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Multifactorial Positive Influence of Cochlear Implantation on Patients With Single-Sided Deafness

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Objectives: Single-sided deafness (SSD) is an extreme case with profound unilateral hearing loss in the poorer ear and regular hearing in the other ear. The aim of this study is to investigate the impairment in the daily life of SSD patients and the influence of cochlear implants (CI) on their health-related quality of life (HRQoL), the impact on existing tinnitus distress and psychological comorbidities, and audiometric parameters.

Methods: In total, 21 patients (8 male and 13 female) were included, and the Charité Test Battery was applied for all patients. Data on HRQoL were collected with the Nijmegen Cochlear Implant Questionnaire and the Medical Outcome Study Short Form 36 (SF-36) Survey. Tinnitus distress was assessed with the Tinnitus Questionnaire (TQ). Data with regard to psychological comorbidities were collected using four validated questionnaires. Speech perception was assessed with the Freiburg Monosyllable Test (FMS), the Oldenburg Sentence Test (OLSA), and the Oldenburg Inventory (OI).

Results: HRQoL improved in the subdomain social interactions. Tinnitus distress dropped significantly 6 months postoperatively. SSD patients preoperatively showed elevated levels of stress, depressive symptoms, and anxiety. Postoperatively, these psychological symptoms improved with regard to stress, tension, and demands.
The audiometry tools revealed a significant improvement in directional hearing (OI), speech perception in silence, and in the speech intelligibility threshold (OLSA).

Conclusion: There was an improvement in HRQoL and a reduction of tinnitus and cognitive distress. The preoperatively elevated stress level decreased significantly, and psychological comorbidities such as depressive symptoms and anxiety all improved postimplantation.

Key Words: Cochlear implantation, single-sided deafness, quality of life, stress, tinnitus.

Level of Evidence: II-2

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INTRODUCTION

For many years, cochlear implantation (CI) has been a common treatment modality for patients with bilateral deafness as well as patients with severe to profound hearing loss. During the last few years, the indication criteria for CI has expanded to patients with unilateral severe-to-profound hearing loss as studies have validated the positive audiometry results and a tinnitus reduction in patients with additional tinnitus distress.[1–7]

Single-sided deafness (SSD), or unilateral hearing loss, is defined as deafness in the poorer ear and normal hearing in the other ear.[8,9] The better ear does not exceed the hearing loss threshold of 30 dB in the four-frequency pure tone average. SSD is an extreme case, which only occurs in 12 to 20 cases per 100 thousand individuals.[9,10] SSD in adults can be caused by sudden and idiopathic sensorineural hearing loss, vestibular schwannoma or other cerebellopontine angle tumors, meningitis, temporal bone fracture, Ménière's disease, and acoustic trauma as well as bacterial and viral infections. In children, SSD may also result from cochlear nerve deficit, mumps, or other viral infections and anomalies of the inner ear.[9–11] Other causes of SSD are very rare.

Although SSD patients have one well-functioning ear, their ability to understand speech in background noise is impaired, as is their directional hearing.[1,2,12] These limitations lead to increased listening effort and fatigue.[3] Furthermore, many individuals with profound hearing loss or deafness suffer from tinnitus.[4–7,10,13,14] Some theories state that subjective tinnitus occurs by lower auditory input and that there may be spontaneous neuronal activity in the auditory cortex in patients with hearing loss.[15,16] The parameters speech perception in background noise and directional hearing, listening effort, and fatigue as well as tinnitus lead to a handicap in daily life and in human relationships and may lead to isolation and thus to a reduced quality of life (QoL).[6,17,18]

Previous studies, including our own, have evaluated the positive influence of CI on health-related quality of life (HRQoL) and also on psychological comorbidities after CI in bilaterally deaf patients.[19–22] During the last few years, CI has increasingly been used in SSD patients with tinnitus

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and impairment of HRQoL.[18] There are some studies that have investigated audiometric outcome,[1,2,4,24,25] tinnitus distress,[26–29] or HRQoL[30–33] in CI patients with SSD, but these studies concentrated on audiometric outcomes in SSD. Because there is a relationship between hearing impairment, tinnitus distress, HRQoL, and psychological comorbidities in bilaterally deaf patients, we aimed to evaluate these parameters in SSD patients. The current study evaluated the preoperative impairment of SSD patients and the rapid impact of CI on their speech perception, HRQoL, psychological comorbidities, and tinnitus distress during a 6-month follow-up period.

