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Journal of the American Audiological Society, Vol 3:215-220,1992.

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J Am Acad Audiol 3: 215-220 (1992)

Clinical Forum

Evaluation of Occupational Hearing Loss and Presbycusis Using a Microcomputer

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Abstract

Occupational noise-induced hearing loss remains a common problem in industry. This report presents a systematic method of patient evaluation and describes software that is capable of calculating hearing handicaps from audiometric data and the proportion of the handicap due to presbycusis. The software also has the capability of subtracting the effects of presbycusis from the current audiometric thresholds and to estimate hearing thresholds at any future age of the patient. Four patients are presented that illustrate the utility of this type of computer analysis.

Key Words: Presbycusis, occupational hearing loss, noise-induced hearing loss, microcomputer, hearing disorders, software

Hearing handicaps can be calculated by a variety of equations. Table 1 summarizes six such formulas. All formulas determine the average hearing loss for a range of frequencies. A "Low Fence" decibel value is subtracted from this average, the difference is then multiplied by a factor to determine the unilateral hearing handicap. The "Low Fence" is usually equal to 25 dB, which represents the range of normal hearing. Since a unilateral handicap is not as disabling as a bilateral handicap, the better ear is usually weighted. Thus a 50 percent unilateral handicap in both ears results in a 50 percent total hearing handicap; a 100 percent handicap in one ear and a 0 percent handicap in the opposite ear will result in a 17 percent total hearing handicap (AAO-1979 equation). In most states "Medical Evidence" or the American Academy of Otolaryngology and Ophthalmology equation (AA00-1959) is used to calculate hearinghandicaps (Stander,1987). The AA00-1959 equation utilizes frequencies of250 Hz, 500 Hz, and 1000 Hz. In 1979, the American Academy of Otolaryngology and the American Council of Otolaryngology revised the AA00-1959 equation to include the frequency of 3000 Hz (AAO and ACO, 1979). The testing at 3000 Hz was included to adjust for hearing difficulties that occur in noisy environments and with distorted speech. This new equation (AAO-1979) is one of the most common equations used to calculate hearing handicaps in the United States.

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Determination of the Portion of the Handicap due to Industrial Noise

In determining the portion of the handicap attributable to industrial noise, a complete history and a physical examination must be taken. The difficulty that the patient is having with his hearing acuity along with any tinnitus should be determined. The history should also cover all other possible causes of sensorineural hearing loss. Specifically, any family history of hearing loss, birth trauma, ototoxic medications, viral illnesses, meningitis, head trauma, vertigo, and hearing acuity fluctuations should be documented. In addition, the patient should

Table 1 Various Formulas Used to Calculate Hearing Handicaps

Formula	*Frequencies*	*Fence*		*Weight between Ears*[#]
		Low	*High*	
AAO-1979	0.5, 1, 2 & 3 kHz	25	92	5:1
AA00-1959	0.5, 1 & 2 kHz	25	92	51
NIOSH-FECA*	1, 2 & 3 kHz	25	92	5:1
Wisconsin State Formula	1, 2, & 3 kHz	35	92	4:1
Oregon State Formula	0.5, 1, 2, 3, 4 & 6 kHz	25	92	7:1
British Society of Audiology[t]	1, 2 & 4 kHz	25	92	5:1

*National Institute of Occupational Safety and Health-Federal Employees' Compensation Act.
[t] Formula modified with high and low fences.
[#] Good ear is weighted more than the poor ear.

be questioned regarding other exposure to high-intensity noise, specifically, any other home machinery (i.e., chain saws, tractors), hunting, military service, and employment in other working environments. The use of (or absence of) ear protection in all of these environments should be recorded.

Audiometric examination should include air and bone conduction along with discrimination scores. Noise-induced hearing loss (NIHL) characteristically produces a 4000 Hz notch with good discrimination (Sataloff and Sataloff, 1987). Industrial exposure almost always produces a bilateral symmetric loss, unless the worker is in a fixed position with one ear consistently toward the noise source. In contrast, gunfire usually produces a unilateral loss with the left ear having the greatest hearing toss in a right-handed shooter. The shape of the audiogram is important. Flat or upward sloping hearing losses are rarely due to NIHL. A high-frequency hearing loss, without any recovery at 8000 Hz, is rarely due to noise-induced hearing loss alone. However, a high-frequency or 4000-Hz notch is not necessarily diagnostic of NIHL. Many other etiologies exist including: viral infections, acoustic neuromas, and perilymphatic fistulas (Sataloff, 1980).

