Noise-Induced Hearing Loss: A Preventable Occupational Disease

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DR. TOM GLADFELTER *(Assistant Professor, Department of Family Medicine)*: Hearing loss is a common problem encountered in the practice of family physicians. We tend to consider hearing loss in a majority of patients to be due to the aging process, but this is not always true. Hearing loss is often due to a variety or combination of causes, which may require multiple disciplinary approaches for the diagnosis and management, particularly for hearing loss suspected to be noise induced and related to employment. Under this circumstance, the patient, the employer, the community, and the law courts are involved in the proper evaluation and disposition of the case in an interrelated fashion. Noise-induced hearing loss is the kind of health problem that the family physician can contribute to preventing in an important way, from acting as advisor to the patient (who is frequently the employee) for his personal health care to acting as advisor to the employer in the administration and supervision of planning a hazard-free work environment. Without full awareness of all possible ramifications and without careful planning, it is possible for physicians to provide less than optimal management of a case and find themselves caught in a legal dispute. In the following discussion, we will focus on noise-induced hearing loss (NIHL) related to occupation or work exposure.

Dr. Alexiou, the Director of the Regional Center for Occupational Safety and Health at the University of South Florida College of Medicine, will provide a briefing on the basics of noise trauma and the requirements of law.

DR. NICHOLAS ALEXIOU *(Assistant Professor, Department of Comprehensive Medicine)*: Hearing loss is becoming an increasingly important health hazard of concern to family physicians because of the relative increased intensity and duration of worker exposure to noises associated with industrial societies. Although hearing loss can occur from a variety of insults, the noise-induced hearing loss is the matter of current concern.

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Acoustic trauma occurs in the wedge-shaped organ of Corti in the cochlea of the ear. This structure, resting on the basilar membrane, has three outer rows and one inner row of hair cells with the tectorial membrane suspended above them. The hair cells have stereocilia projecting toward the tectorial membrane. The energy of sound causes vibration of these cilia; this vibration is then coded into nerve impulses in the acoustic nerve located beneath the hair cells. These hair cells are quite susceptible to the trauma of loud noise. Noise-induced anatomic changes are seen in the cell bodies, which swell and eventually are destroyed.[1-3] Once destroyed, they are lost forever, leading to loss of function. It is known that sound frequencies in the 1,000- to 4,000-Hz range are transmitted best to the cochlea, which partially explains the typical finding of greatest loss of hearing acuity at 4,000 Hz in acoustic trauma.[3]

Since the mid-1800s work-related hearing loss has been recognized by state legislators, who have set limitations to noise exposure. Federal legislation was passed creating the Noise Control Act of 1972. Attempts to publish a standard for noise control and hearing conservation programs for workers' health and safety have long been frustrated by a variety of interest groups. The Occupational Safety and Health Administration (OSHA) estimates that 1 million workers have noise-induced hearing loss in the United States.[4] Recently OSHA issued a final ruling requiring hearing conservation programs in work places.[5] Effective April 7, 1983, the ruling required employers to administer a hearing conservation program when employee noise exposure equaled or exceeded an 8-hour time-weighted average (TWA) sound level of 85 dB measured on the A scale (dBA). This ruling meant that unless engineering or administrative controls were effective, employees would be prohibited from working without protective hearing devices such as earmuffs or earplugs. The concept of the time-weighted average implies that louder noises could be tolerated for shorter exposure times. A scale was developed to guide directors of hearing conservation programs to help control the dose of noise exposure (Table 1). Workers can tolerate up to 80 dBA for 8 hours a day without developing hearing impairment, but when the level of 85 dBA or more is exceeded, increasing num-

TABLE 1. EQUIVALENT NOISE EXPOSURE OF DIFFERENT SOUND LEVELS AND THEIR DURATIONS

Sound Level (dBA)	Duration in Hours
90	8
92	6
95	4
97	3
100	2
102	1½
105	1
110	½
115	¼ or less

bers of workers will suffer hearing loss.

