectors and trained in their correct use and care. Employees need feedback about their audiometric monitoring results annually.

Employers need to monitor program effectiveness by using appropriate techniques for analysis of group audiometric data. By detecting problem areas, managers can prioritize resource allocations and modify company policies to achieve effectiveness. Potential benefits include reduced costs for worker's compensation, enhanced worker morale, reduced absenteeism, fewer accidents, and greater productivity.

Enactment of uniform regulations for awarding worker's compensation for occupational hearing loss would stimulate employers' interest in achieving effective hearing conservation programs. Equitable criteria for compensability should be developed based on scientific investigations of the difficulties in communication and other aspects of auditory function encountered in everyday life by persons with differing degrees of NIHL.

General Strategies

Both nonoccupational and occupational NIHL could be reduced by implementing broader preventive efforts. Labeling of consumer product noise emission levels should be enforced according to existing regulations. Incentives for manufacturers to design quieter industrial equipment and consumer goods are needed along with regulations governing the maximum emission levels of certain consumer products, such as power tools. Reestablishment of a Federal agency coordinating committee with central responsibility for practical solutions to noise issues is essential. Model community ordinances could promote local planning to control environmental noise and, where feasible, noise levels at certain spectator events. High-visibility media campaigns are needed to develop public awareness of the effects of noise on hearing and the means for self-protection. Prevention of NIHL should be part of the health curricula in elementary through high schools. Self-education materials for adults should be readily available.

WHAT ARE THE DIRECTIONS FOR FUTURE RESEARCH?

The panel recommends that research be undertaken in two broad categories: (1) Studies that use existing knowledge to prevent NIHL in the immediate future, and (2) research on basic mechanisms to prevent NIHL in the long-term future.

- Development of rationale and collection of empirical data to evaluate systems for combining sound level and duration to predict NIHL.
- Longitudinal studies to further delineate responses of the ear to noise over time in different groups of people with varying levels of exposure.
- Continued investigation of engineering noise measurement and control techniques, such as acoustic intensity measurement, active noise-cancellation systems, and cost-benefit analyses of noise reduction.
- Development and investigation of hearing protector designs that provide improved wearer comfort, usability, and more natural audition.

- Development of repeatable laboratory procedures that incorporate behavioral tests to yield realistic estimates of hearing protector attenuation performance that are accepted for device labeling purposes.
- Empirical evaluation of the efficacy of hearing conservation programs and the field performance of hearing protection devices in industry.
- Development and validation of evaluation techniques for detection of the following: a) subtle changes in hearing resulting from noise exposure and b) early indicators of NIHL.
- Determination of the pathophysiological correlates of TTS and PTS.
- Investigation of the anatomic and physiologic bases of presbycusis and interactive effects with NIHL.
- Investigation of genetic bases for susceptibility to NIHL, using contemporary techniques, including molecular biology.
- Further studies of drugs (e.g., vasodilating agents) and other pre-exposure conditions (e.g., activation of efferent systems or exposure to “conditioning” noise) that have been suggested in preliminary reports to protect the inner ear from NIHL and elucidation of the underlying mechanisms.
- Investigation into the physiologic mechanisms underlying the synergistic effects of certain drugs and noise exposure in animal models.

CONCLUSIONS AND RECOMMENDATIONS

- Sounds of sufficient intensity and duration will damage the ear and result in temporary or permanent hearing loss at any age.
- NIHL is characterized by specific anatomic and physiologic changes in the inner ear.
- Sounds with levels less than 75 dB(A), even after long exposures, are unlikely to cause permanent hearing loss.
- Sounds with levels above 85 dB(A) with exposures of 8 hours per day will produce permanent hearing loss after many years.
- There is a broad range of individual differences among people in the amount of hearing loss each suffers as a result of identical exposures.
- Current scientific knowledge is inadequate to predict that any particular individual will be safe when exposed to a hazardous noise.