MATERIALS AND METHODS

The present prospective study was conducted at the Department of Otolaryngology of the Charité–Universitätsmedizin Berlin, Germany. The local ethics committee approved this study (appl. no.: EA2/030/13). After obtaining written informed consent, 21 patients (8 male: 38.1%, 13 female: 61.9%) patients) who had been evaluated with the Charité Test Battery (Fig. 1) before and 6 months postoperatively were prospectively included in this study. SSD was defined as severe-to-profound hearing loss in the poorer ear (average hearing loss ≥70 dB) and normal hearing in the better ear. The hearing level in the better ear did not exceed the hearing loss threshold of 30 dB in the four-frequency pure tone average (500 Hz, 1000 Hz, 2000 Hz and 4000 Hz). Another inclusion criterium was age >18 years; patient age varied between 25 and 80 years. Furthermore, German had to be the patient's first language. All patients had to test a contralateral routing of signals (CROS) hearing aid before CI to assess if there was a benefit from using a hearing aid.

Cochlear implantation with a multichannel CI supplied by Med-El (Synchrony or Concerto; Med-El, Innsbruck, Austria) or by Cochlear (Nucleus; Cochlear, Sydney, Australia) was conducted between 2011 and 2016 in the Department of Otorhinolaryngology and Head and Neck Surgery of the Charité–Universitätsmedizin Berlin.

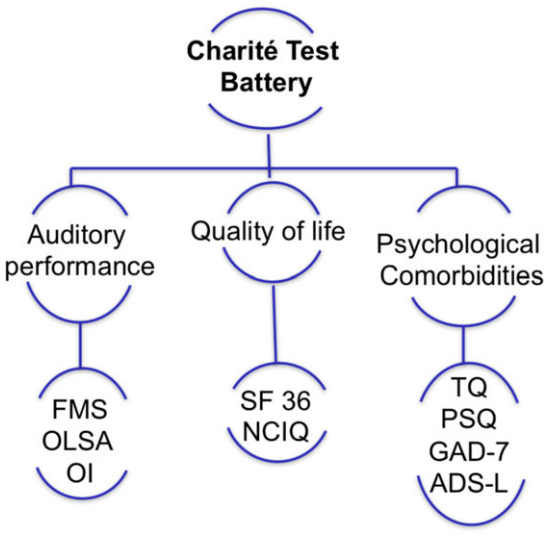

Fig. 1. The Charité Test Battery and its subdomains: auditory performance, quality of life, psychological comorbidities. ADS-L = General Depression Scale; FMS = Freiburg Monosyllable Test; GAD-7 = 7-item Generalized Anxiety Disorder questionnaire; NCIQ = Nijmegen Cochlear Implant Questionnaire; OI = Oldenburg Inventory questionnaire; OLSA = Oldenburg Sentence Test; PSQ = Perceived Stress Questionnaire; SF-36 = 36-Item Short Form Survey; TQ = Tinnitus Questionnaire by Göbel and Hiller.[33] [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

HRQoL was measured using the Nijmegen Cochlear Implant Questionnaire (NCIQ)[19] and the 36-Item Short Form Survey (SF-36). The NCIQ is a disease-specific questionnaire for CI users that was first developed and published in 2000 by Hinderink et al.[19] This questionnaire comprises three general domains: physical, psychological, and social. These are divided into six subdomains. The physical subdomains are basic sound perception (NCIQ 1), advanced sound perception (NCIQ 2), and speech production (NCIQ 3). The psychological subdomain is self-esteem (NCIQ 4); and the social subdomains are activity limitations (NCIQ 5) and social interactions (NCIQ 6). The six subdomains can be summarized in a total score. The total scale ranges from 0 (very poor HRQoL) to 100 (optimal HRQoL).

