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MAIN ARTICLE

Cochlear implantation in elderly patients: stability of outcome over time

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Abstract

Background: Cochlear implantation is the standard of care for treating severe to profound hearing loss in all age groups. There is limited data on long-term results in elderly implantees and the effect of ageing on outcomes. This study compared the stability of cochlear implantation outcome in elderly and younger patients.

Methods: A retrospective chart review of cochlear implant patients with a minimum follow up of five years was conducted.

Results: The study included 87 patients with a mean follow up of 6.8 years. Of these, 22 patients were older than 70 years at the time of implantation. Hearing in Noise Test scores at one year after implantation were worse in the elderly: 85.3 (aged under 61 years), 80.5 (61–70 years) and 73.6 (aged over 70 years; $p = 0.039$). The respective scores at the last follow up were 84.8, 85.1 and 76.5 ($p = 0.054$). Most patients had a stable outcome during follow up. Of the elderly patients, 13.6 per cent improved and none had a reduction in score of more than 20 per cent. Similar to younger patients, elderly patients had improved Short Form 36 Health Survey scores during follow up.

Conclusion: Cochlear implantation improves both audiometric outcome and quality of life in elderly patients. These benefits are stable over time.

Key words: Cochlear Implants; Aged; Treatment Outcome

Introduction

Cochlear implantation is now the standard of care for treating severe to profound hearing loss. As implantation criteria expand and our global population ages, the treatment rate and number of elderly implantees are rapidly increasing. The prevalence of age-related hearing loss is high: more than half of the population aged over 60 years suffers from hearing loss,[1,2] which is severe or profound in 1 per cent.[3] The latter group are thus potential candidates for cochlear implantation. Hearing loss in the elderly was found to be associated with social isolation and an increased risk of cognitive impairment.[4–8]

Data on the functional outcome of cochlear implants in elderly patients is contradictory: some studies demonstrate outcomes comparable to those of younger patients,[9–15] while others demonstrate poorer results in the elderly.[16–21] However, these studies were all retrospective, used short-term data and different criteria for defining elderly patients (age between 60 and 80 years), and used a variety of devices, coding strategies, and soundfield tests.

Regardless of the audiometric outcome in elderly *vs* younger patients, it is well accepted that elderly patients benefit significantly from implantation in terms of satisfaction and quality of life.[9,15,17,22–25]

There are limited long-term data on the effect of ageing on audiometric outcomes in cochlear implantees. Long-term function may be affected by neurodegenerative processes and reduced neural plasticity in elderly patients. Spitzer *et al*. evaluated 23 cochlear implantees aged over 60 years, and demonstrated overall stability of functional outcome over time (average follow up, 8.4 years; range, 1.5–13.8 years).[26] However, longitudinal performance was highly variable: for long-term speech recognition for monosyllabic words, 17 per cent of patients decreased by more than 20 per cent, while 26 per cent improved by more than 20 per cent.

Ruffin *et al*. demonstrated that elderly patients had a poorer audiometric performance after cochlear implantation.[27] However, this tended to stabilise at 24 months post-implantation, and there was no increased risk of long-term deterioration during a mean follow-

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up period of 93 months. Similarly, Dillon *et al*. followed 14 patients aged over 65 years and found that their audiometric performance stabilised between 5 and 10 years post-implantation.[28]

Choi *et al*. showed that older age at implantation is associated with increased rates of discontinuing regular cochlear implant use over a mean follow up of 5.2 years.[29] The most commonly reported reasons for discontinuation were poor hearing benefit (45 per cent), pain or discomfort (23 per cent), and not needing to hear on a daily basis (23 per cent).

This study aimed to evaluate the stability of cochlear implantation outcome over time in elderly patients compared with younger adults.

Materials and methods

A total of 798 patients received implants in our centre between 1989 and 2008. A retrospective chart review was performed for all adult patients with a minimum follow up of five years ($n = 87$). Inclusion criteria were pre-operative bilateral severe to profound hearing loss with word discrimination scores of less than 50 per cent and Hearing in Noise Test ('HINT') scores (60 dBA at 1 m under quiet conditions) available at one and five or more years after implantation.