- Because sources of potentially hazardous sound are present in both occupational and nonoccupational settings, personal hearing protection should be used when hazardous exposures are unavoidable.
- Vigorous enforcement of existing regulations, particularly for the workplace and consumer product labeling, would significantly reduce the risk of workplace NIHL. Regulations should be broadened to encompass all employees with hazardous noise exposures.
- Application of existing technologies for source noise control, especially in the manufacture of new equipment and construction of new facilities, would significantly reduce sound levels at the ear.
- In addition to existing hearing conservation programs, a comprehensive program of education regarding the causes and prevention of NIHL should be developed and disseminated, with specific attention directed toward educating school-age children.

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N I D C D

FACT SHEET

Noise-Induced Hearing Loss

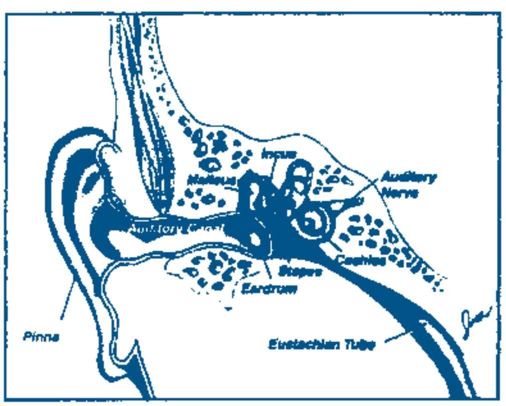
What Is Noise-Induced Hearing Loss?

Every day we experience sound in our environment, such as the television, radio, washing machine, automobiles, buses, and trucks. But when an individual is exposed to harmful sounds—sounds that are too loud or loud sounds over a long time—sensitive structures of the inner ear can be damaged, causing Noise-Induced Hearing Loss (NIHL).

More than 30 million Americans are exposed to hazardous sound levels on a regular basis. Individuals of all ages, including children, adolescents, young adults, and older people, can develop NIHL.

How Do We Hear?

Hearing is a series of events in which the ear converts sound waves into electrical signals and causes nerve impulses to be sent to the brain, where they are interpreted as sound. The ear has three main parts: the outer, middle, and inner ear. Sound waves enter through the outer ear and reach the middle ear, where they cause the eardrum to vibrate. The vibrations are transmitted through three tiny bones in the middle ear called the ossicles. These three bones are named the malleus, incus, and stapes (and are also known as the hammer, anvil, and stirrup). The eardrum and ossicles amplify the vibrations and carry them to the inner ear. The stirrup transmits the amplified vibrations through the oval window and into the fluid that fills the inner ear. The vibrations move through fluid in the snail-shaped hearing part of the inner ear (cochlea) that contains the hair cells. The fluid in the cochlea moves the top portion of the hair cells, called the hair bundle, which initiates the changes that lead to the production of the nerve impulses. These nerve impulses are carried to the brain, where they are interpreted as sound. Different sounds move the population of hair cells in different ways, thus allowing the brain to distinguish among various sounds, for example, different vowel and consonant sounds.



What Sounds Cause NIHL?

NIHL can be caused by a one-time exposure to loud sound as well as by repeated exposure to sounds at various loudness levels over an extended period of time. The loudness of sound is measured in units called decibels. For example, usual conversation is approximately 60 decibels, the humming of a

(over)

refrigerator is 40 decibels, and city traffic noise can be 80 decibels. Examples of sources of loud noises that cause NIHL are motorcycles, firecrackers, and small arms fire, all emitting sounds from 120 to 140 decibels. Sounds of less than 75 decibels, even after long exposure, are unlikely to cause hearing loss.

Exposure to harmful sounds causes damage to the sensitive hair cells of the inner ear and to the nerve of hearing. These structures can be injured by noise in two different ways: from an intense brief impulse, such as an explosion, or from continuous exposure to noise, such as that in a woodworking shop.

What Are the Effects of NIHL?

The effect from impulse sound can be instantaneous and can result in an immediate hearing loss that may be permanent. The structures of the inner ear may be severely damaged. This kind of hearing loss may be accompanied by tinnitus, an experience of sound like ringing, buzzing, or roaring in the ears or head, which may subside over time. Hearing loss and tinnitus may be experienced in one or both ears, and tinnitus may continue constantly or intermittently throughout a lifetime.

