Single-Sided Deafness: The Effect of Cochlear Implantation on Quality of Life, Quality of Hearing, and Working Performance Test Gabi

Rüdiger Müller-Isberner, Christoph R. Meier

Department of Otorhinolaryngology, Tampere University Hospital and the University of Tampere, Tampere, Finland; Department of Otorhinolaryngology, Helsinki University Central Hospital, Helsinki, Finland

Key Words
Cochlear implant · Single-sided deafness · Working performance · Quality of life · Quality of hearing

Abstract
Aims: To evaluate the effect of cochlear implant (CI) on quality of life (QoL), quality of hearing (QoH), and working in patients with single-sided deafness (SSD). Methods: Using specific questionnaires, we measured QoL, QoH, and working performance in seven SSD patients scheduled for CI surgery of the affected ear. Sound localization and speech perception in noise were also assessed. All questionnaires and tests were performed before the CI surgery and at six and 12 months after CI activation. Results: The QoL, QoH, sound localization, and speech perception in noise improved statistically significantly after the CI. Communication with co-workers became easier, and the patients were less fatigued after the working day. Conclusions: CI clearly improves QoL, QoH, and working performance in patients with SSD.

Introduction
Postlingual single-sided deafness (SSD) is in most cases caused by Ménière's disease, trauma or sudden sensorineural hearing loss of unknown origin. SSD
causes difficulties in determining the direction of sound and separating background noise from target sounds, such as speech. Moreover, many patients may suffer from incapacitating tinnitus in their affected ear. In some patients, SSD may lead to remarkable problems in managing at work, for example, in business negotiations, customer service, and meetings. A hearing deficit may result in progressive absences from work and early retirement. Although, to our knowledge, there are not any studies about single sided deafness on work performance. However, most SSD patients manage with their hearing loss and do not want or need any hearing rehabilitation.

Current rehabilitation options for SSD include the contralateral routing of signal (CROS) or bone conduction devices (BCD). However, only a few patients benefit from these options, and even the best rehabilitation conditions do not compensate for the lack of binaural hearing [1, 2]. In previous studies, only 25–40% of SSD patients chose an implantable BCD or CROS hearing aid after a short trial period [2, 3]. Most patients found it unpleasant to have an earmold with partial occlusion in their hearing ear or to have an abutment in their skull that required diligent care.

The latest rehabilitation option in SSD is the cochlear implant (CI). Recent review studies have shown that cochlear implantation in SSD leads to improved sound localization performance and speech perception in noise [4, 5]. Moreover, Arndt et al. [6] found that cochlear implantation is superior to implantable BCD or CROS hearing aids in patients with SSD. Their results showed significant improvement in localization ability as well as in speech comprehension in most presentation configurations with the CI. Interestingly, unilateral tinnitus resulting from SSD can be alleviated with electrical stimulation via a CI. Tinnitus loudness and distress decreased significantly after cochlear implantation in 21 SSD patients with intractable tinnitus [7].

Cochlear implantation in SSD is not a routine practice in Finland. However, the importance of hearing at work and in everyday life is invariably increasing, and patients are well aware of the benefits of cochlear implantation. This has put a lot of pressure on public healthcare to provide CIs for SSD patients as well. The purpose of our study was to evaluate the effect of CI on quality of life (QoL), quality of hearing (QoH), and working performance in adult patients with SSD.

Materials and Methods

Seven consecutive patients (five women and two men, mean age 48 years, range 36–61 years) with SSD who were referred to audiological consultation because of difficulties in managing at work were included in the study. The aetiology of SSD was sudden deafness of unknown origin in five patients and stapes surgery in two patients. The average time between deafness and cochlear implantation was 2.5 years (range 1–7 years). All patients had normal contralateral hearing with a pure tone average (PTA; the mean of 0.5, 1, 2, 4 kHz) ≤20 dB HL. None of the patients had used a CROS hearing aid or BCD before the CI surgery. Preoperatively, six patients had moderate tinnitus in their affected ear. All patients were implanted with a Cochlear™ Nucleus® CI 24 RE (CA) implant with a Nucleus® CP810 processor. The study was conducted at Tampere University Hospital, Tampere, Finland and approved by the Ethics Committee of Pirkanmaa Hospital District, Tampere University Hospital.

Preoperative hearing tests included PTA and speech discrimination (SD) with recorded bisyllabic, phonetically balanced words in the Finnish language in quiet, which have been validated for adults [8]. Binaural hearing (PTA and SD) was tested in a sound field before the CI surgery, and then at six and 12 months after CI activation.

The patients’ QoL, QoH, tinnitus perception, working performance, and work-related stress were evaluated using specific questionnaires. Work-related stress and QoH questionnaires were completed
before the CI and at six and 12 months after CI activation. The QoL questionnaire was completed six and 12 months after CI activation, and the working performance questionnaire was completed, on average, 22 months after CI activation. The possible change in tinnitus perception was evaluated, on average, 28 months after CI activation.

Work-related stress was measured using the Occupational Stress Questionnaire from the Finnish Institute of Occupational Health. The questionnaire contains 53 negative claims to respond to; each response is placed on a six-point scale ranging from a total disagreement to total agreement. The questionnaires measuring working performance and work-related stress have not been validated.

