SUCCESSFUL AGING

Hear Ye? Hear Ye! Successful Auditory Aging

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Age-related hearing loss (presbycusis) is a multifactorial process that affects nearly all people in their senior years. Most cases are due to a loss of cochlear hair cell function and are well mediated by communication courtesy and modern amplification technology. Severe hearing loss is generally due to cochlear problems or age-related diseases and may require speech reading, assistive listening devices, and cochlear implants, depending on the degree of loss. Presbycusis may seriously impair communication and contribute to isolation, depression, and possibly dementia. Accurate diagnosis and prompt remediation are widely available but are frequently underused. Geriatric health care and well-being is enhanced by the detection and remediation of communication disorders.

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Hearing loss is a frequent problem in the senior years of life, but the magnitude of the hearing loss varies widely. Some older persons have minimal, nonconsequential hearing impairment, and others become isolated from friends and family because of their hearing. Hearing loss impairs communication, subtly at first and increasing with the magnitude of the loss. Hearing impairment contributes to social isolation, depression, and loss of self-esteem and has been implicated as a cofactor in senile dementia.[1]

Presbycusis—literally, elder hearing—is the general term applied to age-related hearing loss and is used to signify the sum of all the processes that affect hearing with the passage of time. The aging process has three distinct components: intrinsic or physiologic degeneration, extrinsic insults, and intrinsic insults. In the auditory system the extrinsic component is called nosocusis, which includes hearing loss due to otologic disease, hazardous noise exposure, acoustic trauma, and ototoxic agents. The intrinsic component, called sociocusis, indicates the wear-and-tear effects of the everyday sounds of normal living.[2] Goycoolea and co-workers showed that both nosocusis and sociocusis are avoidable in the quiet environment of Easter Island.[3]

Hearing clearly steadily worsens with age. The rate of change, however, is not linear, is highly variable, and is only weakly associated with chronologic age per se. For example, in comparing the change in hearing thresholds of the Framingham Heart Study cohort, less than 10% of the variance was accounted for solely by age.[4] This suggests that other factors affect hearing more than age alone. In our industrialized society, it is difficult to escape from noise pollution. It is likely that much of the variance in levels of presbycusis is due to unmeasured effects of noise damage, which is clearly more common than other forms of ototoxicity. The effects of systemic disease are still incompletely understood, and we will discuss these.

Pathology

Four types of presbycusis have been described, based on histopathology, and different mechanisms have been postulated for each.[5] These types are sensory (hair cell loss), neural (ganglion cell loss), metabolic (strial atrophy), and cochlear conductive (stiffness of the basilar membrane). Our longitudinal studies of the Framingham Heart Study cohort are providing insight into the progression of presbycusis. Sensory presbycusis is the dominant type, affecting more than 75% of the group. The magnitude of the presbycusis varies so widely, however, that it is difficult to ascribe what proportion of the loss is due to pure aging and what proportion to acquired loss from noise exposure, ototoxicity, and the effects of systemic disease. We are currently examining the children of the cohort in an attempt to identify a genetic component that might explain some of this variability. Presbycusis is well known to be more prevalent in

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selected families than in others. The genetic basis for this variation is not known.

Environmental noise exposure is a major risk factor for sensory presbycusis. The well-known effects of hazardous occupational and recreational noise exposure contribute substantially to an earlier onset of hearing loss than would be expected from aging alone. It is difficult, however, to ascribe portions of the hearing loss separately to noise and to aging, which is being attempted in various compensation litigations. We now know that gerbils raised in quiet have as much hearing loss with age as groups of noise-reared animals, and some have even more.[6] Of interest, the variation in hearing level of the quiet-reared animals is far greater than that of the noise-exposed group, which suggests some degree of homogenization due to noise. Given that noise and aging both affect the high-frequency regions of the cochlea, we suggest that sensory presbycusis be considered as the cumulative effects of either or both agents and that noise simply accelerates the time course of sensory presbycusis.