The damage that occurs slowly over years of continuous exposure to loud noise is accompanied by various changes in the structure of the hair cells. It also results in hearing loss and tinnitus. Exposure to impulse and continuous noise may cause only a temporary hearing loss. If the hearing recovers, the temporary hearing loss is called a temporary threshold shift. The temporary threshold shift largely disappears within 16 hours after exposure to loud noise.

Both forms of NIHL can be prevented by the regular use of hearing protectors such as earplugs or earmuffs.

What Are the Symptoms of NIHL?

The symptoms of NIHL that occur over a period of continuous exposure increase gradually. Sounds may become distorted or muffled, and it may be difficult for the person to understand speech. The individual may not be aware of the loss, but it can be detected with a hearing test.

Who Is Affected by NIHL?

More than 30 million Americans are exposed to hazardous sound levels on a regular basis. Ten million Americans have suffered irreversible NIHL. Individuals of all ages, including children, adolescents, young adults, and older people, can develop NIHL. Exposure occurs in the workplace, in recreational settings, and at home. There is an increasing awareness of the harmful noises in recreational activities, for example, target shooting or hunting, snowmobiles, go-carts, woodworking and other hobby equipment, power horns, cap guns, and model airplanes. Harmful noises at home may come from vacuum cleaners, garbage disposals, lawn mowers, leaf blowers, and shop tools. People who live in either urban or rural settings may be exposed to noisy devices on a daily basis.

N I D C D

FACT SHEET

Can NIHL Be Prevented?

NIHL is preventable. All individuals should understand the hazards of noise and how to practice good hearing health in everyday life.

- Know which noises can cause damage (those above 75 decibels).
- Wear earplugs or other hearing protective devices when involved in a loud activity (special earplugs and earmuffs are available at hardware stores and sporting good stores).
- Be alert to hazardous noise in the environment.
- Protect children who are too young to protect themselves.
- Make family, friends, and colleagues aware of the hazards of noise.
- Have a medical examination by an otolaryngologist, a physician who specializes in diseases of the ears, nose, throat, head, and neck, and a hearing test by an audiologist, a health professional trained to identify and measure hearing loss and to rehabilitate persons with hearing impairments.

What Research Is Being Done for NIHL?

Scientists focusing their research on the mechanisms causing NIHL hope to understand more fully the internal workings of the ear, which will result in better prevention and treatment strategies. For example, scientists have discovered that damage to the structure of the hair bundle of the hair cell is related to temporary and permanent loss of hearing. They have found that when the hair bundle is exposed to prolonged periods of damaging sound, the basic structure of the hair bundle is destroyed and the important connections among hair cells are disrupted, which directly lead to hearing loss.

Other studies are investigating potential drug therapies that may provide insight into the mechanisms of NIHL. For example, scientists studying altered blood flow in the cochlea are seeking the effect on the hair cells. They have shown reduced cochlear blood flow following exposure to noise. Further research has shown that a drug that promotes blood flow and is used for treatment of peripheral vascular disease (any abnormal condition in blood vessels outside the heart) maintains circulation in the cochlea during exposure to noise. These findings may lead to the development of treatment strategies to reduce NIHL.

Continuing efforts will provide opportunities that can aid research on NIHL as well as other diseases and disorders that cause hearing loss. Research is the way to develop new, more effective methods to prevent, diagnose, treat, and eventually eliminate these diseases and disorders and improve the health and quality of life for all Americans.

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APPENDIX B

The article, “The Consequences of Untreated Hearing Loss in Older Persons”, from the National Council on the Aging is used with permission from the National Council on the Aging

NCOA Research

The Consequences of Untreated Hearing Loss in Older Persons

May 1999
Study conducted by the Seniors Research Group
An alliance between The National Council on the Aging and Market Strategies Inc.

Introduction

Hearing loss is one of the most prevalent chronic conditions in the United States. More than nine million Americans over the age of 65 have a hearing loss. More than 10 million middle-aged Americans (between the ages of 45 and 64) have a hearing loss. (Between 1971 and 1990, hearing loss in this age group increased by 26 percent, according to the National Health Interview Survey.) Six out of seven middle-aged Americans with hearing loss do not use hearing aids. About three out of five older Americans with hearing loss don't use hearing aids.