The law specified that if the sound level cannot be reduced below the 85-dBA level by engineering controls, the employers must monitor the environmental noise level and keep measurements for the record. To protect the hearing of workers, employers must measure workers' baseline hearing acuity with pure tone audiogram against which subsequent audiograms can be compared. Hearing protectors must be provided and workers must be trained in their use. The audiogram should be repeated annually and the records kept permanently. Employers must keep employee work-place noise-exposure records from obtained sound level measurements for two years. If a worker demonstrates a hearing loss when monitored audiometrically, it indicates that the current conservation program is not effective and additional measures need to be taken to prevent further loss of function.

It is now required that the baseline audiogram be conducted within six months of an employee's first exposure at or above the 85-dBA level. Pure tone audiometry should be performed at 500-, 1,000-, 2,000-, 3,000-, 4,000-, and 6,000-Hz testing frequencies by a licensed or certified audiologist, otolaryngologist, qualified physician, or by a technician who is certified by the Council of Accreditation on Occupational Hearing Conservation. It is important to remember before testing that the employee not be exposed to loud noise for at least 14 hours before the baseline audiogram is taken. This precaution is required to reduce the chance of recording a "temporary threshold shift" of the hearing acuity commonly seen after noise exposure. Ideally a baseline audiogram should be conducted for all employees prior to their employment, but the regulation allows the test to be performed as late as six months after employment. One can see a possible problem arising from this policy if high-frequency hearing loss is identified six months after a person has been working in a noisy environment.

I would like to share with you the experience in our own university screening program. Thirty-one university physical plant employees were given baseline audiograms for the first time in the early part of 1983. The results indicated that eight needed otolaryngological consultations because of severe or profound hearing loss. Twelve were advised to have a recheck in six months and 11 were considered normal. That means about 65 percent of workers had abnormal test results or results that suggested hearing loss. None of the workers had complained about hearing loss. It is difficult to say what the university's liability is because no pre-employment physical examinations were conducted that included a baseline audiogram for later comparison. The university is likely to be held responsible in two ways: as causing the loss, or as aggravating a preexisting condition. A private physician's audiogram record would be helpful to explain what had occurred. The value of work-place exposure records of noise levels is obvious to protect the employer and the employee's interests. If the exposure records indicate high ambient noise levels, the university will have difficulty avoiding responsibility, especially if it cannot prove that hearing loss existed before this employment.

This issue introduces the role of the family physician. In performing a preplacement or preemployment physical examination or in presenting ourselves as protectors of patients' health, it is important that we have good baseline information. A routine physical examination seldom includes a pure tone audiogram. Hearing function is usually assessed by striking a tuning fork, whispering words to the patient, or holding a wristwatch to the ear to assess grossly hearing acuity. This type of screening does not give a reliable or valid test. A valid audiogram is the only record that will stand up in court. If the audiometer test results are on the record, then the physician can serve to protect the interests of the patient.

To sum up, work-related hearing loss is a common problem in American society. With the new regulation, family physicians can no longer superficially examine the hearing function in the routine physical examination. They must obtain audiograms as part of their office medical examinations to protect the interests of their patients and to continue providing quality comprehensive care.

RESIDENT PHYSICIAN: What audiogram machines are accessible for use in the office setting?

DR. ALEXIOU: There are a variety of portable units that can be used for screening purposes. The cost of the machine is minimal, about $200 to $300.

RESIDENT PHYSICIAN: Are those reliable as screening devices?

DR. ALEXIOU: Definitely! But remember, as mentioned earlier, a test is valid only when it is done on patients who have been free from noise exposure for at least 14 hours, when it is administered by qualified personnel on calibrated equipment, and when it takes place in a controlled environment. A soundproof booth is required for diagnostic purposes, but not for a screening procedure. If findings suggest something abnormal using this type of inexpensive testing, it would be appropriate to refer the patient to an otolaryn-

gologist or audiologist for further workup. Referral in this case would mean suspecting a hearing loss of more than 25 decibels at 500, 1,000, or 2,000 Hz or other unusual irregularity.[6]

RESIDENT PHYSICIAN: How do we know whether there has been a significant change after a person has been working for some time and whether this is work related?

DR. ALEXIOU: A significant change is demonstrated by a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2,000-, 3,000-, and 4,000-Hz frequencies in either ear, or a 20-dB or more reduction at any frequency. There is an expected annual decrement of hearing acuity that is age related, which must be considered in evaluating a significant change in hearing acuity.[5,7] By the age of 60 years in man, there is about 10-dB average loss in hearing acuity in speech frequencies.

