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Lessons learned in delayed identification of a misplaced electrode array in the vestibule

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ABSTRACT

To report a case of cochlear implantation with a misplaced electrode array in the vestibule and the causes for the delay in identification. A 23-year-old male with left single-sided deafness underwent cochlear implantation. The intraoperative assessment did not reveal any major red flags of electrode array misplacement. He did not display any vestibular symptoms postoperatively but showed poor speech performance, even though the aided tone audiometry revealed good sound detection thresholds. High-resolution computed tomography (HRCT) showed that the entire perimodiolar electrode array was situated within the vestibule, and a revision surgery was conducted. Retrospective analysis of the neural response telemetry (NRT) revealed subtle differences in responses between the misplaced and correctly placed electrode arrays. Unlike previously reported cases, the patient did not display vestibular symptoms despite the misplacement of the electrode in the vestibule due to existing weakness in otolithic function. Further investigation is warranted when a motivated patient with normal inner ear anatomy does not show benefit with the cochlear implant post-operatively.

List of abbreviations

c-VEMP	Cervical vestibular evoked myogenic response
HRCT	High-resolution computed tomography
NRT	Neural response telemetry

1. Introduction

Cochlear implantation is a treatment option for individuals with moderate to profound bilateral sensorineural hearing loss who do not derive sufficient benefit from conventional hearing aids (Buchman et al., 2020). While post-operative complications can occur, they are relatively uncommon. Revision surgeries with re-implantation are typically required due to reasons such as wound infection or complication, device extrusion, device failure, and electrode misplacement (Kim et al., 2020; Wang et al., 2014; Webb et al., 1991). Electrode misplacement has a detrimental impact on cochlear implant performance, leading to unsatisfactory progress in speech perception for patients (Cheung et al., 2022; Holden et al., 2013; Muzzi et al., 2012). This case report details a case of electrode array misplacement within the vestibule, which was detected several months post-operatively when the patient did not show progress with the cochlear implant. Notably, it highlights the rarity of a situation where the patient did not experience any vestibular symptoms postoperatively despite the electrode being positioned in the vestibular system.

2. Case details

A 23-year-old male patient was referred to the Ear, Nose, Throat (ENT) specialist in a tertiary hospital due to left single-sided deafness identified during a health screening before military enlistment. The duration of hearing loss is unknown, as he was unaware of it until it was detected during the health screening. He did not recall any significant

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event precipitating the hearing loss. His birth history is uneventful and there is no family history of hearing loss. There was no record of newborn hearing screening being performed. He denied having any vestibular symptoms in the past and no craniofacial abnormalities were noted. The patient did not have any other medical condition.

A preoperative audiological assessment for cochlear implant was conducted and he was cleared for the surgery. He was found to have severe to profound sensorineural hearing loss with poor speech recognition score in the left ear. Hearing levels in his right ear were within normal limits. His vestibular function was also assessed with the caloric test, video head impulse test, and cervical vestibular evoked myogenic potentials (c-VEMPs). Vestibular test results were generally normal except for absent c-VEMP response when the left ear was stimulated (Fig. 1). Preoperative HRCT and magnetic resonance imaging of the temporal bone revealed normal anatomical morphology of the cochlea and internal auditory meatus bilaterally.

Following extensive counselling by the team, the patient underwent left cochlear implant surgery in March 2021. Intraoperative monitoring of the facial nerve was uneventful. A Cochlear Nucleus Profile CI532 implant with a Slim Modiolar electrode (Cochlear Pty Ltd, Sydney, Australia) was completely inserted through the round window. A narrow facial recess was noted during the surgery. Intraoperative impedance measurements (Monopolar1, Common Ground, Monopolar1+2, and Monopolar2) for all electrodes were within normal limits (between 5 and 15 kiloOhms), indicating good electrode-tissue contact. Intraoperative NRT indicated the presence of neural responses for all electrodes. However, the NRT thresholds were observed to be higher than normal, with levels recorded between 235 and 240. An intraoperative imaging was performed, and it did not reveal any apparent misplacement of the electrode array (Fig. 2).

