

Current Trends in Treating Hearing Loss in Elderly People: A Review of the Technology and Treatment Options – A Mini-Review

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Key Words

Presbycusis · Hearing loss in the elderly · Adults with hearing loss · Sensorineural hearing loss · Cochlear implants · Hearing aids · Amplification

Abstract

Background: According to the World Health Organization (WHO), by 2025 there will be approximately 1.2 billion people in the world over the age of 60, which marks a shift in world population to a greater proportion of older people. An estimated 70–80% of adults between 65 and 75 years of age suffer from presbycusis, or age-related, bilateral sensorineural hearing loss (HL) in the high frequencies. Presbycusis is correlated with decreased quality of life (QoL) and depression and according to WHO, is a leading cause of years lived with disability in the adult years. **Objective:** The purpose of the current study was to review the body of literature on treatment options and considerations for the elderly population, as there is a variety of audio-technology available today to treat presbycusis. **Methods:** A PubMed literature search was conducted using the keywords 'presbycusis/presbycusis/geriatric AND hearing aids/cochlear implants/electric acoustic stimulation/middle ear implants' and 'elderly AND cochlear implants'. References were also mined from papers found. **Results:** 431 articles were considered in this review of treatment options for elderly patients suffering from presbycusis. **Conclusion:** Hearing aids and cochlear

implants (CIs) are the most commonly used devices for treating mild-severe presbycusis. Reported outcomes with hearing aids indicate they are an effective method for treating mild-moderate HL in cases where the patient is appropriately fitted and is willing, motivated, and able to use the device. Depending on the type and severity of the HL and the specific needs of the patient, electric-acoustic stimulation and active middle ear implants may also be appropriate solutions for treating presbycusis. Finally, very positive QoL and speech perception outcomes have been documented in treating severe-profound presbycusis with CIs. In some studies, QoL outcomes have even exceeded expectations of elderly patients.

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Introduction

According to the World Health Organization (WHO) [1], by 2025 there will be approximately 1.2 billion people in the world over the age of 60. This marks a shift in population demographics, from a greater proportion of young people to a more balanced proportion of young and old. This aging of the world's population has been attributed to a decrease in fertility and an increase in life expectancy in many countries [1]. An estimated 25% of people aged 65–75 years and 70–80% of people over age 75 suffer from sensorineural hearing impairment associ-

ated with aging (known as presbycusis) [2]. According to the Royal National Institute for Deaf People (RNID), there are already over 300 million people in the world with presbycusis and by 2050, it is projected that there will be 900 million [3].

Presbycusis is most often characterized by a bilateral, symmetrical hearing loss (HL) which begins in the high frequencies. Many speech sounds are high frequency sounds, which means that even a mild loss in these frequencies can greatly impair speech understanding. For these reasons, an elderly patient with presbycusis will typically complain first that he cannot understand people's speech, not necessarily that he cannot hear [4]. Causes of presbycusis are assumed to be the slow aging of the system, including: loss of or damage to hair cells from everyday noise exposure over time, loss of blood supply to the cochlea referred to as 'metabolic' presbycusis by Schuknecht [5], and loss of nerve fibers and neural elements. While all of these factors may contribute to presbycusis, metabolic changes appear to be the most predominant factor. While there is some evidence that age-related pathology also occurs in the central auditory system, more research is needed to explore this. Depending on the patient, other factors may contribute to these aging processes, such as acquired auditory stresses, trauma, or otological diseases [4]. Though the layperson commonly associates advanced age with HL, the impact of presbycusis on everyday functional communication and emotional well-being is often underestimated.

Noise-induced HL (NIHL) is the second leading cause of adult-onset HL after presbycusis. In the current elderly population, suspecting that an individual's HL derives from both NIHL and presbycusis is not uncommon, especially among veterans of war and retired industrial workers. Some estimate that prevalence of NIHL will continue to rise as the current generation ages, partly because of the popularity of personal stereo systems capable of producing sound above 85 dB and also because of exposure to loud music in clubs, or 'recreational noise'. NIHL resulting from recreational noise and occupational hazards can add to presbycusis, producing a more severe HL in old age.

