Archives of the Balkan Medical Union
vol. 61, no. 3, pp. 416-421
September 2026
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CASE SERIES

HIGH IMPEDANCE OF THE REFERENCE ELECTRODE IN COCHLEAR IMPLANT PATIENTS: THREE CASE REPORTS AND SURGICAL CONSIDERATIONS

Evis BENDO[1]✉, Trifon KIRATZIDIS[2,3]

[1] University Hospital "Mother Teresa", ENT Department, Tirana, Albania
[2] Veria Medical Center, Veria, Greece
[3] Cochlear and Acoustic Implant Center, General Clinic of Thessaloniki, Greece

Received 26th June 2026, Accepted 21st Aug 2026
https://doi.org/10.31688/ABMU.2026.61.3.11

Abstract

Introduction. Electrode impedance telemetry is essential for evaluating cochlear implant (CI) function. Increased impedance of the reference electrode may compromise the performance of all active electrodes and lead to deterioration of auditory outcomes. Reports focusing specifically on reference electrode dysfunction remain limited.
Cases presentation. We report three cochlear implant recipient patients who developed excessively high reference electrode impedance with impaired auditory outcomes. The first case involved a 2-year-old girl with congenital deafness, implanted with a MED-EL Pulsar device in infancy, who developed progressively increasing impedance due to burial of the reference electrode leaves within the temporal bone. The second case concerned a 15-year-old girl implanted with a MED-EL Combi-40+ device who presented with progressive hearing deterioration and elevated impedance secondary to osseous overgrowth around the electrode. The third case involved an 18-year-old male with bilateral implants who developed fluctuating hearing secondary to the mechanical separation of the reference electrode from its leaves. In all three cases, surgical

Résumé

Impédance élevée de l'électrode de référence chez les patients porteurs d'implants cochléaires: trois cas cliniques et considérations chirurgicales

Introduction. La télémétrie d'impédance des électrodes est essentielle pour l'évaluation du fonctionnement des implants cochléaires (IC). Une augmentation de l'impédance de l'électrode de référence peut compromettre les performances de toutes les électrodes actives et entraîner une détérioration des résultats auditifs. Les publications portant spécifiquement sur les dysfonctionnements de l'électrode de référence demeurent limitées.
Rapport des cas. Nous présentons trois patients porteurs d'un implant cochléaire ayant développé des valeurs excessivement élevées de l'impédance de l'électrode de référence, associées à une altération des performances auditives. Le premier cas concernait une fillette de 2 ans atteinte de surdité congénitale, implantée en petite enfance avec un dispositif MED-EL Pulsar, qui a présenté une augmentation progressive de l'impédance en raison de l'enfouissement des ailettes de l'électrode de référence dans l'os temporal. Le deuxième cas

✉ Address for correspondence: Evis BENDO
ENT Department, University Hospital Center "Mother Teresa", Tirana, Albania
Address: Dibra's Street, No 370, Tirana, Albania
Email: drbendo@gmail.com; Phone +35-569-2087471

exploration identified the underlying abnormality, and corrective surgery resulted in a substantial reduction of impedance values, restoration of implant function, and improvement of auditory performance without device replacement.

Conclusions. Bone remodeling around the reference electrode may occur in patients implanted during infancy and may significantly impair cochlear implant performance. Regular long-term telemetry evaluation is recommended for pediatric cochlear implant recipients. Routine long-term telemetry monitoring is valuable for early detection of these complications and may allow successful surgical correction while preserving the implanted device.

Keywords: cochlear implant, electrode impedance, telemetry, bone remodeling, cochlear implant complications.