Collected data included age at implantation, sex, pure tone averages (PTAs; of 0.5, 1 and 2 kHz) for both implanted and contralateral ears, aetiology of deafness, side of implantation, make and model of the cochlear implant, and previous hearing aid use. Test score stability was calculated as the difference between scores at one year and at the last follow up (i.e. the score at last follow up minus the score at one year), with positive values signifying hearing improvement and negative values signifying deterioration in outcome during follow up.

Short Form 36 ('SF-36') Health Survey questionnaires were used to compare physical and mental health scores before implantation and one year after implantation. Pre- and post-implantation scores were available for 76 and 72 patients, respectively. In all, 60 patients with both pre- and post-implantation questionnaire scores were included in the analysis.

Ethical standards

All procedures complied with the ethical standards of the relevant national and institutional guidelines on human experimentation (Sunnybrook Health Sciences Centre Research Ethics Board) and with the Helsinki Declaration of 1975, as revised in 2008.

Statistical analyses

Hearing in Noise Test scores at one year and the last follow up were compared with the age at implantation using Spearman's correlation testing. Patients were stratified into three age groups: 60 years and younger, 61–70 years, and 71 years and older. Demographic data were compared between age groups using the Kruskal–Wallis test for independent samples. A second analysis compared data from patients aged 60 years and under and those aged 71 years and above using the Mann–Whitney U test. The distribution of categorical variables was compared between these groups using the chi-square and Fisher's exact tests. Averages of pre- and post-operative Short Form 36 scores were calculated for all three age groups, and score improvement was analysed using paired Student's *t*-tests. A p value of greater than 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS statistics software version 21 (Armonk, New York, USA).

Results

Patients

Patient demographic data are summarised in Table I. A total of 87 patients were followed up for 5 years or more (mean, 6.8 years). At the time of implantation, 32 patients were aged 60 years or younger, 33 were aged between 61 and 70 years, and 22 were older than 70 years. Fifty-four patients were women (62 per cent), and 75 (86 per cent) used hearing aids prior to implantation. The right ear was implanted in 48 per cent of patients, and the left in 41 per cent; 9 patients (10 per cent) underwent sequential bilateral implantation. None of the bilateral implantees was aged over 70 years at implantation (age range, 42–68 years).

Mean pre-operative PTAs were 107 dB HL for patients aged 60 years and younger, 97 dB HL for those aged 61–70 years, and 95 dB HL for those aged over 70 years for the implanted ear and 108 dB HL, 97 dB HL, and 92 dB HL, respectively, for the non-implanted ear. PTAs were significantly lower in patients aged 60 years and younger. The mean pre-operative percentages of correctly repeated sentences were higher in elderly patients (25.3 *vs* 16 per cent), but the difference was not statistically significant.

The most common aetiology for hearing loss in patients older than 70 years was progressive idiopathic loss (59 per cent), followed by hereditary progressive loss, Ménière's disease and otosclerosis. There was a similar proportion of pre-implantation hearing aid use in all age groups.

Functional outcomes at one year after implantation and the last follow up

Hearing in Noise Test scores at one year after implantation were 85.3 per cent for patients aged under 60 years (range, 22–100 per cent), 80.5 per cent for those aged 61–70 years (range, 13–100 per cent) and 73.6 per cent for those aged over 70 years (range, 0–98 per cent; $p = 0.039$). Spearman's correlation analysis between age at implantation as a continuous variable and hearing score at one year after implantation showed a non-significant trend toward a better outcome for younger patients ($r = -0.18$, $p = 0.096$). Figure 1a shows the association between age and hearing scores at one year after implantation.