Regardless of etiology, HL in people over 60 years of age can have devastating effects on quality of life (QoL) [6–8] and overall functioning [8]. In fact, a strong correlation between HL and depression has been found in older patients [9]. Left untreated, these effects become an ongoing contributor to the decline of health with age. Using WHO terminology, HL ranks third after depression and other unintentional injuries as a leading cause of

years lived with disability (YLDs) in adults [10]. In the case of HL, many of these YLDs presumably occur during the elderly years.

HL in people over 60 years of age is treatable in most cases. Treatment options, depending on the type and severity of HL, may include assistive devices, adaptation of the environment, training of communication partners, amplification with hearing aids (HAs), middle ear implantation, electric acoustic stimulation (EAS), or direct stimulation of the cochlea via a cochlear implant (CI). The purpose of this paper is to present and discuss possible solutions for treating HL in patients over 60 years of age.

Methods

431 articles were considered in this review of treatment options for elderly patients suffering from HL: 419 identified through PubMed search using the keywords 'presbycusis/presbycusis/geriatric AND hearing aids/cochlear implants/electric acoustic stimulation/middle ear implants' and 'elderly AND cochlear implants'; 5 identified through a general internet search; and 7 from reference mining.

Review of Hearing Technology

Hearing Aids

HAs can be effective in treating presbycusis, depending on the type and severity of the HL. The audiologist is key in HA selection, as some HA models and features are more appropriate for certain types of HL than others, and some models with smaller controls may not be appropriate for older adults with poor fine motor skills. Nowadays, HAs come in a variety of shapes and sizes, including traditional behind the ear, in the canal, completely in the canal, and open fit models. Multidirectional microphones are also an option. Two types of electronics are used in HAs today: analog and digital.

Analog HAs pick up sound waves through a microphone, convert them into electrical signals, amplify them, and send them through the ear canal to the tympanic membrane. They can be programmed to have different settings for different listening situations. As a rule, analog HAs are less expensive than digital HAs and work on a more linear model of amplification across frequencies.

Digital hearing aids allow the implementation of many additional features not possible with analog hearing aids. Fully digital hearing aids can be programmed with multiple programs that can be selected by the user, or that

operate automatically and adaptively. These programs reduce acoustic feedback, reduce background noise, detect and automatically accommodate different listening environments, control additional components such as multiple microphones to improve spatial hearing, transpose frequencies (shift high frequencies that a wearer may not hear to lower frequency regions where hearing may be better), and implement many other features. Fully digital circuitry also allows control over wireless transmission capability for both the audio and the control circuitry.

Outcomes with HAs

Several studies have shown that HAs provide improved hearing for older patients [11]. Mulrow et al. [12] showed sustained benefits of HAs in the areas of social-emotional, communication, and depression after 12 months of use in a group of 192 elderly (over 64 years old), hearing-impaired veterans. Though the group was quite homogenous and 70% of patients had HLs of 40 dB or less (considered a mild HL), the patients saw significant benefits from baseline to post-HA fitting. The average decibel gain the group had from the HAs was 16.3 dB (S.D. = 2.4 dB). Benefit in the area of QoL has also been shown for elderly HA users [8, 12].

There is a growing body of evidence that aural rehabilitation (communication programs) accompanying HA fitting in elderly adults yield better QoL outcomes [13, 14]. Most research into QoL in this group focuses on the problems they and their partners may experience, with limited available publications specifically discussing the improvement in quality of life provided by hearing aids. Further studies need to be done in order to identify what types of aural rehabilitation programs are most efficacious for elderly adults in the long term.

Another consideration when examining potential benefit of HAs in the elderly population is the acceptance of the device itself. Many people in this age group see HAs as cosmetically unappealing because they associate them with 'old'. It is estimated that only about 20% of potential users of HAs actually purchase them [15] and the majority of older people are hesitant to do so [15, 16]. Once fitted with HAs, 25–40% of adults will either stop wearing them or use them only occasionally [17]. Yet another subgroup of elderly patients continues to wear HAs but receives only limited benefit from them [11]. Another reason may be limited benefit received from HAs, e.g. in patients with a reduced dynamic range due to hypersensitivity to loud sounds (known as loudness recruitment), a common problem of patients with sensorineural HL.