RESIDENT PHYSICIAN: If there is a change from the pre-employment and the follow-up audiogram, does the company check the lifestyle of the employee to see whether there are other factors causing the hearing loss?

DR. ALEXIOU: No, this is generally not done. The hearing loss is presumed to be work related, particularly if records document that the employee had been working in a 80- to 90-dBA environment or above. In such a case the company is liable, and the potential monetary award can be significant. Prevention is the real goal. An effective noise control program does not have to be expensive, but it should reduce noise levels to a TWA of 85 dBA or less. An inexpensive set of earplugs can attenuate noise levels that could cause damage, would cost about 5¢, and could be worn all day. Remember, the preferred additional control measures are (1) engineering controls to reduce the origin of the noise, (2) employee education programs to improve the awareness of employees of the need to wear protective devices, and (3) enforcement, which is the proper administration of the hearing protection program by supervisors. These are the three E's to remember.

DR. GLADFELTER: From the viewpoint of the family physician who conducts periodic or pre-employment physical examinations, the inclusion of an audiogram means additional cost for trained personnel, equipment, a quiet room or a soundproof booth, and the time required to conduct the test. The cost effectiveness of providing testing depends on the sound level exposure experienced by the patient. Audiograms are not routinely necessary for people working all day in a quiet office, but these baseline data are definitely needed for people who are going to work in noisy places, such as factories and construction sites. An inquiry into the occupational history will identify people at risk. It is also important to ask about a history of other symptoms often associated with noise trauma. Difficulty in hearing conversation in noisy places, transient tinnitus, or speech or other sounds muffled after work are important indicators of possible noise-induced hearing loss.[8] Patients often may not verbalize or volunteer such symptoms during physical examination, yet these are the symptoms we need to identify for an audiogram. Remember, however, that when these symptoms are present, permanent damage may have already occurred.

Next, let me introduce Dr. Saraceno, an otolaryngologist, who will discuss the clinical evaluation of hearing loss.

DR. CARMELO SARCENO *(Associate Professor, Department of Otolaryngology)*: What Dr. Alexiou has been talking about is becoming increasingly important in industrialized society; we can expect patients coming to us with chief complaints of hearing loss. Now how do we evaluate the complaint and identify those patients with NIHL?

I will limit my efforts to NIHL, presbycusis, otosclerosis, and drug-induced hearing loss in the following discussion. Patients with these disorders are often adults with few or no symptoms, their otoscopic examinations are often normal, and their disorder can be hard to differentiate by history and physical examination alone.

With the exception of otosclerosis, these disorders are due to sensorineural hearing loss with the pathology found in the inner ear—the cochlea and acoustic nerve, where the sound energy is encoded into nervous impulses. If you question patients closely, sensorineural hearing loss usually presents with the symptoms mentioned earlier by Dr. Gladfelter. Patients have difficulty in understanding when in crowded and noisy rooms, and there may be tinnitus. Both symptoms are common in sensorineural hearing loss. In contrast, otosclerosis is a conductive hearing loss, often found in young to middle-aged women. The pathology presents in the middle ear with sclerotic changes in the ossicles leading to a reduction of sound energy transmission to the inner ear. These patients can experience tinnitus, but they often have a lesser problem of hearing conversation in a crowded room; in fact, they may hear better, a phenomenon known as "paracusia willisiana."[9] It serves as a good indicator of otosclerosis or other conductive hearing losses.

Vertigo is another important symptom to look for, as it is one of the first presenting symptoms of inner-ear pathology. The labyrinth is part of the inner ear. Any etiological factor involving the cochlea will likely involve the labyrinth, and the patient will suffer from vertigo. Meniere's disease is a good example, with its characteristic triad of vertigo, hearing loss, and tinnitus.[10] Vertigo and high-pitched tinnitus are early signs of acoustic neuroma. Both are also frequently present with ototoxicity resulting from medicine or drugs. Seldom found in patients with NIHL and presbycusis, vertigo is important in discriminating Meniere's disease and ototoxicity of drugs from the other causes of sensorineural hearing loss.