List of abbreviations:
MED-EL – Medical Electronic Devices

concernait une adolescente de 15 ans implantée avec un dispositif MED-EL Combi-40+, présentant une détérioration progressive de l'audition et une augmentation des valeurs d'impédance secondaire à une prolifération osseuse autour de l'électrode. Le troisième cas concernait un jeune homme de 18 ans porteur d'implants cochléaires bilatéraux, qui a présenté des fluctuations auditives dues à une séparation mécanique entre l'électrode de référence et ses ailettes.
Dans les trois cas, l'exploration chirurgicale a permis d'identifier l'anomalie sous-jacente. La correction chirurgicale a entraîné une diminution importante des valeurs d'impédance, une restauration du fonctionnement de l'implant et une amélioration des performances auditives, sans nécessité de remplacement du dispositif.
Conclusions. Un remodelage osseux autour de l'électrode de référence peut survenir chez les patients implantés durant la petite enfance et altérer significativement les performances de l'implant cochléaire. Une surveillance télémétrique régulière à long terme est recommandée chez les enfants porteurs d'un implant cochléaire. La surveillance télémétrique prolongée constitue un outil précieux pour la détection précoce de ces complications et peut permettre une correction chirurgicale efficace tout en préservant l'implant en place.

Mots-clés: implant cochléaire, impédance électrodique, télémétrie, remodelage osseux, complications des implants cochléaires

Introduction

Cochlear implantation is an established treatment modality for patients with severe to profound sensorineural hearing loss[1,2]. Modern cochlear implant systems rely on stable electrode impedance values to ensure appropriate electrical stimulation and optimal auditory performance[3-8].In monopolar stimulation mode, the impedance of each active intracochlear electrode is measured in relation to the reference electrode[4-8]. Consequently, abnormalities involving the reference electrode may influence the function of all active electrodes and result in impaired speech perception, fluctuating hearing, or unsuccessful fitting sessions[4,5,9,10].The reference electrode is commonly positioned beneath the fascia temporalis on the surface of the temporal bone. However, long-term complications related to bone remodeling, especially in children implanted during infancy, are rarely described in the literature[11-13]. This report aims to describe three rare cases of cochlear implant dysfunction caused by abnormalities of the reference electrode and to discuss the underlying mechanisms and surgical management.

Cases presentations

Case 1

A 3-year-old congenitally deaf girl received a right-sided cochlear implant (MED-EL Pulsar) in June 2005 at the age of 10 months. Two and a half years after implantation, during routine follow-up, progressively increasing impedance values were observed. Active electrode impedances ranged from 9.29 to 13.40 kΩ, while the reference electrode impedance reached 4.24 kΩ. Imaging studies were not considered necessary. Surgical exploration revealed the three leaves of the reference electrode deeply buried within the skull bone. Using a diamond burr, we identified the exact position of the electrode leaves. (Fig. 1, B and C) They were released from the surrounding bone using a sharp surgical hook (Fig. 1A), leaving them free on the surface of the bone.

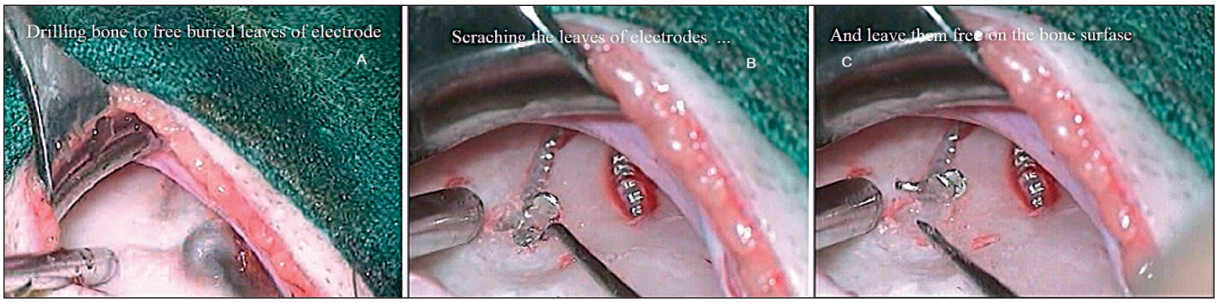


Figure 1. Surgical management of osseous incorporation of the reference electrode (Case 1). (A) Identification of the buried reference electrode leaves using a diamond burr. (B–C) Release of the electrode leaves from the surrounding newly formed temporal bone using a surgical hook. Following the liberation of the electrode leaves, impedance values normalized, and implant performance improved.