Tinnitus distress was measured by using the Tinnitus Questionnaire (TQ) published by Goebel and Hiller,[34] a well-validated questionnaire. In Germany, it is the most popular questionnaire used to evaluate and monitor tinnitus distress. There are six subcategories: emotional and cognitive distress, intrusiveness, auditory perceptual difficulties, sleeping disturbances, somatic complaints, and total score. There are four tinnitus severity levels: low (score 1–30), moderate (31–46), severe (47–59), and very severe (60–84).

The Perceived Stress Questionnaire (PSQ)[35] is a questionnaire to measure the stress level of patients. The questionnaire has four subscales: worries, tension, joy, and demands, and it comprises 36 items. The four subscales are summarized in a total score. Fliege et al.[36] reported a PSQ score of 0.33 in healthy adults and of 0.48 in patients with tinnitus.

The Brief-COPE questionnaire (COPE)[37,38] evaluates coping strategies and comprises 28 questions with 14 subcategories, which are summarized in four domains: evasive coping, seeking support, focus on positive, and active coping.

The Generalized Anxiety Disorder Questionnaire (GAD-7)[39] is a screening instrument for anxiety disorders and their severity. It is a 7-item scale, and the total score ranges from 0 to 21 (mild to severe anxiety).

The General Depression Scale was developed and published in 1993 by Hautzinger and Bailer[40] and assesses depressive symptoms. We applied the full version of the General Depression Scale (ADS-L), which includes 20 items. The cutoff score for a depressive disorder is 23.

For evaluation of subjective hearing ability after surgery, we used the Oldenburg Inventory Questionnaire (OI). This consists of 12 questions about different hearing situations that are grouped in three different categories: hearing in a quiet environment, hearing in a noisy environment, and directional hearing. These categories are summed in a total score. Questions can be answered with always, often, rare, sometimes, or never. The total score ranges from 1 (worst subjective hearing) to 5 (best subjective hearing).

The Freiburg Monosyllable Test (FMS) was used to measure auditory performance in a quiet environment at 65 dB SPL (sound pressure level) with a hearing aid before surgery or the speech processor after CI.

The Oldenburg Sentence Test (OLSA) measures the speech intelligibility threshold in a noisy environment (65 dB background noise) and was conducted in three different configurations without and with CI: $S_{CI/-45}N_{NH/45}$ with speech in the CI ear (at 45° from the front) and noise in the normal hearing ear (at 45° from the front), S_0N_0 with speech and noise from the front, and $S_{NH/45}N_{CI/-45}$ with speech in the normal hearing ear (at 45° from the front) and noise in the CI ear (at 45° from the front).

The results were calculated using the nonparametric Wilcoxon-signed-rank test and the nonparametric Spearman's rank correlation

coefficient. Statistical analysis was performed, and graphs were constructed using SPSS software (SPSS Statistics for Windows version 24.0; IBM Corp., Armonk, NY) and Statistica (StatSoft, Hamburg, Germany). Statistical significance was set at a level of $P < 0.05$.

RESULTS

We included 21 patients (8 male (38.1%), 13 female (61.9%) patients) with a mean age of 52.6 ± 14.1 years in this prospective study. The causes of SSD were sudden hearing loss (38.1%), meningitis (9.5%), Ménière's disease (9.5%), varicella zoster virus (4.8%), trauma (4.8%), and unknown causes (28.6%) (Fig. 2).

The NCIQ and the SF-36 measure HRQoL. The NCIQ was developed especially for CI patients, whereas the SF-36 is nondisease-specific. Already 6 months postoperatively, there was a statistically significant improvement in the NCIQ subcategory social interactions (NCIQ 6) from 55.3 ± 17.9 preoperatively to 61.7 ± 19.0 ($P < 0.05$) (Fig. 3). The NCIQ total score improved from 65.7 ± 12.8 preoperatively to 68.9 ± 13.7 at 6 months postoperatively; however, the difference was not statistically significant ($P > 0.05$). The subcategories basic sound perception (NCIQ 1), advanced sound perception (NCIQ 2), speech production (NCIQ 3), self-esteem (NCIQ 4), and activity limitations (NCIQ 5) did not change significantly.

There was no statistically significant change in the physical sum score or the mental sum score of the SF-36 ($P > 0.05$).

