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# Cochlear implantation in early deafened, late implanted adults: Do they benefit?

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Objectives: The aim of this study was to quantify the benefit gained from cochlear implantation in pre- or peri-lingually deafened patients who were implanted as adults Methods: This was a retrospective case-control study. Auditory (BKB/CUNY/3AFC/Environmental sounds), quality of life (GBI/HUI3) and cognitive (customized questionnaire) outcomes in 26 late implanted pre- or peri-lingually deafened adults were compared to those of 30 matched post-lingually deafened, traditional cochlear implant users.
Results: There was a statistically significant improvement in all scores in the study group following cochlear implantation. BKB scores for cases was 49.8% compared to 83.6% for controls (p=0.037). CUNY scores for cases was 61.7% compared to 90.3% for controls (p=0.022). The 3AFC and environmental sounds scores were also better in controls compared to cases but the difference was not statistically significant. Quality of life scores improved following implantation in cases and controls but the improvement was only statistically significant in the controls. There was a 7.7% non-user rate in the cases. There were no non-users in the control group.
Discussion: Early deafened,,late implanted patients can benefit audiologically from cochlear implantation and in this study the improvement in speech discrimination scores was greater than expected perhaps reflecting careful selection of patients. Nevertheless, audiological benefits are limited compared to traditional cochlear implant recipients with the implant acting as an aid to lip reading in most cases.
Conclusion: With careful selection of candidates, cochlear implantation is beneficial in early deafened, late implanted patients.

**Keywords:** Cochlear implant, Quality of life, Congenital deafness, Cochlear implant outcomes, Pre-lingual deafness

## Introduction

Cochlear implants (CIs) are well established as a successful means for providing access to sound in individuals with bilateral severe to profound hearing loss. The benefits of early cochlear implantation in pre-lingual congenitally deafened children have been consistently demonstrated. These children generally develop normal speech and language over time and are able to function almost as well as a normally hearing individual, socially and professionally (Castro *et al.*, 2005). In post-lingually profoundly deafened adults who receive limited benefit from conventional hearing aids, CIs also generally provide excellent auditory outcomes, often allowing the individual to hear exceptionally well even in very challenging listening situations (Orabi *et al.*, 2006).

It has become clear, since the advent of cochlear implantation, that the auditory pathways of the human brain are subject to neural plasticity such that if the auditory pathways are not stimulated during early development, their function becomes reallocated and they no longer function as auditory neurones (Sharma *et al.*, 2007). Thus, beyond approximately the age of 5, a profoundly congenitally deafened individual or an individual with a profound early acquired hearing loss will gain significantly less benefit, if any, from delayed cochlear implantation (Lammers *et al.*, 2015). Such individuals would not have acquired normal speech because of the lack of appropriate auditory stimulation in the developmental years and are usually, to a lesser or greater extent dependent on lip reading and sign language to assist communication. It also remains unclear as to

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whether there are certain subgroups of early profoundly deafened individuals who would benefit more than others from delayed cochlear implantation. This might include those who have been peri-lingually deafened and those who have had a small amount of auditory stimulation despite profound congenital deafness.

This study aimed to compare outcomes of cochlear implantation in early deafened, late implanted adults with traditional post-lingually deafened adults using speech discrimination testing and more subtle outcome measures such as quality of life (QoL). The hypothesis was that the early deafened late implanted group would gain limited benefit from their CI and perform less well than the post-lingually implanted control group.

## Methods

The study was a retrospective case–control study to assess the auditory, communication and QoL outcomes from cochlear implantation in early deafened late implanted adults implanted between 2003 and 2014. Ethical approval was obtained from the Institutional Ethics Committee in January, 2015.

All patients were either deafened at birth before 3 years of age. Those deafened before the age of 18 months were defined as pre-lingually deafened. Those deafened between the age of 18 months and 3 years were defined as peri-lingually deafened. All had acquired some degree of spoken communication in childhood. The degree of spoken communication varied between individuals. All patients were implanted as adults (18 years or over) with normal cochleae and cochlear nerve anatomy and all had had auditory deprivation for at least 15 years. Those who had significant surgical complications or incomplete electrode insertion were excluded. Similarly, those with additional disabilities were also excluded. All patients underwent single sided implantation in the ear that was felt to offer the best possible auditory outcome.

Data was collected pre-implant and at 3, 6, and 12 months post-implantation using the following outcome measures:

(a) Recognition of environmental sounds.
(b) Speech pattern perception test using the Three Alternative Forced Choice (3AFC) test.
(c) Speech discrimination tests without lip reading using Bamford–Kowal–Bench (BKB) Sentences in quiet and in noise.
(d) Speech discrimination tests with lip reading using City University of New York (CUNY) Sentences.
(e) QoL was measured using the Glasgow Benefit Inventory (GBI) and Health Utilities Index Mark 3 (HUI3).
(f) Custom designed condition specific QoL questionnaire. This probed issues that are not measured by traditional auditory testing such as cognition, emotional wellbeing, self-esteem and social interaction (see supplementary material).

