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Improved speech discrimination after cochlear implantation in the Southern Cochlear Implant Adult Programme

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Abstract

Aim To assess the rate and amount of improvement in speech discrimination scores following cochlear implant (CI) at the Southern Cochlear Implant Programme—Adult (SCIPA).

Methods A retrospective review of those implanted between 1999 and 2008 at SCIPA. We recorded type of implant, age of onset of deafness, age at implant, aetiology, and speech discrimination test (hearing in noise test, HINT) results pre-implant and over time post-implant.

Results The mean post-implant HINT score (auditory alone) for the 78 patients who had follow-up up to nine months was 74%, and at 18 months (52 patients) was 81%, compared with a mean pre-implant score of 15%. Performance plateaued at around 6 months post-implant. Age at operation was unrelated to outcome but earlier onset of deafness (and higher percentage of life deaf) gave a poorer outcome. Medium pre-implant scores were associated with lower post-implant scores than those with low or high pre-implant scores.

Conclusions Our results compare favourably with world-wide standards. Benefit in speech discrimination appears to plateau 6 months post-implant. A shorter duration of deafness or percentage of life spent deaf gives better results, but patients with very poor pre-implant functioning may in fact perform better at long term follow-up than those with slightly better pre-implant functioning.

Glossary of abbreviations

SCIP: Southern Cochlear Implant Programme

SCIPA: Southern Cochlear Implant Programme- Adult

HINT: Hearing in Noise Test (described in introduction)

HINT A: auditory cues alone

HINT AV: audiovisual cues

S/O: Switch- on of cochlear implant

BKB sentence test: Bench, Kowal and Bamford sentence lists—open-set sentence lists (i.e. response options not prescribed in advance) similar to HINT

CID sentence test: Central Institute for the Deaf everyday sentence lists- open-set sentence tests similar to HINT

K-CID sentence test: Korean version of the CID test

NVA speech recognition: Nederlands Vereninging Audiologie—Dutch open-set speech recognition tests consisting of monosyllabic (consonant-vowel-consonant) word lists

NU-6 words: Northwestern University Auditory Test No. 6: open-set lists of monosyllabic words

A cochlear implant (CI) is an electronic device which bypasses the auditory function of the outer, middle and inner ear and stimulates the cells of the spiral ganglion (and therefore the cochlear nerve) directly. Cochlear implants are indicated in severe and profound sensorineural hearing loss (SNHL) when hearing aids provide insufficient information for understanding speech.

Cochlear implantation was first performed in New Zealand in 1986.[1] An initially small national programme was based in Auckland. Cochlear implants were first performed in Christchurch in 1998. The Southern Cochlear Implant Programme (SCIP) was established in 2003. Located in Christchurch it serves the South Island and lower North Island. It is divided into separate Adult (SCIPA) and paediatric programmes. The SCIPA comprises two surgeons, two audiologists and a rehabilitationist. Potential candidates are referred to the programme, principally by audiologists and otolaryngologists, and undergo assessment by all three components of the CI team. Currently 80% of referrals are found to be suitable candidates.

The key audiologic test performed is aided speech discrimination, details of which are provided below. This testing aims to determine how well the candidates can utilise their aided hearing to understand speech. The same testing processes are used post-implant to assess the effectiveness of the CI.

Previous research has indicated that there are many factors contributing to the outcome of CI including age, duration of deafness/age at onset of deafness, anatomic issues as determined by radiology, other handicaps, speech and language abilities, functional hearing, family and social support, expectations/motivation, educational setting, communication mode, availability of support services, and the intensity of post-implant rehabilitation therapy.[15,4]

Many studies have shown a significant negative correlation with duration of deafness,[4,7,9,11,12] and a positive correlation with age at onset of deafness, hearing aid use, and progressive hearing loss.[7] In particular, hearing loss prior to development of speech and language inhibits its development and also reduces the effectiveness of cochlear implantation later on.

There are differing findings in the literature regarding the time after CI that maximal benefit is obtained. Some studies indicate that this is reached as early as 3 months,[10] others suggest it is as late as 2 years.[4] This is an important factor to be able to counsel patients about before and after their CI, so they will have some idea of their likely long-term outcome as they carry out their rehabilitation.