Presbycusis is another important factor and an adjustment should be made in the determination of hearing handicaps caused by industrial noise exposure (Lobo and Reddell, 1972; Dobie, 1990). Two equations are available to calculate hearing presbycusis levels based upon stimulus frequency, sex, and age. The first method was published by Spoor (1967). He plotted the hearing level as a function of age and sex, based upon data collected from a number of different population studies. He found good uniformity in the data from these various studies. The second method was reported by Robinson and Sutton (1979) who combined data from 14 studies and determined equations for predicting the mean and standard deviations for hearing loss as a function of stimulus frequency, age, and sex. Table 2 illustrates that Robinson and Sutton's method tends to predict a slightly lower hearing loss in the speech frequencies than Spoor's method.

METHOD

Presbycusis and Hearing Handicap Software

In order to facilitate evaluations of patients with suspected occupational hearing loss, a software package, Delta Hearing Handicap and Presbycusis Software was written in Omnis 5 for the Macintosh Computer. The program is a 70 k template that requires a hard disk drive and 1 megabyte of RAM. The program is shareware and distributed by Delta Medical Shareware, Inc., (Bartlett, TN).

The program is a turn-key application that operates using pull-down menus and screen push buttons. Figure I illustrates the user interface for storing, retrieving, and editing audiometric data.

Table 2 Comparison of Spoor's and Robinson-Sutton's (R-S) Methods for Predicting Hearing Loss due to Presbycusis

Frequency (Hz)	*Hearing Loss (dB)*			
	60 Yr Male		*80 Yr Male*	
	Spoor	*R-S*	*Spoor*	*R-S*
250	*6.89*	*5.29*	*17.38*	*11.57*
500	*7.67*	*6.17*	*19.96*	*13 45*
1000	*7.84*	*7.06*	*20.68*	*15.38*
2000	*14.85*	*12.35*	*36.31*	*26.91*
3000	*22.17*	*20.29*	*47.64*	*44.21*
4000	*28.38*	*28.22*	*55.12*	*61.50*
6000	*33.33*	*31.75*	*62.65*	*69.19*
80c0	*35.20*	*38.81*	*74.49*	*84.57*

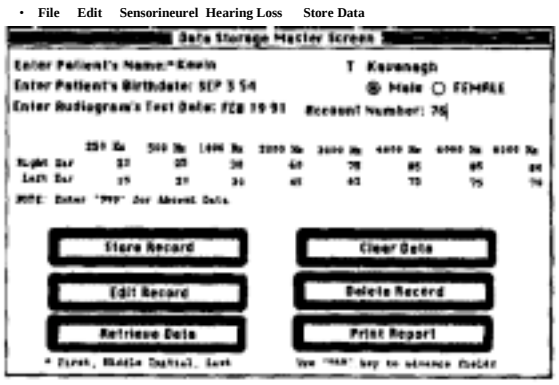

Figure 1 User interface for Delta Hearing Handicap and Presbycusis Software.

The amount of hearing loss due to presbycusis can be calculated by either Spoor's or Robinson-Sutton's method. The user specifies which method he wants to use in a start-up section of the program. Hearing handicaps can be calculated by a variety of methods shown below and in Table 1:

1. American Academy of Otolaryngology 1979
2. American Academy of Otolaryngology and Ophthalmology 1959
3. National Institute of Occupational Safety and Health (NIOSH)
4. Wisconsin State Formula (CHABA)
5. Oregon State Formula
6. British Society of Audiology Formula

In the calculation of the amount of hearing loss due to presbycusis, the software assumes that the effects of NIHL and presbycusis are independent and additive. This assumption has been shown to be valid by a variety of researchers (Robinson, 1968; Macrae, 1971). Macrae (1971) also demonstrated that if a patient leaves the noisy environment, his hearing loss will progress as predicted by Spoor's presbycusis equations (Spoor, 1967). The proportion of the handicap allotted to presbycusis versus other pathology is calculated according to the method proposed by Lobo and Reddell (1972). Using this method, the proportion of the total amount of hearing loss due to presbycusis (using the frequencies in the hearing handicap equation) is taken as the proportion of the hearing handicap due to presbycusis. This method ignores the low fence in allotting the handicap proportion. Thus, if the hearing loss due to NIHL and presbycusis is equal and neither one by itself creates a hearing handicap, each would still be responsible for 50 percent of the handicap caused by the combination of their losses. This is the fairest method possible, since one could argue that the portion of the handicap caused by either NIHL or presbycusis could be ignored because the hearing loss created by each fell below the value imposed by the low fence.