The recent discovery that the outer hair cells are motile has provided an explanation for the source of the cochlear amplifier, that is, the nonlinear biologic mechanism that increases our sensitivity to sounds of low intensity without enhancing loud sounds.[7] The outer hair cells are stimulated by the mechanical vibration of sound waves to contract within the electrical environment of the cochlea. The rate of contraction exceeds that of all known contractile systems. A manifestation of that process is the generation of low-amplitude signals that may be detected in the ear canal known as otoacoustic emissions. Otoacoustic emissions may be generated by specific auditory inputs, the most clinically useful of which are the distortion-product otoacoustic emissions. Equipment to measure distortion-product otoacoustic emissions is now commercially available. Alterations in these emissions can be detected well in advance of clinically detectable changes in auditory thresholds. The measurement of these emissions is useful for monitoring patients receiving chemotherapy or other ototoxic medications.

Neural presbycusis is uncommon, accounting for less than 2% of the cases in the Framingham Heart Study cohort.[8] Unfortunately, the term "nerve deafness" is firmly entrenched in the lay literature and popular usage, even though it has led to frequent misunderstanding of the potential of rehabilitation. The term is a shortening of "sensorineural," which has been used to indicate nonconductive hearing loss of an undetermined site of lesion. With contemporary audiometric techniques that reveal the site of a lesion, this term will be used less often. Given that the vast majority of hearing impairment is due to the loss of the motor and sensory hair cells, to imply that neural lesions are involved is inappropriate and misleading. Amplification through modern hearing aids provides substantial benefit to people with sensory hearing loss due to hair cell loss. A person with a pure neural lesion has limited benefit from amplification, whether the lesion is in the eighth nerve (for example, an acoustic neuroma), in the brain stem (as in multiple sclerosis), or in the midbrain (as in Alzheimer's disease).[9] Thus, the use of contemporary techniques to identify the site of a lesion and the use of appropriate terms are important so that patients and health care professionals alike may be correctly oriented toward optimal treatment or rehabilitation.

The stria vascularis is the metabolic pump that generates the strongly negative endocochlear potential. Strial atrophy is seen histologically in many people with a flat hearing loss, that is, elevated thresholds for all frequencies. We have shown that poor low-frequency hearing, which is typical of strial or metabolic presbycusis, is associated with cardiovascular diseases (heart attacks, stroke, intermittent claudication) and that this effect is present in both men and women but is stronger in women.[10] We postulated that postmenopausal estrogen decline might be a factor in this association in women. In examining the hearing of a small group of older women in a separate study (unpublished data, September, 1996), however, we found no association of postmenopausal estrogen replacement therapy with hearing thresholds in otherwise healthy women. Although it appears that low-frequency presbycusis is associated with general cardiovascular disease, and it is known that postmenopausal estrogen replacement therapy is generally protective against cardiovascular disease in women, we cannot suggest, based on these data, that this therapy would prevent strial presbycusis.

Cochlear conductive or mechanical presbycusis is characterized by a sharply sloping loss and normal hair cell and strial function. Clinically, this audiometric pattern is uncommon and is more of theoretic than practical interest, as the rehabilitative implications of this subtype are not different from those of the sensory or strial forms.

Diagnosis

Hearing loss is often a silent disorder, characterized more by what is missed than what is heard. In the vast majority of cases, family and friends are more aware of the problem than the patient. In many instances, the hearing loss is accompanied by tinnitus—the perception of a sound in the ears or head that is often described as a ringing sound. Tinnitus is usually a sign of hearing loss and should be assessed to exclude treatable disease as a cause.

Although it would seem prudent for health care professionals to screen for one of the most prevalent chronic conditions affecting older patients, this is unfortunately not the practice with hearing loss identification.[11] Moreover, even when older patients have discussed their hearing difficulties with their primary care physicians, they are often told that their hearing loss is minor or that it cannot be improved with a hearing aid.[12] When we consider the adverse effects of hearing loss on the quality of life of older persons and that such effects are reversible with hearing aids, it is surprising that in-office

