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Cochlear Implant Rehabilitation in Older Adults: Literature Review and Proposal of a Conceptual Framework

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Abstract

Hearing loss is a prevalent consequence of aging and also poses special challenges for older adults. Particularly when superimposed on other age-related conditions, presbycusis (age-related hearing loss) places the older adult at risk for social isolation and associated psychological and general health sequelae. The increasing cognitive demand of verbal communication, as well as the diminished sense of social and physical connectedness, can furthermore contribute to a feeling of vulnerability and poor health that worsens with advancing presbycusis. This cascade of downstream effects of hearing loss has implications for the self-assessment of health related quality of life (HRQL) and resulting estimates of associated costs. There is accumulating evidence of a potential role for cochlear implants (CI) in older adults with poor word understanding despite conventional hearing aid (HA) usage. In our review of the literature we identify strong evidence for the restoration of communication capacity in the deaf and hard of hearing geriatric population, little published work on communication performance in the real world and HRQL, and significant gaps of knowledge regarding how CI rehabilitation interacts with changing psychosocial and functional status. We therefore propose a broader conceptual framework than is currently available for the role of CI rehabilitation in the management of severe-to-profound hearing loss in older adults. We posit that the use of such a model in future investigations is needed to guide multidisciplinary investigations into the unique challenges of hearing loss in older adults as well as open new opportunities for innovation.

Keywords

presbycusis; hearing loss; aging; older adults; cochlear implant; communication; conceptual framework; cascade

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INTRODUCTION

Hearing loss is the third most common chronic health condition in individuals over 65 years-of-age, surpassed only by arthritis and hypertension. [1] The aging auditory system gradually loses its ability to precisely detect, resolve and represent the distinguishing physical properties of speech sounds due to degenerative changes in the cochlea and central nervous system, a process known as presbycusis. [2] These changes are most detrimental to communication in ambient noise from which relevant sounds are increasingly indistinguishable. Approximately 25% of people aged 65–75 years and 70–80% of people over age 75 suffer from hearing loss. [3] Associated communication difficulties impact several domains critical to successful aging. Demographic trends, including greater longevity and growing numbers of older adults, highlight the importance of understanding and managing hearing loss as a component of geriatric care. [4]

Management Strategies

The impact of hearing loss can be mitigated by timely and appropriately administered sound amplification, e.g., assistive listening devices and hearing aids (HA). [5, 6] Gains in communication function are associated with the reversal of depression and maladaptive responses including social isolation. [5] In advanced presbycusis, however, HAs may increase sound detection without improving speech perception and communication.

Increasing evidence demonstrates a role for cochlear implants (CI) in older adults who continue to experience poor word understanding despite appropriately fitted HAs. [7] The CI is a surgically-placed device consisting of an externally-worn speech processor and an internally-placed receiver/stimulator connected to an electrode array that is coiled within the cochlea. The electrode array directly stimulates the auditory nerve, delivering the unique electrical representation of each speech sound. Depending on the quality and clarity of hearing with the CI, the older adult may spontaneously recognize words with practice the assistance of rehabilitation therapy. CI candidacy is determined using standardized tests of speech perception in which sentences are presented without visual cues while wearing hearing aids. The indication for CI surgery according to the FDA is a score of 60% or worse, [8] whereas the Centers for Medicare and Medicaid Services (CMS) currently use a standard of 40% or worse.

Consequences of Hearing Loss in Older Adults

Presbycusis has several implications for physical, mental and social well-being. According to the WHO's International Classification of Functioning, measures of auditory function such as hearing threshold and speech perception, reflect "communicative capacity" which should be distinguished from "communicative performance" in everyday life. [9] It is increasingly evident that the study of auditory perception alone is inadequate to understand the cascade of cognitive, psychological and behavioral processes that accompany the progression of presbycusis. [10–14] Key interactions between top-down (cognition) and bottom-up (auditory) processing exist in older adults. [15, 16] Effective speech comprehension is challenged when the flow of auditory information is disrupted in either of these pathways. Attempts to characterize the efficacy of the CI have primarily focused on changes in communication capacity measured in the clinic setting, with inadequate emphasis placed on communicative performance and other outcomes in everyday settings. No single evaluation instrument provides reliable and comprehensive estimates of CI outcomes in this population. Hearing-specific surveys such as the Hearing Handicap Inventory for the Elderly, [17] assess self-perceived everyday communicative performance, but benefits cannot be compared to those of other health interventions. Health related quality of life (HRQL) measures, by comparison, assess a person's overall well-being, and quantifies the

extent to which an intervention is found useful relative to another. [18] Increasing demand for evidence-based and cost-effective health care necessitates careful characterization of auditory and non-auditory benefits of the CI in the management of presbycusis. As observed in children, the capacity to perceive speech may not correlate with real world performance. [19] In addition, HRQL measures may not be adequately specific. General health status and individual and environmental characteristics, all of which may change during aging, are likely to influence HRQL and communication outcomes after CI surgery. [20]

We undertook a comprehensive examination of the literature to explore the impact of CI surgery on various outcomes relevant to successful aging. The first objective was to review studies investigating CI outcomes in older adults. The second objective was to develop a broader conceptual framework demonstrating important interactions between characteristics of hearing disability, aging and the CI intervention that may guide future investigations, instrument development and new clinical strategies.

METHODS

Search Strategy

A literature search was conducted using PubMed (1953–2005), EMBASE (1974–2010), CINAHL (1982–2010), PsychoInfo (1887–2010), and Web of Science (1945–2010) using the search strings: [cochlear implant] AND [adult] AND [older]; [cochlear implant] AND [adult] AND [elderly]; [cochlear implant] AND [adult] AND [geriatric].

Study Selection

Inclusion criteria were: Title containing the words: cochlear implant, and generic term referring to older adults or numerical value for age greater than 65 years (Figure 1). The exclusion criterion was: Primary language not English.