For the evaluation of tinnitus distress, we included 18 of the patients who suffered from tinnitus. Three patients did not report having tinnitus; thus, the tinnitus prevalence was 85.7%. The total score measured with the TQ improved significantly from 32.4 ± 25.2 preoperatively to 28.5 ± 24.8 at 6 months postoperatively ($P < 0.01$). Already 6 months postoperatively, four of six TQ subcategories also improved after CI: emotional distress (9.2 ± 7.3 → 8.1 ± 7.2; $P < 0.05$), cognitive distress (6.5 ± 5.2 → 5.6 ± 5.0; $P < 0.05$), intrusiveness (8.0 ± 5.3 → 6.8 ± 5.3; $P < 0.05$), and auditory perceptual difficulties (5.3 ± 4.7 → 4.6 ± 4.4).

Six patients (33%) reported aggravation of tinnitus distress. The total scores and subcategories are illustrated in Figure 4.

The PSQ revealed an elevated preoperative total stress level of 0.45 ± 0.24 (Fig. 5) compared to the score in the general population (0.33) reported in the study by Fliege et al.[36] At 6 months postoperatively, the score of the subdomain tension already improved significantly ($P < 0.05$) from 0.54 ± 0.30 to 0.30 ± 0.25, and the results for the subdomain demands also improved significantly (0.38 ± 0.23 → 0.20 ± 0.2; $P < 0.05$). There was a tendency for an improvement in the total score postoperatively, but the difference was not

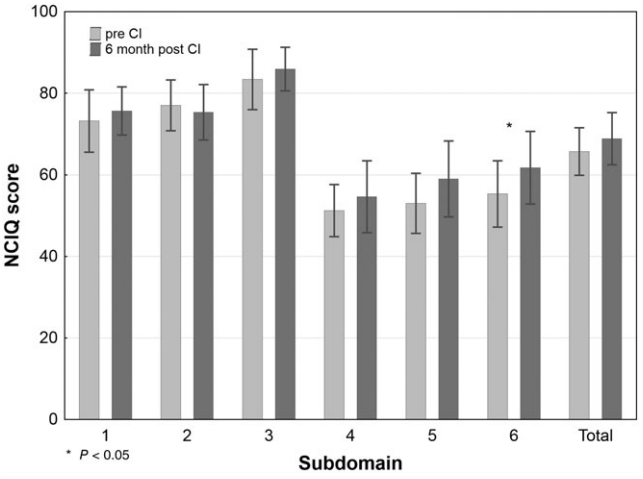

Fig. 3. Results of the Nijmegen Cochlear Implant Questionnaire. The lighter bars show the preoperative results; the darker bars show the postoperative results. 1 = basic sound perception; 2 = advanced sound perception; 3 = speech production; 4 = self-esteem; 5 = activity limitations; 6 = social interactions; CI = cochlear implant; NCIQ = Nijmegen Cochlear Implant Questionnaire.

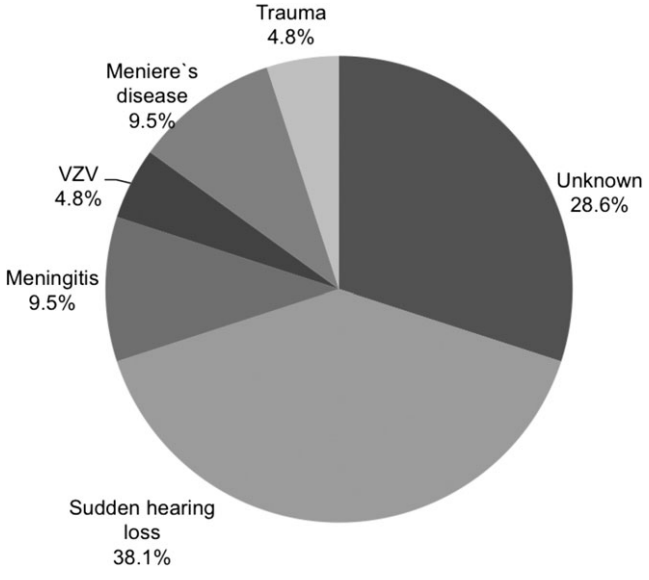

Fig. 2. Causes of single-sided deafness. VZV = varicella zoster virus.

