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Vestibular and taste disorders after bilateral cochlear implantation

Jan H. Wagner · Dietmar Basta · Friederike Wagner · Rainer O. Seidl · Arneborg Ernst · Ingo Todt

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Abstract The objective of this study was to investigate the occurrence of vestibular receptor deficiency and taste disorders after bilateral cochlear implantation in postlingually deafened patients and to find out whether the risk for these complications is higher for the second implantation. In a retrospective cohort study, we examined 20 patients (11–58 years, mean age 41.5 years), implanted sequentially between 2000 and 2007 (mean period between cochlear implantation 32.9 ± 25 months). Pre- and postoperative vestibular testing was performed by subjective rating [Dizziness Handicap Inventory (DHI)], caloric irrigation [vestibuloocular reflex (VOR)] and by vestibular-evoked myogenic potential (VEMP) recordings for saccular function. The sense of taste was evaluated pre- and postoperatively by a questionnaire and testing (sour/sweet/bitter/salty bilaterally on the tongue). DHI evaluation showed a moderate not significant mean increase by 2.7 ± 7.7 SD points after the first and a significant increase by 9.4 ± 16.6 SD points after the second implantation. Ipsilateral VEMP responses disappeared in three ears (27.3%) after the first and in two ears (18.2%) after the second operation. VOR disappeared only once (5.9%) after the first implantation. One (5%) patient complained of a persisting disturbance of taste in the questionnaire after unilateral and 3 (15%) after bilateral implantation. Specific testing showed in one case (5%) a unilateral taste disorder after ipsilateral cochlear implantation. Our data show that there is a higher risk for subjective vertigo after the second implantation. The occurrence of unilateral and/or bilateral vestibular dysfunction and the potential risk of taste disorder should be included in the risk counseling before bilateral cochlear implantation to increase patients' and medicolegal safety in the decision-making process.

Keywords Bilateral cochlear implantation · Complications · Gustatory function · Vestibular function

J. H. Wagner (✉) · D. Basta · F. Wagner · R. O. Seidl · A. Ernst · I. Todt
Department of Otolaryngology at UKB, Hospital of the University of Berlin (Charité Medical School), Warener Str. 7, 12683 Berlin, Germany
e-mail: jan.wagner@ukb.de

Introduction

Cochlear implantation has become one method of choice for the rehabilitation of young and adult patients with postlingual deafness. On one hand, different studies from several centers around the world have shown that a bilateral cochlear implantation can improve sound localization and speech perception in noise [1–3]. On the other hand, bilateral cochlear implantation is associated with an increased risk of surgical complications for the implantee. In general, complications in cochlear implantation are rare nowadays because the procedure has been standardized to minimize any patient's risk. Specific surgical complications (apart from inflammation and bleeding) reported in the literature include an electrode dislocation, facial nerve lesion, but also dizziness and taste disorders [4–8]. The latter potential risks of vestibular and/or taste impairment have to be carefully discussed with the patients when a bilateral implantation is considered. These possible risks of an additional sensory impairment have to be outweighed against the known advantage of a bilateral cochlear implantation for hearing-in-noise and spatial orientation.

It was, therefore, the aim of the present study to evaluate whether there is a higher incidence of vestibular and taste disorders after bilateral as compared to unilateral cochlear implantation.

Materials and methods

Patients

In this retrospective, non-randomized study, 20 patients (11–58 years) with a mean age of 41.5 ± 18.5 years were included. The patients (or their parents, respectively) gave their informed, written consent to participate in the study. All patients suffered from postlingual deafness and were implanted with a Nucleus 24M, RCS, RCA (Cochlear Pty., Sydney, Australia), Clarion II or a 90K implant (Advanced Bionics Corporation, Sylmar, CA, USA). With one exception, all surgeries were performed by two surgeons at our center between 1999 and 2007. The time period between first implantation and subsequent second (bilateral) implantation varied between 7 months and 8 years (mean 32.9 months).