Data Extraction

Each article was reviewed by two independent readers and compiled into evidence tables. Tables were compared to ensure the integrity and completeness of the results. Characteristics of the study cohort and outcome measures were recorded. The reference lists of all articles found to be eligible for systematic review were reviewed for missed manuscripts. [21–51]

RESULTS

Overview of Findings

The search yielded 17392 citations of which 31 manuscripts were eligible for systematic review (Figure 1). The age criterion for inclusion was 65y or older in 23 papers. The other 8 papers included younger patients with some extending to the 50's. Table 1 summarizes the outcomes examined by these papers. The studies were of prospective design in 3 papers, and the rest were predominantly retrospective. Speech perception results were reported in 27 papers and were the only outcome in 12 of these. Nineteen studies included measures other than auditory function tests such as speech perception. Emotional symptoms related to hearing loss were explored in 4 studies using subtests of the Hearing Handicap Inventory for Adults (HHIA) [34], Hearing Handicap Inventory for the Elderly (HHIE), Hearing Handicap Questionnaire (HHQ) [24], Ontario Health Utility Index mark 3 (HUI-3) [40], and a non-standardized questionnaire [48]. Standardized instruments were used for self-reported assessment of verbal communication in 4 papers using HHIE [25, 27], HHIA [34], HHQ and Speech, Spatial and Qualities of hearing scale (SSQ) [25] (Table 2). Non-standardized questionnaires were used to assess communication benefits in 5 papers. The impact of the CI

on role functioning was examined in 12 studies. Most of these assessments used non-standardized questionnaires and were limited to communication activities such as telephone usage. Three papers used subscales of the HHIE, HHQ [25] and Glasgow Benefit Inventory (GBI) to examine CI impact on social functioning. [32, 34] Psychological effects of CI were examined in only 1 paper, which measured levels of depression and loneliness [29]. Quality of life was examined in 8 reports, of which standardized instruments were used to examine HRQL in 3: HUI-3 [40] and GBI [32, 34].

Assessment of Symptoms and Communicative Capacity after CI

Speech perception without visual cues was significantly improved following CI. Within the first 6 to 12 months after surgery there was no difference in mean reported speech perception for older and younger adults (Figure 2). [22, 24, 35, 38, 44, 50] Sixteen citations reported comparable speech perception performance in quiet between younger and older adult cohorts. [21, 25, 28, 29, 30, 32, 33, 36, 37, 38, 39, 44, 45, 46, 50] Vermiere et al [34], however, reported significantly larger gains in younger patients and Chan et al [30] report faster gains for younger patients in the first 6 months after CI activation. Speech understanding with a CI in background noise was found to be more difficult for older than younger age groups [29, 32, 43]. Other variables found to impact speech perception performance with the CI included pre-operative level of speech perception and duration of deafness [24, 36]. For both papers in which duration of hearing loss was taken into consideration, age was not found to be predictive of speech perception outcome. [30, 36] Francis et al also observed a strong correlation between hours of CI use per day and speech perception performance [40].

Assessment of Communicative Performance after CI and Impact on other Functional Domains

Patient-reported communicative performance with the CI was examined in the context of social and role functioning in 15 papers of which 9 provided relatively detailed assessment of improved function although standardized instruments were not always used. Greater confidence and participation in social activities (Table 1) were reported in 81–94% and 50–80% of patients, respectively using a questionnaire similar to that of Horn et al [40, 41, 46, 50, 51]. As summarized in Table 2, improved postoperative scores were demonstrated for most subtests across all standardized inventories, suggesting a perceived improvement of communicative performance in older adults after CI. For unilateral CI, there was no difference in self-reported communication function between older and younger CI recipients. In patients with bilateral CIs, however, there was a negative correlation between age and improved spatial hearing according to Speech and Spatial subscales of the SSQ [25]. Vermiere et al reported a correlation between speech perception and scores of the Hearing Handicap Inventory for Adults in the middle age group. [34] Francis et al. observed larger speech perception gains for those who reported increased social activity after CI. [40] Although improved, patients continued to be challenged by use of the telephone, and by conversations in noise and in groups.

An improvement in psychological functioning was evidenced by reduced depression in the only paper that addressed this concern. [29] Elevated self-worth and social participation were reported by several authors. [40, 45, 48, 51] Francis et al [40] reported an overall improvement in the emotional subscale for a cohort aged 50 to 80 years. Although suggestive that some maladaptive responses to hearing loss are normalized, direct measure of these changes has been limited. Facer et al., for example, reported no significant change in the feelings of patients about their hearing loss and no difference in their ability to cope with breakdowns in communication after CI [48]. Vermiere made a similar observation for subjects over the age of 70 years [34]. No papers addressed the impact of CI on cognitive

function or other role functions not directly related to communication. Physical function and activities of daily living were not studied. There was also no evaluation of how personality, socioeconomic status, family support and other individual or environmental characteristics affect auditory capacity, communication performance and quality of life.

Health Related Quality of Life

The perceived effects of the CI on quality of life were explored in 8 citations [32, 33, 34, 40, 41, 46, 50, 51], of which 3 used validated instruments [32, 34, 40]. All papers reported improvements after CI. Francis et al. found the largest and most significant increase for *hearing* and *emotion* domains. [40] No differences were detected between older and younger cohorts. It was also noted that the greater the speech perception gains, the larger the improvement of HRQL. Furthermore, scores of the Ontario Health Utility Index-3 (HUI-3) were closely correlated to self-reported changes in confidence, social participation and telephone use. Despite reduced periods of benefit compared to younger recipients, significant gains in HRQL resulted in a favorable cost-utility estimate of \$9,530 per QALY for CI in older adults (mean 66y, range 50–83y). [40] Vermiere et al. reported similar improvements in Glasgow Benefit Inventory (GBI) scores across 3 adult age-groups. [34] Significant gains were observed in social, emotional and situational subscales for the aggregate cohort, with general and social subscales demonstrating the greatest improvement for their geriatric group (mean 74y, range >70y). Vermiere et al reported correlations between speech perception and the Glasgow Benefit Inventory for the entire study cohort, but not for their geriatric group alone. [34] Orabi et al. also found an improvement in overall HRQL and general health subscale using the GBI. No improvement was detected for social support and physical health scores. [32] The impact of health status and of characteristics of the individual or their environment on HRQL was not examined in any study.

