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CASE REPORT

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Multi-mode grounding and monophasic passive discharge stimulation avoid aberrant facial nerve stimulation following cochlear implantation

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Abstract

We report on a case with severe facial nerve stimulation via a cochlea-facial nerve dehiscence that was most likely the result of prolonged occlusive hydrocephalus. The successful treatment of this adverse effect demonstrates for the first time its complete resolution using a multi-mode grounding and monophasic passive discharge stimulation.

KEYWORDS

cochlea-facial nerve dehiscence, cochlear implantation, device failure, facial nerve stimulation, monophasic passive discharge, multi-mode grounding

1 | INTRODUCTION

Aberrant facial nerve stimulation (AFNS) can be a serious limitation for hearing rehabilitation following routine cochlear implantation. Its prevalence was estimated at 5.6% (range: 0.68–43%) in a recent systematic review assessing over 5000 patients.[1] The underlying pathological correlate for this postoperative complication is cochlea-facial nerve dehiscence (CFD), which was first described in two patients in 2014.[2] In the majority of cases, reimplantation can be avoided and further use of the device safeguarded by appropriate programming of the device; however, hearing benefit is variable and limited. We represent a rare case in which the effect of different electrical stimulation strategies on AFNS could be compared in the same patient.

2 | CASE REPORT

In 2019, a 32-year-old male patient with asymmetrical bilateral sensorineural hearing loss who no longer had benefit from a conventional hearing aid in the left ear was fitted with a cochlear implant (CI) at a tertiary clinic. As a child, he suffered chronic progressive headache, the underlying cause of which was a pineocytoma that was diagnosed once additional visual disturbances occurred. The tumor was first removed via left-sided parietal craniotomy in 1996 and subsequently three years later following recurrence. He suffered repeated bilateral sudden sensorineural hearing loss. The implant used was the *HiRes*^{TM} *Ultra* implant (Advanced Bionics, Valencia, USA) coupled with the *Slim J* electrode array with monopolar biphasic pulse stimulation (Table 1, Figures 1A, 2A).

The operation was performed without complication, and the postoperative computed tomography scan (CT) showed full insertion of the electrode array (EA) in the scala tympani. The subsequent initial activation of the implant resulted in immediate and severe AFNS, which meant that only the six basal electrodes could be activated. Review of the preoperative CT confirmed the suspected CFD between the cochlear basal turn and the labyrinthine segment of the fallopian canal not only on the affected side,

TABLE 1 Characteristics of the two lateral wall electrode arrays

Type	Active length (mm)	Cross section (d = mm)		Contacts (n)	Contacts form
		Proximal	Distal		
SlimJ (Advanced Bionics)	20	0.76 × 0.56	0.55 × 0.26	16	*Planar* on medial surface, platinum
Classic (Oticon)	25	1.07	0.5	20	*Full-band*, titanium–iridium

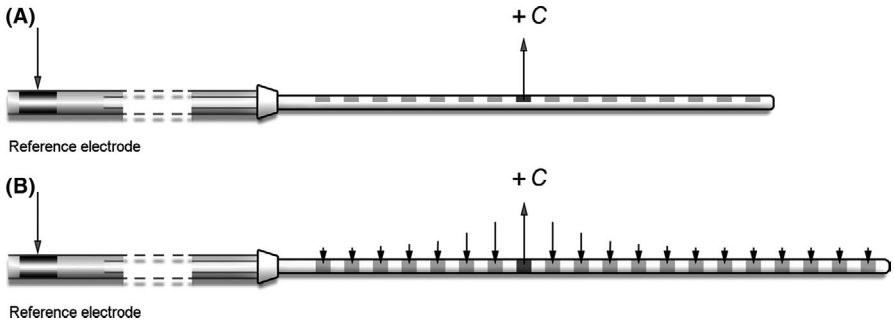

FIGURE 1 Schematic representation of the different grounding methods of the first (A) and the second CI (B). A, In the extracochlear monopolar grounding method, most of the electric charge (+ *C*) returns to the reference EA and the end of the EA. B, In the multi-mode grounding method, during the active phase, every electrode contact is a path for the electric charge to return additional to the reference electrode