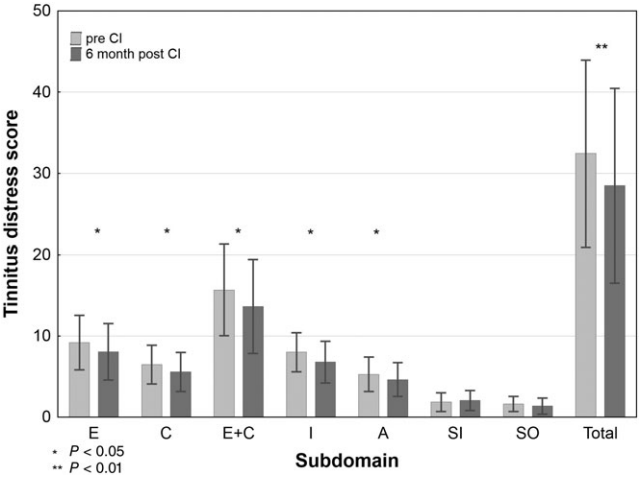

Fig. 4. Results of the Tinnitus Questionnaire. The lighter bars show the preoperative results; the darker bars show the postoperative results. A = auditory perceptual difficulties; C = cognitive distress; CI = cochlear implant; E = emotional distress; I = intrusiveness; SI = sleeping disturbances; SO = somatic complaints.

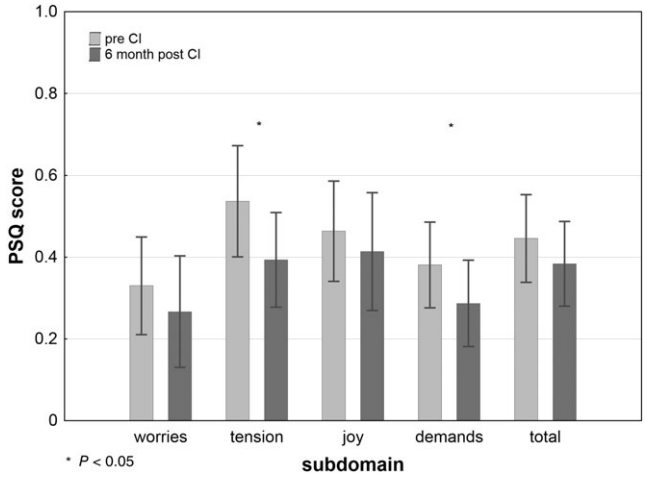

Fig. 5. Results of the Perceived Stress Questionnaire. The lighter bars show the preoperative results; the darker bars show the postoperative results. CI = cochlear implant; PSQ = Perceived Stress Questionnaire.

statistically significant (0.38 ± 0.22 at 6 months postoperatively; $P < 0.05$). For the COPE, which measures coping strategies, there was a statistically significant improvement in the subcategories evasive behavior and looking for support ($P < 0.05$). There was no significant change in the score of the GAD-7, which measures anxiety, and the ADS-L, which measures depressive symptoms.

The OI (Fig. 6) evaluates subjective hearing ability. There was no significant improvement in the subdomain hearing in quiet 6 months after CI, but there was a statistically significant improvement in the subdomain hearing in noise (preoperatively: 2.7 ± 0.7; 6 months postoperatively: 3.1 ± 0.8 [$P < 0.05$]) as well as localization hearing (preoperatively: 1.9 ± 1.0; 6 months postoperatively: 3.0 ± 1.2 [$P < 0.05$]).

The total score had also improved significantly from 3.1 ± 0.5 preoperatively to 3.5 ± 0.7 postoperatively ($P < 0.05$).