Despite the prevalence of hearing loss among older Americans, relatively little is known about the effect of hearing loss and the impact of treatment (i.e. using a hearing aid) on the quality of their lives.

About the NCOA Study

A review of previous studies pointed to the need for a large-scale, national survey to document the effect of hearing loss and lack of treatment among older Americans with hearing impairments. NCOA commissioned the Seniors Research Group (an alliance between NCOA and Market Strategies Inc.) to conduct a large-scale, national survey of older Americans that would quantify the social, psychological, and functional effects of hearing loss.

The goal of the study was to assess the effects of hearing loss on quality of life and compare these effects for those who wear hearing aids and those who do not. Respondents in the survey included hearing aid users, hearing-impaired seniors who do not use hearing aids (non-users), and significant others (spouse, close family member, or best friend of the hearing-impaired respondent). A total of 2,304 hearing-impaired people responded and an additional 2,090 family members or close friends responded to a parallel questionnaire that asked about the hearing-impaired person. The National Council on the Aging (NCOA) received an unrestricted grant from the Hearing Industries Association to conduct this research.

Some of the specific objectives for the survey include the following:

- Measure the effect of untreated hearing loss on quality of life among the hearing impaired
- Compare perceptions of the hearing impaired with family members
- Identify the reasons that those with hearing impairments do not seek treatment
- Assess the impact of using hearing aids on the quality of life of users

Results

Older people with hearing impairments that go untreated suffer many negative effects. Compared to older, hearing-impaired people who use aids, those who do not use hearing aids are more likely to report:

- sadness and depression
- worry and anxiety
- paranoia
- less social activity
- emotional turmoil and insecurity

These differences remain when controlling for other factors such as the respondent's age, gender, and income.

On the other hand, seniors whose hearing loss is treated often report benefits that include:

- better relationships with their families
- better feelings about themselves
- improved mental health
- greater independence and security

How Data is Reported

This summary report divides the survey responses by several categories. First, it divides the older, hearing-impaired respondents into users and non-users of hearing aids. This summary also divides respondents into levels of hearing loss-"milder" and "more severe." The study rated respondents' severity of hearing loss based on their answers to a modified version of the five-minute hearing test developed by the American Academy of Otolaryngology, which measures self-reported responses to such statements as, "I miss hearing some common sounds like the phone ringing or doorbell ring." Using the resulting severity scores, respondents were divided into five equally sized groups (quintiles) ranging from least to most severe. To simplify the results, this summary of data collapsed the responses into just two severity levels: "milder" and "more severe." The "milder" level was created by combining the two lowest quintiles, which represents the least hearing loss severity. The "more severe" level was created by combining the top three quintiles for hearing loss severity.

Sadness, Depression

Respondents who do not use hearing aids were more likely than hearing aid users to report that there had been a period of two weeks or more in the past year during which they felt "sad, blue, or depressed." This difference remains when controlling for other factors such as the respondents' age and income. The percentage of those reporting depression increases with the severity of their hearing loss (see Figure 1).

FIGURE 1
FELT SAD OR DEPRESSED FOR TWO OR MORE WEEKS DURING PAST YEAR

Level of Hearing Loss	Use Hearing Aid	Don't Use Hearing Aid
Milder	14%	23%
More Severe	22%	30%

Question 22

Worry, Anxiety

Examining responses to several questions about worry and anxiety, the study found that respondents who do not use hearing aids were more likely to report these feelings than users. For example, non-users were more likely to say there had been a period lasting a month or longer during the past year when they felt worried, tense, or anxious (see Figure 2).

FIGURE 2
FELT WORRIED, TENSE, ANXIOUS FOR MONTH OR MORE DURING THE PAST YEAR

Level of Hearing Loss	Use Hearing Aid	Don't Use Hearing Aid
Milder	7%	12%
More Severe	12%	17%

Question 26

Less Social Activity

Social isolation is a serious problem for many older people who gradually lose vital contacts with their family, friends, and neighbors. The study shows that hearing-impaired seniors who don't use hearing aids participated significantly less in organized social activity, compared to users. Among those with milder hearing loss, non-users were more than 20 percent less likely than users to regularly participate in social activities. Among respondents with more severe hearing loss, non-users were more than 24 percent less likely to participate in social activities (see Figure 3).