Several authors reported patients' responses to a single query regarding changes in their quality-of-life. For their cohort, Francis et al. found a strong correlation between HRQL gains measured using the HUI-3 instrument and the declaration of improved quality-of-life by 89% of post-lingually deafened individuals [40]. Using a custom-made survey Horn *et al.* found that 86% of recipients reported improved quality-of-life which was also associated with an increase in social activities (63%) and confidence (81%). [51] Using the same survey, Kelsall et al. found improved quality-of-life in 84% of recipients, with 55% and 85% reporting gains in social activities and confidence respectively. [50] Kunimoto et al. using a self-constructed questionnaire found that despite persistent impairments in the understanding of speech in the presence of background noise and in multi-talker situations, 80% of older adults and their families reported communication benefit in family and social activities and an associated improvement in quality-of-life after CI. [46] Haensel et al. also reported high levels of satisfaction and hearing benefit with 100 percent indicating that the CI had a positive impact on their quality-of-life. [33]

Other Outcomes

Age was not found to influence operative time or length of hospital stay. [44] There was no age effect reported on CI program settings. [31] The rates of surgical complication were also found to be comparable between older and younger CI recipients [29, 33, 37, 39, 41, 45]. The level of general health was found to be a better predictor of medical outcome than age alone, [26] although Carlson et al [22] found that patients over the age of 80 years were more likely to have non-surgical complications such as cardiac arrhythmia, delirium or urinary retention (2–4%) that required hospitalization.

DISCUSSION

The literature reveals strong evidence that cochlear implantation in older adults is safe, improves speech understanding, and in so doing, improves communication, social participation as well as mental health. Yet, there appears to be greater variability in the magnitude of CI benefit for older adults. Speech perception is a predictor of communication performance and quality-of-life gains for patients over the age of 50 years [40], but this association is weaker for an older cohort of patients. [34] Older adults tend to progress more slowly with smaller gains in speech perception and quality-of-life. [21, 54] Length of deafness, however, is a robust predictor of auditory and quality-of-life outcomes [22, 23, 36, 52, 53, 54, 55]. The cumulative degenerative or psychosocial effects of hearing loss, rather than actual patient age, may better guide our clinical decision making and research agendas. These effects, however, may become amplified by challenges that accompany advancing age. Therefore multidisciplinary competences in geriatric care must be used to minimize the pervasive downstream effects of hearing loss in older CI patients. Early intervention is one clinical strategy that stands out from an analysis of the literature. Despite this, CMS limits reimbursement to patients with more advanced deficits despite expanding FDA criteria. [8]

Given the demonstrated ability to improve communication capacity in deaf and hard of hearing older adults, what additional interventions will maximize HRQL? First, we should consider the effects of hearing loss in the larger context of aging. In older adults with hearing loss, there is evidence of a psychological toll, maladaptive behaviors and cognitive effects that accumulate during auditory deprivation and pose unique challenges to rehabilitation [10–14, 56, 57]. Severe hearing loss directly and/or indirectly augments the consequences of aging, making effective management more demanding and uncertain.

We suggest a modified HRQL conceptual model (Figure 3) originally proposed by Wilson and Cleary [20]. We have applied peer-reviewed evidence as well as hypothesized relationships to render this a HRQL conceptual model of CI rehabilitation in older adults [20]. As in the original Wilson and Cleary model, both biomedical and social science paradigms are used to demonstrate the relationships between clinical variables and HRQL, as well as intervening variables and effects. We present a comprehensive view of the complex interactions between the aging experience, hearing loss, and the rehabilitation process, including variables that are often ignored and undervalued by approaches focused solely on cost-effectiveness. Our literature review suggests that most scholarly efforts have focused on the relationships between biomedical and device factors (box 1), and auditory symptoms (box 2) with very little consideration of the psychosocial interactions that impact communicative function and quality-of-life. This model promises to advance a multidisciplinary approach to better rehabilitation outcomes.

The functional, psychosocial and quality of life implications of CI rehabilitation depends first on the symptom response (auditory, cognitive and emotional) as mediated by characteristics of the individual and his/her environment (Figure 3). [14] Any deviations from optimal surgical placement and programming of a fully functional CI (Figure 3, box 1) have implications on the relief of auditory symptoms and on other domains of the conceptual framework. Higher communication demands on attention and maladaptive emotional responses are symptoms of hearing deprivation that can limit social interaction and engagement in rehabilitation. The increased mental effort of communicating contributes to the perception that mental concentration, and the performance of complex motor and cognitive tasks are declining. [56, 57] A critical clinical question is whether improvements in audition can lead to a reduction in cognitive load [15, 16]. Under a cognitive resource capacity model proposed by Kahneman [58], improved speech perception would make more attentional resources available to other cognitive subsystems (e.g. memory, executive

functions). Clinical trials are needed to examine the impact of HAs and the CI on cognitive trajectories in older adults.

A cascade of social, role, and psychological effects ultimately impact general health perceptions (Figure 3, box 4) and HRQL (box 5). [10, 59] These trends have been associated with real declines in activities of daily living and higher mortality rates [59, 60]. Hearing loss is also independently and significantly associated with the incidence of dementia, [12] and future studies could explore the role of hearing rehabilitation in slowing cognitive decline or in improving communication outcomes in those with early dementia. Ongoing interaction between symptoms of hearing deprivation and functional status (Figure 3, boxes 2 and 3) therefore establishes a downward spiral that poses an increasing burden on health, independence and the CI rehabilitation process.