Using the Delta Hearing Handicap and Presbycusis Software, the following data can be produced:

1. Calculation of the patient's hearing handicap and the percentage of the handicap due to presbycusis.
2. Projection of the audiogram into the future, to determine future hearing levels and handicaps, along with the percentage of the handicap due to presbycusis. This function assumes that the patient leaves the high intensity noise environment. Projection of future audiograms is important to determine if the patient's present handicap is due to past employment and to predict handicaps that will develop as the patient grows older.
3. Displaying the audiometric data without the effects of presbycusis in order to determine audiometric shape.

CASE REPORTS

Four case reports are presented to illustrate the utility of computer analysis of suspected occupational hearing loss. All patients were employed by the railroad and a complete history and physical examination was performed, as outlined in the introduction. Only positive findings are presented. Hearing handicaps are calculated using the American Academy of Otolaryngology equation that was published in the Journal *of the American Medical Association* in 1979. Presbycusis is estimated using Spoor's equations, since their utility in predicting future hearing results was independently confirmed by Macrae (1971).

Case 1

The patient was a 38-year-old who had complained of hearing loss and tinnitus for 3 years. The only difficulty he reported was understanding children's voices. He worked in the defendant's machine shop for 11 years and in the engine rooms and machine shops of other employers for 6 years. He operated tractors and lawn mowers at home without ear protection and had a significant history of hunting and service in the militarv. The audiometric results

Table 3 Case 1: Audiogram at Age 38.98 Years. Sex: Male

	Hz					
	500	*1000*	*2000*	*3000*	*4000*	*6000*
Right Ear	*5*	*5*	*20*	*40*	*20*	*15*
Left Ear	*5*	*15*	*40*	*50*	*45*	*30*
Presbycusis	*1.57*	*1.56*	*3.30*	*5.83*	*8.51*	*10.48*

Hearing handicap: *AAO-1979, 0.62;* Percent of handicap due to presbycusis, *15.98.*

shown in Table 3 revealed a handicap of less than 1 percent and exposure to multiple sources of industrial and environmental noise.

The patient had a weak case in trying to prove that damages existed and that the defendant had caused the damages. At age 65 this patient would be expected to have a handicap of 11.8 percent; 51.0 percent of which would be attributed to presbycusis.

Case 2

The patient was a 61-year-old whose chief complaint was the gradual onset of hearing loss over many years that affected his ability to understand "soft talking and ladies voices," along with tinnitus that was described as "no big problem." He was employed by the defendant for 15 years and worked in a machine shop. After leaving the defendant's employment he worked 9 years in another machine shop. He had a positive history of hunting and military service. The patient could not remember whether or not he ever wore ear plugs. On presentation, the patient had a bilateral high - frequency hearing loss with asymmetric dis- crimination of 48 percent and 64 percent. His hearing handicap was 24.25 percent, 33.9 percent accounted for by presbycusis (Table 4).

An audiogram obtained 8 years previously, at the time the patient left the defendant's employment, revealed a significant progression of the patient's hearing loss. Projecting this audiogram to the date of the current evaluation,

Table 4 Case 2: Audiograrn at Age 61.22 Years. Sex: Male

	Hz					
	500	*1000*	*2000*	*3000*	*4000*	*6000*
Right Ear	*25*	*30*	*20*	*75*	*85*	*85*
Left Ear	*20*	*30*	*45*	*65*	*75*	*75*
Presbycusis	*8.22*	*8.41*	*15.85*	*23.45*	*29.81*	*34.93*

Hearing handicap *AAO-1979, 24.25;* Percent of handicap due to presbycusis, *33.89*