Hearing-Assistive Technologies

A variety of devices which support listeners with hearing impaired are currently available on the market. Some are listening aids, while some alert or signal the user via auditory, visual, or tactile modalities. Some may be used in combination with other hearing instruments, e.g. telecoils which attach to HAs or CIs. Some are available to hearing impaired listeners attending events in public venues.

Harkins and Tucker [18] recently surveyed a group of 423 adults with HL, 48% of which were 61 and older and all of which were either using HAs (78%) or CIs (22%). 84% of respondents in the survey indicated using assistive listening technologies in the last 2 years. Though satisfaction with these assistive devices varied across different listening situations, most respondents reported some benefit to using these, especially for better speech understanding in difficult listening situations. For a more detailed review of the types of hearing assistive technologies available to adults, the reader is referred to the American Academy of Audiology's recently adopted guideline [19].

FM systems, which pick up a speaker's signal from a microphone near the mouth and transmit it directly to a receiver worn by the listener, are also a popular option. FM systems provide a high quality speech signal because having a microphone so close to the sound source offers a favorable signal-to-noise ratio (15–25 dB) [20]. This can be especially helpful in situations where adults with HL are attending lectures in large rooms or rooms with poor acoustics, e.g. some churches.

Chisolm et al. [21] reported on results from a study of 36 veterans ranging from 58 to 85 years of age trying FM systems. In their group, the mean HL was 70 dB (corresponding to a moderately severe HL). All 36 patients chose to continue using the FM systems after the termination of the study, and 30 of 36 were found to be using the systems one year later. Interestingly, the subgroup of 30 who were long term users were older on average than the original group (range 68–80). Chisolm et al. [21] also reviewed previous studies on FM system use in adults and found that while there are many studies highlighting good benefit, trials of the actual systems have been disappointing, possibly because more training and counseling around system use are needed. Kricos [22] drew similar conclusions about FM system use in her overview of best practices in the management of older adults with HL. Another explanation for the lack of acceptance of FM systems may be that they usually require additional equipment to be connected to the HA. While this equipment

has arguably become less cumbersome over the years, it still makes hearing impairment more visible and the HA itself even more cosmetically unappealing or conspicuous. Finally, a study by Stika et al. [23] found that only about 30% of audiologists even discuss the option of assistive listening devices with patients, indicating that lack of awareness may be a contributor to lack of use.

Active Middle Ear Implants

Elderly adults who cannot wear conventional HAs for medical or personal (cosmetic) reasons and whose HL is not severe enough to make them suitable candidates for CIs, may be good candidates for active middle ear implants (AMEIs). AMEIs, such as the MED-EL Vibrant Soundbridge, are used to treat adults with mild-to-severe sensorineural HL (including presbycusis) or other types of HL (mixed and conductive). The Otologics Carina is a fully implantable ossicular stimulator designed to meet the needs of adults with moderate to severe sensorineural hearing loss. All components, including the microphone and battery, are implanted under the skin. No papers deal specifically with the use of the Carina in the elderly, as found by the literature search methodology.

The Vibrant Soundbridge also has an implant component and an audio processor, but nothing is worn in the ear canal. Instead, a vibrating ossicular prosthesis (VORP) is implanted under the skin and the floating mass transducer (FMT) is clipped to the incus or other structure during a simple surgery called vibroplasty. Audio signals are received by the microphone on the audio processor, which is worn externally. These signals are then sent to the subcutaneous VORP and converted into mechanical vibrations carried out by the FMT. The back and forth motion of the FMT mechanically vibrates the middle ear structures, delivering frequency information up to 8 kHz.