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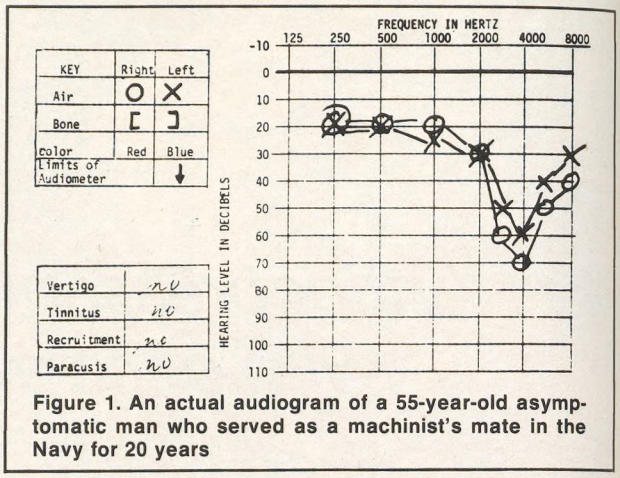

Figure 1. An actual audiogram of a 55-year-old asymptomatic man who served as a machinist's mate in the Navy for 20 years

I will mention briefly making a diagnosis based on otoscopic examination. In general, all patients with sensorineural hearing losses, including NIHL, have normal-appearing eardrums.[11] The same is true for otosclerosis, but occasionally by careful inspection it is possible to detect a few cases of otosclerosis by looking at the incus through the semitransparent tympanic membrane for a faint pink blush representing the increased vascularity in the otosclerotic bone (Schwartze's sign). The tuning fork is used in the physical examination for the Rinne and the Weber tests. These tests help locate the site or identify the type of hearing loss, but as Dr. Alexiou has pointed out, they should not be used to detect the degree of hearing loss.

With a pure tone audiogram, the degree of hearing loss can be quantitated for the various frequencies of sound. In otosclerosis, the hearing loss occurs in all frequencies when the sound stimulus is presented by the air. When the sound stimulus is presented to the bony surface of the patient, the hearing is improved, which explains the so-called air-bone gap seen in conductive hearing loss. In sensorineural hearing loss, hearing by air and bone conduction are about equal.

So how do we differentiate accurately the hearing loss of NIHL from that of presbycusis or ototoxicity of drugs? This audiogram shows what you should look for in the case of NIHL (Figure 1). Notice a dip at the 4,000-Hz frequency while the speech frequencies (500 to 2,000 Hz) are normal. The predominant loss of hearing acuity around 4,000 Hz with preservation of 8,000 Hz is typical of NIHL. Later on in the process of disease, when the hearing loss becomes progressively worse, the 4,000-Hz loss will become more pronounced and the lower speech frequencies and higher 8,000-Hz frequencies will also become affected.[12] In presbycusis, the pattern is an increased hearing loss in the higher frequencies, with a greater loss in 8,000-Hz than in 4,000-Hz range. If you see this pattern, then the presumptive diagnosis is presbycusis. To complicate the diagnosis, the audiometric finding of hearing loss

due to ototoxicity of drugs is similar to that of presbycusis. In such cases, we have to rely heavily on the medication history to make the differential diagnosis. The drugs known to cause hearing loss include aminoglycoside antibiotics, furosemide, and salicylates, all of which are familiar to us.[13,14] Fortunately, in most circumstances hearing loss that is due to drugs is reversible. It allows us a chance to withdraw the drug. A repeat audiogram should demonstrate improvement with drug withdrawal. In NIHL and presbycusis, however, the loss is permanent, and there is no change in the audiogram with repeated examinations.