The patients’ QoL was measured by the Glasgow Benefit Inventory (GBI) questionnaire [9]. The GBI scores after the CI depict the positive or negative impact of the CI on the patient’s QoL compared to the former condition. The test contains 18 questions and the response to each question is placed on a five-point scale ranging from a large deterioration to a large improvement in health status. The GBI consists of a total score and three subscores (general, social support, and physical health). The total score is transposed onto a benefit scale ranging from −100 (maximum negative benefit), through 0 (no benefit), to +100 (maximum positive benefit) [10].

QoH was measured with the Speech, Spatial and Qualities of Hearing Scale (SSQ; version 3.1.2) questionnaire, where patients use a visual analogue scale (VAS, from 0 to 10) to evaluate their current hearing. The SSQ questionnaire is divided into three categories: speech intelligibility, spatial perception, and sound quality.

Speech recognition in noise and localization performance were assessed in an acoustically shielded room for sound field audiometry, as described in an earlier study on sequential bilateral cochlear implantation in the clinic, see Härkönen et al. [11]. In the present study, speech-in-noise and localization tests were performed over loudspeakers preoperatively without amplification in the single-sided deafness condition (SSD+NH), and postoperatively at 6 and 12 months after the activation of the cochlear implant in the deafened ear (CI+NH).

The setup for the speech-in-noise and the localization tests consisted of five loudspeakers at 0°, ±45° and ±90° of azimuth in the horizontal plane. For the speech-in-noise test, phonetically balanced bisyllabic Finnish words [8] were presented at 65 dB SPL from the frontal loudspeaker (0° of azimuth), while uncorrelated, unmodulated noise with a long-term spectrum that corresponded to human speech [12] was presented from the other four loudspeakers. The level of the noise signal was varied in 5 dB steps to achieve a psychometric function for six different signal-to-noise ratios (SNRs) ranging from −5 to +20 dB. For the localization test, short speech segments were played back randomly from each of the five loudspeakers. The presentation level was 65 dB SPL and it was roved within ±5 dB to avoid the participants using loudness as a cue to localize sound. Sound localization accuracy was quantified by an error index (EI) ranging from 0 to 1, 0 corresponding to perfect localization accuracy and 1 being chance performance. For more details on the setup, see Härkönen et al. [11].

At each assessment, the participants first listened to the word lists in noise with the six SNRs in a random order, and they then took the localization test. The participants were instructed to face the loudspeaker at 0° azimuth in front of them and to not move their heads during the test. Depending on the test, they were instructed either to repeat the word they heard or to name the loudspeaker from which they thought the sound signal was emanating. The participants’ responses were collected via a microphone in the test room by an audiologist performing the test. Speech-in-noise and localization data for a normally hearing control group were collected in connection with the earlier study Härkönen et al. [11].

The data were analysed with SPSS for Windows statistical software, version 19.0. The comparison between the pre- and postoperative data was performed using a nonparametric test (Wilcoxon Signed Rank Test). Bonferroni corrections were used in the SSQ analysis. The differences were considered statistically significant at a value of \( p < 0.05 \).

Results

The GBI scores showed a statistically significant positive effect of CI on QoL. The mean total GBI score was +23 (\( p = 0.028 \)) six months after CI activation. The mean subscore was +35 (\( p = 0.018 \)) for general health, +2 (not significant; ns) for social support, and −5 (ns) for...
physical health. After the one-year follow-up, the mean score for total GBI was +28 (p = 0.018). The mean subscore was +42 (p = 0.018) for general health, +7 (ns) for social support and -5 (ns) for physical health (table 1).

The mean VAS scores of the SSQ categories (spatial perception and speech intelligibility) improved statistically significantly after the cochlear implantation. In the spatial perception category, the mean VAS score was 3.4 before the CI surgery; this improved to 5.1 (p = 0.018) six months after CI activation, and the score was maintained twelve months (VAS 5.1; p = 0.043) after CI activation. In the speech intelligibility category, the corresponding VAS score was 4.0 preoperatively and 5.9 (p = 0.018) at the six-month follow-up and 5.7 (p = 0.034) at the 12-month follow-up. In the category of sound quality, the mean VAS score was 6.2 with unilateral hearing. After the CI, the score improved to 6.7 (ns) at the six-month follow-up and then to 7.0 (ns) at the 12-month follow-up (table 2). The mean pre- and postoperative VAS scores for tinnitus perception in the affected ear were obtained 28 months after CI activation. Before the surgery the score was 6.1; this decreased to 1.2 during the follow-up (p = 0.027).

Sound localization with the CI improved statistically significantly during the follow-up. The EI score was 0.94 without the CI. Six months after CI activation, the score had decreased to 0.41 (p = 0.017), and after one year to 0.31 (p = 0.018). In the control group, the EI was 0.

During the follow-up, speech perception in noise was statistically significantly better with the CI, at ~5 SNR. Compared to measurements before the CI, the percentage of correct words increased from 70 to 85 (p = 0.027). At 0 SNR, the percentage increased from 90 to 98 (ns). In the control group, the speech perception in noise was 98% at 0 SNR and 98% at ~5 SNR (fig. 1).