Outcomes with AMEIs in the elderly population as a subgroup have not been specifically reported but have been documented within the larger adult patient group. Luetje et al. [27] reported on VSB results in a group of 53 patients ranging in age from 28–86 (average age 58.7 years), including one subject diagnosed with presbycusis. Results in this group demonstrated functional gain in hearing, word recognition, and subjective measures. After 5 months of VSB use, all patients reportedly preferred using their VSB to using conventional acoustic HAs. Uziel et al. [28] found the VSB significantly improved speech comprehension, listening ease in difficult listening situations, and overall satisfaction in a group of 6 patients ranging in age from 32 to 67 years (mean = 56). This

group of patients had tried conventional amplification in the form of analogue or digital HAs but cited the following reasons for dissatisfaction with them: insufficient benefit (83%), cosmetic issues (83%), poor sound quality (67%), feedback (50%), and harshness of sounds. Similarly, in 125 patients aged 24–81 years (mean = 56) consecutively implanted with the VSB, Sterkers et al. [29] found significantly increased speech understanding in quiet and found most patients (83%) were either satisfied or very satisfied with the VSB.

Given these positive results, it seems that the elderly population could benefit from VSB implantation. The VSB may be ideally suited to elderly individuals who have difficulty manipulating HA controls and cleaning ear molds or who may have collapsed ear canals (not uncommon in the elderly due to loss of skin elasticity). Other conditions from which elderly people suffer, though perhaps unrelated to presbycusis, may also make the VSB preferable over an HA. Some examples of these are: chronic (suppurative) otitis media, cholesteatoma, chronic otitis externa, chronic skin conditions, excessive cerumen, or middle ear pathologies resulting in severe mixed HL.

Electric Acoustic Stimulation

Electric acoustic stimulation (EAS) is the use of an HA and a CI together in one ear [24]. This combined method addresses the specific needs of patients presenting with good low frequency hearing (a mild-to-moderate sensorineural HL in frequencies up to 1,000 Hz) but poorer hearing in the high frequencies (sloping to 60 dB or worse HL above 1,000 Hz). Many of these patients receive little or no benefit from HAs alone. The HA component of the EAS system amplifies residual low frequency hearing while the CI provides electrical stimulation of the high frequency regions of the cochlea. Contraindications for EAS include: progressive HL; autoimmune disease; HL related to meningitis, otosclerosis, or ossification; malformation of the cochlea; a gap in air conduction and bone conduction thresholds of greater than 15 dB; or external ear contraindications (or unwillingness) to using amplification devices. Because presbycusis is characterized by HL in the high frequencies, older patients without these contraindications and with relatively good hearing in the low frequencies may be candidates for EAS.

Because EAS is a relatively newer technology, there are fewer studies of results in elderly patient groups than there are studies of patients with HAs. In general, however, results from adult patient groups (which include some patients over the age of 60) have shown a greater overall benefit from this combined device than from use

of an HA alone when low frequency hearing is preserved during surgery [e.g., 25]. However, results in EAS patients also show significant benefit in the CI-only condition. The study [25] also shows that, although there is a risk for losing hearing with EAS, users still perform well when using the cochlear implant only (when implanted with an electrode of 18–22 mm) and all users achieve better results than they did preoperatively using a high-power HA. Yao et al. [26] argued that EAS is appropriate for aging adults because presbycusis accounts for only a very slow rate of ongoing HL in the low frequencies over time (approximately 1.05 dB/year). Clearly, more research on EAS in the geriatric population is needed in order to uncover the impact such a surgery may have on the slowly progressive HL seen in presbycusis.

Cochlear Implants

While some people over the age of 60 can benefit from the use of hearing assistive technologies, HAs, EAS, or AMEIs, for many others, including those who suffer from more severe HL, other devices for rehabilitation must be considered. While HAs are capable of providing functional gain for many patients, they are not sufficient for patients with more severe hearing losses (thresholds greater than 70 dB) above 1 kHz. These patients do not receive sufficient gain in speech recognition from HAs [30].

Many people with severe to profound HL (defined as thresholds of 80 dB or worse) attributed to presbycusis and other factors (e.g. NIHL) reach a point where HAs no longer provide sufficient gain or benefit. Audiologists' anecdotal reports describe older HA users who realize that while an HA or assistive technology may have once provided 'good enough' hearing, these interventions become insufficient in the presence of a new set of communication demands accompanying lifestyle changes such as retirement or having grandchildren. In these cases, increased communication demands, plus a HL which may have worsened since the last visit to the audiologist, necessitate reevaluation of the treatment approach.