Question	Yes	No	Sometimes
1. Does a hearing problem cause you to feel embarrassed when meeting new people?	☐	☐	☐
2. Does a hearing problem cause you to feel frustrated with talking to members of your family?	☐	☐	☐
3. Do you have difficulty hearing when someone speaks in a whisper?	☐	☐	☐
4. Do you feel handicapped by a hearing problem?	☐	☐	☐
5. Does a hearing problem cause you difficulty when visiting friends, relatives, or neighbors?	☐	☐	☐
6. Does a hearing problem cause you to attend religious services less often than you would like?	☐	☐	☐
7. Does a hearing problem cause you to have arguments with family members?	☐	☐	☐
8. Does a hearing problem cause you difficulty when listening to TV or radio?	☐	☐	☐
9. Do you feel that any difficulty with your hearing limits or hampers your personal or social life?	☐	☐	☐
10. Does a hearing problem cause you difficulty when in a restaurant with relatives or friends?	☐	☐	☐

Figure 1.—This Hearing Handicap Inventory for the Elderly–Short Form hearing questionnaire is an effective screening tool for hearing loss.[20]

screening for hearing loss is not common practice. The short form of the Hearing Handicap Inventory for the Elderly (HHIE-S) consists of ten questions that can be answered quickly by most seniors (Figure 1).[13] This is an excellent screening instrument for substantial hearing loss.

The medication history should be explored to determine possible ototoxicity. The use of aminoglycoside antimicrobial agents, cisplatin, loop diuretics, or anti-inflammatory agents may contribute to hearing loss.

The findings of physical examination of the ear canal, tympanic membrane, and middle ear are normal. The use of tuning forks, the whispered or spoken voice, or finger-friction tests is not effective or reliable in identifying hearing loss. Screening audiometry can be quickly and easily administered by a trained office nurse or medical assistant. The equipment needed for screening audiometry is light-weight and low cost. There are portable, battery-operated audiometers and even specially developed otoscopes with audiometric capabilities available for practitioners. We typically have our office nurse screen hearing at 1, 2, and 3 kHz at intensity levels of 25 dB (normal), 40 dB, and 60 dB. Failure at any one frequency at 25 dB for younger adults or 40 dB for senior adults suggests the need for referral for a complete audiologic evaluation by an otologist or audiologist. The identification of hearing impairment and the determination of hearing-aid candidacy serve to remove a hearing-impaired senior from isolation, withdrawal, and decreased quality of life. Physicians who provide primary care to elderly persons should screen for hearing impairment with the HHIE-S, by screening audiometry, or both.

Central auditory tests are widely available and should be used when the possibility of early dementia exists. We have shown that poor performance on a standard central auditory test, Synthetic Sentence Identification With Contralateral Competing Message, precedes the clinical onset of dementia.[14] With the possibility of treatments to forestall the progression of Alzheimer's disease, early identification is of great importance.

Imaging studies are not done except where the loss is unilateral or considerably asymmetric or where tinnitus is unexplained by an audiogram. Screening magnetic resonance imaging using the T2 fast-spin echo technique provides superb visualization of the eighth nerve and brain stem and can detect tumors in the millimeter range, even before hearing is affected.[15]

A metabolic evaluation is indicated if a patient has not had a recent health examination. Diabetes mellitus, hypertension, and hyperlipidemia should be excluded as cofactors. Patients receiving renal dialysis often have poorer hearing than would be expected from age alone. The use of diuretics is known to affect strial function, and certain disorders, such as aminoglycoside toxicity, affect both the kidneys and the inner ear.

Effects of Presbycusis

Presbycusis affects both of the critical dimensions of hearing; namely, it reduces threshold sensitivity and reduces the ability to understand speech. The loss in threshold sensitivity is insidious in onset, involving the highest frequencies initially and slowly progressing to become clinically manifest in the fifth to sixth decades. Most often, patients with presbycusis do not express dif-

ficulty in hearing per se but are more likely to report problems in understanding speech. The common complaint of "I can hear, but I can't understand" reflects the encroachment of the sensitivity loss into the important high-frequency speech range (0.5 to 3 kHz). The louder and lower frequency segments of speech, such as the vowels, can be heard, but the high-frequency voiceless consonants, such as *t*, *p*, *k*, *f*, *s*, and *ch*, are not heard due to the high-frequency sensitivity loss. A person then confuses and misinterprets what is being spoken: "Did you say 'mash,' 'math,' 'map,' or 'mat'?"