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TABLE I
DEMOGRAPHIC DATA AND OUTCOMES STRATIFIED BY AGE GROUP

	Age group				*p* value	
	≤ 60 y ($n = 32$)	61–70 y ($n = 33$)	> 70 y ($n = 22$)	Total ($n = 87$)	All age groups	≤ 60 *vs* > 70 y
Sex (% male)	44	36	32	38	0.65	0.4
Laterality, %					0.075	0.06
– Right ear	44	46	59	48.3		
– Left ear	34	48	41	41.4		
– Bilateral	22	6	0	10.3		
Pre-operative PTA, mean (SD)						
– Implanted ear	106.6 (13)	96.9 (18)	95.3 (18)	100.1 (17)	0.013	0.01
– Contralateral ear	107.6 (14)	96.9 (21)	91.7 (18)	99.5 (19)	0.004	0.001
Pre-operative word discrimination score, mean (SD)						
– Implanted ear	5.1 (9)	6.2 (8)	8.5 (11)	6.4 (9)	0.5	0.44
– Contralateral ear	4.8 (12)	12.6 (13)	17.3 (16)	11.3 (14)	0.013	0.011
Pre-operative sentence percentage (HINT), mean (SD)	15.0 (22)	16.7 (17)	25.3 (24)	18.3 (21)	0.26	0.13
Aetiology						
– Hereditary, progressive	21.9	3.0	13.6	12.6	–	–
– Idiopathic, progressive	15.6	78.8	59.1	50.6	–	–
– Early idiopathic	12.5	3.0	0	5.7	–	–
– Meningitis	9.4	0	0	3.4	–	–
– Idiopathic, rapidly progressive	9.4	3.0	0	4.6	–	–
– Otosclerosis	6.3	3.0	9.1	5.7	–	–
– Rubella	6.3	0	0	2.3	–	–
– Cogan's syndrome	3.1	0	0	1.1	–	–
– CSOM	3.1	0	0	1.1	–	–
– DFNA36	3.1	0	0	1.1	–	–
– Ménière's syndrome	3.1	3.0	13.6	4.6	–	–
– Mitochondrial	3.1	0	0	1.1	–	–
– Trauma	3.1	0	0	1.1	–	–
– Turner's syndrome	0	3.0	0	1.1	–	–
– Radiochemotherapy	0	3.0	0	1.1	–	–
– Scarlet fever	0	0	4.5	1.1	–	–
Pre-operative hearing aid usage, %	81.3	93.9	81.8		0.26	0.99
Device implanted, %					–	–
– NC	31.3	21.2	9.1	21.8		
– C90 K	21.9	63.6	77.3	51.7		
– N22 M	18.8	0	0	6.9		
– N24 M	9.4	0	0	3.4		
– CII	9.4	0	0	3.4		
– C1.2 s	6.3	0	0	2.3		
– C2HF1	3.1	0	0	1.1		
– NCA	0	6.1	0	2.3		
– NF	0	3.0	0	1.1		
– PLSR	0	3.0	9.1	3.4		
– SON	0	3.0	4.5	2.3		
HINT score 1 year after implantation, mean (SD)	85.3 (17)	80.5 (26)	73.6 (23)	80.5 (23)	0.039	0.013
HINT score at last follow up, mean (SD)	84.8 (18)	85.1 (19)	76.5 (21)	82.8 (19)	0.054	0.038
HINT score change during follow up, %						
– Improvement (> 20%)	3	12	13.6	9.2		
– Stable	94	88	86.4	89.7		
– Deterioration (< −20%)	3	0	0	1.1	0.37	0.88

Y = years; PTA = pure tone average; SD = standard deviation; HINT = Hearing in Noise Test; CSOM = chronic suppurative otitis media; DFNA36 = autosomal dominant deafness-36; NC = Nucleus Contour; C90 K = Advanced Bionics 90k 1j; N22 M = Nucleus 22; N24 M = Nucleus 24; CII = Advanced Bionics c2; C 1.2 s = Advanced Bionics 1.2 standard; C2HF1 = Advanced Bionics HiFocus 1; NCA = Nucleus Contour Advance; NF = Nucleus Freedom; PLSR = Med El Pulsar; SON = Med El Sonata

Hearing scores at the last documented follow-up appointment were 84.8 per cent for patients aged under 60 years (range, 28–100 per cent), 85.1 per cent for those aged 61–70 years (range, 25–100 per cent) and 76.5 per cent for those aged over 70 years (range, 0–99 years; $p = 0.054$), Spearman's correlation analysis between age at implantation and hearing score at the last follow up showed no statistically significant relationship ($r = -0.16$. $p = 0.140$). Figure 1b shows the association between age and hearing scores at the last follow up.