The patient with a history of military service, working with noisy machinery, attending musical gatherings, especially to hear modern rock-and-roll music, or other occupational historical events that exposed him or her to high noise level may have developed hearing difficulty insidiously over the years. If the physical examination shows normal eardrums, and the audiogram has the typical dip at 4,000 Hz in both ears without air-bone gap, then you can generally make a fairly accurate diagnosis of NIHL. But you should raise questions if the hearing loss is unilateral. Since noise affects both ears, the impairment is always bilateral except in certain circumstances when each ear is exposed to different noise levels; firing a rifle is a good example. Once asymmetry is significant, other causes of hearing loss need to be evaluated. A disproportionately impaired ability to understand speech is usually diagnostic of an acoustic nerve pathology rather than cochlear pathology.[13]

Audiometric testing requires thorough cooperation from the patients. When the patient is not cooperative, tympanometry, which simply measures the middle-ear pressure and gives an indication of presence of middle-ear pathology,[11] such as fluid accumulation and otosclerosis, can be used. One part of tympanometry is the acoustic reflex, which tells whether the sensory neural level is grossly abnormal. This acoustic reflex measures the stapedius muscle contraction in the nontest ear when a loud sound is delivered to the ear being tested. If a reflex is recorded, the ear is obviously not totally deaf and the entire neural pathway is probably intact. The last diagnostic test I will mention is called auditory brain-stem response audiometry. It is similar to electroencephalography except that it tracks the brain-stem response to auditory stimuli.[11,15] It is especially valuable for people who complain about hearing loss and their audiometric test is not entirely normal or when legal matters are involved.

Otosclerosis is amenable to treatment by surgical procedures. There is no good treatment for sensorineural hearing loss. The only good treatment for NIHL is prevention by protection of the worker and altering the environment to eliminate the unwanted noise. It is very important, especially for the family physician, to treat any concurrent medical problem such as hypertension and diabetes mellitus, and not take for granted that the hearing loss is associated with the normal aging process. Aggressive therapy for a concurrent medical problem should at least prevent further deterioration of the hearing function.[16,17] This applies to the treatment of presbycusis as well.

For the patient with a disabling hearing loss, a hearing aid will sometimes provide relief. A patient with a high-frequency loss that has a mild effect on speech frequencies can be helped by a high-frequency gain aid.[18] However, if the patient has severe impairment in discriminating between words with close phonation, the likelihood of benefit from a hearing aid is greatly reduced. Tinnitus, which always accompanies mild to severe NIHL, can be sometimes treated by "tinnitus maskers." In this instance a less annoying noise is introduced to mask the presence of the tinnitus.

As a final reminder, when you have a patient with hearing loss, it is very important to sit down with the family members and explain what it means to not be able to hear. Frequently the family will believe the patient hears only what he wants to hear or may not hear when something is inconvenient. It is important for the physician to tell the family that the audiometric test shows the patient has impaired hearing and the family should be understanding and supportive. Sometimes patient and family can be helped to understand each other by attending speech reading courses for persons with different types of disorders in communications.

RESIDENT PHYSICIAN: What level of street noise can result in damage to hearing?

DR. ALEXIOU: Eighty decibels and above can result in hearing damage. There is individual variation, and sensitive individuals may be susceptible to damage at 80 decibels, but most of the population will be protected if they experience less than 85 decibels of sound level pressure.[19] For reference purposes, noise measurement in a quiet room will be about 40 dB, conversation at 3 feet will measure 60 dB, a home vacuum cleaner will measure 70 dB, a garbage disposal unit at 3 feet will measure 80 dB, a power lawn mower will measure at the operator's ear 100 dB, and a power saw will measure 110 dB.

DR. SARACENO: Generally speaking, the shorter the exposure, the louder the noise has to be to cause temporary or permanent hearing loss. Continuous exposure to noise is worse than intermittent exposure. Middle- or high-frequency noises are more harmful than low-frequency noise.

RESIDENT PHYSICIAN: Have you seen hearing loss caused by loud music played on a portable stereo with earphones?

DR. SARACENO: I have not seen that yet, but I suspect I may see a few patients in the future. A recent Federal Drug Administration bulletin warned about the use of the cordless telephone, which when placed over the ear while it is still ringing can give up to 135 dB of noise and cause severe damage.[20]

DR. GLADFELTER: This has been a productive presentation and discussion. I would like to sum this up by urging family physicians to (1) take an occupa-

tional history, (2) selectively use the audiometer for pre-employment physical examinations for high-risk workers, (3) educate your patients to wear protective devices such as earmuffs or plugs, and (4) participate actively as consultant to the employer to help set up hearing conservation programs that comply with the safety regulations to reduce the possibility of litigation and the number of worker compensation claims. We also have the role of coordinators of all medical disciplines to provide the best service to our patients, should the need arise.

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