In 2005 our Programme introduced the Nucleus® Freedom™ (Cochlear Ltd, Lane Cove, New South Wales, Australia) device which superseded the older technology from the same company of the Nucleus 22 and the later Nucleus 24 cochlear implants. Anecdotally we thought our patients were experiencing more rapid improvements in speech discrimination and slightly higher levels of peak performance, but wished to accurately investigate this.

The objective of this study was to assess the outcome with respect to improvement in speech discrimination test results after CI in patients enrolled at SCIPA, and to determine how long after a CI there is a plateau in performance. We also aimed to assess the effect of duration of deafness and percentage of life spent deaf on results, and the effects of a new CI device.

Methods

A retrospective review of all files of patients receiving follow-up in Christchurch for CI between 1999 and Dec 2008 was undertaken. Exclusion criteria were patients under age 18 (these would be under the Paediatric Programme), and patients with no or inadequate pre-implant data. Some patients had CI performed by the Southern Cochlear Implant Programme – Adult, then moved to the Northern Cochlear Implant Programme (NCIP) for follow-up. Most of these were included, as follow-up data was sent from the NCIP. Some patients had received their CI in NCIP and then moved to the SCIPA for follow-up. These were included if we had a copy of their pre-implant data sent from NCIP.

Files were obtained and the following were recorded: age, sex, type of implant: Nucleus® Freedom™ versus older devices – Nucleus 22 and Nucleus 24, age of onset of deafness, age at implant, percentage of life spent deaf (calculated from above), cause of deafness where known, and speech discrimination test results. We originally intended to measure both age at onset of hearing loss and age when hearing aids were first fitted, along with which sides were aided.

Due to lack of consistent information we were only able to estimate age of onset of deafness with any degree of accuracy. Speech discrimination was measured using the hearing in noise test (HINT), which is a standardized test of speech recognition using sentences delivered in a sound field of 55 dB HL sound pressure level. In determining cochlear implant candidacy, HINT is performed without background noise, despite its name. HINT consists of 25 equivalent 10-sentence lists, two lists are used at each assessment.

The tests are played on a DVD with a speaker/amplifier and are tested both with audiovisual (AV) cues (watching the presenter read the lists whilst listening) and with only auditory (A) cues (visual display turned off). The patient is scored for the percentage of words correctly identified on the lists. This is carried out pre-implant with their hearing aid on, at switch-on (s/o) of CI, then at 1 month, 3 months, 6 months, 9 months, 12 months, 18 months and 3 years post-implant where available.

The following were assessed: improvement in HINT A and AV over time post-CI, overall improvement at 9, 12 and 18 months, characteristics of patients lost to follow-up or with missing data, relationship between final outcome and duration of deafness, percentage of life spent deaf and type of implant used.

Statistical methods: All analyses were carried out using SAS 9.1. To investigate the time course of recovery up to 9 months after an implant, measures A and AV were analysed separately using repeated measures analysis of variance (PROC ANOVA) with time as the repeated measure (pre-implant, s/o, 1 month, 3 months, 6 months and 9 months), and a between subjects factor based on division of the patients into approximately three equal-sized groups based on their pro-operation scores.

The Huynh-Feldt adjustment for non-sphericity was used for repeated measures sources of variance. Chi-square tests and t-tests were used to compare those who had complete data up to 9 months and those who did not on pre-implant variables. Prediction of long-term outcome used data from 18 months if available and otherwise the 12 month values were used. Including 12 month values in this way increased the number of A outcome observations from 40 to 46 and the number of AV observations from 37 to 44.

Prediction of outcome was carried out using one way analysis of variance (PROC GLM). Because of ceiling effects, particularly for AV, Welch's test was used if Levene's test for the homogeneity of variance was significant with α=0.10, although this precaution mostly made little difference.

Results

A total of 171 patients were on the cochlear implant rehabilitation files at SCIPA. Of this total, 57 were excluded for the following reasons: 11 had been implanted too recently for analysis (2 months or less), 12 had transferred from the Paediatric Programme so did not apply to our study, 17 had been implanted prior to 1997 so speech discrimination tests other than HINT had been used for their pre-implant and post-implant assessments, nine had no follow-up notes available, four were non-users (discussed later), and four did not have pre-implant speech discrimination tests available.