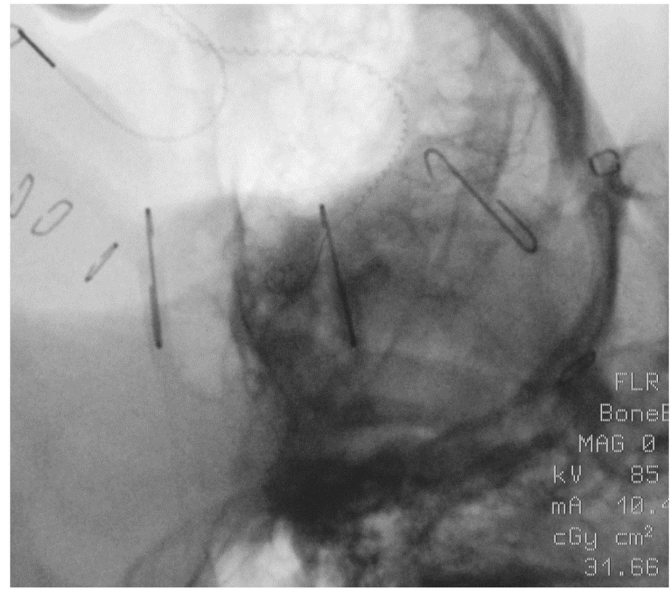

Fig. 2. Intraoperative imaging during the initial implant surgery.

2.1. Initial activation

The initial activation of the implant was uneventful. The patient did not experience any non-auditory symptoms during the activation of the Cochlear Nucleus 7 sound processor. Impedance measurements did not reveal any short or open circuits. AutoNRT was performed with Cochlear Nucleus Fitting Software on five electrodes (2, 6, 11, 16, and 22). The software recorded responses, and the levels were determined to be between 148 and 212. Ling-6 Sound Test was conducted to check on the patient's access to a range of speech sounds and the patient was able to detect all six sounds.