Stability of outcome during follow up

Outcome stability was calculated by subtracting hearing scores at one year after implantation from those at the last follow up. Using a 20 per cent

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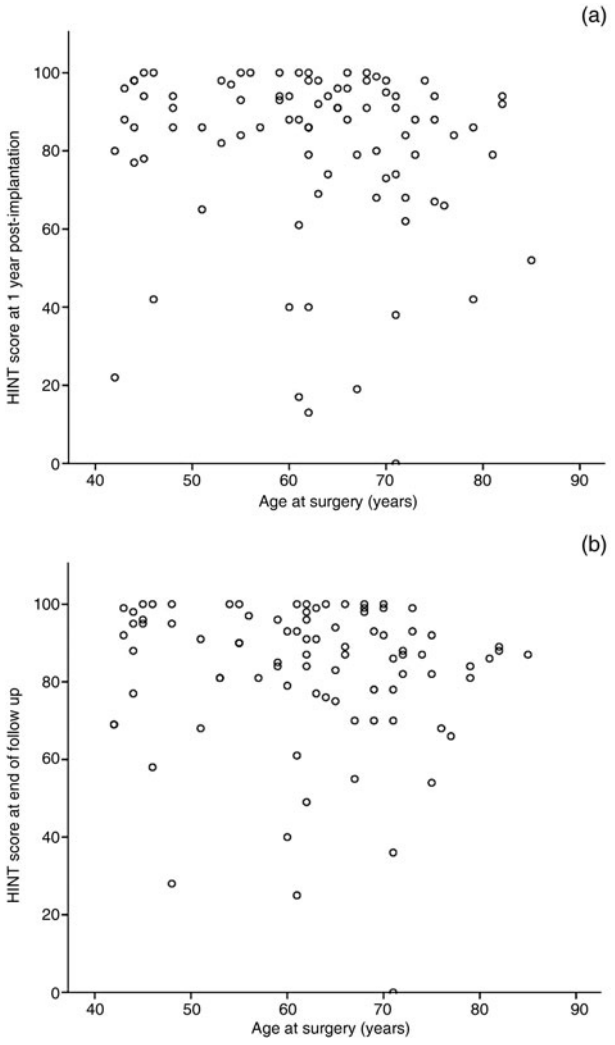

FIG. 1

Scatterplots showing the distribution of audiometric outcome (Hearing in Noise Test under quiet conditions) at (a) one year and (b) the last follow up by age at implantation.

change in hearing scores as the cutoff to indicate clinical significance (as suggested by Spitzer and colleagues[26]), the vast majority of patients in all age groups had a stable outcome (Fig. 2). Interestingly, 13.6 per cent of elderly patients improved by more than 20 per cent and none deteriorated during this time period. There were no significant differences in hearing score change during follow up among age groups ($p = 0.37$).

Short Form 36 Health Survey results

A total of 60 patients completed Short Form 36 questionnaires both prior to and 1 year after implantation: 22 were aged under 60 years, 21 were aged between 61 and 70 years, and 17 were aged 71 years or over.

Health survey scores are presented in Table II. Similar to younger patients, cochlear implantation in those older than 70 years was associated with significant improvements in the 'Social Functioning', 'Emotional Role Functioning' and 'Mental Health' categories. In contrast to younger patients, elderly patients

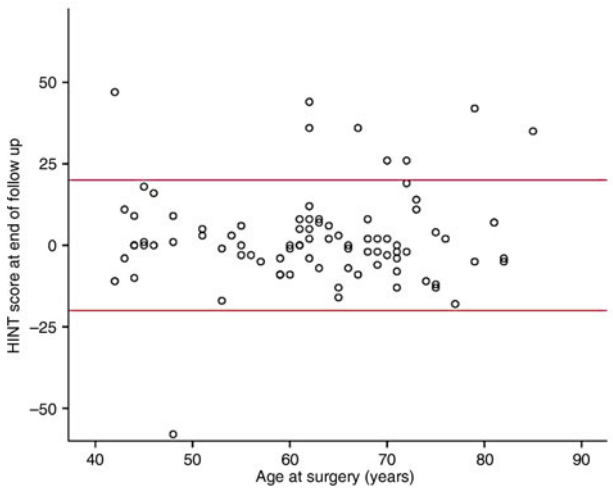

FIG. 2

Scatterplot showing the distribution of changes in Hearing in Noise Test score during follow up by age at implantation. The red lines define stable results, i.e. a change of less than 20 per cent from the Hearing in Noise Test score at one year.

also perceived their 'Physical Role Functioning' performance to be significantly improved, with pre- and post-operative scores of 60 and 88.3, respectively.