FIGURE 3
PARTICIPATE REGULARLY IN SOCIAL ACTIVITIES

Level of Hearing Loss	Use Hearing Aid	Don't Use Hearing Aid
Milder	47%	37%
More Severe	42%	32%

Non-users were also less likely to participate in senior center activities (see Figure 4).

FIGURE 4
PARTICIPATE IN SENIOR CENTER ACTIVITIES

Level of Hearing Loss	Use Hearing Aid	Don't Use Hearing Aid
Milder	24%	15%
More Severe	21%	16%

Paranoia

Another measure of an emotional distress is the perception that “other people get angry at me for no reason,” which psychologists often identify as an indicator of paranoia. People with untreated hearing problems may well sense anger directed at them “for no reason” as they misinterpret what they hear or as they have to ask people to repeat what they are saying. As Figure 5 shows, those who do not use hearing aids were nearly twice as likely to agree that “people get angry with me for no reason.” Among those with more severe hearing loss, the difference between users and non-users is even greater (14 percent of users agreed, vs. 36 percent of non-users agreed with the statement).

FIGURE 5
PEOPLE GET ANGRY WITH ME USUALLY FOR NO REASON

Level of Hearing Loss	Use Hearing Aid	Don’t Use Hearing Aid
Milder	13%	24%
More Severe	14%	36%

Question 12-5

Emotional Turmoil

Seniors with untreated hearing loss also reported a greater tendency to describe themselves as feeling insecure, irritable, fearful, or tense — especially those with more severe levels of hearing loss. Among seniors with more severe hearing loss, 11 percent of hearing aid users said the word “insecure” describes them, compared to 17 percent of non-users (Figure 6).

FIGURE 6
THE TERM “INSECURE” DESCRIBES ME

Level of Hearing Loss	Use Hearing Aid	Don’t Use Hearing Aid
Milder	8%	10%
More Severe	11%	17%

Benefits of Treatment

On the other hand, most users of hearing aids reported significant improvements in the quality of their lives since they began to use hearing aids. Half or more reported better relationships at home and improved feelings about themselves. Many also reported improvements in their confidence, independence, relations with children and grandchildren, and view about life overall (Figure 7).

Along every dimension, family members of the hearing-impaired person were even more likely to report improvements. The majority of family respondents reported that use of hearing aids had resulted in improvements in their relative in terms of relations at home, feelings about themselves, life overall, and relations with children or grandchildren.

FIGURE 7
PERCENTAGE OF USERS AND FAMILY MEMBERS REPORTING IMPROVEMENTS FROM USING HEARING AIDS

	All	All	Milder Loss		More Severe	
Improvement	**Users**	**Family**	**Users**	**Family**	**Users**	**Family**
Relationships at home	56%	66%	44%	59%	60%	68%
Feelings about myself	50%	60%	40%	54%	53%	61%
Life overall	48%	62%	33%	53%	53%	64%
Mental health	36%	39%	29%	37%	38%	39%
Self-confidence	39%	46%	28%	35%	42%	48%
Relationships w/children, grandchildren	40%	52%	28%	44%	43%	53%
Participate in group activities	34%	44%	23%	33%	37%	47%
Sense of independence	34%	39%	27%	30%	36%	41%
Sense of safety	34%	37%	25%	32%	37%	38%
Play card/board games	31%	47%	25%	39%	33%	49%
Social life	34%	41%	27%	28%	36%	45%
Physical health	21%	24%	21%	21%	21%	25%
Dependence on others	22%	31%	17%	26%	24%	32%
Relationships at work	26%	43%	19%	37%	28%	45%
Ability to play sports	7%	10%	8%	11%	7%	9%
Sex life	8%	N/A	4%	N/A	9%	N/A

Barriers to Treatment

Denial and Cost

Why would someone with hearing loss not use a hearing aid or not seek medical advice? Among non-users, the most common reason cited for not using a hearing aid was their belief that they do not need hearing aids (see Figure 8). Even among those non-users who characterized their hearing loss as severe or profound, more than half denied needing hearing aids. Others cited the expense, their belief that hearing aids do not work, lack of confidence in professionals who treat hearing loss, and the stigma of wearing hearing aids.