2.2. Subsequent follow-up sessions and limited functional progression

Stimulation levels were gradually increased during the subsequent

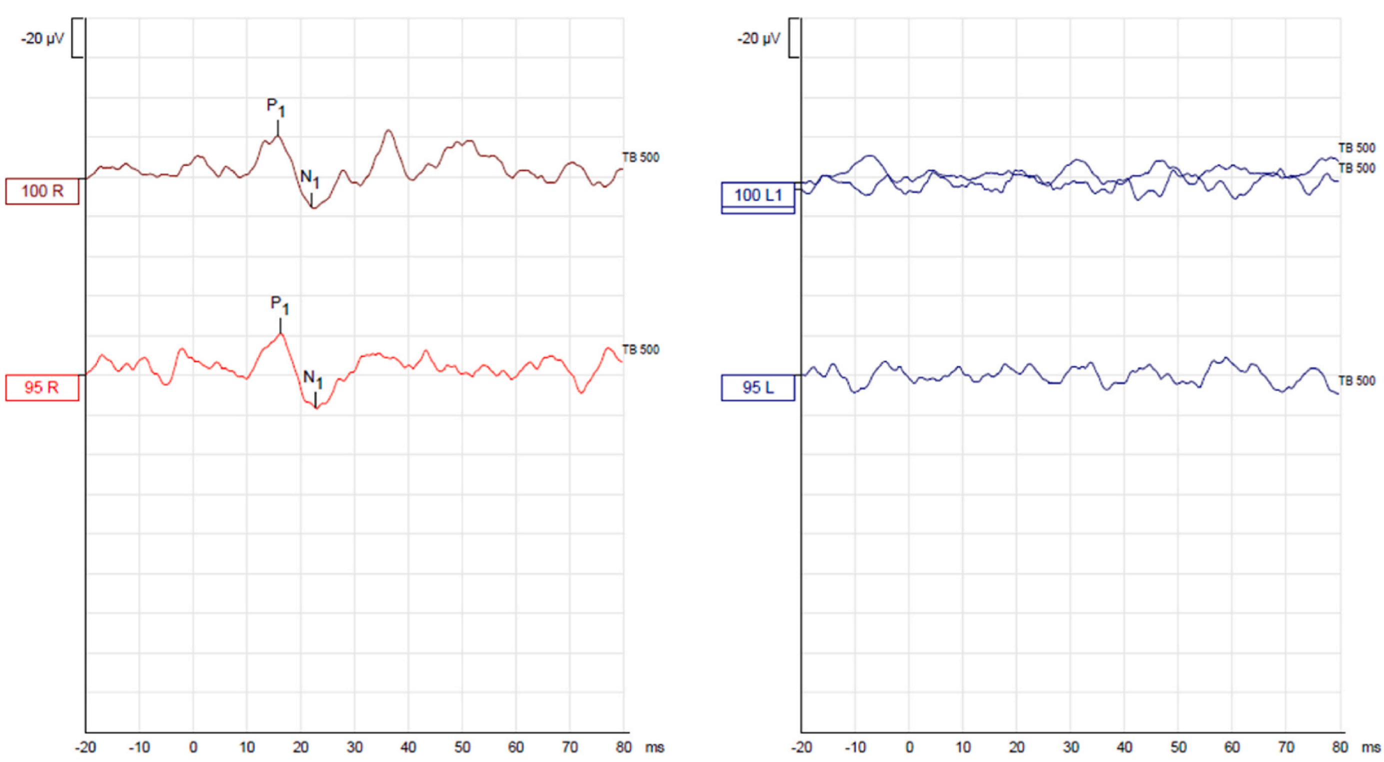

Fig. 1. cVEMP response of the patient with 500Hz tone burst.

mapping session as the patient perceived the sounds from the implant to be soft. However, the patient reported a vibrating or jolting sensation at high current levels with a small pulse width. With a longer pulse width, the patient subjectively perceived an increase in loudness when the current levels were raised. There were no instances of facial nerve stimulation observed throughout the mapping session. To conserve the battery life of the processor, the stimulation rate was reduced. Surprisingly, the patient could not perceive any sound when the stimulation rate was reduced. He detected sound when the stimulation mode was switched to Monopolar1+2 or Monopolar2. However, he only detected vibrotactile sensation when the stimulation mode was switched to Monopolar1. During the mapping sessions, the patient detected all the Ling-6 sounds but identified them all as the sound/i/(ee).

At the 3-month post-activation mark, AutoNRT was conducted to monitor any changes in neural responses using specific electrodes (1, 2, 3, 4, 6, 11, 16, and 22). No responses were noted for electrodes 1 to 3. Functional progression with the cochlear implant was monitored at 3 months and 6 months postoperatively. Aided audiometry assessments were performed, with masking applied to the non-test ear. The assessments revealed good aided thresholds from 250Hz to 8000Hz. However, there was no significant improvement in the aided speech audiometry score compared to the preoperative assessment results. This is despite consistent usage of the device and the patient's commitment to post-surgery aural rehabilitation with the audiologist and speech-language pathologist.

A postoperative HRCT scan of the temporal bone was performed because of the poor outcome. The CT scan revealed that the electrode array did not enter the cochlea. After entering the round window, it was directed 90° anteriorly and curled within the vestibule (Fig. 3).

2.3. Reimplantation

Re-implantation was performed by reinserting the same implant. The full electrode array was inserted into the cochlea, which was confirmed through a repeat HRCT scan (Fig. 4). Intraoperative NRT was present for all electrodes during the revision surgery. Impedance measurements did not show any significant differences compared to the previous measurements. The device was reactivated three weeks after the surgery, and NRT thresholds were obtained for all electrodes. Subtle differences in the postoperative NRT waveforms were observed after the initial and revision surgery (Fig. 5). The patient is currently doing well with the cochlear implant and has shown significant improvement in aided speech assessment at the 3-month postoperative follow-up.

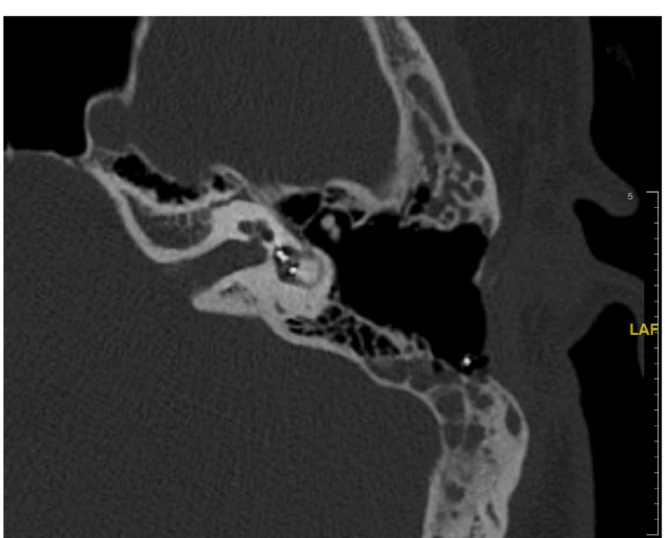

Fig. 3. HRCT scan (axial view) reveals the electrode array within the vestibule.