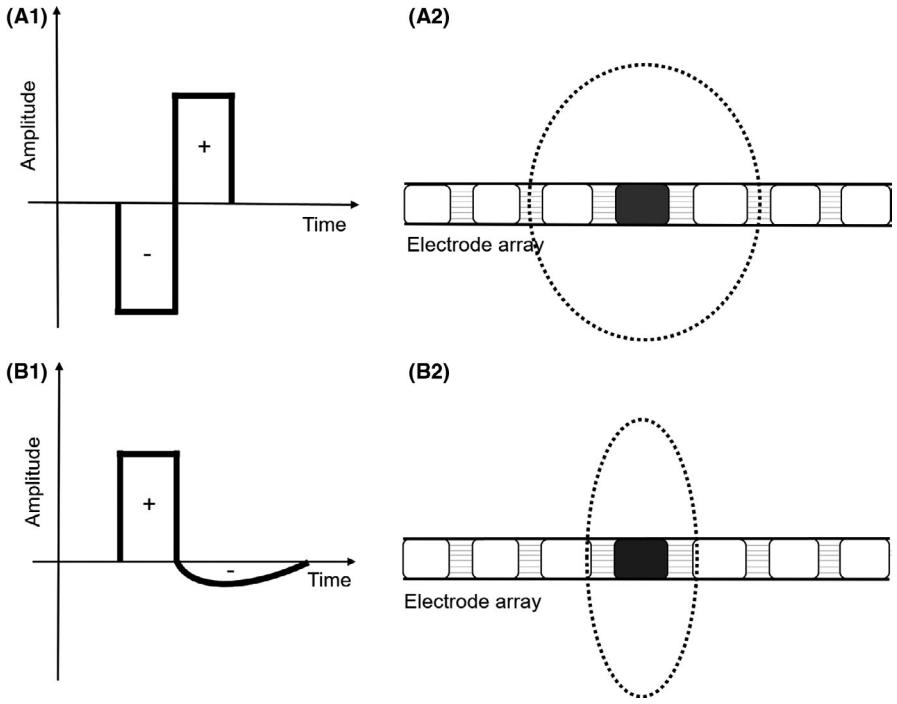

FIGURE 2 Schematic representation of the different electrical stimulation between the first (A) and the second CI (B). Monopolar biphasic pulse (cathodic first, A1) leads to broad spread of excitation in the cochlea (marked with *dotted line*, A2). Monophasic passive discharge stimulation (anodic first, B1) leads to selected stimulation with increase of the pulse duration, which results in focused excitation of the neurons

but also on the contralateral side (Figure 3). Despite the implementation of all management strategies reported in the literature such as reprogramming with lower C-Level and different pulse width, as well as deactivating channels, the AFNS continued to limit hearing performance. Six months after initial fitting, speech intelligibility, as determined by the German Freiburg monosyllabic word test in quiet,[3] was 50% and remained the same after one year. However, this hearing performance was only possible due to weakening of the AFNS by means of botulinum toxin injections.

Subsequently, it rapidly decreased to 12.5%. An implant check showed the typical constellation of electrophysiological measurements including low electrode impedances

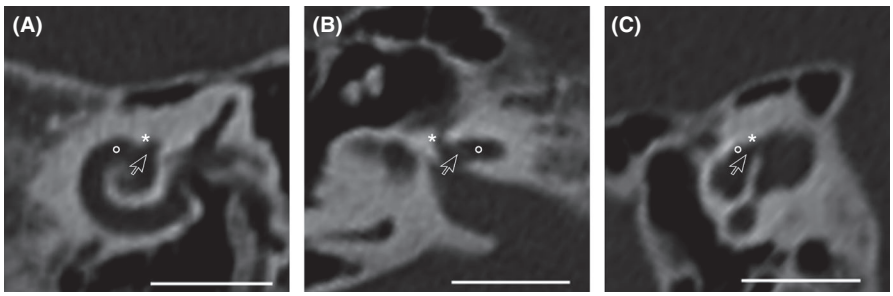

FIGURE 3 Cochlea-facial nerve dehiscence on preoperative CT images by means of open-source software Osirix MD (Pixmeo, Los Angeles, California) using three-dimensional multiplanar reconstruction. The main plane (A) is adjusted parasagittal through the basal turn of the cochlea (*dot*). Its crossing point with the other two orthogonal planes (B, axial, and C, mid-modiolar) is the dehiscence (*arrow*). *Asterisk*: labyrinthine segment of the facial nerve. Left ear; 1 mm slice thickness; Scale bar: 1 cm

in combination with lack of increase in loudness growth perception, suggestive of a delayed technical device failure in a case already published with this implant series.[4] Following detailed unbiased counseling about all technical options and surgical risks, the patient chose to change the device manufacturer and try an alternative electrical stimulation.

The fact that even stimulation from basal electrode contacts led to AFNS suggested that reimplantation from the lateral wall to a perimodiolar EA would not be sufficient on its own to resolve the problem. We therefore sought an implant with a different stimulation strategy with minimal electrical current spread from the EA in the surrounding tissue irrespective of its contour design. Our search led us to the *Neuro Zti* implant with *Classic* 20-channel EA, Oticon Medical, Vallauris, France, which employs multi-mode grounding and monophasic passive discharge stimulation (Table 1, Figures 1B, 2B). Intraoperatively, an intracochlear dose of a mixture of hyaluronic acid (2mg/ml) and dexamethasone (8mg/ml) was administered after explantation of the initial device to reduce friction forces and to protect the neural structures. Cochlear patency was checked with an insertion probe. Subsequently, the *Classic* EA could be fully inserted without resistance. During the operation, there was no AFNS detected using the new electrical stimulation, even at high current levels. However, measurement of the electrically evoked compound action potentials, which (with this system) can only be measured with a monopolar biphasic pulse, resulted in facial nerve stimulation even at low current levels, as demonstrated by facial nerve monitoring.