Outcomes were compared with results from a control group of post-lingually deafened adult implant users. The controls were age-matched post-lingually deafened adults with normal inner ear anatomy, who had auditory deprivation for less than 5 years and had received unilateral cochlear implantation uneventfully and had auditory rehabilitation during the same period as the cases. Statistical comparison of cases and controls was performed by using an independent *t*-test for normally distributed, quantitative data. The level of significance was set at $p < 0.05$. Pearson parametric correlation was used to assess the correlation between auditory outcome scores and QoL measures.

There were 26 candidates in the study group and 30 patients in the control group. Study patients were aged 18–68 years (mean age 36.8 years). They had a diverse aetiological spectrum for hearing loss. Of the pre-lingually deafened group, 24% were congenital syndromic and 38% were congenital non-syndromic. Of the

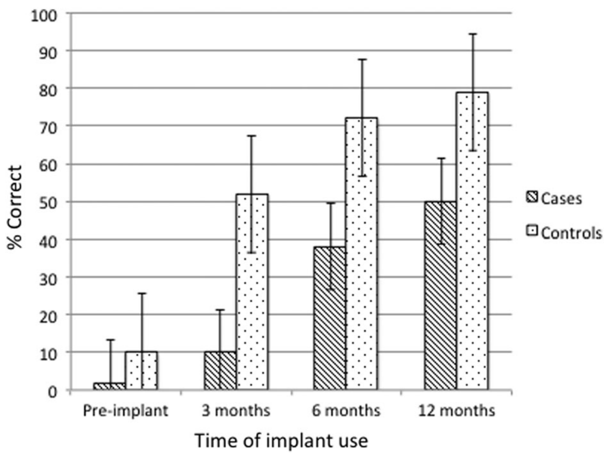


**Figure 1 BKB in noise scores: pre-implant versus post-implant up to 1 year. Error bars represent standard error of the mean.**

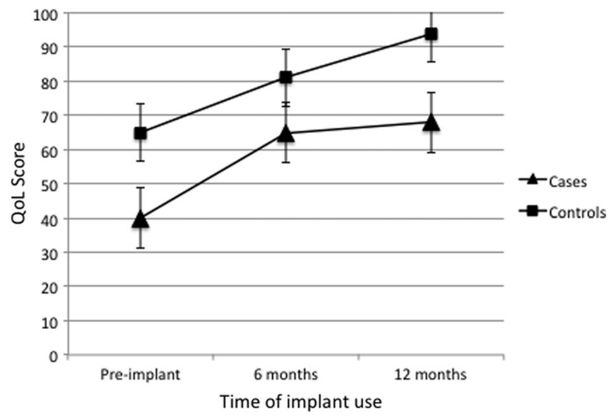


**Figure 2 GBI scores: pre-implant versus post-implant up to 1 year. Error bars represent standard error of the mean.**

peri-lingually deafened group, 27% were idiopathic while 12% had a history of meningitis. Evaluation of duration of hearing loss showed 53.1% to have >15 years, 36.7% to have >30 years and 10.2% to have >45 years of deafness, respectively. Prior to implantation, 63% of these individuals used lip reading and/or sign language in combination with powerful hearing aids. Thirty seven per cent used only lip reading and signing with no hearing aid use.

## Results

Speech perception scores on all tests among the study group significantly improved with CI. The mean BKB score was 49.8% (p=0.044), mean CUNY score was 61.7% (p=0.038), mean 3AFC score was 83.3% (p=0.029) and mean ENV sound score was 88.9% (p<0.025) at 12 months respectively. There was a steady improvement in scores over the first 12 months. In the control group, the mean BKB score was 83.6%, mean CUNY score was 90.3%, mean 3AFC score was 93% and mean ENV sound score was 97%, at 12 months. The mean BKB and mean CUNY scores in the control group were statistically significantly better compared to the cases (p=0.037 for BKB and p=0.022 for CUNY) whereas the mean 3AFC and mean ENV scores were not statistically significantly different (p=0.064 for 3AFC & p=0.089 for ENV sounds). The BKB outcomes for both groups in noise are shown in Fig. 1. The changes in CUNY scores were similar. The good 3AFC and environmental sounds scores reflects the relative ease of the tests.

GBI and HUI3 QoL scores improved with CI in the study group but the improvement was smaller than the control group and the change itself was not statistically significant in the study group ($p > 0.05$). In contrast, the improvement in QoL scores was statistically significant in the control group ($p < 0.05$) (Fig. 2). The size of the change was statistically significantly different between the two groups ($p < 0.05$).

From the patient feedback questionnaire, 92.3% (24/26) of study patients felt that their CI augmented their communication skills while signing/lip reading. They also felt that it improved their cognition, emotional wellbeing, self-esteem and social interaction. 84.6% (22/26) of study patients continued to lip read/sign while using their implants. 7.7% (2/26) of study patients were able to stop using lip reading/signing as their primary mode of communication. They did, however, continue to use them to a lesser extent in addition to their CI. 7.7% (2/26) of patients were non-users because they gained no subjective benefit from their CI. They had poor auditory and QoL scores and continued only to lip read and sign.