Depression is also more likely with increasing hearing deficits. [13, 14] Its bidirectional interactions with other functional domains (within box 3) and all outcome levels of the model, [20] highlight the importance of psychological status on engagement in the rehabilitation process and its perceived or actual results. The cognitive load associated with hearing loss is further compounded by the presence of depressive symptoms, reflecting the multiple pathways by which hearing loss can pose challenges to an older person. The failure to account for these down-stream effects of hearing loss is likely to explain the greater variability of CI outcomes in older adults. Future studies could further evaluate the effect of depression and its appropriate management on CI outcomes.

Individual characteristics such as mastery and self-esteem are likely to influence the emotional response to progressive hearing loss (box 6) [61] and its impact on functional domains and quality-of-life. Whereas some individual characteristics influence the severity of symptoms, others (personal values and preferences) are more likely to influence the perceptions of general health and quality-of-life. [20] Future studies could evaluate the predictive power of these characteristics for communication and HRQL outcomes with the CI, possibly leading to the design of customized supplemental rehabilitation strategies.

Characteristics of the environment (support by family, friends and professionals) likely influence the results of CI rehabilitation and its perceived benefit (Box 7). Socioeconomic status often determines access to timely and appropriate hearing rehabilitation services and may determine the risks of early hearing disability. Social circumstances can either improve or worsen feelings of isolation and the sense that one's identity is unraveling as conversation and other vital listening activities remain out of reach. [62] Future studies will likely demonstrate that strong social support networks help to 1) reduce maladaptive emotional responses; 2) encourage and facilitate practice of speech perception with the CI and its use in spoken communication and 3) provide logistical support for improved access to care.

Several limitations of this review should be considered. First, since we have limited our search protocol to titles addressing the CI in older adults, we may have excluded relevant data. Other studies, however, do not typically segregate results by age group. Variable age criteria used for subject inclusion may confound our ability to effectively compare studies. Second, the available literature often contains retrospective data with small sample size that limits our ability to generalize findings. Third, the utilization of non-standardized quality-of-life instruments in some manuscripts reduced the value of the reported findings and prevented cross-study comparison. Lastly, changing technology makes it difficult to compare and contrast studies that address different generations of CI technology. These limitations serve to emphasize that further research is necessary to better understand the significant role of hearing rehabilitation in the maintenance of independence and quality-of-life among older adults with severe to profound hearing loss. The lack of data also highlights

the importance of utilizing validated outcome measures and controlling for influential factors indicated in the conceptual framework.

In summary, peer-reviewed literature supports the CI as a safe and effective intervention for treatment of severe to profound sensorineural hearing loss in older adults. However, the amelioration of cognitive, psychological and social consequences of hearing loss has received minimal attention despite the potential relevance to hearing rehabilitation outcomes and their importance to the aging experience. An improved understanding of how the CI affects these psychosocial determinants of daily communication and function may guide the development and evaluation of evidence-based rehabilitation protocols for older adults.

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References

1. Healthy People 2010. [accessed January 31, 2011] Hearing Health Progress Review. 2004. http://www.nidcd.nih.gov/health/healthyhearing/what_hh/progress_review_04.asp#ref23
2. Schuknecht HF, Gacek MR. Cochlear pathology in presbycusis. *Ann Otol Rhinol Laryngol*. 1993; 102(1 Pt 2):1–16. [PubMed: 8420477]
3. Lin FR, Thorpe R, Gordon-Salant S, et al. Hearing loss prevalence and risk factors among older adults in the United States. *J Gerontol A Biol Sci Med Sci*. 2011; 66(5):582–90. Epub 2011 Feb 27. [PubMed: 21357188]
4. Institute of Medicine. Retooling For An Aging America, Building The Health Care WorkForce. The National Academies Press; Washington DC: 2008.
5. Mulrow CD, Aguilare C, Endicott JE, et al. Quality of life changes and hearing impairment: A randomized trial. *Ann Int Med*. 1990; 113:188–194. [PubMed: 2197909]
6. Chisolm TH, Johnson CE, Danhauer JL, et al. A systematic review of health-related quality of life and hearing aids: Final report of the American Academy of Audiology Task Force on the health-related quality of life benefits of amplification in adults. *J Am Acad Audiol*. 2007; 18:151–183. [PubMed: 17402301]
7. Yeagle JD, Ceh KM, Francis HW. Geriatric Cochlear Implantation. *Operative Techniques in Otolaryngology Head and Neck Surgery*. 2010; 4 (21):266–271.
8. [Accessed January 30, 2012] Medicare Benefit Policy Manual. Available at: <https://www.cms.gov/medicare-coverage-database/details/nca-decision-memo.aspx?NCAId=134&ver=15&NcaName=Cochlear+Implantation&NCDId=245&ncdver=1&IsPopup=y&bc=AAAAAAAAEAAA&>
9. World Health Organization. International classification of functioning, disability, and health: ICF. Geneva: WHO; 2001.
10. Sommers MS. Speech perception in older adults: the importance of speech-specific cognitive abilities. *J Am Geriatr Soc*. 1997; 45(5):633–7. [PubMed: 9158590]
11. Baker MW. Creation of a model of independence for community-dwelling elders in the United States. *Nurs Res*. 2005; 54(5):288–95. [PubMed: 16224314]
12. Lin FR, Metter EJ, O'Brien RJ, et al. Hearing loss and incident dementia. *Arch Neurol*. 2011; 68:214–20. [PubMed: 21320988]
13. Hallam R, Ashton P, Sherbourne K, et al. Acquired profound hearing loss: mental health and other characteristics of a large sample. *Int J Audiol*. 2006; 45(12):715–23. [PubMed: 17132560]
14. Gopinath B, Wang JJ, Schneider J, et al. Depressive symptoms in older adults with hearing impairments: the Blue Mountains Study. *J Am Geriatr Soc*. 2009; 57(7):1306–8. [PubMed: 19570163]
15. Sarampalis A, Kalluri S, Edwards B, et al. Objective measures of listening effort: effects of background noise and noise reduction. *J Speech Lang Hear Res*. 2009; 52(5):1230–40. [PubMed: 19380604]