A total of 114 patients were then left for analysis. However, among this group there was much missing data. Only 55 had complete data for A and 53 for AV. Comparison of those with complete data and the remaining patients showed no significant differences in any of the background characteristics or of pre-implant functioning.

We used complete data only for the analyses as imputation of data was deemed inappropriate due to the ceiling effect of the results. This was to ensure internal validity, i.e. comparing people across time for the same people. Pre-implant characteristics are shown in Tables 1–3, and the pre-implant scores on HINT are shown in Tables 4 and 5.

Table 1. Characteristics of those with a cochlear implant between 1999 and 2008

Variables	Number assessed	Mean (SD)	Range
Age (years)	113	50 (15.3)	20–83
Age (years) of onset of deafness	111	21 (19.4)	1–63
Duration of deafness (years)	111	30 (14.5)	1–63
Percentage of life deaf	111	64% (30.5)	2–99
HINT pre-implant A	112	15 (16.8)	0–65
HINT pre-implant AV	111	67 (23.9)	0–100

Table 2. Mean HINT AV scores (% correct) at pre-implant, switch-on (s/o), and 1–9 months post-implant: 53 patients

Variables	Mean HINT AV score	SD	Range
Pre-implant	66	24	0-100
s/o	82	17	32-100
1 month	93	10	67-100
3 months	96	9	57-100
6 months	96	6	74-100
9 months	98	4	79-100

Table 3. Mean HINT A scores (% correct) among those with complete data up to 9 months by grouping based on pre-implant scores (55 patients)

HINT A scores pre-implant	Number	Mean pre-implant score (SD)	Mean s/o score (SD)	Mean score at 1 month (SD)	Mean score at 3 months (SD)	Mean score at 6 months (SD)	Mean score at 9 months (SD)
0	18	0 (0)	33 (27)	60 (27)	71 (29)	77 (27)	83 (21)
1–15	17	6 (4)	23 (28)	44 (31)	53 (33)	65 (31)	69 (29)
16+	20	34 (12)	46 (29)	69 (29)	79 (22)	82 (24)	83 (25)
Total	**55**	**14 (17)**	**34 (29)**	**58 (30)**	**68 (30)**	**75 (28)**	**79 (25)**

Table 4. Mean HINT AV scores (% correct) among those with complete data up to 9 months by grouping based on pre-implant scores (53 patients)

HINT AV scores pre-implant	Number	Mean pre-implant score (SD)	Mean s/o score (SD)	Mean score at 1 month (SD)	Mean score at 3 months (SD)	Mean score at 6 months (SD)	Mean score at 9 months (SD)
0-60	18	39 (20)	75 (20)	93 (7)	94 (10)	96 (7)	97 (5)
61-78	17	69 (5)	80 (19)	92 (11)	93 (11)	96 (4)	98 (4)
79+	18	90 (7)	90 (9)	92 (11)	98 (4)	97 (6)	98 (4)
Total	**53**	**66 (25)**	**82 (17)**	**93 (10)**	**95 (9)**	**96 (6)**	**98 (4)**

There was significant heterogeneity in aetiology. The recorded causes included idiopathic, genetic, maternal rubella, meningitis, otosclerosis, endolymphatic hydrops and large vestibular aqueduct syndrome.

The mean post-implant HINT scores at nine months were 74% for A only (78 patients, range 11–100%), and 96% for AV (74 patients, range 62–100%). The mean scores at 18 months were 81% for A only (52 patients, range 14–100) and 98% for AV (50 patients, range 70–100). Improvement over time following CI was assessed by comparing HINT scores pre-implant with those at follow-up appointments, for both A and AV (Tables 6 and 7). As mentioned earlier, this was only possible for 55 patients for A and 53 patients for AV due to lack of complete data on the remaining patients.