GBI/HUI showed moderate correlation with 3AFC/ENV scores in the study group ($r = 0.42$ at 6 months, $r = 0.57$ at 12 months), while correlation in control group was much higher ($r = 0.91$ at 6 months, $r = 0.93$ at 12 months). GBI/HUI showed poor correlations with BKB/CUNY scores in the study group ($r = 0.09$ at 6 months, $r = 0.23$ at 12 months), in contrast to the control group in whom there was a strong correlation ($r = 0.78$ at 6 months, $r = 0.89$ at 12 months).

Overall, peri-lingually deafened patients tended to have better auditory and QoL outcome scores, compared to pre-lingually deafened individuals. The peri-lingual group scored higher than the pre-lingual group by an average of 11.1% in BKB, 13.5% in CUNY, 7.8% in ENV sounds, 18% in 3AFC, 22% in GBI and 0.4 in HUI3. Those with greater than 45 years of deafness prior to implantation had the poorest auditory and QoL outcomes with their CI (two of the five patients in this group were non-users).

## Discussion

This study shows that early deafened, late implanted patients can benefit audiologically from cochlear implantation with a significant improvement in speech discrimination scores following implantation. The improvement in speech discrimination scores was greater than expected and this may reflect careful selection of patients for cochlear implantation. Nevertheless, the audiological benefits are limited compared to traditional CI recipients. Users tend to continue to sign/lip read as their primary means of communication and the implant tends to be an aid to lip reading and aid to hearing environmental sounds. The lack of correlation between QoL improvement and speech discrimination scores and the stronger correlation between QoL and 3AFC and environmental sounds testing probably reflects this. There are, however, tangible benefits in more subtle measures including improvements in cognition, emotional wellbeing, self-esteem and social interaction. These subtle benefits probably originate from the acquisition of additional auditory cues.

The findings of this study are comparable to those of others. For example, Santarelli *et al.* (2008) found that speech perception scores improved following cochlear implantation but that the improvement was limited compared to post-lingually deafened adults (Santarelli *et al.*, 2008). Zwolan *et al.* (1996) found no improvement in speech recognition scores at 12 months. There are similarly limited benefits to music appreciation in early deafened late implanted patients (Fuller *et al.*, 2013). It may, however, take up to 4 years for speech discrimination scores to peak, unlike more traditional CI recipients (Nava *et al.*, 2009; Santarelli *et al.*, 2008; Zhang *et al.*, 2011; Zhao *et al.*, 2008).

The literature also highlights that the more subtle benefits from implantation, beyond audiological measures, are important. For example, Most *et al.* (2010) used self-reported questionnaires to assess some non-audiological factors that may be affected by cochlear implantation including education, work, social skills and personal satisfaction and found significant improvements in most variables following implantation. Similarly, Jeffs *et al.* (2015) found that CI in this group aided recipient's sense of identity and improved their emotional wellbeing. Peasgood *et al.* (2003) have also found that implantation in late implanted, early deafened individuals resulted in a similar increase in QoL compared to post-lingually implanted patients despite the fact that there was no parallel improvement in their auditory outcomes. Straatman *et al.* (2014) also found that implantation resulted in significant improvement in QoL and that there was no significant correlation between improvement in QoL and improvement in speech perception scores. It is therefore important to assess these more subtle aspects in this group of patients. Adequate counselling regarding expectations is, however, very important in this group of patients if the non-user rate is to be minimized (Summerfield and Marshall, 2000; Jeffs *et al.*, 2015).

While the number of patients included in this study was not enough to allow statistical analysis of the factors influencing outcome, those who had a shorter duration of deafness, those that were deafened in early childhood and those who had some early audition tended to achieve better outcomes. Other authors have shown similar findings. Santarelli *et al.* (2008) found that that age of deafening (i.e. early pre-lingual rather than peri-lingual deafening), very late implantation, lack of pre-implant aiding, additional learning difficulties, degree of pre-implant hearing loss are among the most important factors influencing outcome. Speech intelligibility prior to implantation may also be a predictor of cochlear implant outcome with those with better pre-implant speech intelligibility having better auditory outcomes with implantation (Van Dijkhuizen *et al.*, 2011). This is likely to reflect degree of early life auditory stimulation.



## Conclusion

This study shows that there is benefit to be gained from cochlear implantation in early deafened, late implanted adults but these benefits are limited. In some cases, the implant may act to provide additional auditory cues to enhance communication with signing/lip reading. It is important to note, however, that there is a small non-user rate in this group. The study also suggests that there may be certain factors that predict better outcome. Case selection is likely to be very important and novel means of assessing patients such as QoL measures and speech intelligibility scores may have a particular role to play in both pre and post-operative assessment. It may also take longer for patients to achieve their optimum outcome. Counselling to ensure appropriate expectations following implantation is also critical.

## Disclaimer statements

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**Conflicts of interest** None.

**Ethics approval** None.

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