The difficulties in understanding speech not only may reflect a sensitivity loss but also may be due to the effects of central nervous system auditory deterioration.[1] Seniors often have more difficulty in understanding speech than younger persons with comparable sensitivity loss. When pure-tone sensitivity loss is held constant and speech understanding is evaluated by decade, a systematic decrement of speech intelligibility is shown with increasing age. Moreover, whenever the speech message is degraded, an elderly listener's difficulties increase dramatically more than younger listeners. Older persons have considerably greater problems than younger persons in understanding rapid speech, foreign accents, or speech transmitted through poor transmitting equipment or under unfavorable acoustic conditions. Such problems are thought to be due to a central integrative and synthesizing hearing disability that reflects a progressive deterioration of the central nervous system. Therefore, a senior person's problems in understanding speech may be due to cochlear hair cell deterioration (sensory presbycusis), auditory neural deterioration (neural presbycusis), or central auditory processing deterioration (or all three).

Mulrow and colleagues demonstrated the effect of presbycusis on quality of life and found reversible changes through hearing-aid use.[16]

Treatment

Prevention

Although some degree of sensory presbycusis is inevitable, it may be minimized by avoiding exposure to hazardous noise. If noise cannot be avoided, the use of suitable hearing protection is essential. Inserted earplugs provide about 15 to 25 dB of attenuation and may permit people to work in otherwise hazardous areas with a reduced risk of damaging their hearing. The effects of noise accumulate over a lifetime, and exposure to gunshot noise and loud music during adolescence will contribute to communication difficulties in the senior years. Unfortunately, many people are not farsighted enough to act prudently in this regard.

The use of ototoxic agents such as cisplatin for cancer chemotherapy and aminoglycoside antimicrobial compounds may cause any degree of hearing loss, from a mild high-frequency loss indistinguishable from sensory presbycusis to profound hearing loss and deafness. Although the search for protective agents continues, diligent monitoring provides the best method for early detection and the opportunity to modify the treatment plan. Some persons have specific mitochondrial defects that appear to predispose them to catastrophic hearing loss from the use of gentamicin sulfate.[17]

Risk factors for cardiovascular disease and cardiovascular disease itself affect hearing to some extent. Hypertension, hyperlipidemia, and diabetes mellitus have all been associated with excessive hearing loss. Therefore, it is logical that maintaining good general health would minimize the risk of hearing loss due to systemic disease. High-lipid diets are associated with poorer hearing.[18]

Rehabilitation

Although hearing loss due to conductive deficits (such as otosclerosis, otitis media, and eardrum perforations) can be most often successfully treated with medical or surgical intervention, the most common type of hearing loss is caused by dysfunction in the cochlea or associated neural structures. Of all patients with cochlear hearing loss, less than 5% can be helped medically. Consequently, the most important rehabilitative approach for hearing-impaired elderly persons is the hearing aid. Hearing aids are the principal resource for improving communication and reducing hearing handicaps in persons with sensorineural hearing loss. Unfortunately, only 10% of people who might benefit from an aid actually own one, which indicates a substantial underservice.

A hearing aid is a miniature personal loudspeaker system designed to increase the intensity of sound and deliver it to the ear with as little distortion as possible. Important improvements in hearing-aid design have made possible greater flexibility in selecting and fitting hearing aids for the typical hearing loss patterns associated with aging. In the past decade, an increase in technologic innovations has occurred that has made possible a wide assortment of hearing aids both in physical size and technologic advancement. Current hearing aids include devices that fit behind the ear, in the ear, in the canal, and most recently, completely in the canal. Because many persons unfortunately associate hearing loss with the "stigma" of aging, the introduction of the smaller devices that fit entirely in the ear canal has had obvious appeal. Those seniors with dexterity problems or vision impairments are often unable to insert and adjust the smaller aids properly and are better served with larger hearing aids. The hearing aid fitter-dispenser should review such issues with the hearing-impaired person during the prefitting session.