The mean preoperative PTA in the affected ear was 96 dB HL (range 78–118 dB HL). One year after CI surgery, the sound field PTA was, on average, 22 dB HL (range 18–25 dB HL). The preoperative SD was 0% in six patients and 44% in one patient. After one year of CI use, the mean sound field SD was 82% (range 68–92%) and the speech reception threshold was 28 dB HL (range 20–32 dB HL).

The most prominent work-related hearing difficulty with SSD was communication with co-workers and customers, especially in noisy conditions when the speech came from the patient's deaf side. Cochlear implantation clearly improved working performance. Communication with co-workers was easier and the patients were more active in their working environment. Fatigue after the working day decreased and the CI had a positive influence on the patients’ career development or planning (table 3). The mean work-related stress score did not change statistically significantly after the CI.

**Discussion**

This study demonstrated that cochlear implantation raises QoL and QoH in patients with SSD, and it improves their working performance. The GBI results show the statistically significantly positive benefits of CI on QoL. It is probable that better QoH (spatial hearing and hearing in noise) leads to better working performance and explains the improvement in QoL. This is in line with our study in sequentially bilaterally implanted adult patients, where the benefit of a second CI was almost as eminent as the first [11]. Binaural hearing diminished environmental difficulties in speech perception and sound localization at work.

Cochlear implantation enhanced SSD patients' working performance. With CI it was easier to cope with one's work and there was less fatigue after the working day. Furthermore,
the ease of communication with co-workers or clients made the patients more active in their working environment. These factors definitely reduce the risk for burn out or sick leave in professions dependent on hearing.

Patients with SSD become aware of the importance of binaural hearing in their daily life in terms of social interaction and communication [13]. In our study, the patients’ spatial hearing was statistically significantly better after cochlear implantation. The EI score increased by an average of 67% compared to the situation before the CI surgery. The patients’ speech perception in noise also improved, on average by 21%, after the CI. Our finding is in line with the study by Arndt et al. [6], who found that localization error reduced significantly after cochlear implantation compared to the pre-implant condition with either a CROS device, an implantable BCD or an unaided condition.

Tinnitus is often related to sensorineural hearing loss, and CI has been successfully utilized to treat incapacitating tinnitus in SSD patients. Arndt et al., Van de Heyning and Tavora-Vieira et al. [6, 7, 14] have reported significant reductions of tinnitus distress and loudness after cochlear implantation. In our study, six out of seven patients suffered from tinnitus before the cochlear implantation, and they all reported relief in their tinnitus perception after the CI surgery.

Despite modest results, the current practice to rehabilitate SSD is to use an implantable BCD or a CROS device. Niparko et al. [1] demonstrated that sound localization was poor with both devices, and speech perception in noise was better only in selected tasks. Peters et al. [15] showed that neither a CROS nor an implantable BCD device provided a benefit regarding speech perception in noise, sound localization or QoL. Subjective speech communication improved moderately, however.

Even though cochlear implantation offers more benefits than conventional devices in SSD, it is difficult to predict its place as a routine rehabilitation mode in the near future. The high-level-of-evidence studies concerning CI in patients with SSD are sparse, although the current literature suggests important benefits regarding sound localization, QoL, and tinnitus [16]. Furthermore, its cost-effectiveness may be questionable, since most SSD patients manage well without any rehabilitation. In our institution, cochlear implantation is provided to the SSD patient if his/her hearing is unexpectedly lost due to ear surgery or the patient has incapacitating tinnitus or working ability is threatened.

**Conclusion**

This prospective study showed that working performance, quality of life (QoL), and quality of hearing (QoH) improved and tinnitus perception decreased after cochlear implantation in patients with SSD.

**Acknowledgements**

We wish to express our gratitude to Professor Mark E. Lutman and Filip Asp, M.Sc. for access to and guidance in utilizing their localization and speech-in-noise test software. We would also like to thank Anne Mustaparta and Marja-Leena Oksanen for their assistance in testing the patients.
Conflicts of Interest and Source of Funding

The authors have no financial relationships or conflicts of interest to disclose. Dr Kati Härkönen was supported by grants from the Finnish Cultural Foundation, the Ear Research Foundation, the Finnish Medical Foundation, and the Finnish Audiological Society.

References

Fig. 1. Speech perception in noise. Individual and mean results before and 12 months after the cochlear implantation.

Table 1. The mean scores for the Glasgow Benefit Inventory test Gabi

<table>
<thead>
<tr>
<th></th>
<th>6 months after CI activation</th>
<th>12 months after CI activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total (SD)</td>
<td>+23 (15)*</td>
<td>+28 (10)*</td>
</tr>
<tr>
<td>General</td>
<td>+35 (22)*</td>
<td>+42 (18)*</td>
</tr>
<tr>
<td>Social support</td>
<td>+2 (12)</td>
<td>+7 (9)</td>
</tr>
<tr>
<td>Physical health</td>
<td>−5 (21)</td>
<td>−5 (13)</td>
</tr>
</tbody>
</table>

* p < 0.05; SD = standard deviation.