16. Peelle JE, Troiani V, Grossman M, et al. Hearing loss in older adults affects neural systems supporting speech comprehension. *J Neurosci*. 2011; 31(35):12638–43. [PubMed: 21880924]
17. Ventry IM, Weinstein BE. The hearing handicap inventory for the elderly: a new tool. *Ear Hear*. 1982; 3(3):128–34. [PubMed: 7095321]
18. Furlong WJ, Feeny DH, Torrance GW, et al. The Health Utilities Index (HUI) system for assessing health-related quality of life in clinical studies. *Ann Med*. 2001; 33(5):375–84. [PubMed: 11491197]
19. Lin FR, Niparko JK. Measuring health-related quality of life after pediatric cochlear implantation: a systematic review. *Int J Pediatr Otorhinolaryngol*. 2006; 70(10):1695–706. [PubMed: 16806501]
20. Wilson IB, Cleary PD. Linking clinical variables with HRQL. A conceptual model of patient outcomes. *JAMA*. 1995; 273(1):59–65. [PubMed: 7996652]
21. Oyanguren V, Gomes MV, Tsuji RK, et al. Auditory results from cochlear implants in elderly people. *Braz J Otorhinolaryngol*. 2010; 76(4):450–3. [PubMed: 20835531]
22. Carlson ML, Breen JT, Gifford RH. Cochlear implantation in the octogenarian and nonagenarian. *Otol Neurotol*. 2010; 31(8):1343–9. [PubMed: 20729782]
23. Migirov L, Taitelbaum-Swead R, Drendel M, et al. Cochlear implantation in elderly patients: surgical and audiological outcome. *Gerontology*. 2010; 56(2):123–8. [PubMed: 19713692]
24. Friedland DR, Runge-Samuelson C, Baig H, Jensen J. Case-control analysis of cochlear implant performance in elderly patients. *Arch Otolaryngol Head Neck Surg*. 2010; 136(5):432–8. [PubMed: 20479370]
25. Noble W, Tyler RS, Dunn CC, et al. Younger- and older-age adults with unilateral and bilateral cochlear implants: speech and spatial hearing self-ratings and performance. *Otol Neurotol*. 2009; 30(7):921–9. [PubMed: 19692936]
26. Coelho DH, Yeh J, Kim JT, et al. Cochlear implantation is associated with minimal anesthetic risk in the elderly. *Laryngoscope*. 2009; 119(2):355–8. [PubMed: 19160385]
27. Eshraghi AA, Rodriguez M, Balkany TJ, et al. Cochlear implant surgery in patients more than seventy-nine years old. *Laryngoscope*. 2009; 119(6):1180–3. [PubMed: 19301411]
28. Williamson RA, Pytynia K, Oghalai JS, et al. Auditory performance after cochlear implantation in late septuagenarians and octogenarians. *Otol Neurotol*. 2009; 30(7):916–20. [PubMed: 19672204]
29. Poissant SF, Beaudoin F, Huang J, et al. Impact of cochlear implantation on speech understanding, depression, and loneliness in the elderly. *J Otolaryngol Head Neck Surg*. 2008; 37(4):488–94. [PubMed: 19128581]
30. Chan V, Tong M, Yue V, et al. Performance of older adult cochlear implant users in Hong Kong. *Ear Hear*. 2007; 28(2 Suppl):52S–55S. [PubMed: 17496647]
31. Pedley K, Psarros C, Gardner-Berry K, et al. Evaluation of NRT and behavioral measures for MAPping elderly cochlear implant users. *Int J Audiol*. 2007; 46(5):254–62. [PubMed: 17487673]
32. Orabi AA, Mawman D, Al-Zoubi F, et al. Cochlear implant outcomes and quality of life in the elderly: Manchester experience over 13 years. *Clin Otolaryngol*. 2006; 31(2):116–22. [PubMed: 16620330]
33. Haensel J, Ilgner J, Chen YS, et al. Speech perception in elderly patients following cochlear implantation. *Acta Otolaryngol*. 2005; 125(12):1272–6. [PubMed: 16303673]
34. Vermeire K, Brokx JP, Wuyts FL, et al. Quality-of-life benefit from cochlear implantation in the elderly. *Otol Neurotol*. 2005; 26(2):188–95. [PubMed: 15793403]
35. Hay-McCutcheon MJ, Pisoni DB, Kirk KI. Audiovisual speech perception in elderly cochlear implant recipients. *Laryngoscope*. 2005; 115(10):1887–94. [PubMed: 1622216]
36. Leung J, Wang NY, Yeagle JD, et al. Predictive models for cochlear implantation in elderly candidates. *Arch Otolaryngol Head Neck Surg*. 2005; 131(12):1049–54. [PubMed: 16365217]
37. Sterkers O, Mosnier I, Ambert-Dahan E, et al. Cochlear implants in elderly people: preliminary results. *Acta Otolaryngol Suppl*. 2004; (552):64–7. [PubMed: 15219050]
38. Chatelin V, Kim EJ, Driscoll C, et al. Cochlear implant outcomes in the elderly. *Otol Neurotol*. 2004; 25(3):298–301. [PubMed: 15129109]
39. Pasanisi E, Bacciu A, Vincenti V. Speech recognition in elderly cochlear implant recipients. *Clin Otolaryngol Allied Sci*. 2003; 28(2):154–7. [PubMed: 12680835]