Table 5. Age at operation vs longterm HINT A and AV scores: 58 patients

Age (years) at operation (number of patients)	Mean longterm A score (% correct) (SD)	Mean longterm AV score (% correct) (SD)
20–44 (22)	75 (28)	96 (7)
45–59 (19)	79 (23)	97 (5)
60+ (17)	83 (16)	99 (2)
p-values	0.46	0.33

Table 6. Age of onset vs longterm HINT A and AV scores: 56 patients

Age (years) of onset (number of patients)	Mean longterm A score (% correct) (SD)	Mean longterm AV score (% correct) (SD)
<3 (13)	63 (28)	95 (8)
3-19 (17)	79 (27)	98 (5)
20+ (26)	86 (14)	99 (2)
p-values	0.01	0.07

Table 7. Percentage of life deaf vs longterm HINT A and AV scores: 56 patients

Percentage of life deaf (number of patients)	Mean longterm A score (% correct) (SD)	Mean longterm AV score (% correct) (SD)
<50% (19)	88 (12)	99 (2)
51-89% (22)	80 (25)	98 (4)
90%+ (15)	64 (26)	95 (8)
p-values	0.006	0.11

We also assessed improvement by initial scores (for both A and AV) divided into three groups: Table 8 (A) and Table 9 (AV).

Table 8. Implant model (Nucleus Freedom vs Nucleus 22 and 24) vs longterm HINT A and AV scores: 58 patients

Implant (number of patients)	Mean longterm A score (% correct) (SD)	Mean longterm AV score (% correct) (SD)
Freedom (21)	89 (14)	99 (3)
Nucleus 22 & 24 (37)	73 (26)	97 (6)
p-value	0.01	0.15

Table 9. Pre-implant HINT A score vs longterm A and AV scores (% correct): 58 patients

Pre-implant A score (number of patients)	Mean longterm A score (SD)	Mean longterm AV score (SD)
0 (18)	82 (20)	99 (2)
1–15 (18)	67 (26)	95 (7)
16+ (22)	86 (20)	98 (5)
p-value	0.02	0.06

Predicting longer term outcome: only 52 patients had 18 month follow-up for A and 50 for AV. However by adding in 12 month data for those missing 18 month data, the numbers were increased to 58 and 57 respectively. The effect of age at operation, age of onset of deafness, and percentage of life spent deaf were assessed in terms of A and AV scores at long-term follow-up.

Age at operation was unrelated to outcome but the earlier the onset of deafness (and higher percentage of life deaf), the poorer the outcome, as would be expected (see Tables 5–7). There was no outcome difference between the sexes but patients with Nucleus Freedom implants did better at long-term follow-up than those with older implants (see Table 8). In terms of pre-implant functioning, medium pre-implant levels of A (scores of 1–15%) were associated with lower post-implant A scores, as was also found when looking at recovery up to 9 months.

Pre-implant AV scores had no significant effect on long-term outcome (see Tables 9–10). Multivariate analysis was not possible due to the small numbers of patients. The ceiling effect for AV was such that there was little ability to predict this outcome as it was mostly very good with means all over 90%.

Table 10. Pre-implant HINT AV score vs longterm A and AV scores (% correct): 57 patients

Pre-implant AV score (number of patients)	Mean longterm A score (SD)	Mean longterm AV score (SD)
0–60 (16)	84 (19)	99 (8)
61–78 (17)	72 (26)	98 (3)
79+ (24)	80 (24)	97 (5)
p-value	0.38	0.75

We looked at the highest and lowest performers within the group of 114 patients. We defined the very high performers as a post-implant HINT A score of at least 95% (at most recent assessment), and low performers as postoperative HINT A score of less than 60%. There were 43 high performers and 20 low performers out of the 114 patients.

Overall for the low performers the percentage of life spent deaf was more than 50% except for one patient, and for the high performers about half (22) of the patients had spent more than 50% of their life deaf while 21 of the patients had spent less than 50% of their life deaf.

For the high performers, 15 out of the 43 had pre-implant HINT A scores of more than 30. Nine of these were at least 25 years old at onset of deafness and had mainly progressive aetiology (e.g. otosclerosis), the other three being younger at onset but also progressive causes, and three with congenital deafness. A further 15 with lower pre-implant scores were at least 25 years old at onset and mainly progressive causes and had spent less than a third of their life deaf. One further patient had a congenital hearing loss that was made worse by otosclerosis over time.

There were 13 patients who would not have been expected to be high performers, with congenital deafness, implanted between ages 20-43 and pre-implant HINT A scores ranging from 0 to 30%.