Postoperative CT again confirmed optimal insertion of the EA. At implant activation, all electrode contacts could be stimulated without eliciting AFNS. The hearing performance rapidly improved, and after three months, the speech intelligibility was 70%, better than with the first CI before the technical failure was diagnosed. Vestibular function remained intact. A test of the explanted CI confirmed device failure due to a short circuit within the electrode array.

3 | DISCUSSION

This is the first case report to demonstrate that electrical stimulation through a multi-mode grounding and monophasic passive discharge prevents AFNS. The presented patient had no otosclerosis, temporal bone fracture, or inner ear malformation, which are considerable risks for CFD.[5] The serial technical failure of the device alone does not cause AFNS.[4] Thorough study of his medical record showed that he had a prolonged obstructive hydrocephalus due to the pineocytoma, which was subsequently treated with ventricular drainage. Intracranial hypertension is believed to cause pressure-induced deossification and is discussed in the literature as a potential cause for superior canal dehiscence[6] and is therefore the most likely cause for the bilateral CFD in this case.

This rare bone dehiscence site was not preoperatively detected on the CT scan (Figure 3). The mean distance between the labyrinthine canal of the facial nerve and the cochlear otic capsule varies among patients. Fang et al. found on coronal histologic sections in over 1000 temporal bone specimens that this distance was 0.23 mm (range, 0–0.92 mm) and in only 0.6% was a complete CFD observed.[7] However, in nearly 35% of specimens, both structures were separated by a less than 0.1 mm bony plate, which cannot be reliably seen on high-resolution CT scans. Song et al., who found a significantly higher prevalence of CFD on CT scans of 5.4% in 406 ears,[8] confirmed this discrepancy between histologic and radiologic findings. Because of resolution limitations and partial volume averaging effects, they questioned the validity of the radiographic CFD. Therefore, it is difficult to predict from CT images whether AFNS will occur.[9] However, in the current case, the broad contact between the upper basal turn and the labyrinthine segment of

the facial nerve makes a CFD very likely and explains the severe AFNS.

Examination of the CT for the diagnosis of dehiscence using only one plane can be deceptive. In the literature, measuring of the distance between the abovementioned structures is not standardized. Using a three-dimensional multiplanar reconstruction as shown on Figure 3 makes the evaluation of the data set easier. Furthermore, this case underlines the importance of evaluating the preoperative CT scan for CFD particularly in cases with history of chronic hydrocephalus, since this is relevant for the choice of the appropriate CI device. Crucial in such cases is not primarily the design of EA, but rather the strategy for electrical stimulation with minimal current spread out of the cochlea. The dimensions of both lateral wall EA used in the presented case are similar (Table 1). Although the *Classic* EA has full-band electrode contacts in contrast to the *Slim J* EA, which has planar contacts toward the modiolus, there was no AFNS upon device activation.

The most efficient tool to prevent current loss is the grounding strategy, which enables the selective single-phase pulse shape. In the monopolar stimulation mode, the ground path for the current is the reference electrode outside the cochlea; therefore, most of the current permeates through the cochlear wall (Figure 1A). Approximately 15% of the current is actually going to the modiolus, while 22% is spreading to the basal end of the cochlea and 64% leaking into the periphery where it could stimulate the facial nerve.[10] The *Neuro Zti* implant provides a multi-mode grounding method, which allows in the active phase that each of the 20 electrode contacts inside the cochlea are also a path for the current to return in addition to the reference electrode outside the cochlea (Figure 1B).

An alternative stimulation mode is the partial tripolar configuration, by which 75% of the current returns to the intracochlear and 25% to the extracochlear electrodes and has been shown to provide better speech perception in noise.[11] The fact that post reimplantation, no stimulation of the facial nerve occurred suggests that the multi-mode grounding with monophasic passive discharge stimulation could similarly provide reduced spread of the electrical stimulation into the periphery.