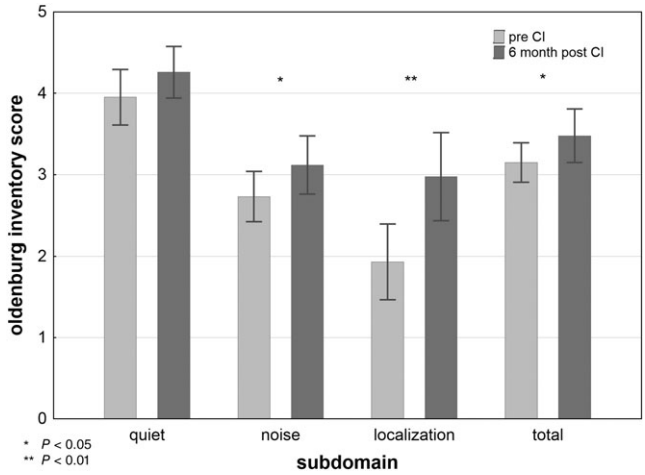

Fig. 6. Results of the Oldenburg Inventory questionnaire for hearing in quiet, hearing in noise, localization hearing, and the total score. The lighter bars show the preoperative results; the darker bars show the postoperative results. CI = cochlear implant.

The FMS was measured preoperatively at 65 dB in free-field conditions with a hearing aid, and the mean score for the deaf ear was 3.6% ± 11.3%. Six months after CI surgery, the mean score was 44.6% ± 27.6% and thus had improved significantly.

The speech intelligibility threshold in the configuration $S_{CI/-45}N_{NH/45}$ assessed by the OLSA was −0.92 ± 2.37 dB when unaided by the CI. The CI aided result was −3.46 ± 3.03 dB, giving a gain of 2.54 dB. This result illustrates the impairment by the head shadow effect.

The SSD patients in this study used their CI s for 12.5 ± 2.1 (mean ± standard deviation) hours per day at 6 months postoperatively.

DISCUSSION

In this study, there was an improvement in HRQoL and a reduction of tinnitus and cognitive distress by CI in SSD patients. The preoperatively elevated stress level decreased significantly, and psychological comorbidities such as depressive symptoms and anxiety all improved postimplantation. The audiometry parameters that were collected indicated a successful rehabilitation of SSD with a CI; hearing ability recovered, especially with regard to directional hearing.

Health-Related Quality of Life

The NCIQ is a QoL questionnaire especially designed to meet the needs of CI users and has been used in earlier bilateral deafness and SSD studies. In this patient cohort, we already detected a significant improvement in the subdomain social interaction 6 months after CI. Louza et al.[33] reported an improved score of the subcategory basic sound perception 1 year after CI. Rösli et al.[31] reported an improvement in all subdomains apart from speech production 7 months after surgery.

This is the first study to use the SF-36 Questionnaire for the QoL evaluation of CI patients with SSD. However, we must keep in mind that it is a generic questionnaire. In this study, there was no statistically significant improvement in the subdomains physical and mental sum score, although there was a tendency for an improvement in the mental sum score. Arndt et al.,[6] Vermeire and Van de Heyning,[4] and Távora-Vieira et al.[27] used the Speech, Spatial and Quality of Hearing Scale (SSQ) for the evaluation of hearing-specific HRQoL; in all studies, there was a significant improvement in the subcategories speech and spatial.

Tinnitus Distress

In this study, the prevalence of tinnitus in patients with SSD was 85.7% (18 of 21 patients), and the total score of the TQ, which measures tinnitus distress, improved statistically significantly from 32.4 preoperatively to 28.4 already at 6 months postoperatively. Interestingly the cognitive subscale cognitive distress also improved significantly during the 6-month follow-up. The tinnitus prevalence in previous SSD studies was in the range 46.4% to 90.9%.[2,13,28] There are several studies that reported a positive influence

of CI on tinnitus distress in SSD patients[4,5,26–29,41,42]; however, in some studies there are heterogeneous groups with patients with SSD and asymmetric hearing loss, and there is no standardized test used for the evaluation of tinnitus distress.

Van de Heyning et al.[26] reported about SSD patients with decompensated tinnitus who were not responsive to drug therapy or psychotherapy and who were treated with CI. There was an improvement in 82% of cases and a total tinnitus reduction in 14% of cases. The mean total score dropped significantly from 58.4 before implantation to 33.3 1 month after first fitting of the CI. Távora-Vieira et al.[27] demonstrated that there was a decrease in tinnitus distress up to 24 months after CI. Therefore, it would be worthwhile to conduct a long-term follow-up study of this effect because we also report a decrease in tinnitus distress postoperatively. In addition to the mentioned positive results on tinnitus distress, we have to keep in mind that there are also patients who experience an aggravation of symptoms. It is important to clarify this fact ahead of CI.

