When the impedance of an electrode contact is highly increased in a cochlear implant, a failure of the appropriate electrode seems obvious. We present a case where impedances of some electrodes were at the lower edge of the normal range and not regarded as suspicious neither by the clinical fitting software nor by in-vivo tests conducted by the implant manufacturer. However, speech comprehension was substantially degraded and sound perception distorted. Also, on the affected electrodes, loudness perception was compromised and responses of the electrically evoked compound action potential were no longer measurable. After re-implantation, the subjective sound percept was clear again and speech comprehension scored much better than before. Later, inspection of the explant revealed shorts on the device and the implant was classified as device failure. Our case shows the importance of collecting longitudinal data of cochlear implant patients, i.e. device related technical measurements and hearing performance data, and the consideration of all these data in cases of patient complaints or suspected implant failures.

**Key Words:** Device failure, cochlear implant, ECAP, speech comprehension, impedance.

---

**INTRODUCTION**

A cochlear implant (CI) can be a successful device to restore hearing in profoundly deaf people. Although reliability is high, device failures may occur due to different reasons. A device failure may be easily detectable (eg, if no communication at all between implant and speech processor can be established). With a partial malfunction of the device, diagnostics usually become more difficult. If single electrodes fail they have to be deactivated. But re-implantation is unnecessary if speech perception is not compromised. Often, electrode failures are reflected in unusual impedance values being measured by the clinical fitting software of the CI system. However, in cases where impedances are still within normal limits despite an implant malfunctioning, it becomes more complicated to identify possible failures. For this reason, we present the following case report.

---

**CASE REPORT**

In the case of a woman with bilateral progressive hearing loss since childhood (at the age of 5 years), a provision with a hearing aid was carried out only on the right side at the age of 6 years. A sudden hearing loss took part during pregnancy on the right side at the age of 40 years. Pure tone audiometry revealed complete hearing loss on the right side, while pantonal hearing loss of about 80 dB was found on the left side. At the age of 41 years, she was implanted unilaterally on the right side with a CI, model Ultra HiFokus Mid-Scale (Advanced Bionics), in May 2018. We applied our standard surgical technique. A bone bed was drilled to insert the implant. A connecting tunnel to the mastoid was created to insert the electrode. The round window membrane was opened with a sharp cannula. The electrode array was inserted atraumatically in a slow procedure by means of the manufactures’ electrode insertion tool. The electrode carrier was fixed in a bone slit in the posterior tympanostomy. No kinking of the electrode was observed. No pull-back technique of the electrode was applied. After the week of initial fitting, 49 days postoperatively, performance was already good (Fig. 1). Impedances, measured with the clinical software SoundWave (vers. 3), were within normal limits (Fig. 2). Subjectively determined M-levels (Most Comfortable Levels) (ie, loudness levels that are well tolerable for the CI user) are shown in Figure 3. Responses of the electrically evoked compound action potential (ECAP) were recorded with the NRI (Neural Response Imaging) task and measurable on all 16 electrode contacts.

At the follow-up visit 245 days postoperatively, the patient complained about distorted sound perception. Impedances on two electrode contacts (E09, E10) were...
much lower than values on remaining contacts (Fig. 2). Perceived loudness did not increase with increasing stimulation charge on these two electrodes and were therefore deactivated. Speech comprehension scores did not change (Fig. 1).

At the follow-up 321 days postoperatively, the patient still complained about sound quality. Now, impedances on five electrodes E09–E13 were particularly low (Fig. 2). The formerly determined M-Levels were inaudible or very soft on these channels and had to be significantly increased to reach sufficient loudness perception (Fig. 3). Also, the NRI measurement failed to retrieve responses on these five electrode contacts (Fig. 4). The device was tested on the same day in-vivo by the manufacturer, but all test results, including electrical field imaging (EFI)4 were found to be within normal limits. Speech comprehension, especially in noise, was severely degraded (Fig. 1) and re-implantation was therefore indicated.

The patient was re-implanted with a HiRes 90 K Advantage HiFokus Mid-Scala. Now, ECAP responses could be obtained again on all electrode contacts (Fig. 4) with thresholds being comparable to values measured with the previous implant at a time before problems occurred. Impedances and M-Levels also changed back to original values (Figs. 2 and 3). Speech comprehension at the end of the initial fitting, 36 days after re-implantation, scored much better than before (Fig. 1).