Technologic advances in hearing aids now offer patients a wide variety of amplification options. Hearing aids no longer merely provide linear amplification, but may include compression circuitry to reduce the amplification for loud sounds, automatic loudness-adjusting circuits that automatically decrease the amplification of continuous background sounds, and also

hearing aids without volume controls that automatically increase the loudness of soft sounds while decreasing loud-level inputs. Because a single amplification paradigm may not be of benefit for all listening situations, hearing aids are available that include several programs for use at the listener's discretion. A person may choose a wide-frequency amplification for quiet environments, another program that eliminates low frequencies for noisier situations, and a program specifically suited for telephone use. These hearing aids are digitally programmed by an external programmer through the use of a controlling microchip within the hearing aid itself. Individual programming of the hearing aid enables the dispenser to make substantial electroacoustic modifications to an individual wearer's needs. Such multimemory hearing aids typically include a user-operated remote control to facilitate program or volume changes. Some hearing aids now incorporate several microphones, one for use to improve directionality in background noise situations and another for use in other environments where a broad range of acoustic input is desired. The most recent introduction in hearing-aid technology is the fully digital instrument, which has the processing power of a desktop personal computer and can be fit into the small canal-sized instruments. These aids have many features not available in analogue hearing aids and will undoubtedly provide hearing-impaired persons with improved hearing in future years.

The new innovative hearing-aid systems do require a higher level of training and sophistication on the part of the user and the fitter-dispenser. In addition, these new amplification systems are considerably more expensive than conventional hearing aids. The digital in-the-canal aid currently costs about $2,500 for one aid, and binaural aids are typically more beneficial. Neither Medicare nor most insurance carriers provide financial coverage for hearing aids. The specific hearing needs, lifestyle, and adaptability of a hearing-aid wearer must be taken into account during the prefitting process.

Hearing-Aid Candidacy

Once a hearing loss has been identified and it is clear that medical or surgical treatment is not indicated, referral should be made to a certified clinical audiologist. The clinical audiologist is a university-trained professional in the nonmedical management of hearing loss, whether with hearing-aid amplification, rehabilitation therapies, assistive listening devices, or a combination of rehabilitative approaches. Although some hearing-aid dealers are relatively skilled in evaluating hearing aids, others possess only minimal training or are more oriented to sales. Many states, in fact, require that a hearing-aid dealer meet only the minimum requirement of being 18 years old and passing a state licensing examination; there are typically no education requirements. Clinical audiologists, on the other hand, hold at least a master's degree in the evaluation and rehabilitation of hearing loss. Audiologists are uniquely qualified to provide a full range of auditory assessment and rehabilitative services to elderly persons.

After the necessary interview and evaluation, an audiologist-dispenser will recommend the type of hearing aid or aids, specify the acoustic requirements of the aids, and provide training in the use of amplification. The possible advantages and limitations of hearing aids are reviewed, and follow-up is provided during the initial trial and after purchase. It is usual to provide patients with a free or low-cost hearing-aid trial period of 30 days before purchasing the aid(s). This trial period gives patients the opportunity to wear the aid(s) in their own home and social environment to determine their satisfaction.

Hearing-Aid Prognostic Factors

Adapting to hearing-aid use is at times difficult because successful adjustment depends to a large degree on a patient's personality dynamics. Often a senior adult is resistant to amplification because of the social stigma associated with hearing loss. Because our culture unfortunately views hearing loss as a consequence of aging, resistance to a hearing aid is inevitable. Factors of motivation, personal adjustment, and family support can be instrumental in hearing-aid satisfaction.

Assistive Listening Devices

Although substantial improvements have been achieved in hearing-aid design and application, few hearing-impaired persons can ever come close to achieving "normal" auditory function with the use of a hearing aid alone. The inherent physiologic restrictions imposed by age-related hearing loss, coupled with the electronic constraints of hearing aids, renders normal hearing impossible, especially considering the levels of noise and background interference found in most public places. The amplification of unwanted sounds (such as several speakers in groups, background noise, ventilation) by hearing aids often causes the desired message to be rendered unintelligible.

Assistive listening devices compose a growing number of situation-specific amplification systems designed for use in difficult listening environments. They commonly use a microphone placed close to the desired sound source (such as a television, theater stage, or speaker's podium), and sound is directly transmitted to the listener; transmission methods include infrared, audio loop, FM radio, or direct audio input. Such transmission of sound directly to the listener improves the signal-to-noise ratio. That is, the desired sounds are enhanced, and competing extraneous noises are decreased, thus permitting improved understanding. These assistive listening devices are becoming more available in churches, theaters, and classrooms, enabling hearing-impaired seniors to avoid the isolation imposed by the inability to hear a sermon, play, or public address.