Of the 20 lowest performers, 14 had congenital deafness, 11 with pre-implant HINT A scores of less than 15%, and 19 of whom were older than 35 at implant. There were two older patients: one aged 72 with progressive hearing loss and duration of deafness of 36 years, pre-implant HINT A score of 9%, and one aged 79 with endolymphatic hydrops as likely aetiology, duration of deafness of 49 years, and pre-implant HINT A score of 14%.

The remaining four low performers were aged between 49 and 55 and had differing background characteristics: a 55 year old with unknown aetiology, duration of deafness of 47 years and pre-implant HINT A score of 18, a 53 year old with chronic middle ear disease, duration of deafness of 48 years and pre-implant HINT A 18, a 52 year old with otosclerosis, duration of deafness of 32 years and pre-implant HINT A score of 55, and a 49 year old with chronic middle ear disease, duration of deafness of 4 years and pre-implant HINT A score of 0.

Only four out of 20 of the lowest performers' scores had not improved post-implant compared with pre-implant measurements. The remaining lowest performers had still improved significantly, despite having a low post-implant score compared with the average for the group. The mean post-implant score for HINT A for the 20 lowest performers was 33 (range 14-56), compared with a mean pre-implant score of 15 (range 0-55).

Four patients are now not using their cochlear implants. One patient was found to be a malingerer, the patient is able to converse on the telephone without a hearing aid or cochlear implant. The second patient has superficial siderosis of the CNS, presumably with a large neural component towards his hearing loss meaning the device is ineffective. The third patient had a right petrous apex chondrosarcoma treated with surgery and radiotherapy and a left acoustic neuroma treated with radiotherapy. He could not perceive any sound from his right CI despite pre-implant testing suggesting a functioning auditory nerve on the right. The final patient had many psychosocial issues and significant negative thought processes which were thought to be the main cause of failure.

Discussion

Our medium-to-long term results after CI in adults compare favourably with others in the literature. This can be difficult as most studies have used different speech perception tests, so direct comparisons can not be made, however, the difference between pre-implant and post-implant scores can still be seen.

Our patient group was defined as adults receiving a CI, and includes those with prelingual and postlingual deafness, which can make it more difficult to draw comparisons. However our result of a mean of 74% correct HINT (A) score at 9 months and 81% at 18 months compared with a mean pre-implant score of 15% compares well even with studies of adults with postlingual deafness only (who would be expected to have a better result).

A Manchester study of 34 patients with postlingual deafness aged at least 65 years having a CI between 1989 and 2002 (with a mean duration of deafness of 11 years) had similar results to our study with a BKB sentence test mean score of 73% at 9 months (compared with a mean of 0 pre-implant), despite a shorter duration of deafness.[2] A Minnesota group of 33 patients over the age of 18 (average 52 years) with postlingual deafness who had CI before 2002 achieved a mean CID sentence test score of 54% at one year compared with 14% pre-implant.[3]

A Korean group of 13 postlingually deaf patients (average duration of deafness 9 years) with CI between 1988-1998 had a mean K-CID sentence test score of 52% at 12 months (pre-implant scores were not recorded).[4] A study of 37 postlingually deaf adults with CI between 1989-1997 in the Netherlands obtained an average score in NVA open-set speech recognition of 36% at very long-term follow-up (6 years or more after CI).[5]

A Tennessee study of 27 patients over age 50 with postlingual deafness, with CI before 2004 had mean HINT score of 5.4% pre-implant, and 66% at mean of 4 years post-implant.[6] A study of 33 postlingually deaf patients in the Netherlands implanted before 1994 obtained mean scores on speech perception testing (test not specified) of 28% at 12 months compared with 0% pre-implant.[8]

A Swedish study of patients aged over 16 (mean 50 years) and mean duration of deafness of 15 years with CI before 1994 had a mean open set spondee word score of

20% at one year (0% pre-implant).[9] A study of 89 postlingually deaf CI patients in Antwerp with average age 58 years showed a mean post-implant NVA phoneme score of 47%-68% (differing means depending on differential age groups) at 12 months compared with 5-7% pre-implant.[13]

Studies have shown a significant increase in health-related quality of life following CI, which correlates with results in speech perception tests.[12] A quality-of-life study conducted by our programme has shown significant differences between implanted patients and patients on the waiting list for CI and also in the quality-of-life of their significant others.[14]

Patients with lower scores on speech perception can still obtain the benefits of being able to hear environmental sounds (e.g. a dripping tap, the doorbell, improvement in driving awareness etc), all four of the patients whose speech discrimination did not improve did receive some benefit from improved hearing of environmental sounds with their implant.