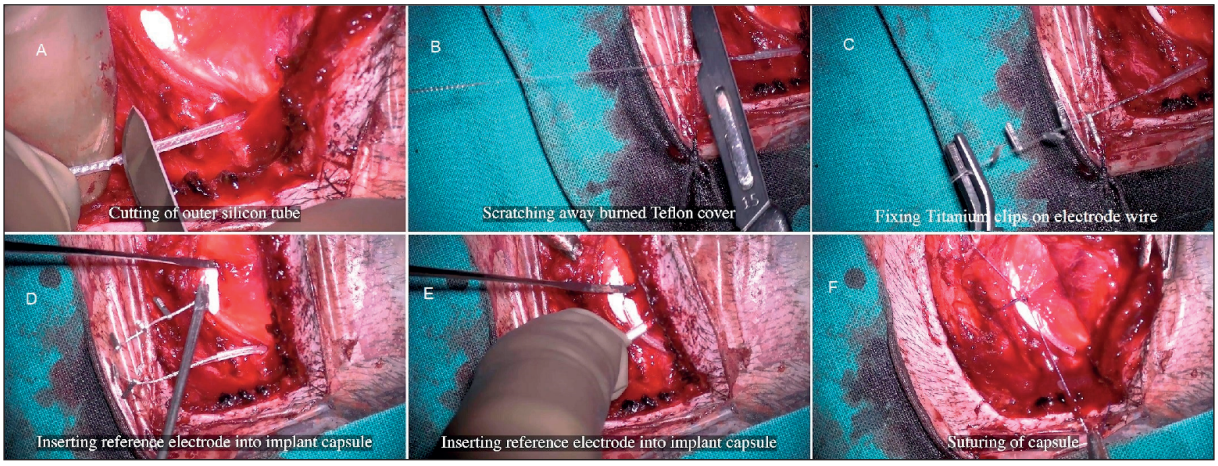


Figure 2. Reconstruction of a mechanically separated reference electrode (Case 3). (A) Exposure of the detached reference electrode after opening the silicone covering. (B) Removal of the insulating coating from the iridium conductors. (C) Placement of titanium clips on the exposed conductors. (D–E) Repositioning of the reconstructed electrode within the fibrous capsule surrounding the implant. (F) Final fixation following capsule closure.

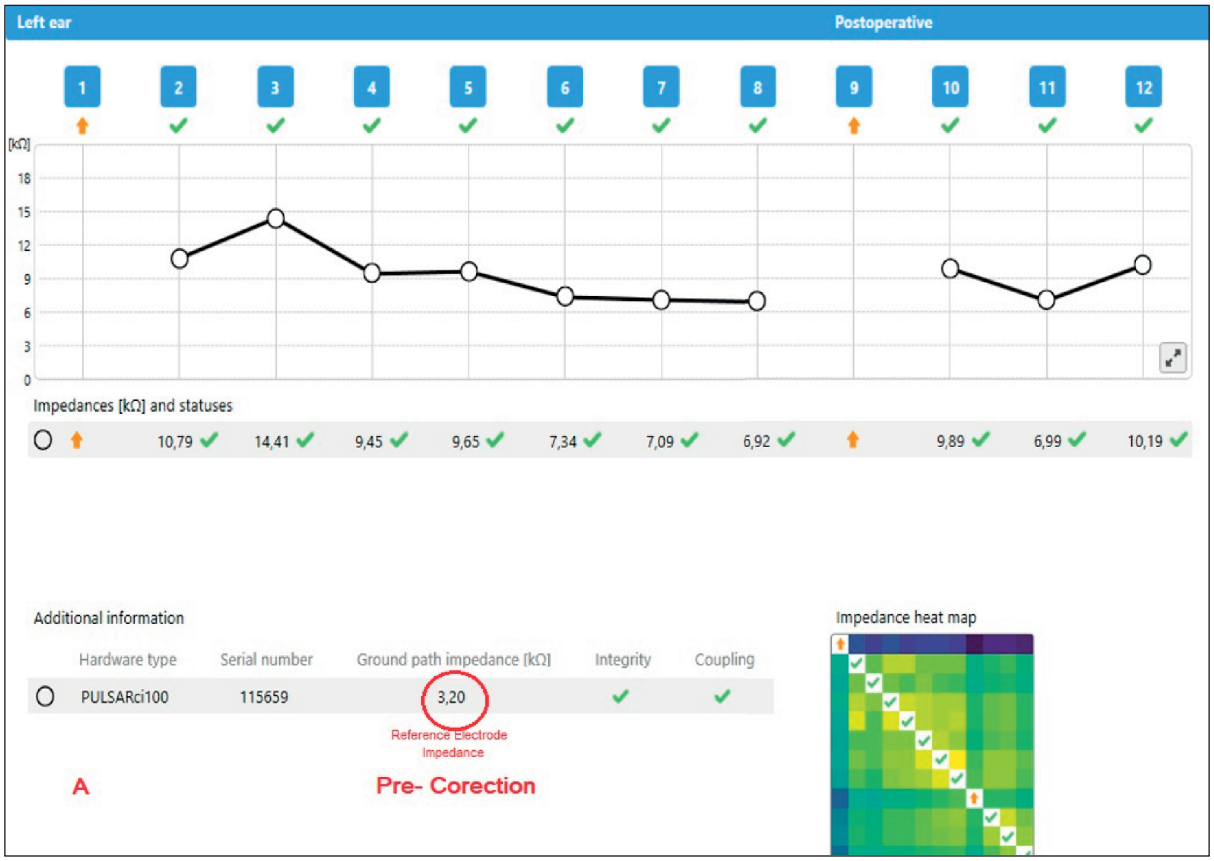
Following this liberation of the electrode leaves from the bone, all the impedance values significantly improved immediately.