Cochlear implants were established to be effective for people over 60 years of age in the 1990s [31–33], and intraoperative and postoperative complication rates were found to be low [32]. However, because surgical risks involved must be appropriately weighed for any age group and according to individual medical history, this aspect of cochlear implantation in the elderly is not discussed here [see 34 for more information]. Beyond evaluation of surgical risk, the following indications should be considered: no medical contraindications, bilateral sensorineu-

ral HL, demonstrated lack of benefit from rehabilitation with HAs, a strong desire/commitment on the part of the candidate, and adequate support (family, caregivers, etc.) in the environment.

Cochlear implants (CIs), unlike HAs, do not amplify sound. CIs work by bypassing the ear canal, middle ear, and hair cells in the cochlea to provide electric stimulation directly to the auditory nerve. This means that patients must have a functioning auditory nerve in order to be candidates. Patients with a CI system receive incoming sounds through the microphone in the audio processor component, which resembles a small HA resting on the superior pinna. The audio processor then converts these sounds into a special pattern of coded electrical impulses and sends them to the magnetic coil, located on the skin directly above the implanted part of the system. The coil transmits these across intact skin via radio waves to the subcutaneous component of the CI system. The pulses then travel to the electrode array and along the electrodes where they are delivered at different points in the cochlea, depending on frequency information. The electrodes stimulate the cochlea at very high rates and the auditory nerve carries these signals to the brain. Receiving a unilateral CI is the most common treatment method for the elderly, however, many users may receive bilateral CIs, either in the same surgery or sequentially. Bilateral CIs allow users more access to binaural cues such as head shadow effect and localization. Other users may wear a CI in one ear and a HA in the other ear – allowing a bimodal fit, which may access some binaural cues. Often, bimodal fitting is the choice of the user. The literature on CI in the elderly mostly focuses on unilateral fittings.

Speech Perception Outcomes in CI Users

Several studies have documented effective use of CIs by patients over the age of 65, including significant improvement in speech recognition abilities and results which are not significantly different from those obtained by younger patient groups [35–40].

Specifically, Orabi et al. [36] compared results in two groups of consecutive patients receiving Nucleus (Cochlear Corp.) and C40+ (MED-EL) CIs between 1989 and 2002: 34 patients aged 65–80 and a group of patients aged 16–64 years. While both groups had better speech recognition abilities postoperatively, there was no significant difference in performance between the two groups on Bench, Kowal and Bamford (BKB) sentences, CUNY (The City University of New York) sentences, and Arthur Boothroyd (AB) word test in quiet and noise. The elderly group's perceived improvement after CI exceeded preop-

erative expectations. Furthermore, while the older group did have somewhat lower speech-in-noise scores, they were not significantly lower.

In another study, Nakajima et al. [40] compared a group of 12 patients aged 65 and older (average age 73) with a group of 15 patients under 65 years (average age 48) using CIs with the SPEAK strategy. Both groups received CIs and were tested on syllables and sentences spoken with slow and normal speech rates in quiet and noise. No significant difference was found between groups in quiet and with slower speech rates; though the older group had significantly poorer speech recognition scores in noise and with a normal speech rate.

Another interesting finding was made by Leung et al. [37] who compared a group of 258 CI patients aged 65–91 with a group of 491 CI patients aged 14–64 years. While Leung et al. [37] did not test for speech recognition in noise; they did find that duration of deafness, not age, correlated with poorer speech recognition. In this study, patients from the older group who had durations of deafness greater than 25 years actually performed better than the younger group.

In a study of 20 patients 65 years and older who were implanted with a variety of cochlear nucleus CIs at a single center over a span of 12 years, Cambron [41] found that all patients scored higher on speech perception testing postoperatively and that age had little to no bearing on postoperative performance.

These results are in contrast to the earlier belief that the elderly population would not benefit from CIs because of central processing impairments that are a natural part of aging. While there may be some deficits in central processing which result from advanced age, the above studies provide ample evidence that people over the age of 60 benefit from cochlear implantation. Having said this, older listeners may benefit even more from CIs when background noise is reduced, speech rate slowed [39], and when conversation partners are trained in the use of clear speech [42]. How much of this added benefit is due to central processing challenges arising with age and how much is due to natural human communication needs at any age, the literature has yet to definitively determine. However, it is clear that postoperative rehabilitation is an essential component in the treatment and care of users (both young and old) who receive a CI. Rehabilitation allows the users to develop their listening skills to maximum effect, to manage communication issues that may have arisen during their time with a hearing loss, and to help manage any central processing challenges they may experience due to age.