Table 5 Case 2: Audiogram at Age 52.44 Projected to Age 61.22 Years Using Spoor's Equations. Sex: Male

	Hz					
	500	*1000*	*2000*	*3000*	*4000*	*6000*
Audiogram at Age 52.44						
Right Ear	*5*	*15*	*20*	*60*	*65*	*65*
Left Ear	*5*	*5*	*0*	*60*	*60*	*55*
Audiogram Projected at Age 61.22 (Spoor's Equations)						
Right Ear	*8*	*19*	*26*	*68*	*75*	*76*
Left Ear	*8*	*9*	*6*	*68*	*70*	*66*
Presbycusis	*8.21*	*8.40*	*15.83*	*23.43*	*29.79*	*34.92*
Audiogram Projected for Age 61.22 (Robinson-Sutton's Equations);						
Right Ear	*7*	*18*	*25*	*68*	*76*	*77*
Left Ear	*7*	*8*	*5*	*68*	*71*	*67*
Presbycusis	*6.54*	*7.47*	*13.08*	*21.48*	*29.89*	*33.62*

* Hearing handicap: *AAO-1979, 1.33;* Percent of handicap due to presbycusis, *57.94.*

t Hearing handicap: *AAO-1979, 1.10;* Percent of handicap due to presbycusis, *52.37.*

produced a hearing handicap of only 1.33 percent with 57.9 percent of this handicap due to presbycusis (Table 5).

Tables 5 and 6 illustrate the hearing loss values, along with standard deviations for presbycusis, obtained using Robinson-Sutton's equations. It is evident that the patient's present hearing thresholds are more than a standard deviation above predicted for 500 Hz through 2000 Hz (see Table 6).

This patient also has a weak case, and although a significant handicap exists, its presentation occurred after employment with the defendant. Also, the positive history of hunting and military service point to other contributing factors to any NIHL and the unilateral phenomic regression indicates that other hearing pathologies, i.e., acoustic neuroma, should be considered.

Table 6 Hearing Thresholds and Standard Deviations for Age 61.22 as Predicted by Robinson-Sutton's Equations

Hz	Hearing *Loss*	*SD*
250	*5.60*	*8.24*
500	*6.54*	*8.12*
1000	*7.47*	*8.49*
2000	*13.08*	*11.73*
3000	*21.48*	*15.59*
4000	*29.89*	*19.45*
6000	*33.62*	*21.95*
8000	*41.10*	*22.95*

Table 7 Case 3: Audiogram at Age 60.90 with and without the Expected Effects of Presbycusis.

Sex: Male

	Hz							
	250	*500*	*1000*	*2000*	*3000*	*4000*	*6000*	*8000*
Audiogram at Age 60.30								
Right Ear	*30*	*40*	*55*	*65*	*65*	*65*	*70*	*60*
Left Ear	*35*	*40*	*45*	*55*	*65*	*70*	*65*	*60*
Presbycusis	*7.24*	*8.07*	*8.25*	*15.57*	*23.10*	*29.42*	*34.50*	*36.64*
Thresholds Minus Presbycusis:								
Right Ear	*23*	*32*	*47*	*49*	*42*	*36*	*36*	*23*
Left Ear	*28*	*32*	*37*	*39*	*42*	*41*	*31*	*23*

Case 3

The patient was a 60-year-old whose chief complaint was the gradual onset of hearing loss over many years causing him difficulty in understanding the television. Tinnitus was absent. The patient worked for 39 years for the railroad as an engineer, conductor, and brakeman, He also had a positive history of hunting and military service. He did not use ear protection. Audiometric testing revealed a hearing handicap of 40.4 percent, 26.4 percent of which could be accounted for by presbycusis. Discrimination results were 64 percent and 68 percent. Although this patient has a significant history for NIHL, Table 7 demonstrates that the shape of his audiogram is highly suggestive of another etiology; this becomes more evident once values are adjusted for presbycusis.

Case 4

The patient is a 59-year-old whose chief complaint was the gradual onset of hearing loss over a 1- to 2-year period and tinnitus for the past 1 year. The patient worked for 22 years testing new engines in a noisy environment. He also had a positive history of hunting and military service. He was a right-handed hunter, and did not use ear protection. He denied any ear surgery, but a myringotomy tube was found in his ear canal and his tympanic membranes were retracted and thin.