Another unique characteristics of the *Neuro Zti* implant are the way pulses are presented. The traditional shape of a pulse in a CI system is a monopolar biphasic pulse (Figure 2A). In the cathodic phase, the nerve is stimulated, and in the second anodic phase, it recovers. Each phase has equal duration and generates a different excitation profile in the current path, which leads to spectral smearing because different groups of neurons are stimulated at the same time, and also individual neurons respond differently to different phases.[12]

A stimulation that provides a lower amplitude and a lower most comfortable level, as in biphasic pulse stimulation, is the triphasic stimulation used by another manufacturer.[13] This can prevent an AFNS if high electric charges are needed for the patient, but in our case, the electric charge that affected the facial nerve was very low (under 5,5 nano coulomb (nC)) with the *HiRes™ Ultra* device, and we therefore expected no improvement of the AFNS with this stimulation mode. The *Neuro Zti* implant uses an asymmetric stimulation method. To be more selective, the system uses an initial anodic phase monophasic passive discharge stimulation to save power and allows the charge of the capacitors to recover as shown in Figure 2B. This eliminates the extra phase in the monopolar biphasic stimulation and results in a more focused excitation of the neurons.

4 | CONCLUSION

In patients with a medical history of prolonged obstructive hydrocephalus, the preoperative CT prior to cochlear implantation should be thoroughly evaluated for cochlea-facial nerve dehiscence. In such cases, the selection of the CI device should enable electrical stimulation of the cochlea with minimal current leakage in the surrounding tissue. AFNS can be avoided with multi-mode grounding and monophasic passive discharge stimulation.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare especially in concern of the mentioned device manufacturer.

AUTHOR CONTRIBUTIONS

NZ: wrote the manuscript with input of all authors. RH: involved in cochlear implant fitting and data interpretation. PJ: collected the data and analyzed the hearing outcome. MB: reviewed the literature and supervised the study. SL: performed the surgery, designed the study, and helped drafting the manuscript. All authors discussed the results and contributed to the final manuscript.

CONSENT

Written informed consent was obtained from the patient to publish this report in accordance with the journal's patient consent policy.

ETHICAL APPROVAL

The patient consent is available in the medical record and from the corresponding author.

DATA AVAILABILITY STATEMENT

All data regarding the above case are present within this manuscript.

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REFERENCES

1. Van Horn A, Hayden C, Mahairas AD, Leader P, Bush ML. Factors Influencing aberrant facial nerve stimulation following cochlear implantation: a systematic review and meta-analysis. *Otol Neurotol*. 2020;41(8):1050-1059.
2. Blake DM, Tomovic S, Vazquez A, Lee HJ, Jyung RW. Cochlear-facial dehiscence–a newly described entity. *Laryngoscope*. 2014;124(1):283-289.
3. Hahlbrock KH. *Sprachaudiometrie - Grundlagen und praktische anwendung einer sprachaudiometrie für das deutsche sprachgebiet*. Stuttgart: Georg Thieme Verlag; 1957:1-182. doi:10.1288/00005537-195801000-00015
4. Lyutenski S, Zellhuber N, Helbig R, James P, Bloching M. Cochlear reimplantation from mid-scala to lateral wall electrode array: Surgical and hearing outcome. *Clin Case Rep*. 2021;9(6):e04210.
5. Pires JS, Melo AS, Caiado R, Martins JH, Eloi Moura J, Silva LF. Facial nerve stimulation after cochlear implantation: our experience in 448 adult patients. *Cochlear Implants Int*. 2018;19(4):193-197.
6. Park JH, Kang SI, Choi HS, Lee SY, Kim JS, Koo JW. Thickness of the bony otic capsule: etiopathogenetic perspectives on superior canal dehiscence syndrome. *Audiol Neurootol*. 2015;20(4):243-250.
7. Fang CH, Chung SY, Blake DM, et al. Prevalence of cochlear-facial dehiscence in a study of 1,020 temporal bone specimens. *Otol Neurotol*. 2016;37(7):967-972.
8. Song Y, Alyono JC, Bartholomew RA, Vaisbuch Y, Corrales CE, Blevins NH. Prevalence of radiographic cochlear-facial nerve dehiscence. *Otol Neurotol*. 2018;39(10):1319-1325.
9. Hatch JL, Rizk HG, Moore MW, et al. Can preoperative CT scans be used to predict facial nerve stimulation following CI? *Otol Neurotol*. 2017;38(8):1112-1117.
10. Tran P, Sue A, Wong P, Li Q, Carter P. Development of HEATHER for cochlear implant stimulation using a new modeling workflow. *IEEE Trans Biomed Eng*. 2015;62(2):728-735.
11. Srinivasan AG, Padilla M, Shannon RV, Landsberger DM. Improving speech perception in noise with current focusing in cochlear implant users. *Hear Res*. 2013;299:29-36.
12. Shepherd RK, Javel E. Electrical stimulation of the auditory nerve: II. Effect of stimulus waveshape on single fibre response properties. *Hear Res*. 1999;130(1–2):171-188.
13. Dhanasingh A, Hochmair I. Signal processing & audio processors. *Acta Otolaryngol*. 2021;141(sup1):106-134.

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