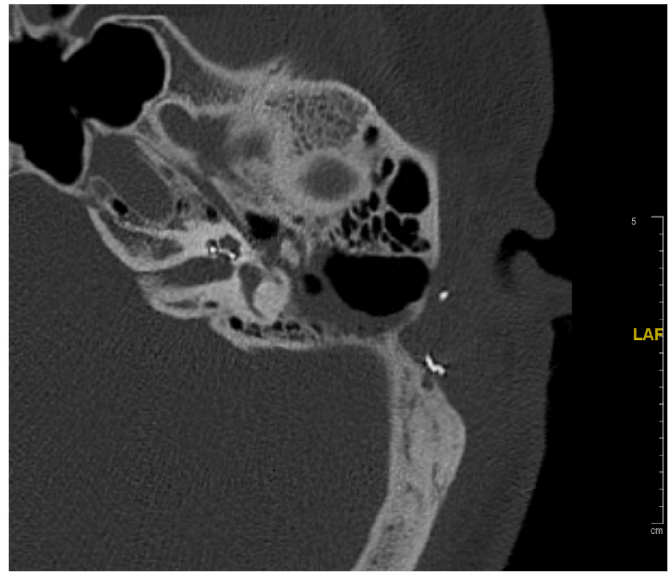

Fig. 4. HRCT scan (axial view) performed after the revision surgery. The perimodiolar electrode enters the round window and its tip was seen at the middle turn of the cochlea.

3. Discussion

Extracochlear misplacement of the cochlear implant electrode array, in the absence of inner ear malformations, is a rare complication. This complication has been previously reported in several case reports (Cheung et al., 2022; Mehanna et al., 2019; Pau et al., 2009; Shin et al., 2022; Viccaro et al., 2009; Ying et al., 2013). The vestibule and lateral and superior semicircular canals are identified as the common locations for misplacement. The average incidence rate reported in the published literature ranges from 0.37% to 0.49% (Shin et al., 2022; Ying et al., 2013). However, the actual incidence rate may be underestimated, as cases of poor performance or implant-related issues may not be identified or attributed to electrode misplacement.

In this case, the misplacement of the electrode array in the vestibule was not initially detected in the early months postoperatively due to a few factors. The patient was initially suspected of having long-standing hearing loss in the left ear because he could not recall any specific incident of sudden hearing loss or vestibular symptoms. It was only discovered during a health screening that he had left-sided hearing loss of which he was previously unaware. Long-term auditory deprivation is known to potentially result in slower progression in speech performance after cochlear implantation (Blamey et al., 2013; Cohen and Svirsky, 2018). Intraoperative imaging was taken to ascertain the position of the electrode array. Due to the constraints of positioning the patient, the need to avoid contact with the operative field and the technical limitations of portable equipment, these images are often obtained at less-than-optimal angles. The suboptimal angle resulted in the perimodiolar electrode having a radiological appearance consistent with the correct positioning of the electrode array. Both intraoperative and postoperative impedance and NRT measurements also appeared to be normal at first glance. The patient also did not exhibit any postoperative vestibular symptoms like vertigo or nausea, unlike other reported cases (Mehanna et al., 2019; Muzzi et al., 2012; Pau et al., 2009). In the months after activation, the patient was able to detect Ling-6 sounds and subjectively perceive an increase in loudness as simulation intensity increased. Aided tone audiometry, with appropriate masking applied to the non-test ear, also showed satisfactory results, leading to the assumption that the implant was correctly positioned within the cochlea.