Discussion

Cochlear implantation improves communication skills and quality of life in the elderly. Functional outcome after cochlear implantation largely depends on neural plasticity, which may be compromised in this age group. In this study, we demonstrated that cochlear implantation improves the quality of life to a similar degree in both patients older than 70 years and younger patients. Functional outcomes at one year after implantation and at the last follow up were significantly better in younger patients, although differences in hearing scores were less than 15 per cent. There are concerns that neurodegeneration in elderly patients may affect outcome stability over a period of years. However, this study found that hearing scores were very stable over a follow up period of 6.8 years in all age groups. Specifically, none of the 22 elderly patients had a drop in hearing scores of more than 20 per cent.

The functional outcomes of cochlear implantees were previously reported to be similar or poorer in elderly patients compared with younger patients.[9–21] Differences in outcome may be attributed to ageing and decreased memory function rather than to cochlear implant function. In a comparison of 14 older and 12 younger patients with normal hearing, Meister *et al.* demonstrated that younger patients performed better with a background masker.[30] Working memory function was the only significant predictor of this difference. Similarly, Zekveld *et al.* and Anderson Gosselin and Gagné demonstrated that older patients expend more listening effort to recognise speech in a noisy background.[31,32] Gordon-Salant and Fitzgibbons showed that age and hearing impairment are independent risk

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TABLE II
SF-36 PRE- AND POST-IMPLANTATION SCORES PER DOMAIN FOR THE THREE AGE GROUPS

SF-36 domain	Age group											
	≤60 years (n = 22)			61–70 years (n = 21)			> 70 years (n = 17)			All patients (n = 60)		
	Pre	Post	p	Pre	Post	p	Pre	Post	p	Pre	Post	p
Physical functioning	81.46	81.67	0.937	81.43	85.24	0.159	74.00	78.00	0.37	79.6	82	0.329
Role functioning (physical)	77.08	84.38	0.296	94.05	82.14	0.162	60.00	88.33	0.033*	78.8	84.6	0.272
Bodily pain	76.17	77.25	0.915	70.52	70.90	0.715	67.87	78.67	0.295	72.1	75.4	0.331
General health perception	68.88	72.54	0.312	71.86	77.43	0.032*	71.13	74.93	0.242	70.5	74.9	0.018*
Vitality	57.08	66.67	0.026	68.57	72.86	0.05	62.67	71.00	0.221	62.5	69.9	0.002
Social functioning	74.13	90.21	0.004*	79.33	91.76	0.012*	64.33	86.73	0.008*	73.5	89.9	< 0.001*
Role functioning (emotional)	69.46	95.83	0.008*	84.62	95.24	0.138	64.47	91.13	0.035*	73.5	94.5	< 0.001*
Mental health	70.17	81.00	0.007*	71.43	81.90	< 0.001*	72.53	85.60	0.028*	71.2	82.5	< 0.001*

*P value < 0.05. SF-36 = Short Form 36 health Survey; pre = pre-implantation; post = post-implantation

factors for diminished speech recognition in elderly listeners.[33] Carlson *et al.* made a similar observation: older cochlear implantees had lower scores in the AzBio Sentence Test, while scores for other post-operative speech recognition tests were similar in both age groups.[14] The authors considered this to be a consequence of the higher memory and executive demands of the AzBio Sentence Test. In the present study, the Hearing in Noise Test performed under quiet conditions was the main outcome measure. There is some concern about the sensitivity of this test because of its ceiling effect, and more challenging tests are also commonly used, such as AzBio and CNC sentence tests. However, many of our patients were recruited during an earlier period when the Hearing in Noise Test performed under quiet conditions was the standard pre- and post-implantation objective measurement of outcome. Furthermore, such testing may be better when applied across such a wide age range because it is less confounded by differences in memory function.

- **Cochlear implantation is beneficial to elderly patients**
- **It significantly improves audiological measures and quality of life**
- **Cochlear implant outcomes are stable for all age groups, including the elderly**