CI surgery

The surgical procedure consisted of a regular mastoidectomy with posterior tympanotomy, followed by a modified round window insertion or an anterior approach dependent on the time of implantation (i.e. our surgical approach was modified over time) [9]. The one implantation performed elsewhere could not be specified with respect to the surgical approach.

Neurotological test battery

Vestibular-evoked myogenic potentials (VEMP) were elicited by acoustic stimuli delivered via air conduction (95 dB HL). If air conduction could not successfully elicit an electromyogenic (EMG) response (see below), stimulation was performed by bone conduction (for methodology, see [10]). The stimuli (tone bursts, 500 Hz, 7 ms duration, 5/s) were delivered ipsilaterally by a VIKING IV system (Viasys Healthcare Corp., USA), monaurally via a bone conductor (type B-70B, RadioEar Corp., USA) placed at the mastoid directly behind the auricle. The stimulator was calibrated in accordance with the ISO 389 standard. The EMG of the sternocleidoid muscle (SCM) was recorded ipsilaterally by surface electrodes. The active electrode was placed over the middle of the SCM and the reference electrode over the upper sternum. The ground electrode was placed at the forehead. The subjects had to turn the head to the contralateral shoulder before starting the measurement and hold this position during the whole recording period to achieve a constant tonic activation of the SCM (50–200 μV). The EMG signals were amplified (5,000×), averaged (130×), filtered (bandpass 20–1,500 Hz) and recorded with the Viking IV.

Caloric irrigation (30 and 44°C) of the lateral semicircular canal (SCC) for vestibuloocular reflex (VOR) testing was done and evaluated according to Jongkees et al. [11].

Evaluation of the subjective dizziness was done by means of the validated German version of the Dizziness Handicap Inventory (DHI) questionnaire [12] ranging from 0 to 100 with 100 representing the worst handicap. The implants were asked to fill in the questionnaires before surgery and 6–8 weeks after each cochlear implantation. A change in the total DHI scores by >6 points after implantation was considered as statistically significant [13]. Because the data were not normally distributed, we used a non-parametric test (Wilcoxon) with a level of significance of 0.05 for statistical analyses.

Taste tests were done pre- and postoperatively bilaterally on the tongue by standardized solutions (0.1% with the major qualities bitter, sweet, sour and salty).

In addition, a questionnaire had to be filled in by each patient postoperatively. It consisted of three questions:

- How was your taste before the implantation (normal, changed, null)?
- Did a postoperative change of taste occur (if yes: how did it taste and for how long)?
- Do you have a permanent change of your taste sense?

The patients had to fill in the questionnaire after each implantation.

The study protocol was approved by our Institutional Review Board ("Ethikkommission").

Results

Preoperative evaluation of vertigo and neurootological and taste tests

The mean score of the DHI before cochlear implant surgery was 14.9 ± 24.4 SD (range 0–68) before the first and 13.3 ± 24.3 SD (range 0–68) before the second operation. Before any implantation, 11 (55%) of the patients did not complain about any vertiginous symptoms at all and the DHI score was zero. 3 (15%) of the patients had a score <5 points and 6 of them (30%) had scores between 18 and 68.

Preoperative VEMP testing with stimulation via air or bone conduction on the implant side showed no response in 18 ears (45%), while the remaining 22 ears (55%) had regular VEMP responses. There was no difference in VEMP response between ipsi- and contralateral side.

27 (67.5%) ears had a regular VOR response upon caloric irrigation. In six ears (15.0%), a canal hypofunction

was found preoperatively on the implant side. Seven ears (17.5%) showed no caloric response at all prior to surgery. None of the patients reported ipsilateral taste abnormality or had pathological test results before surgery. All results of questionnaires and testing are summarized in Table 1.

Postoperative evaluation of subjective vertigo (DHI)

After the first cochlear implantation, five of the patients (25%) showed an increase in the DHI score (>6 points). The mean DHI score increased by 2.7 ± 7.7 SD points to a mean of 17.6 ± 22.2 SD which was statistically not significant. 13 of the patients (65%) had no changes in the DHI score, in 1 patient (5%) it was decreased.