Psychological Comorbidities

It is a well-known fact that there is an association between hearing impairment and psychological comorbidities and that there is a higher rate of psychological comorbidities in hearing-impaired patients than in the general population.[43,44] Olze et al.[21] reported a significant reduction in stress, depressive symptoms, and anxiety after CI in bilaterally deaf patients. As far as we know, there has been no previous study about psychological comorbidities in SSD CI patients. Therefore, one of the aims of this study was the evaluation of perceived stress, coping strategies, anxiety, and depressive symptoms in tinnitus- and hearing-impaired patients.

The total PSQ score of this SSD patient cohort was elevated preoperatively (0.45 ± 0.24) compared to the score in the general population (0.33) reported in the study by Fliege et al.[36] In that study, tinnitus inpatients with a high level of impairment in daily life had a score of 0.48; therefore, we have to keep in mind that the elevated stress level may not only be due to the hearing impairment but also to the high tinnitus prevalence of 85.7%. Postoperatively, the scores of the subdomains tension and demands improved significantly compared to the preoperative score.

Coping strategies are the patients' cognitive and behavioral efforts to deal with stress as defined by Lazarus.[45] In our study, two of the four subcategories of the Brief-COPE Questionnaire, which measures coping strategies, improved statistically significantly: evasive behavior and looking for support. This means that the patients in this study did not evade stressful situations and did not have to look for support as much as before the CI. Olze et al.[46] found a significant change in the subdomains evasive behavior and positive thinking in bilaterally deaf CI patients.

Anxiety symptoms were measured with the GAD-7 questionnaire. Preoperatively, the SSD patients in this study reported an elevated anxiety level with a mean score of 7.05 ± 5.38, which is defined as mild generalized anxiety. Compared to that, Löwe et al.[47] detected a mean score of 2.95 in the general population. Six months postoperatively, there was an improvement in the score, but it did not reach statistical significance.

There was no elevated score with regard to depressive symptoms measured with the ADS-L questionnaire preoperatively (18.5 ± 12.8; mean score for the general population: 23[37]), and the score did not change significantly 6 months after CI.

SSD patients are usually not noted as handicapped or impaired in daily life; to date, psychological comorbidities are not usually considered in SSD patients. In this study, we observed significant results with regard to lowering elevated stress levels in SSD patients and improvements in tension, demands, and social interactions as well as coping strategies. Consequently, further studies are needed to confirm our results and to show that there is also a socioeconomic benefit when we help our SSD patients improve their mindset with CI.

A negative aspect of this study is the short-term follow-up of 6 months and the assumption that there will be further improvement with time, especially with regard to tinnitus distress, psychological comorbidities, and QoL. A further investigation with a long-term follow-up is in progress. In addition, we are planning to include more patients in future studies.

Positive aspects of this study are the prospective study design and consequently no recall bias, the homogenous patient cohort with straightforward inclusion criteria, a representative number of patients, and reliable and well-evaluated questionnaires and audiometry.

The multifactorial positive outcome for these SSD patients is also confirmed by their daily usage of the CI with a mean time of 12.5 ± 2.1 hours per day.

Speech Perception

As far as we know from our literature research, we are the first to use the OI for the evaluation of subjective hearing ability in silence, in noise, and for directional hearing. In earlier studies and especially in the English literature, the SSQ was used. In our study, the score of the OI for directional hearing was low preoperatively, and the score improved statistically significantly 6 months postoperatively. There was also an improvement in the score for hearing in noise but no statistically significant improvement of the score for hearing in quiet. The results of the OI demonstrate the everyday problems of patients with SSD: they experience directional hearing as the biggest problem and are also impaired in listening situations with background noise. In previous studies, which used the SSQ for measurement of subjective hearing ability, the results were very similar with regard to speech perception and directional hearing.[12,26,32]