Case 2

The second patient was a 15-year-old girl. She was born in 1993, and she had a history of premature birth, infant incubators, neonatal infections, and dehydration. She used hearing aids for 4 years, which helped her follow the speech therapy program, but with not very good results. By the 6th year, her hearing deteriorated, and in December 1999, she underwent left-sided cochlear implantation with a MED-EL Combi-40+ device. With this device, she followed mainstream education successfully. Nine years later, at the age of 15, progressive hearing deterioration started, and elevated telemetry values were noted, especially the reference electrode impedance value. Imaging studies were not considered necessary. Surgical exploration again demonstrated bone overgrowth around the reference electrode leaves, which was corrected surgically, exactly as previously described, with significant improvement in telemetry values and hearing performance.

Case 3

The third case involved an 18-year-old patient. He was born on 30/05/2007 with congenital genetic deafness. He underwent a bilateral cochlear implantation on 28/08/2008, with MED-EL Pulsar devices. On May 25/2025, he started having fluctuating hearing, with progressive deterioration of auditory performance. Repeated telemetry demonstrated elevated impedance of the reference electrode despite normal imaging studies. On surgical exploration, during surgical dissection of the reference electrode, this slipped free out of its reactive tube, revealing mechanical separation of the electrode from its three contact leaves. The reference electrode was then repaired in three stages (Fig. 2A), cutting the outer silicon tube of the electrode, leaving the iridium wires free (Fig. 2B), scratching the wires with a blade to remove the teflon cover from its surface (Fig. 2C), fixing titanium clips on the electrode wires, the same clips used for



