Hearing Loss in the Elderly

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KEYWORDS

• Elderly • Geriatrics • Age-related hearing loss • Presbycusis • Hearing aids
• Osseointegrated auditory implants • Cochlear implants • Regenerative therapies

KEY POINTS

- Hearing loss is a common sequela of aging and has a significant adverse impact on the health and well-being of the elderly.
- The hearing loss of aging reflects changes in both the peripheral and central auditory systems, with the greatest impact initially on the higher frequencies that are most important to understanding spoken language.
- Older patients, especially those with depression and dementia, benefit significantly from amplification and from cochlear implantation, although use of these technologies is not widespread within the population that could most benefit.
- There is a great deal of promising research focused on the regeneration of inner hair cells, in the areas of gene therapy, pharmacotherapy, and stem cells, that may in the near future markedly improve the lives of those with age-related hearing loss.

INTRODUCTION

Much like the advent of penicillin in 1928, advances in medical technology and health care have led to an increase in life expectancy with a steep rise in the numbers of older Americans. Population reports from the US Census Bureau indicate that the percentage of residents 65 and older grew from 12.4% (35 million) in 2000 to 15.2% (49.2 million) in 2016 with the national median age increasing from 35.3 years in 2000 to 37.9 years in 2016.[1] Life expectancy for those 65 years of age and older increased by 15.2 more years in 1972 and then to 19.1 more years in 2010. A similar trend is seen for individuals 85 and older, from 5.5 more years of life expectancy in 1972 to 6.5 more years of life expectancy in 2010. This is projected to continue with those 65 years and older predicted to have 20.6 more years of life expectancy and those 85 years and older having 7 more years of life expectancy by 2050.[2] This growth within

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the older population presupposes an associated increase in geriatric and degenerative issues. Alterations in sensory functions, vision, balance, and hearing are some of the most common disturbances seen in the aging population and lead to dramatic social and functional disability.

Among the senses affected by increasing age, hearing loss is the most common. Presbycusis, or age-related hearing loss (ARHL), is a term that refers to hearing loss as a result of physiologic and pathologic changes associated with increasing age. As the aging population continues to grow, greater focus is placed on understanding and attempting to reverse this sensory loss for the benefit of geriatric patients. Today, there is an established although still evolving concept of the workings of the outer ear, middle ear, and inner ear. This basis has led to a better understanding of aberrant behavior in both the peripheral and central auditory pathways, resulting in various forms of geriatric hearing loss. With a strong understanding of the foundation of geriatric hearing loss, more focused and novel areas of research are being investigated with promising results.

PRESENTATION

Presbycusis may present insidiously and be confounded by various medical, psychological, and pharmacologic factors. Only after thorough history, examination, and audiological testing can a diagnosis of presbycusis be made after excluding concurrent medical and pharmacologic effects. In general, the first signs of ARHL can be seen in late middle age with high-frequency hearing losses in the realm of conversation frequencies, ultimately progressing subtly to lower frequency tones. The range of human auditory frequencies spans 20 Hz to 20,000 Hz, with speech frequencies ranging from 400 Hz to 5000 Hz, with the greatest loss in hearing seen in frequencies greater than or equal to 2000 Hz.[3,4] The challenge to effortlessly understand speech stems from the natural frequencies of voice used to phonate consonants and vowels. In general, vowels vibrate at frequencies less than 1500 Hz compared with consonants, which vibrate at 1500 Hz or higher and are more softly spoken. Consequently, patients with ARHL have greater trouble hearing consonants within words that convey the bulk of the meaning within a word, are used to separate syllables, and indicate separation of words. The loss of this linguistic information results in many of the complaints in presbycusis. The loss of meaning is seen in deterioration of speech intelligibility, the loss of clear separation between words results in speech sounding mumbled, and the loss of syllables causes difficulty discerning similarly sounding words. Furthermore, similar to the natural frequencies of vowels and consonants, elderly patients may complain of difficulty hearing and understanding women and children, because their vocal registers are set to a higher range than are those for men. Patients with presbycusis rely on conversational, emotional, and postural context clues to compensate for their hearing impairment, requiring a greater amount of higher order cognitive functioning to understand daily conversations.

As the hearing loss progresses into lower frequencies, the difficulty becomes more apparent because a greater frequency range is affected and deficits are seen more often and in a greater number of conversations. Even if subconscious, the increased dependence on higher cognitive functioning to understand daily conversations puts the geriatric patient at increased strain when hearing in difficult hearing environments or with unfamiliar vocation. For example, conversations in noisy and crowded environments, such as restaurants and public areas, or with individuals with accents or faster speech result in a diminished speech intelligibility. As a product of relying on greater

supplementary information to understand individual conversations, patients may seem aloof or inattentive, because they require a greater amount of time to process various information before being able to fully understand a conversation and respond appropriately. Patients having an incrementally difficult time hearing and understanding in these more complicated environments and dialogues are more likely to withdraw from future conversations in similar settings.