FIGURE 8
REASONS FOR NOT USING HEARING AIDS

	All	More Severe	Milder Loss
Denial			
My hearing isn't bad enough	69%	64%	73%
I can get along without one	68%	55%	78%
Consumer Concerns			
They are too expensive	55%	64%	48%
They won't help with my specific problem	33%	36%	31%
I've heard they don't work well	28%	31%	26%
I don't trust hearing specialists	25%	29%	22%
I tried one and it didn't work	17%	20%	15%
Stigma/Vanity			
It would make me feel old	20%	22%	18%
I don't like the way they look	19%	21%	18%
I'm too embarrassed to wear one	18%	21%	16%
I don't like what others will think about me	16%	19%	15%

Implications

Understand the Effects on Individuals

Untreated hearing loss among older persons is a serious and prevalent problem. The study found that from the mildest to the most severe hearing loss level, hearing-impaired older persons who do not wear hearing aids are more likely to experience depression, anxiety, paranoia and emotional turmoil, compared to people who wear hearing aids.

On the other hand, hearing-impaired older persons who do use hearing aids are more likely than non-users to be involved socially in their neighborhoods, in organized social activities, and at senior centers. Most hearing aid users report significant benefits from the aids — in family relationships, mental health, and other areas that affect the quality of their lives. In all categories, family members observe even greater benefits from the use of hearing aids than do the users themselves.

Denial is the most important barrier to hearing aid use. Most hearing-impaired older persons who don't use hearing aids think they don't need them or can get by without them. Cost considerations and vanity are also significant barriers for many older persons.

Increase Family Awareness

Hearing loss affects not only the hearing-impaired person, but often their families as well. Families should be aware of and alert to the potential consequences of untreated hearing loss as well as the benefits of using hearing aids. Family members who suspect that a relative has a hearing loss should actively encourage the person to seek appropriate screening, diagnosis, and treatment.

Raise Awareness among Healthcare Professionals

Because of the potential negative consequences of untreated hearing loss on a person's quality of life and family relationships, hearing loss should be a routine topic of discussion for older persons and their doctors. Physicians and other allied health professionals should encourage older people who are suspected of having a hearing loss to seek appropriate screening, diagnosis, and treatment. Health professionals should also be aware that many older adults with significant hearing impairments tend to deny the extent of their hearing loss and to believe that they do not need treatment. A simple five-minute questionnaire administered to patients could help identify patients in need of referral to a hearing specialist.

Method

In 1998, The National Council on the Aging (NCOA) commissioned the Seniors Research Group to conduct a survey of Americans age 50 and older to determine the effects of hearing loss in their lives. A total of 2,304 hearing-impaired people age 50 and older responded to the mail questionnaire — a response rate of more than 75 percent of the 3,000 persons contacted.

The survey is unique in several respects. It is the largest survey of its kind; it is national in scope and profile; and it systematically includes middle-aged and older men and women who have both treated and untreated hearing loss.

Also, this study is the first hearing loss study to directly measure attitudes and perceptions of other family members. Each hearing-impaired respondent was asked to have a family member respond to a set of questions that parallels the questionnaire filled out by the hearing-impaired person. A total of 2,090 family respondents returned the questionnaire.

The sample of 3,000 hearing-impaired respondents age 50 and older was drawn from the Knowles Electronics 1997-1998 MarkeTrak IV Survey database, conducted using the National Family Opinion Consumer Household Sample.

Other Studies

There have been several small-scale studies that documented negative social and emotional effects that result from lack of treatment for hearing loss. Lack of treatment has been linked to a reduction in effective social functioning (Weinstein & Ventry, 1982), diminished psychological well-being (Thomas & Herbst, 1980; Dye & Peak, 1983), lower self-esteem (Harless & McConnell, 1982), and a reduction in general quality of life (Mulrow, Aguilar, Endicott, et al., 1990; Carabellese, Appollonio, Rozzini, et al., 1993; Bridges & Bender, 1998).