In this prospective study, speech perception by the deaf ear in a quiet environment was measured with the FMS at 65 dB SPL, and the mean score improved statistically significantly from 3.6% preoperatively to 44.6% postoperatively. This result is comparable with the results of the studies by Jacob et al.[28] and Louza et al.[33] with a postoperative speech perception at 12 months of 71% at 60 dB SPL and 46.1% at 65 dB SPL. In Germany, the FMS is a commonly used tool for evaluating speech perception by testing number and

noun test series in hearing impaired patients. Although it has been criticized by some authors for the different degrees of difficulty of the test series, at present there is no comparable test available in German; thus, it remains the most popular audiometric test for speech perception in Germany. In the English literature, mostly the Consonant-Nucleus-Consonant monosyllabic words test has been used.[48,49]

For the evaluation of speech perception in a noisy environment, which is a significant issue especially for patients with SSD, we applied the OLSA. This is a reliable test with a noise level of 65 dB. In the configuration $S_{CI/-45}N_{NH/45}$, the SSD patients in this study had a mean speech intelligibility threshold of −0.92 dB (unaided) and −3.46 dB (CI aided), giving a gain of 2.54 dB when using CI. This gain demonstrates the head-shadow effect in patients with SSD. Arndt et al.[13] reported an improvement from 0 dB to −7 dB 12 months postoperatively. In the study by Rahne and Plontke,[50] the mean speech intelligibility threshold improved from 4.7 dB to −2.8 dB 3 months postoperatively. The OLSA was mainly conducted in the $S_{CI/-45}N_{NH/45}$ configuration in earlier studies because this is the most demanding configuration for these patients and shows the head-shadow effect. It would be interesting to compare the results for the configuration $S_{NH/45}N_{CI/-45}$ with speech on the normal hearing ear (45°) and noise on the CI ear (45°) because patients with SSD mostly turn their normal hearing ear to the sound source of speech. The configuration $S_{NH/45}N_{CI/-45}$ measures the squelch effect for binaural fusion. Arndt et al.[13] did not find a statistically significant change in this configuration when comparing the CI-unaided and CI-aided scores. Seebacher et al.[51] found an influence of the signal delay of the CI processor on the patient's binaural hearing abilities and used the OLSA in the configuration $S_{CI/0}N_{NH/0}$ to measure the speech intelligibility threshold. In the CI-aided situation, the threshold was −4 to −5 dB, which is close to a normal hearing threshold of −7 to −8 dB. Galvin et al.[44] reported about a postoperative threshold of −4.2 dB ($S_{CI/0}N_{NH/0}$).

SSD patients are usually not noted as handicapped or as bilateral deaf patients impaired in daily life, and to date psychological comorbidities are not usually considered in SSD patients. In this study, we observed significant results with regard to lower elevated stress levels in SSD patients and improvements in tension, demands, and social interactions as well as coping strategies. Consequently, further studies are needed to confirm our results and to show that there is also a socioeconomic benefit when we help our SSD patients improve their mindset with CI.

A negative aspect of this study is the short-term follow-up of 6 months and assumption that there will be further improvement with time, especially with regard to tinnitus distress, psychological comorbidities, and QoL. A further investigation with a long-term follow-up is in progress. In addition, we are planning to include more patients in future studies. Another limitation of the study is that results are applicable only to patients who choose CI as therapy for SSD.

Positive aspects of this study are the prospective study design and, consequently, no recall bias; the homogenous patient cohort with straightforward inclusion criteria; a representative number of patients; and reliable and well-evaluated questionnaires and audiometry.

The multifactorial positive outcome for these SSD patients is also confirmed by their daily usage of the CI with a mean time of 12.5 ± 2.1 hours per day.

CONCLUSION

This is the first study to show prospective results of the complex evaluation of QoL, tinnitus distress, and changes in psychological comorbidities and speech perception in SSD patients after CI. Before CI, the SSD patients suffered from poor speech perception in noisy environments, poor directional hearing, and elevated perceived stress levels. The prevalence of tinnitus was 85.7% in our study. After CI, the tinnitus total score, intrusiveness, and cognitive distress were significantly reduced; social interactions improved; and psychological symptoms with regard to stress, tension and demands also improved. Additionally, we measured an improvement in speech perception, especially with regard to noise, and an improvement in directional hearing and the speech intelligibility threshold.

Acknowledgment

Written informed consent was obtained from the patients who were included in this study.

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