Of concern to older patients and their families is that alarm sounds, such as police sirens and fire alarms, sounds that are intended to keep people safe, use high-frequency sounds, which are difficult for this population to hear and recognize. Patients become a danger to themselves and others when they are not able to respond to a police car behind them or to a fire alarm going off in their apartment complexes. A study on sensory impairment and driving found that adults with right-sided hearing impairment were associated with increased risk in motor vehicle accidents in countries with right-sided steering wheels but concluded more studies need to be conducted to strengthen this finding.[5] This serious consequence of high-frequency sensorineural hearing loss is also compounded by difficulty in localizing sounds with age.[6] The effort to identify where a sound is originating from stems from an age-induced increase in neural temporal jitter of the central auditory processing system causing distorted representation of incoming sound.[7] This added complexity makes the ubiquitous use of high-frequency sounds not only a daily nuisance and social issue for the elderly hearing impaired population but also in some circumstances may put them in life-threatening danger.

Patients are forced to cope with the frustration of daily auditory difficulties, a response dependent on personal ability to manage stress. In general, patients may reflect the frustration externally or internally. Externally, patients may claim that their grandchildren mumble or speak too fast or too quietly. Internally, patients may isolate themselves and withdraw from conversations taking place right in front of them. This isolation may, in part, contribute to the delay in treatment of ARHL.

HEARING LOSS AND COGNITION

As discussed previously, hearing loss has a strong association with increased isolation and frustration. Not surprisingly, the reported prevalence of hearing loss in older adults with cognitive impairment is 60%.[8] Mounting evidence indicates that management of hearing loss is a key factor in the management of cognitive decline or dementia.[9] Although pharmacologic therapies for the management of dementia are available, patients with dementia also benefit from active social participation and engagement. The Memory–HEARS (Hearing Equality through Accessible Research Solutions) pilot study found that for the depression and neuropsychiatric outcome measures, participants with high symptom burden at baseline showed improvement at 1-month postintervention.[10] As noted in a recent review, however, hearing aid use has not been shown to improve cognitive function or slow the rate of cognitive decline.[11]

Addressing a hearing loss that impairs good communication is a requirement for a meaningful and engaging interaction and is a critical component of dementia care.[12,13] Hearing-impaired older adults who use hearing aids have a lower incidence of depression, and amplification also has a positive impact on hearing impaired older adults with depression. In older adults who used hearing aids or cochlear implants, there was a significant improvement in depressive symptoms at 6 months after treatment in those using cochlear implants and hearing aids and in those using cochlear implants the improvement persisted at 1 year.[14]

MANAGEMENT

Because patients with a hearing loss may not perceive themselves as having a hearing loss, it is important that those caring for older patients to ask about difficulty with communication and understanding conversation. Fewer than half of patients report being asked about hearing loss by their health care provider.[15] Hearing is assessed using pure-tone audiometry.[16] A pure tone of a specific frequency of increasing loudness is presented to 1 ear in a quiet setting until the sound intensity level at which it is perceived 50% of the time. This point is known as the pure-tone threshold for that ear at that frequency. Speech discrimination testing is performed once a patient's hearing thresholds have been established. The audiogram is a graphical display of those pure-tone thresholds as a function of frequency.[16]

In those older adults in whom a hearing loss is identified, consideration should be given to evaluation by a specialist. The following signs and symptoms should prompt evaluation by an otolaryngologist: pain, sudden-onset hearing loss, dizziness, ear deformity, burdensome or bothersome tinnitus, ear drainage, asymmetric hearing loss, unexplained conductive hearing loss, a history indicating ear infections, noise exposure, autoimmune disorder, ototoxic medication use, or otosclerosis, and visualization of blood, pus, cerumen, or foreign body in the ear canal.[17] In addition to the consideration of hearing aids, teaching communications strategies is important. Minimizing background noise, encouraging face-to-face interaction, and teaching patients to rephrase and summarize what they heard to ensure good comprehension are strategies that help with improving communication.[18]

HEARING AIDS

Medical evidence indicates that hearing aids improve the health-related quality of life by reducing the psychological, emotional, and social effects of hearing loss, particularly for older adults with mild to moderate hearing loss.[11] Improvement in health-related quality of life is seen in older adults who use a standard hearing aid, a programmable hearing aid with settings for different listening environments, or an assistive listening device. Despite marked improvements in hearing aid technology, according to 1 study, no improvements in hearing aid usage were noted over a 15-year period.[19,20]

Hearing aids may be analog or digital. Analog hearing aids are less expensive than digital hearing aids and work on a linear model of amplification, with a microphone collecting sound, the device converting the sound into an electrical signal and then amplifying the sound as it sends the sound through the canal to the tympanic membrane. Although both analog and digital hearing aids can be programmed for different listening conditions, digital hearing aids operate more automatically and adaptively, with programs that reduce acoustic feedback, reduce background noise, and detect and automatically accommodate different listening environments. Digital hearing aids are able to control additional components, such as multiple microphones, to improve spatial hearing, and, for example, transpose frequencies from where a user may have poor hearing to frequencies where the use may have better hearing.[21] Many current digital hearing aids can also connect, or pair, with cell phones, digital music devices, and other electronic devices, allowing for a markedly improved hearing experience.