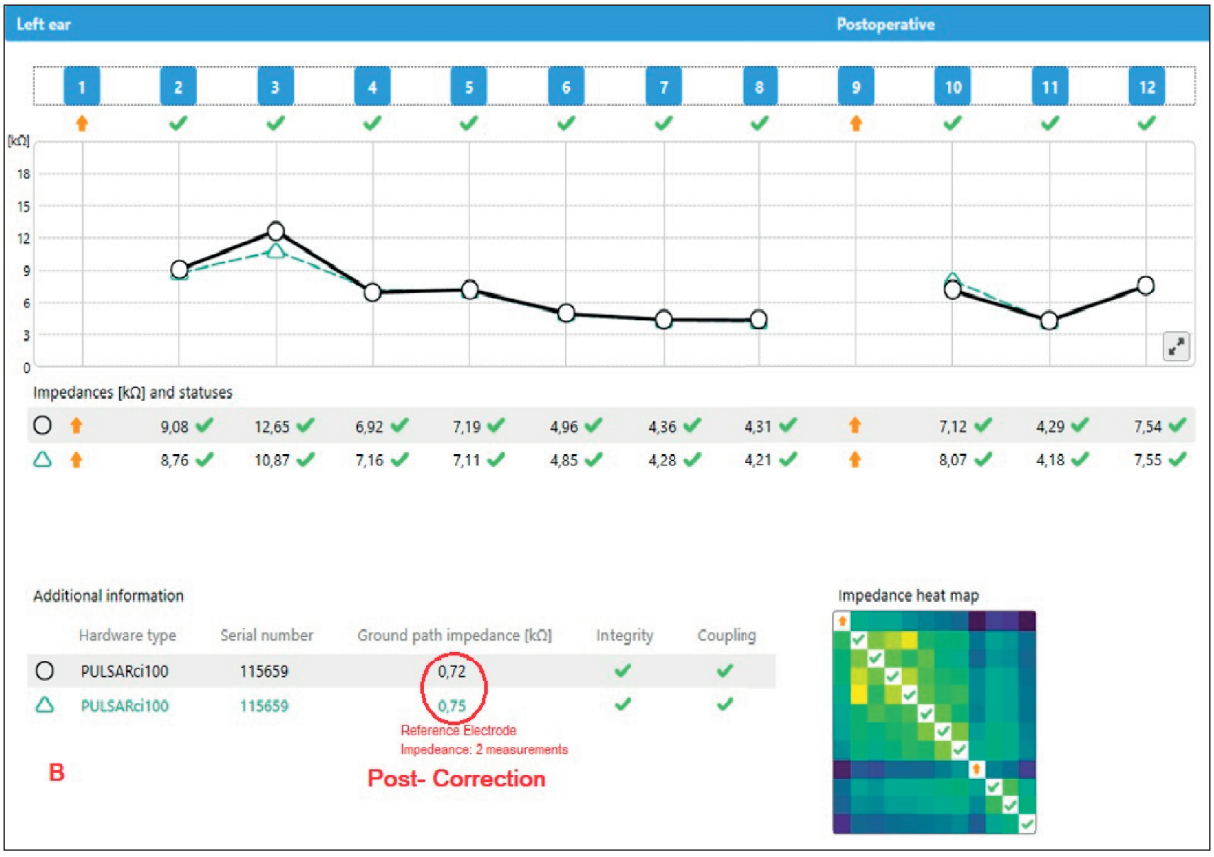


Figure 3. Telemetry measurements in Case 3 before and after revision surgery. Comparison of active electrode impedance values and reference electrode impedance demonstrates a substantial reduction after surgical repair and device refitting.

hemostasis (Fig. 2D and Fig 2E), inserting the electrode with the titanium clips on it in the fibrous capsule of the implant, which was in the vicinity of the electrode, and suturing the capsule (Fig. 2F).The new fitting resulted in stable auditory performance and substantial improvement in hearing function (Fig. 3), and the student started attending his lectures successfully again.All the cases were corrected surgically, without the need to replace the implant.

In the first case, the impedance values of the active electrodes after the correction were reduced between 5.95 and 10.76 kΩ, and the value of the reference electrode was reduced to 0.89 kΩ. In the second case, the impedance values of the active electrodes were reduced between 2.89 and 6.0 kΩ, and the value of the reference electrode was reduced to 0.79 kΩ. The patients then had a new fitting that was successful and satisfying. In the third case, the impedance values of the active electrodes were pre-op between 7 and 14 kΩ and reduced post-op between 5 and 12 kΩ, and the pre-op impedance of the reference electrode was 3.20 kΩ, and the post-op was 0.75 kΩ. The most clinically significant finding in this patient was the vicinity of the endings of the cut wires with their corresponding leaves, making continuous "sparkling" contact, producing noise and fluctuation, both most disturbing to the patient, whereas the other two patients did not experience such disturbances, but only reduced loudness perception.