40. Francis HW, Chee N, Yeagle J, et al. Impact of cochlear implants on the functional health status of older adults. *Laryngoscope*. 2002; 112(8 Pt 1):1482–8. [PubMed: 12172266]
41. Djalilian HR, King TA, Smith SL, et al. Cochlear implantation in the elderly: results and quality-of-life assessment. *Ann Otol Rhinol Laryngol*. 2002; 111(10):890–5. [PubMed: 12389856]
42. Herzog M, Mueller J, Milewski C, et al. Cochlear implantation in the elderly. *Adv Otorhinolaryngol*. 2000; 57:393–6. [PubMed: 11892199]
43. Nakajima S, Iwaki S, Fujisawa N, et al. Speech discrimination in elderly cochlear implant users. *Adv Otorhinolaryngol*. 2000; 57:368–9. [PubMed: 11892191]
44. Labadie RF, Carrasco VN, Gilmer CH, et al. Cochlear implant performance in senior citizens. *Otolaryngol Head Neck Surg*. 2000; 123(4):419–24. [PubMed: 11020178]
45. Shin YJ, Frayssse B, Deguine O, et al. Benefits of cochlear implantation in elderly patients. *Otolaryngol Head Neck Surg*. 2000; 122(4):602–6. [PubMed: 10740189]
46. Kunimoto M, Yamanaka N, Kimura T. The benefit of cochlear implantation in the Japanese elderly. *Auris Nasus Larynx*. 1999; 26(2):131–7. [PubMed: 10214890]
47. Thomas JS. Cochlear implantation of the elderly. *Ann Otol Rhinol Laryngol Suppl*. 1995; 166:91–3. [PubMed: 7668771]
48. Facer GW, Peterson AM, Brey RH. Cochlear implantation in the senior citizen age group using the Nucleus 22-channel device. *Ann Otol Rhinol Laryngol Suppl*. 1995; 166:187–90. [PubMed: 7668629]
49. Waltzman SB, Cohen NL, Shapiro WH. The benefits of cochlear implantation in the geriatric population. *Otolaryngol Head Neck Surg*. 1993; 108(4):329–33. [PubMed: 8483603]
50. Kelsall DC, Shallop JK, Burnelli T. Cochlear implantation in the elderly. *Am J Otol*. 1995; 16(5):609–15. [PubMed: 8588665]
51. Horn KL, McMahon NB, McMahon DC, et al. Functional use of the Nucleus 22-channel cochlear implant in the elderly. *Laryngoscope*. 1991; 101(3):284–8. [PubMed: 2000016]
52. Roditi RE, Poissant SF, Bero EM, et al. A predictive model of cochlear implant performance in postlingually deafened adults. *Otol Neurotol*. 2009; 30(4):449–54. [PubMed: 19415041]
53. Gomaa NA, Rubinstein JT, Lowder MW, et al. Residual speech perception and cochlear implant performance in postlingually deafened adults. *Ear Hear*. 2003; 24(6):539–44. [PubMed: 14663353]
54. Friedland DR, Venick HS, Niparko JK. Choice of ear for cochlear implantation: the effect of history and residual hearing on predicted postoperative performance. *Otol Neurotol*. 2003; 24(4):582–9. [PubMed: 12851549]
55. Maillet CJ, Tyler RS, Jordan HN. Change in the quality of life of adult cochlear implant patients. *Ann Otol Rhinol Laryngol*. 1995; 165(Suppl):31–48.
56. Jansen DA. Attentional demands and daily functioning among community-dwelling elders. *J Community Health Nurs*. 2006; 23(1):1–13. [PubMed: 16445360]
57. Jansen DA, Keller ML. Cognitive function in community-dwelling elderly women. Attentional demands and capacity to direct attention. *J Gerontol Nurs*. 2003; 29(7):34–43. [PubMed: 12874938]
58. Kahneman, D. *Attention and Effort*. Prentice-Hall Inc; Englewood Cliffs, NJ: 1973.
59. Yamada M, Nishiwaki Y, Michikawa T, et al. Impact of hearing difficulty on dependence in activities of daily living (ADL) and mortality: A 3-year cohort study of community-dwelling Japanese older adults. *Archives of Gerontology and Geriatrics*. 2011; 52:245–249. [PubMed: 20546947]
60. Gopinath B, Schneider J, McMahon CM, et al. Severity of age-related hearing loss is associated with impaired activities of daily living. *Age and Ageing*. 2011 Epub ahead of print.
61. Corna LM, Wade TJ, Streiner DL, et al. Transitions in hearing impairment and psychological distress in older adults. *The Canadian Journal of Psychiatry*. 2009; 54(8):518–525.
62. Weinstein BE, Ventry IM. Hearing impairment and social isolation in the elderly. *J Speech Hear Res*. 1982; 25(4):593–9. [PubMed: 7162161]

Conflict of Interest Disclosures

Elements of Financial/ Personal Conflicts	Author 1 Clark JH		Author 2 Yeagle J		Author 3 Arbaje A		Author 4 Lin FR		Author 5 Niparko JK		Author 6 Francis HW		Author 7		Author 8		Author 9	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Employment or Affiliation																		
		X		X		X		X		X		X						
Grants/Funds																		
		X		X	X			X	X			X						
Honoraria																		
		X		X		X		X		X		X						
Speaker Forum																		
		X		X		X		X		X		X						
Consultant																		
		X		X	X			X		X		X						
Stocks																		
		X		X		X		X		X		X						
Royalties																		
		X		X		X		X		X		X						
Expert Testimony																		
		X		X		X		X		X		X						
Board Member																		
		X		X		X		X	X			X						
Patents																		
		X		X		X		X		X		X						
Personal Relationship																		
		X		X		X		X		X		X						

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Figure 1.
Flow chart of report selection from the literature search strategy

Figure 2. Communicative capacity as indicated by mean speech perception scores reported in the literature prior to and 6 to 12 months following CI surgery [22, 24, 35, 38, 44, 50], is similar for older (≥ 65 y) and younger (<65 y) adults. CID Central Institute for the Deaf, CNC consonant–nucleus consonant, HINT Hearing in Noise Test, SP speech perception.