The average time span between operations was 32.9 ± 25 SD months with a wide range of 7–96 months (see Table 1). When our patients presented for the second ear to undergo the bilateral implantation procedure, they were asked again by DHI immediately before and 6–8 weeks after the procedure at first fitting. Most patients reported on an improvement of vertigo in the period between the procedures and the DHI scores had decreased by a mean of 4.3 ± 19.8 SD points as compared to 6–8 weeks after the first operation. In two cases, the scores had increased. When comparing pre- and postoperative results of the second surgery, we found a statistically significant increase in the DHI score of 9.4 ± 16.6 SD points. Not all of the patients that complained about vertigo after the first reported the same after the second operation. When data before the first and after the second procedure were compared, a total of six patients (30%) came out with a significant increase in the DHI scores.

Postoperative evaluation of neurootological and taste tests

A loss of ipsilateral VEMPs was found in 5 out of the 22 ears (22.7%) which initially had regular responses. This was 3 out of 11 ears (27.3%) after the first implantation and 2 out of 11 (18.2%) after the second implantation.

In one case (5.9%) out of the 17 ears that had regular VOR or canal hypofunction preoperatively an ipsilateral canal paresis was observed after the first operation. In the same patient and ear, the VEMP responses had also disappeared. For the 16 contralateral ears with regular VOR or canal hypofunction preoperatively no change was detected after the second procedure.

After the first operation, 1 (5%) patient reported a taste disorder while testing did not show a postoperative change. After the second operation, 3 (15%) patients reported the same. However, ipsilateral specific testing of the four major qualities on the affected side of the tongue—sour, sweet, bitter, salty—confirmed the patients' subjective complaints in only one case (5%) after the second implantation. The results of receptor testing are shown in Figs. 1 and 2.

Discussion

Bilateral cochlear implantation can be beneficial for the implants because improved speech recognition in noise and binaural lateralization ability could be demonstrated by different authors [1–3]. Although cochlear implantation can be regarded as a safe surgical procedure in general, some rare complications—i.e. implant failures, infections, hematoma and vestibular disorders [4, 5, 7, 14–17]—have been described for unilateral implantation. In addition, the chorda tympani nerve (CTN) in the tympanic cavity is at a risk during surgery and an injury may cause a postoperative taste disorder [6, 8, 18]. A persistent taste disorder and/or a persistent dizziness should be considered in this respect when a patient is counseled for bilateral implantation.

Vestibular disorders have a greater incidence in hearing impaired patients per se [5, 19, 20].

Our series demonstrated the subjective occurrence of preoperative vertigo in about 30% of the patients (mean DHI score of 14.9). This is compatible with other findings of about 48 and 45% dizziness in CI candidates (DHI scores of 12.5 and 27.0) [9, 19].

There was only a moderate non-significant increase in DHI scores (mean 2.7 ± 7.7 SD) after the first, but a significant increase (mean 9.4 ± 16.6 SD) after the second operation. This could be due to a bilateral impairment of vestibular receptors even when this was not always clearly reflected in the results of our neurootological test battery. This is in line with Melvin [7] and Enticott [5] whose data also show a poor correlation between the postoperative, subjective rating of vertigo and objective neurootological findings. It should be considered that the utricular maculae were not tested and could have been potentially impaired as well [22].

Our data also shows a moderate not significant diminishment of DHI scores by 4.3 ± 9.8 SD in the period of time between 6 and 8 weeks after the first and immediately before the second implantation. A possible explanation for this is the recovery of impaired receptors and the central plasticity that also helps patients with different inner ear pathologies, such as vestibular neuropathies, for example, to recover over a sometimes long period of time. The reason why the scores were lower for many patients before the second operation than the initial preoperative score remains unclear. A possible explanation might be a better spacial orientation with the implant working or a general better feeling due to the enhanced communication abilities.