Discussion

Electrode impedance telemetry is an essential component of cochlear implant follow-up, because it reflects both device integrity and the characteristics of the electrode-tissue interface. Elevated impedance values have been associated with fibrosis, ossification, inflammatory reactions, alterations in cochlear fluid composition, partial electrode extrusion, and hardware malfunction[4-10,14].

Most published studies have focused on intracochlear causes of impedance elevation. Hughes et al. demonstrated that impedance values vary over time and may reflect biological changes occurring around the implanted electrode array[9]. More recently, Wimmer et al. and Schraivogel et al. suggested that impedance measurements may serve as biomarkers of tissue responses within the cochlea and may provide useful information regarding residual hearing preservation[5,10].

In contrast, abnormalities involving the extracochlear reference electrode have received comparatively little attention. De Rijk et al. highlighted the importance of extracochlear electrode positioning and demonstrated that extracochlear abnormalities may significantly influence implant measurements and performance[11]. However, reports specifically describing isolated reference electrode dysfunction remain scarce.

The present case series demonstrates two distinct mechanisms of reference electrode failure. In the first two patients, progressive osseous overgrowth incorporated the reference electrode leaves into the temporal bone. Both patients had been implanted during early childhood, a period characterized by active cranial growth and continuous bone remodeling. Although bone remodeling is a normal physiological process, its effect on extracochlear implant components has rarely been discussed in the literature[11-13]. Our findings suggest that progressive bone incorporation may increase electrical resistance at the electrode-tissue interface and contribute to global impedance elevation throughout the implant system.

The third patient demonstrated a different pathophysiological mechanism. Mechanical separation of the reference electrode from its terminal leaves produced intermittent electrical contact, resulting in fluctuating impedance measurements and unstable auditory perception. This observation supports previous reports indicating that hardware-related complications may occur despite normal radiological findings and underscores the limitations of imaging in detecting subtle electrode abnormalities[12,13].

An important finding across all three cases was the discrepancy between telemetry abnormalities and radiological investigations. Conventional imaging was either normal or considered unlikely to identify the underlying pathology. These observations further support routine impedance telemetry as a sensitive method for detecting implant dysfunction before structural abnormalities become clinically apparent.

To our knowledge, reports specifically addressing isolated reference electrode impedance abnormalities are limited. The present cases highlight that clinically significant cochlear implant dysfunction may arise from pathology involving the reference electrode, even when standard imaging studies are unremarkable. These observations emphasize the value of routine impedance telemetry as a sensitive tool for the early detection of device-related complications and for guiding timely surgical intervention.

These findings support routine long-term monitoring of reference electrode impedance in pediatric cochlear implant recipients. Early recognition and surgical correction may help restore device function and improve auditory outcomes[5,9,15].

Conclusions

High impedance of the reference electrode may represent an uncommon cause of cochlear implant

dysfunction, particularly in patients implanted during infancy.

The reference electrode of a cochlear implant placed directly on the surface of the temporal bone may become buried by progressive osseous overgrowth associated with cranial growth and bone remodeling. This may affect the device's proper functioning and should be corrected. We propose that:

- Particular attention should be paid to reference electrode impedance values during routine telemetry assessments, especially in patients implanted during early childhood.
- When using an implant with a separate reference electrode, consideration should be given to positioning the electrode close to the device so it can be incorporated in the fibrous capsule.

Although cochlear implant systems with separate reference electrodes are now uncommon, these considerations remain relevant for patients carrying earlier-generation devices. In that case, the surgeon may choose to fix the end of it on the electronic part of the device to be incorporated into the fibrous capsule, instead of seeking a place under the fascia temporalis. This may prevent both types of complications presented in this report, making the procedure simpler.

Author Contributions:

T.K, E.B. were responsible for the diagnostic procedures, clinical diagnosis, and treatment decisions. T.K performed the surgery. E.B. and T.K. wrote the manuscript. All authors have read and agreed to the published version of the manuscript.

Compliance with Ethics Requirements:

"The authors declare no conflict of interest regarding this article"

"The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law. Informed consent was obtained from all the patients included in the study"

"No funding for this study"

Acknowledgements:

None

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