Figure 3.

An adaptation of Wilson and Cleary's conceptual model of patient outcomes [5] showing a continuum of the consequences of hearing loss and the intervening variables that mediate CI outcomes. Listed variables are hypothesized determinants of CI outcome in older adults.

Arrows reflect prominent relationships that mediate perceived and actual impact of the intervention on communication and other functions critical to the maintenance of independence during aging, as well as HRQL. HL hearing loss, SD speech discrimination

^aDuration of HL: Pre-op Hearing; Device Integrity; Surgical Factors; Device Programming

^bHearing Acuity; Speech Perception in Quiet; Speech Perception in Noise; Attentional Burden; Emotional Response

^cCommunication; Cognition; Adaptive Behaviors; Depression; Anxiety

^dPersonality; Motivation; Values; Preferences; Mastery; Self-esteem; Expectations; Adaptability; General Health

^ePsychological Support; Economic Support; Living Arrangements; Social Support; Communication Demands

Table 1
Study design and primary outcome measures as reported in the literature regarding cochlear implantation in older adults.

Author [ref#]	Study Design (Evidence level)	Symptom Status	Functional Status and Quality-of-Life (% subjects with improvement)
Horn <i>et al.</i> [51]	Series without a control group [Level –III]	NA	Social Function: Social Activity (63%); Confidence (81%) Role Function: Communication benefit by location and condition; Hours per day of CI use Quality-of-life (86%)
Kelsall <i>et al.</i> [50]	Series without a control group [Level –III]	Speech Perception: no age effects	Role Function: Social Activity (55%); Confidence (85%) Quality-of-life (84%)
Waltzman <i>et al.</i> [49]	Series without a control group [Level –III]	Speech Perception	NA
Facer <i>et al.</i> [48]	Series without a control group [Level –III]	Emotional: Coping with communication breakdown, feelings about hearing loss	Role Function: Improved performance of communication-intensive tasks of daily living
Thomas <i>et al.</i> [47]	Series without a control group [Level –III]	NA	Social Function
Kunimoto <i>et al.</i> [46]	Series without a control group [Level –III]	Speech Perception: no age effects	Social Function: Social Activity (80%) Role Function: Hours per day of CI use; Improved performance of communication-intensive tasks of daily living Quality-of-life (80%)
Shin <i>et al.</i> [45]	Series without a control group [Level –III]	Speech Perception: no age effects	Role Function: Hours per day of CI use; Improved performance of communication-intensive tasks of daily living
Labadie <i>et al.</i> [44]	Series with a younger control group [Level –III]	Speech Perception: no age effects	NA
Nakajima <i>et al.</i> [43]	Series with a younger control group [Level –III]	Speech Perception: smaller gains in older group	NA
Herzog <i>et al.</i> [42]	Series without control group [Level –III]	Speech Perception	NA
Djaililian <i>et al.</i> [41]	Series without a control group [Level –III]	Speech Perception: no age effects	Social Function: Social Activity (71%); Confidence (94%) Role Function: Communication benefit by location and condition; Hours per day of CI use Quality-of-life (94%)
Francis <i>et al.</i> [40]	Series without a control group [Level –III]	Speech Perception: no age effects Emotional: Improved HUI-3 subtest scores	Social Function: Social Activity (50–58%); Confidence (81–83%) Role Function: Hours per day of CI use Quality-of-life (89%)
Pasanisi <i>et al.</i> [39]	Series with a younger control group [Level –III]	Speech Perception: no age effects	NA
Chatelin <i>et al.</i> [38]	Series with a younger control group [Level –III]	Speech Perception: no age effects	NA
Sterkers <i>et al.</i> [37]	Series without a control group [Level –III]	Speech Perception: no age effects	Role Function: Hours per day of CI use
Leung <i>et al.</i> [36]	Series without a control group [Level –III]	Speech Perception: no age effects	NA
Hay-McCutcheon <i>et al.</i> [35]	Series with a younger control group [Level –III]	Speech Perception: no age effects in auditory-only condition; better integration of visual cues by younger subjects	NA

Author [ref#]	Study Design (Evidence level)	Symptom Status	Functional Status and Quality-of-Life (% subjects with improvement)
Vermeire <i>et al.</i> [34]	Series without a control group [Level –III]	Speech perception: smaller gains in older group Emotional: improved HHIA subscale scores except subjects 70y and older	Social Function: Improved GBI social subscale score independent of age Role Function: Improved HHIA situational subscale score independent of age Quality-of-life: Significant improvement in GBI score
Haensel <i>et al.</i> [33]	Series without a control group [Level –III]	Speech Perception: no age effects	NA
Orabi <i>et al.</i> [32]	Series without a control group [Level –III]	Speech Perception: no age effects	Quality-of-life (100%)
Pedley <i>et al.</i> [31]	Series without a control group [Level –III]	Speech Perception Device mapping	Social Function: Improved GBI subscale score Role Function: Most expectations met or exceeded Quality-of-life: Significant improvement in GHSI score
Chan <i>et al.</i> [30]	Series with a younger control group [Level –III]	Speech Perception group in first 6 mo; duration of deafness and pre-operative scores predictive of post-CI performance	NA
Poissant <i>et al.</i> [29]	Series with a younger control groups [Level –III]	Speech Perception: no age effects	NA
Williamson <i>et al.</i> [28]	Series without a control group [Level –III]	Speech Perception	Social Function: Less loneliness after CI Psychological Function: Resolution of mild depression \$\$\$
Eshraghi <i>et al.</i> [27]	Series without a control group [Level –III]	Speech Perception	Role Function: Hours per day of CI use
Coelho <i>et al.</i> [26]	Series without a control group [Level –III]	NA	Role Function: Hours per day of CI use; Improved communication experienced by most respondents according to HHIE
Noble <i>et al.</i> [25]	Retrospective and prospective [Level –III]	Speech Perception: no age effects Emotional: Improved HHIE subtest and HHQ scores with no age effects	NA
Friedland <i>et al.</i> [24]	Series with a younger control group [Level –III]	Speech Perception: no age effect in quiet; slight advantage for young in noise	Social Function: Improved HHIE and HHQ subtests without age effects Role Function: Improved HHIE, HHQ and SSQ subtests (no age effects on communication for unilateral CI; larger benefits with bilateral CI for younger group)
Migrov <i>et al.</i> [23]	Series without a control group [Level –III]	Speech Perception	NA
Carlson <i>et al.</i> [22]	Series with a younger control group [Level –III]	Speech Perception: no age effects	NA
Oyanguren <i>et al.</i> [21]	Series without a control group [Level –III]	Speech Perception	Role Function: Telephone use (71%)