The explant was tested by the manufacturer and a device failure was confirmed. Fluid ingress at the electrode probably led to short circuits in the electrode pocket of the device. Impedance tests as well as EFI tests on electrode contacts E09–E13 showed considerably lower values compared to typical ranges.

DISCUSSION

We showed in our case report of a CI user a correlation of decreased impedances, increased M-levels and deteriorated ECAP responses, with degraded speech comprehension and distorted sound perception. While the device passed all in-vivo tests, investigation of the explanted device revealed a device failure.

Speech recognition in a newly implanted CI user usually develops slowly. As a prerequisite, a functioning device is necessary. It may occur that single electrode contacts fail; high impedance will clearly indicate that. In our case, however, a different picture emerged. Impedance on affected channels was low, but not indicated as short circuit by the clinical software, therefore the problem remained uncovered. Low impedances are not regarded as problematic since they have advantages like lower power consumption and the possibility of using shorter pulse widths. However, it already has been demonstrated that low impedances may be caused by loss of hermeticity5,6 leading to undesirable current flow across channels.

ECAP measurements are widely used to prove the electrode-nerve interface. ECAP thresholds correlate to
some degree with M-Levels and are therefore used to program the speech processor. In our case, elevated M-Levels and loss of ECAP responses may be misinterpreted as nerve degeneration or cochlea ossification, which could lead to wrong clinical decisions for future treatment of the patient (e.g., providing an auditory brainstem implant or proceeding with elaborate and costly diagnostics including imaging and the burden of radiation).

During the first months of CI usage, speech comprehension and sound quality usually improve. Regular hearing therapy will help the patient to get accustomed to electric hearing. A device failure where electrically shortened channels will confound spectral resolution has to be ruled out wherever hearing performance is lower than expected. A substantial decrement of performance may be rated as “soft failure”\(^1\) and might imply re-implantation. In our case, the impairment of the device occurred early, that is before speech comprehension scores saturated, concealing the negative impact on the patient’s outcomes.

If a device failure occurs prior to initial fitting, the patient will never recognize a degradation as sound quality is compromised from the very beginning.

---

**Fig. 4.** ECAP responses over time after implantation of the first implant (A and B) and after re-implantation (C). As an example, NRI measurements on electrode contact E09 at chosen stimulation levels are shown. Stimulation charge is given in clinical charge units (CU), ECAP amplitude (EP) is given in \(\mu V\). ECAP = electrically evoked compound action potential; NRI = neural response imaging.
For the time being, no test limits for in-vivo as well as for ex-vivo EFI and impedance tests have been established by the manufacturer. This is why, in the case presented, the in-vivo measurement passed. The manufacturer's Explant Review Board assessed the ex-vivo test and decided to consider the test results a failure. At the present time, clinicians may find it difficult to assess whether a device is affected or not. At our clinic, more cases like the one presented already emerged.

CONCLUSION

ECAP responses should be recorded intraoperatively as well as postoperatively on each electrode contact to prove a well-functioning electrode-nerve interface. If electrodes fail to respond, a device failure should be considered, especially in cases where low impedances in combination with lack of increase in loudness percept occur, despite increased stimulus strength. Our case shows the importance of collecting longitudinal data of cochlear implant patients, ie, device-related technical measurements and hearing performance data and the consideration of all these data in cases of patient complaints or suspected implant failures.

BIBLIOGRAPHY

1. Battmer RD, Linz B, Lenarz T. A review of device failure in more than 23 years of clinical experience of a cochlear implant program with more than 3,400 implantees. Otol Neurotol 2009;30:455–463.
2. Lenarz T. Cochlear implant – state of the art. GMS Curr Top Otorhinolaryngol Head Neck Surg 2017;16:Doc04.
3. Hochmair-Desoyer I, Schulz E, Moser L, Schmidt M. The HSM sentence test as a tool for evaluating the speech understanding in noise of cochlear implant users. Am J Otol 1997;18:S83.
4. Vanpoucke FJ, Zarowski AJ, Peeters SA. Identification of the impedance model of an implanted cochlear prosthesis from intracochlear potential measurements. IEEE Trans Biomed Eng 2004;51:2174–2183.
5. Carlson ML, Archibald DJ, Dabade TS, et al. Prevalence and timing of individual cochlear implant electrode failures. Otol Neurotol 2010;31:893–898.
6. Gärtner L, Lesinski-Schiedat A, Büchner A, Lenarz T. Kopfschmerzen und Abnahme des Sprachverstehens bei einem Patienten mit einseitigem Cochlea-Implantat. Laryngorhinootologie 2016;95:559–560.