OSSEOINTEGRATED AUDITORY IMPLANTS

Osseointegrated auditory implants like the bone-anchored hearing aid (BAHA) systems are approved in the United States for patients with single-sided deafness

(SSD) or those with a conductive/mixed hearing loss (CMHL) who cannot use traditional amplification. The use of BAHA systems began in patients with dental implants. These individuals noted the perception of sound through an osseointegrated dental implant. With the advances in BAHA technology and technique, complications have been minimized and are generally minor.[22]

BAHA systems use an external processor to amplify sound waves as vibrations that are delivered to the inner ear. For patients with CMHL, the amplification involves bypassing the external canal and middle ear and using bone conduction to transmit sound energy to the ipsilateral cochlea.[23] For patients with SSD/unilateral sensorineural hearing loss, auditory information is transmitted to the contralateral cochlea.[24] In patients with SSD/CMHL, BAHA systems can provide hearing improvements that are not possible with conventional hearing aids alone, because conventional aids only amplify sound, and they must use the natural conducting mechanism of the outer ear and middle ear.[25] As a result, they have become an attractive alternative to traditional hearing aids in select older patients.

Older patients fitted with a BAHA experience substantially improved hearing and word and speech recognition and obtain greater sound localization, and substantial numbers report improvement in quality of life as measured by instruments, such as as the Glasgow Benefit Inventory,[26] a validated instrument used to assess the benefit of amplification.[27] The most common adverse event is skin reaction, including hypertrophic scarring and generalized irritation, with poor osseointegration and implant failure overall rare but reportedly more common in older populations.[25]

COCHLEAR IMPLANTATION

Although most older patients are appropriate candidates for amplification, up to 10% of older patients with hearing loss suffer from hearing loss severe enough that amplification cannot provide significant benefit.[28] Cochlear implants, devices placed into the inner ear to restore the perception of sound, are an effective intervention for older patients who do not benefit from amplification. Unfortunately, the rate of cochlear implant use in older adults who meet candidacy criteria is less than 5%.[29] Outcomes of cochlear implantation are closely related to the duration of deafness, and counseling patients and their families on reasonable expectations is essential. Cognitive evaluations can help guide assessment and counseling.[30]

Because a detailed description of cochlear implantation in the older patient can be found elsewhere,[31] a brief description follows. Cochlear implantation is a surgery commonly performed under general anesthesia, lasting less than 2 hours. Despite the short nature of the surgery, careful attention must be paid to medical comorbidities.[31] Medical optimization and clearance by patients' primary care provider and other specialists, as appropriate, is prudent to ensure a safe procedure and successful recovery. Older patients on anticoagulation therapy should obtain recommendations from the prescribing physician on how to best bridge the perioperative period. Cochlear implantation in older patients is safe and without significant risk in medically optimized individuals,[32,33] with no perioperative deaths having been reported.[34–36] Significant postoperative pain or nausea is rarely encountered and less common in older adults than in younger adults,[37] with older patients frequently returning to their normal routine within days.

Postoperative rehabilitation in older patients is similar to that in other adult patients, with speech perception testing the most important guide for rehabilitation. As noted in a review of current postoperative audiological and quality-of-life findings, there are

several measures and instruments used to assess the audiological and quality-of-life outcomes achieved by geriatric cochlear implant recipients.[38] Geriatric cochlear implant users enjoy improved speech perception and have outcomes for speech perception in a quiet environment comparable to other cochlear implant users, although younger postlingual cochlear implant users have better speech perception in noise than older cochlear implant users. This differences may reflect a longer duration of hearing loss and poorer preoperative speech perception. Older patients tend to have a somewhat slower rate of speech perception gain, and there is strong correlation between length of daily cochlear implant use and speech perception performance. When preoperative speech perception was taken into account, age was not predictive of postoperative speech perception outcome.[31,37]

Unilateral older and younger cochlear implant users report a similar speech perception benefit, but bilateral older cochlear implant users report less speech perception benefit than either unilateral older or younger cochlear implant users.[37] Many older cochlear implant users report difficulty with telephone conversation and conversation in noise and groups, although larger speech perception gains are reported in those with increased social activity. Speech perception achievements seem stable over the long term and may continue to improve.[37,38] Older cochlear implant users show greater confidence and participation in social settings than they did preoperatively. Moreover, older cochlear implant users and their families also reported high levels of satisfaction and hearing benefits from their devices.