However, the sample sizes in these studies were relatively small, ranging in size from 20 to 251. Some studies looked at matched groups of participants, one group with hearing aids and one without to measure effects. Others were longitudinal studies based on an experimental intervention design with treated and untreated groups followed over time.

Hearing Impairment

Independent Study Test Questions for CME Credit

1. **Veterans are more likely to suffer hearing loss because of their:**
   a) Military experience
   b) Employment history
   c) Age
   d) All of the above

2. **Which is <u>not</u> a disease of the inner ear:**
   a) Noise-induced hearing loss
   b) Otoxicity
   c) Otitis media
   d) Presbycusis

3. **The sensory cells in the inner ear are called:**
   a) Giant cells
   b) Hair cells
   c) Pukinje cells
   d) Glial cells

4. **Which type of hearing loss is <u>not</u> measured by routine hearing tests:**
   a) Conductive hearing loss
   b) Sensorineural hearing loss
   c) Mixed hearing loss
   d) Central hearing loss

5. **What is the most common source of <u>preventable</u> hearing loss?**
   a) Noise
   b) Ototoxicity
   c) Aging
   d) Congenital defects

6. **According to patient surveys, which provider is the most important source of health information on hearing loss:**
   a) ENT physician
   b) Pediatrician
   c) Audiologist
   d) Primary Care Physician

7. **What percentage of primary care physicians routinely screen for hearing loss:**
   a) 18%
   b) 30%
   c) 50%
   d) 75%

8. **Which is not a symptom of otoxicity:**
   a) Hearing loss
   b) Ear pain
   c) Dizziness
   d) Tinnitus

9. **For patients on cisplatin, risk of hearing loss is related to:**
   a) Eye pigmentation
   b) Dose
   c) Kidney function
   d) All of the above

10. **What is the most important preventive action you can take for patients on ototoxic medications or therapeutics:**
   a) Baseline audiogram before administration
   b) Wait for the patient to complain of hearing loss or tinnitus and adjust the dose
   c) Treat the patient because cancer treatment is more important than hearing
   d) Hearing test after administration to check for hearing loss

11. **What percentage of hearing loss is avoidable in occupational settings:**
    a) 20%
    b) 100%
    c) 75%
    d) 50%

12. **Noise causes significant effects including:**
    a) Hearing loss
    b) Anxiety
    c) Fatigue
    d) All of the above

13. **Noise-induced hearing loss can cause damage to the inner ear. This damage is:**
    a) Usually temporary and will recover
    b) Not preventable, but can be treated with medication
    c) Preventable, but not treatable
    d) Rare, but a permanent condition

14. **Noise-induced hearing loss can produce serious quality of life problems. Such problems:**
    a) Are not treatable except with counseling
    b) Are amenable to medication or surgery
    c) Can be helped by hearing aids and aural rehabilitation
    d) Are rare in children and aged adults, but common among working adults

15. **Noise-induced hearing loss is rarely associated with tinnitus.**
    a) True
    b) False

16. **Noise-induced hearing loss may occur:**
    a) Over many years after long-term exposure
    b) Instantaneously, even with one exposure
    c) A and B
    d) Only in occupational situations

17. **Which inner ear structures are most likely to be affected by noise exposure:**
    a) Inner hair cells
    b) Outer hair cells
    c) Deiters cells
    d) Neural dendrites

18. **When counseling a patient about hearing loss, the patient should be told:**
    a) Hearing loss is permanent and nothing can be done about it
    b) Learn to live with it
    c) Hearing loss is treatable by effective amplification and rehabilitation
    d) To return in a year and see if the condition resolves itself

19. **What effects might you see if hearing loss is not treated:**
    a) Sensory deprivation
    b) Psychological changes
    c) Diminished quality of life
    d) All of the above

20. **When is a cochlear implant appropriate:**
    a) Patient doesn't benefit from traditional amplification
    b) Patient has severe to profound hearing loss and limited speech recognition
    c) A and B
    d) Patient has hearing loss due to severe, chronic middle-ear disease