NA not assessed; GBI Glasgow Benefit Inventory; HHIA Hearing Handicap Inventory for Adults; HHIE Hearing Handicap Inventory for the Elderly; HHQ Hearing Handicap Questionnaire; HUI-3 Ontario Health Utility Index mark 3; SSQ Spatial and Qualities of hearing scale

Table 2
Changes in communicative performance after cochlear implantation in older adults

Author [Ref#]	Year	Inventory	n (age)	Inventory score Post – CI Improved	Age differences	Main Points
Horn et al. [51]	1991	Self-constructed questionnaire	67 (>65)	Yes	NA	<ul style="list-style-type: none"> Increase social activities, improved confidence, best performance reported at home and in quiet, greatest challenges noted in noise
Facer et al. [48]	1995	PIPSL ^a Self-constructed questionnaire	20 (55 – 85)	Yes	NA	<ul style="list-style-type: none"> Significant improvement was found for the following indices of PIPSL: Understanding Speech with Visual cues (p=.0007), Intensity - individual's ability to detect everyday sounds and their relative loudness - (p=.0002), Environmental Sound - ability to identify familiar sounds that can be heard but whose source cannot be seen - (p=.004), Understanding Speech with No Visual Cues (p=.028). PIPSL indices which proved insignificant: Response to Auditory Failure - ability to cope with breakdowns in communication- (p=.26), Personal - feeling about their hearing impairment (p=.068) Highest level of functional performance reported for one-on-one communication but continued challenge in groups, with background noise and in use of telephone and electronic media.
Shin et al. [45]	2000	Self-constructed questionnaire	27 (>60) 15 (49 – 59)	Yes	No	<ul style="list-style-type: none"> Most reported the ability to have conversation with a familiar person (89%), or an unfamiliar interlocutor (70%) and being aware of environmental sounds (92%). No patients reported an improvement in conversation in a noisy environment and telephone use in the group of elderly patients was low
Francis et al. [40]	2002	Self-constructed questionnaire	47 (50 – 80)	Yes	NA	<ul style="list-style-type: none"> 27 (65.9%) postlingual hearing loss patients reported that their quality-of-life was much better, and 9 (22%) reported it as somewhat better after CI. None reported worse quality-of-life 24 (58.5%) postlingually hearing impaired patients reported an increase in social activities since CI, which was correlated to speech perception and quality-of-life gains after CI Increased confidence was reported by 33 (80.5%) postlingually hearing impaired post CI 26 (63.4%) postlingually hearing impaired reported being able to converse over the phone post operative There was significant correlation between number of hours reported wearing the CI device and gains in speech perception scores Given what they knew postoperatively 37 (90.3%) of the postlingual hearing loss patient reported that they would again choose to undergo CI

Author [Ref#]	Year	Inventory	n (age)	Inventory score Post – CI Improved	Age differences	Main Points
Vermeire <i>et al.</i> [34]	2005	HHIA ^b SFPHD ^c	33 (17 – 54) 31 (56 – 69) 25 (>70)	Yes	No	<ul style="list-style-type: none"> • HHIA in the older group revealed significant improvement on the Situational (p<.001) subscale but not on the Emotional (p=.14). • Comparing HHIA with postoperative SP did not show significance for the group as a whole (p=.08), however, although a significant correlation was found for the middle age stratum (p=.016)
Orabi <i>et al.</i> [32]	2006	Expectations Questionnaire	34 (65 – 80)	Yes	NA	<ul style="list-style-type: none"> • Patients had the highest expectations in the following: (i) Detect sound (ii) Increase self-confidence (iii) Extent daily life to become easier and less effortful (iv) Allow to lead more independent life. • Patients felt that their hearing has improved by 50% more than they have expected after implantation • Cochlear implantation generally met most of patient's expectations
Poissant <i>et al.</i> [29]	2008	GDS ^d UCLA Loneliness scale	9 (>70) 9 (>70) 8 (<60)	Yes	No	<ul style="list-style-type: none"> • In the Older CI group mild depression existed prior to implantation (mean GDS=10.1), these subjects on average were not depressed (mean GDS=4.4) post CI. • Both younger and older subjects experienced greater degree of loneliness prior to receiving their implant
Eshraghi <i>et al.</i> [27]	2009	HHIE ^e	21 (80 – 92)	Yes	NA	<ul style="list-style-type: none"> • Post-operative HHIE scores demonstrated improvement
Noble <i>et al.</i> [25]	2009	HHIE ^e HHQ ^f SSQ ^g	58 (20–59) 84 (60–91)	Yes	Yes/No	<ul style="list-style-type: none"> • No age-differences for unilateral CI • Larger gains from bilateral CI in younger age group

NA = Not Assessed

^aPerformance Inventory for Profound and Severe Loss

^bHearing Handicap Inventory for adults

^cScale for prediction of hearing disability in SNHL developed

^dGeriatric depression scale

^eHearing Handicap Inventory for elderly

^fHearing Handicap Questionnaire

^gSpeech, Spatial and Qualities of hearing scale