Cochlear implantation is an expensive intervention and many cost–utility studies have been undertaken over the years to evaluate multiple age groups including infants, adolescents, young adults and the elderly. Concerns have been raised that the benefit does not outweigh the cost of cochlear implantation in the elderly population. However, the performance stability over years in this study indicates that cost–benefit ratios should be re-evaluated. Furthermore, outcomes were stable during follow up for all age groups, and none of the elderly patients experienced a decline of more than 20 per cent in hearing scores. Spearman's correlation testing between age as a continuous variable and hearing test stability demonstrated a similar result. This is an important finding because the rates of age-related hearing loss in the general population rise from 25 per cent in the sixth decade to 52 per cent in the seventh.[34] Factors suggested to be associated with age-related hearing loss include diabetic and atherosclerotic changes, noise exposure, ototoxicity, and oxidative stress leading to mitochondrial dysfunction, cochlear degeneration and cochlear nucleus atrophy,[34] as well as changes affecting higher processes in the auditory pathway such as age-related central auditory processing deficits, decreased learning and communication potential, and diminished rehabilitation potential.[14] The most common type of hearing loss in elderly patients in this study was progressive idiopathic hearing loss, which is consistent with age-

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related hearing loss. The outcome function in this population was stable despite the progressive nature of this type of hearing loss and presumed associated degenerative changes in the peripheral and central auditory pathways.

All patients in this study had a minimum follow up of 5 years, with an average follow up of 6.8 years. Ruffin *et al*. and Dillon *et al*. demonstrated that cochlear implant outcome is stable between 5 and 10 years after implantation.[27,28]

This study had several limitations. It was retrospective and groups were limited in size. Cognitive function, which is probably associated with functional outcomes, was not assessed. In addition, patients who may have been lost to follow up were not considered.

Conclusion

Cochlear implantation in patients aged older than 70 years is associated with a significantly improved quality of life. Cochlear implant function as measured by Hearing in Noise Test scores was marginally poorer in elderly than in younger patients, but was stable over time.