Table 1 Results of DHI scores, neurootological and taste testing before and after the first (pre 1/post1) and second (pre 2/post 2) operation

ID	Timespan (months)	DHI				VEMP[a]				Caloric[b]				Taste[c]			
		Pre 1	Post 1	Pre 2	Post 2	Pre 1	Post 1	Pre 2	Post 2	Pre 1	Post 1	Pre 2	Post 2	T/Q pre 1	T/Q post 1	T/Q pre 2	T/Q post 2
1	13	0	0	0	32	+	+	+	+	+	+	+	+	+/+	+/+	+/+	+/+
2	29	4	20	2	6	−	−	−	−	−	−	−	−	+/+	+/+	+/+	+/−
3	25	68	68	68	68	−	−	−	−	+	+	+/−	+/−	+/+	+/+	+/+	+/+
4	11	0	12	0	18	+	+	+	+	+	+	+	+	+/+	+/+	+/+	+/+
5	7	0	22	2	0	−	−	−	−	+	+	−	−	+/+	+/+	+/+	+/+
6	46	0	0	0	0	−	−	−	−	+/−	+/−	+/−	+/+	+/+	+/+	+/+	+/+
7	14	38	42	68	68	+	+	+	+	+	+	+	+	+/+	+/+	+/+	+/+
8	23	68	52	0	54	−	−	−	−	+	+	+	+	+/+	+/+	+/+	+/+
9	23	54	54	54	54	+	−	+	−	+	+	+	+	+/+	+/+	+/+	+/−
10	91	4	4	4	4	−	+	−	−	−	−	−	−	+/+	+/−	+/+	+/+
11	28	0	0	0	38	+	+	+	+	+	+	+	+	+/+	+/+	+/+	+/+
12	62	0	0	0	0	+	+	+	+	+	+	+	+	+/+	+/+	+/+	−/−
13	32	0	0	2	2	+	+	+	+	+	+	+/−	+/−	+/+	+/+	+/+	+/+
14	40	0	0	0	0	−	−	−	−	+/−	+/−	+/−	+/−	+/+	+/+	+/+	+/+
15	18	42	42	4	2	−	−	−	−	−	−	−	−	+/+	+/+	+/+	+/+
16	16	18	26	8	16	+	−	+	+	+	+	+	+	+/+	+/+	+/+	+/+
17	96	2	2	2	2	+	+	+	+	+	+	+	+	+/+	+/+	+/+	+/+
18	30	0	0	0	34	−	−	−	−	+	+	+	+	+/+	+/+	+/+	+/+
19	23	0	0	2	0	+	−	+	+	+	−	+	+	+/+	+/+	+/+	+/+
20	31	0	8	50	56	+	+	+	−	+	+	+	+	+/+	+/+	+/+	+/+
Mean	32.9	14.9	17.6	13.3	22.7												
SD	24.3	24.4	22.2	24.3	25.3												

[a] + Regular VEMPs, − no VEMPs

[b] ± Hyporesponsiveness

[c] *T* test, *Q* questionnaire, + regular, − impairment

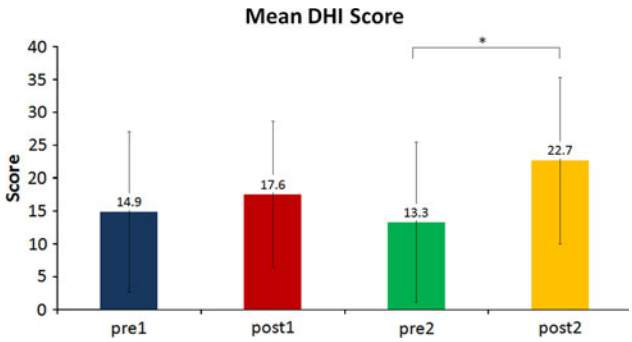

Fig. 1 Mean DHI scores pre- and postoperatively for the first (pre 1 and post 1) and second (pre 2 and post 2) implantation with standard deviation and level of significance 0.05 (Wilcoxon's non-parametric test)