As previously mentioned there are many factors which affect the success or otherwise of cochlear implantation. In this study we have clearly shown that patients with a longer duration of deafness and a higher proportion of their lives with deafness, had significantly poorer results with cochlear implantation. This is consistent with previous findings in the literature [4,7,9,11,12].

The vast majority of these people still had very significant improvement in speech discrimination. Although long periods of deafness without hearing aids also contribute to poor results, our retrospective review was not able to adequately capture this data.

The age of the patient at implantation did not affect their outcome. Although just over 30% of our patients were aged over 60, the vast majority were under 80 years of age at the time of implantation. The literature confirms somewhat poorer results of cochlear implantation over the age of 80. We would expect that, in time, a higher proportion of our patients may be in the older age group.

Our impression of improved performance with the new Freedom device was confirmed with a mean auditory alone (A) score of 89% versus 73% with the older devices. This result could be somewhat confounded by the increased rehabilitation support available to our patients after 2004.

It is always disappointing when expensive technology is not used. We are undertaking an audit of our assessment processes to try to avoid inappropriate implants in those patients who are psychologically not able to benefit from the technology.

Our patient with superficial siderosis and another patient from the Northern Cochlear Implant Programme of New Zealand have been reported in the literature as the first two failures of CI in this condition.[16] We have subsequently successfully implanted a patient with this debilitating condition.[17]

An interesting finding was that in terms of pre-implant functioning, the "middle group" of patients with pre-implant A values of 1-15% had a lower mean final score at 9 months than those with pre-implant scores of 0% (and those with higher pre-implant scores, as expected). This has also been noted in the literature.[9] We have no explanation for this finding.

In terms of the time at which near-maximal benefit is obtained, we appeared to have a near plateau at 6 months, with mean HINT A scores of 75% compared with 79% at 9 months and 81% at 18 months. For AV scores, this was difficult to assess due to the ceiling effect (very high scores near 100%) which restricts the opportunity to observe changes. This is probably why AV scores peak faster.

This "plateau" at 6 months is in general consistent with findings from previous research. The Manchester study previously mentioned, [2] found that most benefit occurred during the first 9 months. The Netherlands study of 33 patients had a plateau at 6 months,[8] and the larger Netherlands study, [13]found a peak at 6-12 months. An Iowa study of adults with postlingual deafness reached a plateau in speech discrimination 6-9 months after CI.

Differing results were from the Korean study,[4] which did not obtain a plateau until 2 years. A Californian study of 46 adults implanted before 1994 with a mean age of 53 years and duration of deafness between 2-69% of lives achieved at least 80% of their 12-month performance levels on open-set CID sentences at the first visit at 3 months, but for a more difficult test (NU-6 words), most improvement occurred in the first 6 months.[10]

There was much missing data which meant we used a smaller sample than initially intended. This is not entirely unexpected as many of the patients do not live locally and have to travel long distanced for follow-up. We noted that patients who had implants in 2004 were far more likely to have incomplete follow-up. This is likely to be because there was a changeover of rehabilitationist that year.

To assess for exclusion bias, we analysed background characteristics of the patients who were not used due to missed data and found there was no difference. Also, it can often be the case that the patients who do not attend for follow-up are actually performing better and feel that they do not need any further rehabilitation.

In conclusion, our study has enabled us to inform patients presenting for CI at SCIPA that our results compare very favourably with world-wide standards, that maximal benefit in terms of speech recognition appears to occur at around 6 months post-implant. Patients with a shorter duration of deafness or percentage of life spent deaf do better on average, but that patients with very poor pre-implant functioning may in fact perform better at long-term follow-up then those with slightly better pre-implant functioning.

Competing interests: None known.

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