References

1 Agrawal Y, Platz EA, Niparko JK. Prevalence of hearing loss and differences by demographic characteristics among US adults: data from the National Health and Nutrition Examination Survey, 1999–2004. *Arch Intern Med* 2008;**168**:1522–30
2 Lin FR, Niparko JK, Ferrucci L. Hearing loss prevalence in the United States. *Arch Intern Med* 2011;**171**:1851–2
3 Lin FR, Yaffe K, Xia J, Xue QL, Harris TB, Purchase-Helzner E *et al*. Hearing loss and cognitive decline in older adults. *JAMA Intern Med* 2013;**173**:293–9
4 Lin FR. Hearing loss and cognition among older adults in the United States. *J Gerontol A Biol Sci Med Sci* 2011;**66**:1131–6
5 Lin FR, Ferrucci L, Metter EJ, An Y, Zonderman AB, Resnick SM. Hearing loss and cognition in the Baltimore Longitudinal Study of Aging. *Neuropsychology* 2011;**25**:763–70
6 Tay T, Wang JJ, Kifley A, Lindley R, Newall P, Mitchell P. Sensory and cognitive association in older persons: findings from an older Australian population. *Gerontology* 2006;**52**:386–94
7 Valentijn SA, van Boxtel MP, van Hooren SA, Bosma H, Beckers HJ, Ponds RW *et al*. Change in sensory functioning predicts change in cognitive functioning: results from a 6-year follow-up in the maastricht aging study. *J Am Geriatr Soc* 2005;**53**:374–80
8 Lin FR, Metter EJ, O'Brien RJ, Resnick SM, Zonderman AB, Ferrucci L. Hearing loss and incident dementia. *Arch Neurol* 2011;**68**:214–20
9 Shin YJ, Fraysse B, Deguine O, Valès O, Laborde ML, Bouccara D *et al*. Benefits of cochlear implantation in elderly patients. *Otolaryngol Head Neck Surg* 2000;**122**:602–6
10 Labadie RF, Carrasco VN, Gilmer CH, Pillsbury HC 3rd. Cochlear implant performance in senior citizens. *Otolaryngol Head Neck Surg* 2000;**123**:419–24
11 Buchman CA, Fucci MJ, Luxford WM. Cochlear implants in the geriatric population: benefits outweigh risks. *Ear Nose Throat J* 1999;**78**:489–94
12 Pasanisi E, Bacciu A, Vincenti V, Guida M, Barbot A, Berghenti MT *et al*. Speech recognition in elderly cochlear implant recipients. *Clin Otolaryngol Allied Sci* 2003;**28**:154–7
13 Sterkers O, Mosnier I, Ambert-Dahan E, Herelle-Dupuy E, Bozorg-Grayeli A, Bouccara D. Cochlear implants in elderly people: preliminary results. *Acta Otolaryngol Suppl* 2004;**552**:64–7
14 Carlson ML, Breen JT, Gifford RH, Driscoll CL, Neff BA, Beatty CW *et al*. Cochlear implantation in the octogenarian and nonagenarian. *Otol Neurotol* 2010;**31**:1343–9
15 Park E, Shipp DB, Chen JM, Nedzelski JM, Lin VY. Postlingually deaf adults of all ages derive equal benefits from unilateral multichannel cochlear implant. *J Am Acad Audiol* 2011;**22**:637–43
16 Mahmoud AF, Ruckenstein MJ. Speech perception performance as a function of age at implantation among postlingually deaf adult cochlear implant recipients. *Otol Neurotol* 2014;**35**:e286–91
17 Vermeire K, Brokx JP, Wuyts FL, Cochet E, Hofkens A, Van de Heyning PH. Quality-of-life benefit from cochlear implantation in the elderly. *Otol Neurotol* 2005;**26**:188–95
18 Chatelin V, Kim EJ, Driscoll C, Larky J, Polite C, Price L *et al*. Cochlear implant outcomes in the elderly. *Otol Neurotol* 2004;**25**:298–301
19 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**:432–8
20 Budenz CL, Cosetti MK, Coelho DH, Birenbaum B, Babb J, Waltzman SB *et al*. The effects of cochlear implantation on speech perception in older adults. *J Am Geriatr Soc* 2011;**59**:446–53
21 Roberts DS, Lin HW, Herrmann BS, Lee DJ. Differential cochlear implant outcomes in older adults. *Laryngoscope* 2013;**123**:1952–6
22 Kelsall DC, Shallop JK, Burnelli T. Cochlear implantation in the elderly. *Am J Otol* 1995;**16**:609–15
23 Haensel J, Ilgner J, Chen YS, Thuermer C, Westhofen M. Speech perception in elderly patients following cochlear implantation. *Acta Otolaryngol* 2005;**125**:1272–6
24 Sanchez-Cuadrado I, Lassaletta L, Perez-Mora RM, Zernotti M, Di Gregorio MF, Boccio C *et al*. Is there an age limit for cochlear implantation? *Ann Otol Rhinol Laryngol* 2013;**122**:222–8
25 Orabi AA, Mawman D, Al-Zoubi F, Saeed SR, Ramsden RT. Cochlear implant outcomes and quality of life in the elderly: Manchester experience over 13 years. *Clin Otolaryngol* 2006;**31**:116–22
26 Spitzer JB, Cellum IP, Bosworth C. Stability of audiometric measures and challenges in long-term management of the elderly cochlear implant patient. *Otol Neurotol* 2013;**34**:1636–41
27 Ruffin CV, Tyler RS, Witt SA, Dunn CC, Gantz BJ, Rubinstein JT. Long-term performance of Clarion 1.0 cochlear implant users. *Laryngoscope* 2007;**117**:1183–90
28 Dillon MT, Buss E, Adunka MC, King ER, Pillsbury HC 3rd, Adunka OF *et al*. Long-term speech perception in elderly cochlear implant users. *JAMA Otolaryngol Head Neck Surg* 2013;**139**:279–83
29 Choi JS, Contrera KJ, Betz JF, Blake CR, Niparko JK, Lin FR. Long-term use of cochlear implants in older adults: results from a large consecutive case series. *Otol Neurotol* 2014;**35**:815–20
30 Meister H, Schreitmüller S, Grugel L, Beutner D, Walger M, Meister I. Examining speech perception in noise and cognitive functions in the elderly. *Am J Audiol* 2013;**22**:310–12
31 Anderson Gosselin P, Gagné JP. Older adults expend more listening effort than young adults recognizing speech in noise. *J Speech Lang Hear Res* 2011;**54**:944–58
32 Zekveld AA, Kramer SE, Festen JM. Cognitive load during speech perception in noise: the influence of age, hearing loss, and cognition on the pupil response. *Ear Hear* 2011;**32**:498–510
33 Gordon-Salant S, Fitzgibbons PJ. Temporal factors and speech recognition performance in young and elderly listeners. *J Speech Hear Res* 1993;**36**:1276–85
34 Yamasoba T, Lin FR, Someya S, Kashio A, Sakamoto T, Kondo K. Current concepts in age-related hearing loss: epidemiology and mechanistic pathways. *Hear Res* 2013;**303**:30–8

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