Audiometric testing revealed asymmetric hearing loss that was flat in the right ear and had a 4000 Hz notch in the left ear. The hearing handicap was 24.9 percent, 30.3 percent of which could be accounted for by presbycusis (Table 8). Discrimination results were 96 percent AD and 88 percent AS. A previous audiogram demonstrated fluctuation of air thresholds (bone thresholds were not obtained).

This patient also had a weak case for occupational hearing loss. The flat loss in his right ear strongly argues for another pathology. The asymmetric 4000 Hz notch in the left ear is most compatible with being a right-handed hunter. Occupational hearing loss is almost always symmetric. The history of fluctuating hearing loss definitely indicates another pathology, possibly from eustachian tube dysfunction orchronic serous otitis media. Other etiologies for asymmetric hearing loss should be searched for and the diagnosis of acoustic neuroma ruled out. Projection of this patient's hearing loss to age 65 yielded a predicted handicap of 31.2 percent of which 36.6 percent was from presbycusis.

DISCUSSION

Audiologists and physicians are taught to be 100 percent certain before giving an opinion, but in the legal realm an opinion some times must be given that has much less certainty. A medical-legal opinion must have reasonable certainty and should be based on a "more probably true than not" judgment. In other words, a proposition would be considered to be true if its probability of being true was 50.0001 percent. For example: a defendant could argue that a plaintiffs hearing handicap should be reduced to account for the effects of presbycusis, as predicted by equations based

Table 8 Case 4: Audiogram at Age 59.26, Sex: Male

	Hz					
	500	*1000*	*2000*	*3000*	*4000*	*6000*
Right Ear	*40*	*40*	*40*	*45*	*40*	*40*
Left Ear	*45*	*40*	*40*	*50*	*70*	*55*
Presbycusis	*7.53*	*7.51*	*14.27*	*21.42*	*27.53*	*32.38*

Hearing handicap: *AAO-1979, 24.87;* Percent of handicap due to presbycusis, *30.33.*

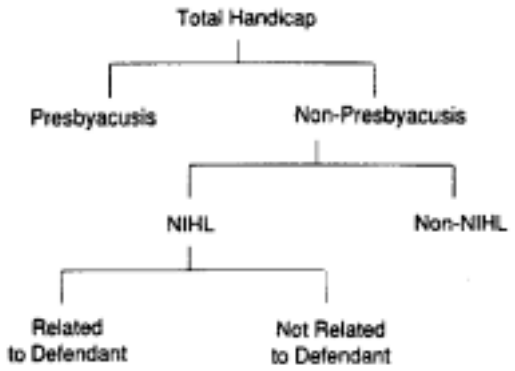

Figure 2 Diagnostic flow chart for occupational noise induced hearing loss.

upon population studies. This is a valid legal argument since the defendant would have a greater than 50 percent chance of having a hearing loss from presbycusis that is equal to or greater than the mean of the general population.

In evaluating patients with occupational hearing loss, one must calculate the handicap based upon a formula dictated by the legal setting. Once the handicap is calculated, it must then be proportioned to the various ear pathologies that may have affected the patient's hearing (Fig. 2).

Calculation of the proportion of the handicap due to presbycusis is important, as illustrated by case 2 where presbycusis was responsible for 34 percent of the hearing handicap. Non-NIHL can be diagnosed by a fluctuation hearing loss (case 4), a relatively flat audiometric configuration (cases 3 and 4) or the presence of vertigo. The audiometric shape should be determined and the effects of presbycusis corrected for. A flat audiogram is strong evidence against NIHL, but a 4000 Hz notch is not diagnostic. Asymmetric hearing loss (case 4) is unlikely to occur with occupational-induced hearing loss, but can occur with hunting and in working in environments where one ear is consistently toward the noise source. In patients with an asymmetric hearing loss, other pathologies, such as a acoustic neuroma, should be sought, especially if poor discrimination (case 4) is present.

Note. A fully functioning demonstration disk for the Delta Hearing Handicap and Presbycusis Software can be obtained by sending a self-addressed, stamped mailer, and a 3.25" diskette to the author. (Macintosh computers only.)

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