Because Medicare uses candidate criteria that are significantly more restrictive than those set forward by the Food and Drug Administration,[39] and because preoperative speech perception is an important predictor of postoperative success, this likely skews the outcomes data, leading to under-representation of the benefit for older patients in whom amplification cannot help. In terms of economic efficacy, geriatric cochlear implantation compares favorably with pediatric and adult cochlear implantation, despite shorter life expectancy.[40] The rates of long-term use and nonuse also compare favorably with children and adult cochlear implant recipients.[41,42] Access challenges to funding and reimbursement are relevant to older patients. According to a RAND Corporation–funded study reviewing payments received for cochlear implants by providers and facilities in the United States, a hospital faced an average loss of $5000 to $10,000 on every Medicare patient implanted, making the provision of cochlear implantation to geriatric candidates economically tenuous.[43,44]

Taken together, the lack of adequate reimbursement and the restrictive candidate criteria risk reduced access to cochlear implantation for many geriatric patients who could benefit.

REGENERATIVE THERAPIES

With an increasing number of patients afflicted by presbycusis, greater attention is focused on novel therapies for treatment of ARHL. Hearing aids, BAHAs, and cochlear implants do not help regain native cochlear function or reverse any of the damage to the cochlear hair cells. ARHL is due in part to the loss of cochlear inner hair cells, which are responsible for the mechanosensory transmission of vibratory frequencies into neural input. There has been a significant interest in methods to regenerate cochlear inner hair cells since a study in 1993 found regeneration of inner ear sensory hair cells within the vestibular sensory epithelium of adult guinea pigs and humans.[45] Current research is focused on the usefulness of gene therapy, stem cell use, and pharmaceuticals to jump start the regeneration of inner hair cells.

GENE THERAPY

Of particular interest to hearing loss has been the role of the Atoh1 transcription factor, which has been found to play a crucial role in the differentiation of cochlear and vestibular hair cells.[46] Atoh1 expression leads to the formation of sensory hair cells and also to neurogenesis and functional inner ear hair cells.[47–50] Cell-cycle modulators is another area of gene therapy being targeted to enhance and tailor the regeneration of hair cells. $p27^{Kip1}$ is a cyclin-dependent kinase inhibitor seen to maintain quiescence of supporting cells and coincides with cell-cycle exit of hair cell and supporting cell progenitors.[51–55] Further work has established safe nondamaging administrative methods for gene therapy and future potential stem cell and pharmacologic therapies.[56]

PHARMACOTHERAPY

Closely linked with gene transcription and downstream effects are cellular signaling pathways and molecules, 2 of the most investigated pathways being the Wnt and Notch signaling cascades. Both are implicated in cellular proliferation and differentiation, whereas Wnt also regulates cellular migration, polarity, and neural patterning, and Notch regulates cellular patterning and apoptosis.[57–63] It has been shown that Notch signaling cascade promotes supporting cell transdifferentiation to regenerate hair cells rather than proliferation, slowly exhausting the population of supporting cells. Furthermore, Wnt activation results in a greater proliferation of supporting cells but a limited growth of hair cells.[64–66]

STEM CELLS

Although some researchers have reported success with hair cell–like cells from mouse embryonic stem cells and induced pluripotent stem cells,[67] others have focused on the development of the neural component of the inner ear system.[68] Several studies have shown success with mesenchymal stem cells in regenerating cochlear spiral ganglion neurons and restoration of some improved auditory brainstem response and otoacoustic emission.[69–71] Work with endogenous stem cells could bypass some challenges of exogenous stem cell use, with the best source for use in hearing restoration under investigation.[72–76]

SUMMARY

Geriatric hearing loss is a byproduct of normal aging with serious implications on individual and public social health and safety. Hearing loss is often an unrecognized concern in older patients with depression and dementia. Management of hearing loss through hearing aids and cochlear implantation has short-term and long-term benefits to quality of life, improving mood and social interaction. Amplification should be combined with the teaching of listening skills to help facilitate communication. Osseointegrated auditory implants and cochlear implantation are important surgical options for those who may not benefit from conventional hearing aids. Cochlear implantation is performed under general anesthesia and is safe and well tolerated by older adults, and older adults perform postoperatively similarly to younger adult cochlear implant patients. Hearing aids and cochlear implants do not prevent or repair the underlying pathophysiology of ARHL. Interest in inner ear regenerative therapies with hopes for more definitive treatment have made significant advancements since interest in the area first grew but still faces many challenges. Among these common hurdles is that each regenerative approach possesses unique advantages and

challenges that in time may be overcome and provide innovative methods to treat geriatric hearing loss.

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