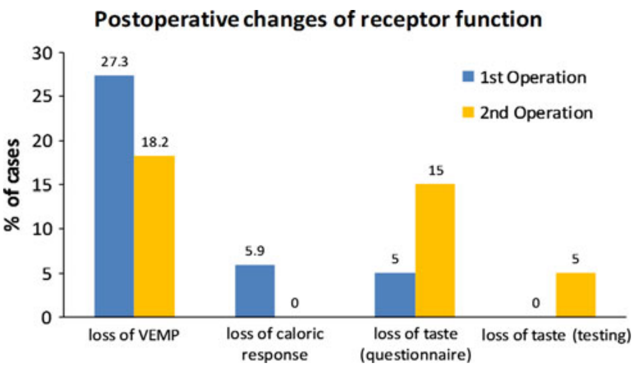

Fig. 2 Sensory disorders (vestibular and taste) after the first and second implantation

Different possible reasons for the occurrence of vertigo have already been addressed in the literature. For example, a co-activation of the inferior vestibular nerve or the saccular macula by electrical stimulation [20] were described and an insertion trauma by the electrode impairing the integrity of the vestibular receptors (saccular macula and/or SCCs) was discussed [4, 21, 22]. A literature overview of the incidence of vertigo after cochlear implantation and the used questionnaires can be seen in Table 2.

In our series, 7 of the ears (17.5%) had a caloric areflexia, 6 ears (15%) had a hyporesponsiveness and 27 of the ears (67.5%) were normal preoperatively. Ito [16] and Jin et al. [20] found a slightly higher rate of canal malfunction (67 and 60%). VEMP testing showed the preoperative absence of responses in 19 of the ears (47.5%) and regular VEMPs in 21 (52.5%) which is in line with the findings of Jin et al. [20]. The same author described a significant increase in negative VEMP responses (6/7) postoperatively. Our lower rate of 5/22 (22.7%) might be due to the modified round window approach with a high rate of atraumatic scala tympani insertions that we had started some years ago [9]. This could also hold true for the fact that only one patient in our series suffered from postoperative canal areflexia after the first operation. Enticott [5] found a total loss of caloric response in 3% of younger subjects and 22% of older subjects which suggests that age also plays a role in postoperative dizziness since age is the major determinant for the vestibular compensation.

Table 2 Incidence of vertigo after cochlear implantation (literature overview)

Study	Percentage of patients with vertigo (n)
Enticott et al. [5]	47 (146)[a]
Filipo et al. [15]	14 (21) Prospective[b]
	25 (72)[b]
Ito et al. [16]	26 (55)[b]
Krause et al. [23]	21 (47)[b]
Melvin et al. [7]	12 (26)[a]
Steenerson et al. [17]	35 (47)[b]
Shoman et al. [19]	23.6 (110)
Todt et al. [9]	17 (62)[a]
Present study	30 (20)[a]

Questionnaires used: [a] DHI, [b] specially developed

Taste disorders can usually be attributed to an injury of the CTN—although Mueller et al. [8] observed transient taste changes in 50% of patients even when the CTN could be preserved. This is supported by the study of Sakagami [18]. Apart from micromechanical injuries during surgery, the electric co-stimulation of the nerve by the implant currents or heat damage, overexpansion or swelling might be causative. Among the four patients complaining about a persisting taste disorder in our series for only one patient this could be confirmed by testing after the second operation. There is no significant difference between the first operation (one patient with subjective taste disorder, but normal test results) and three patients after the second surgery (2 of them normal upon testing). Lloyd et al. [6] observed a long-term change in the sense of taste in 19% of their patients while Mueller et al. [8] only found one patient (4%) with subjective dysgeusia while objective testing of 24 patients did not show pathological results after surgery.

Our data show that bilateral cochlear implantation bears a higher risk of postoperative subjective dizziness than a unilateral implantation.

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Conflict of interest statement There is no conflict of interest of the authors with the Sonnenfeld Foundation that sponsored equipment for measuring systems of our clinic.

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