CIs and QoL

Perhaps an even stronger argument for the suitability of older adults as CI candidates is the existing body of literature on subjective benefits this population receives from CIs. The impact of CIs on QoL in the elderly is fairly well documented, both for the earlier generation of CIs and the more recent technology. In a seminal study, Horn et al. [31] surveyed 67 patients implanted at age 65 or older with a Nucleus 22 (Cochlear Corp.) device and showed similar benefits to younger implant recipients, including increased confidence at work and at home. 63% of the 67 patients reported an increase in social activities and 86% reported an overall improvement in QoL. 88% said they would choose to undergo cochlear implantation again. Kelsall et al. [32] documented significant objective and subjective benefit in 2 groups of CI patients with advanced age (65–69 and 70+ years). Waltzman et al. [33] had similar findings in their group of 20 patients aged 65–85 years implanted with Nucleus CIs. A more recent study by Anderson et al. [43] surveyed 91 MED-EL CI recipients using a 30-item questionnaire based on the 26-item Cochlear Implant Questionnaire of Horn et al. [31]. They then compared their group's results with older results of Horn et al. [31] and Kelsall et al. [32] and found significantly better outcomes in several areas for the newer technology including the ability to distinguish between a man's and a woman's voice, use of the telephone without a code, and overall increase in social activity since implantation.

Vermeire et al. [38] compared subjective and objective results for 3 age groups (up to 55 years, 56–69, and a 70+ group) of patients receiving Laura, Nucleus 24, and MED-EL C40+ CIs. They found that even though the oldest group had poorer speech scores than the two younger groups, all groups experienced significant audiometric postoperative gains and all had similar QoL outcomes (Hearing Handicap Inventory for Adults, Glasgow Benefit Inventory).

In one study relating to functional health status and cost-utility ratio of cochlear implantation in 47 older adults (aged 50–80 years) [39], subjective benefit in hearing and emotional health attributes were major contributors to postoperatively improved scores on the Ontario Health Utilities Index Mark 3 survey scores. These improved scores were correlated with objectively measured improvements in speech perception, and all contributed to the finding of a cost-utility ratio of USD 9,530 per quality-adjusted life-year.

Conclusions

HAs and CIs are the most commonly used devices for treating mild-to-severe presbycusis. Reported outcomes with HAs indicate they are an effective method for treating mild to moderate HL, as long as the patient is appropriately fitted and is willing, motivated, and able to use the device. For those elderly patients with sufficient residual low frequency hearing, EAS may also provide a viable solution. AMEIs may be another attractive option for elderly patients, as they offer the benefit of avoiding ear occlusion and HA handling issues to those who need it. Finally, very positive QoL and speech perception outcomes have also been seen in treating severe-profound presbycusis with CIs. In some studies, QoL outcomes have even exceeded expectations of elderly patients.

In spite of these positive findings on the available technologies to treat presbycusis, it appears that hearing screening is not always a routine part of examination of elderly patients. In a long-term study, Kochkin [44] polled 23,636 patients of all ages in the United States and found that only 17.6% of those aged 65–74 and only 21.6% of those over age 75 received hearing screening during their last physical exam. A few years later, Kochkin [45] found

that the hearing screening rates reported in the US in 1999 had since declined for all age groups. These results were similar to those of Cohen et al. [6], who found that only 11.8% of primary care physicians screen for HL during annual physical exams. Likewise, lack of awareness of the current technologies available and the benefits they offer patients with presbycusis may also be an issue at the primary care level.

Future directions for research and development in the field include the possibility of treating presbycusis through drug delivery, hair cell regeneration (using stem cells), or gene- and cell-based therapies [46]. Efforts to better understand the mechanisms at work in presbycusis and how to prevent it are also ongoing [47]. Prevention of NIHL in the current young generation, which has been shown to be at particular risk for recreational noise exposure [48], is also a factor when considering presbycusis treatment in future generations.

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