Amplified telephones, low-frequency doorbells, amplified ringers, and closed-captioned television decoders are just a few examples of the devices currently available for hearing-impaired persons for everyday use. Flashing alarm clocks, alarm bed vibrators, and flashing smoke detectors provide valuable help for

severely hearing-impaired persons.

Although the treatment of hearing impairments with hearing-aid amplification, assistive listening devices, and aural rehabilitation therapy does not "cure" the impairment or restore hearing and communicative efficiency to normal, the use of such approaches does represent the best treatment to date. They will improve the ability of most older persons to communicate and reduce the handicapping consequences of hearing loss.

Medical Therapy

Once thought to be untreatable, some cochlear lesions are now responding to medical therapy. About a third of people with sudden hearing loss recover hearing. Most people with autoimmune hearing loss recover substantial amounts of the loss with corticosteroid and other anti-immune treatment, such as methotrexate and plasmapheresis. For the vast majority of people with presbycusis, however, definitive treatment must await the results of our ongoing research programs in hair cell regeneration.[19] This section will undoubtedly be expanded in the next decade or two.

REFERENCES

1. Uhlmann RF, Larson EB, Koepsell TD. Hearing impairment and cognitive decline in senile dementia of the Alzheimer type. J Am Gerontol Soc 1986; 34:207–210

2. Working Group on Speech Understanding and Aging. Speech understanding and aging. J Acoust Soc Am 1988; 3:859–895

3. Goycoolea MV, Goycoolea HG, Farfan CR, Rodriguez LG, Martines GC, Vidal R. Effect of life in industrialized societies on hearing in natives of Easter Island. Laryngoscope 1986; 90:1391–1396

4. Gates GA, Cooper JC Jr. Incidence of hearing decline in the elderly. Acta Otolaryngol 1991; 111:240–248

5. Schuknecht HF. Further observations on the pathology of presbycusis. Arch Otolaryngol 1964; 80:369–382

6. Mills JH, Schmiedt RA, Kulish LF. Age-related changes in auditory potentials of Mongolian gerbil. Hear Res 1990; 46:201–210

7. Brownell WE, Bader CR, Bertrand D, de-Ribaupierre Y. Evoked mechanical responses of isolated cochlear outer hair cells. Science 1985; 227:194–196

8. Gates GA, Popelka GR. Neural presbycusis: a diagnostic dilemma. Am J Otol 1992; 13:313–317

9. Sinha UK, Hollen KM, Rodriguez R, Miller CA. Auditory system degeneration in Alzheimer's disease. Neurology 1993; 43:779–785

10. Gates GA, Cobb JL, D'Agostino RB, Wolf PA. The relation of hearing in the elderly to the presence of cardiovascular disease and cardiovascular risk factors. Arch Otol Head Neck Surg 1993; 119:156–161

11. Logan SA, Ahlstrom JB, Bess FH. Identification and referral of hearing impaired elderly by primary care physicians. Asha 1985; 2:47

12. Logan SA, Hedley A. The elderly and hearing loss. Semin Hear 1988; 9:325–330

13. Weinstein BE. Age-related hearing loss: how to screen for it, and when to intervene. Geriatrics 1994; 49:40–45

14. Gates GA, Cobb JL, Linn RT, Rees T, Wolf PA, D'Agostino RB. Central auditory dysfunction, cognitive dysfunction, and dementia in older people. Arch Otolaryngol Head Neck Surg 1996; 122:161–167

15. Shelton C, Harnsberger HR, Allen R, King B. Fast spin echo magnetic resonance imaging: clinical application in screening for acoustic neuroma. Otolaryngol Head Neck Surg 1996; 114:71–76

16. Mulrow CD, Aguilar C, Endicott JE, Tuley MR, Velez R, Charlip WS, et al. Quality-of-life changes and hearing impairment. A randomized trial. Ann Intern Med 1990; 113:188–194