The case highlights the significance of closely monitoring the

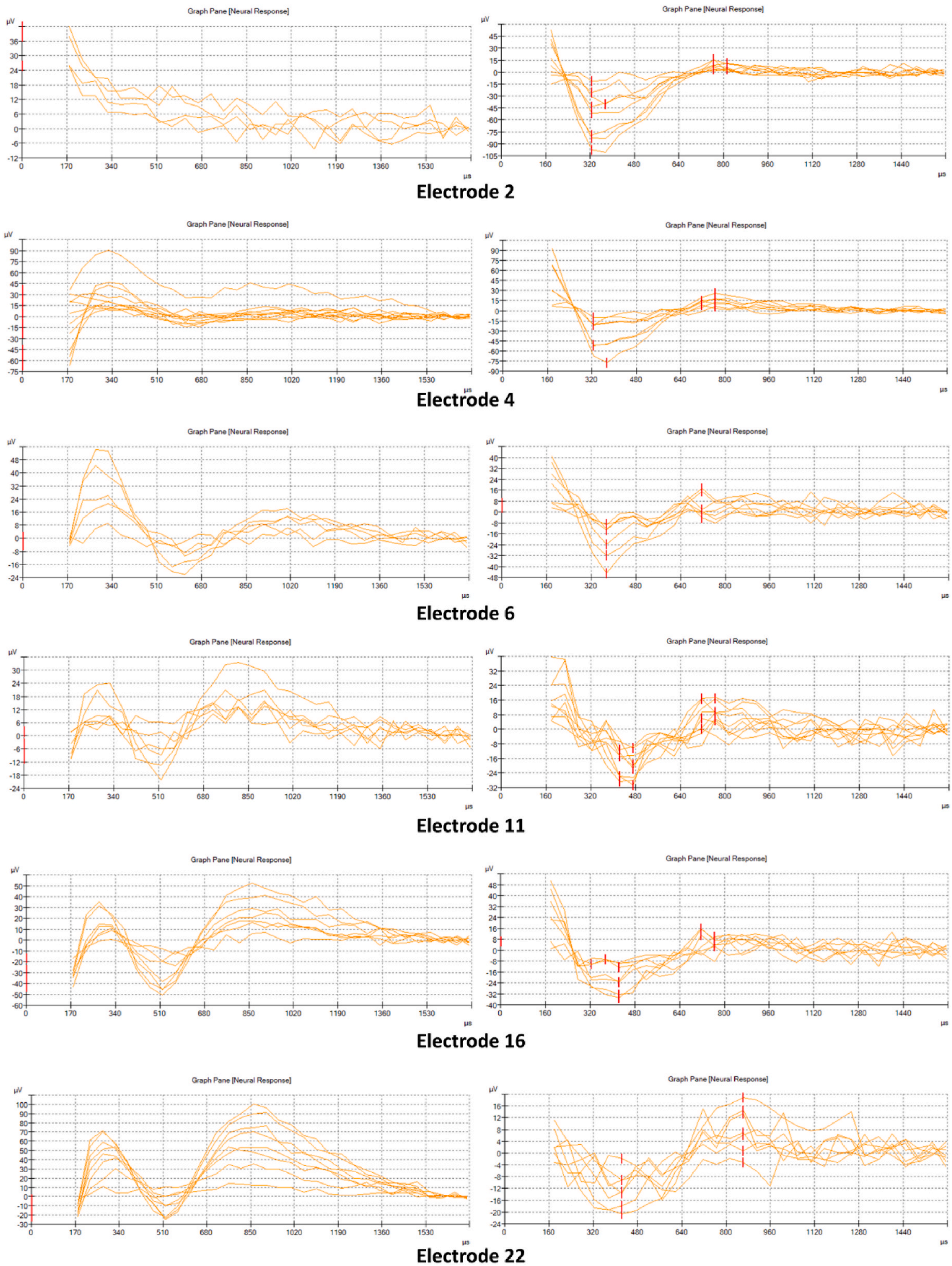

Fig. 5. NRT responses before the revision surgery (Left); NRT responses obtained during implant re-activation after the revision surgery (Right).

patient's functional speech performance and raises concerns about relying on intraoperative imaging and NRT responses to confirm correct electrode array placement.

The measurement of electrode impedance and electrically evoked action potential serves to assess various aspects, such as the integrity of the electrode array, the status of interface contact between the electrode and the tissue, and neural responsiveness. While abnormal recordings may suggest implant failure, this case emphasizes that the presence of NRT responses does not indicate normalcy. Upon retrospectively analysing the actual NRT traces, the team observed subtle differences in responses between the misplaced and correctly placed electrode arrays. The traces exhibited similarities to neural responses reported by Pau et al. (2009) and Ramos de Miguel et al. (2017) for electrode placement within the vestibule. The NRT traces showed a negative peak (N1) followed by a positive peak (P1) at around 800 μs after stimulation, resembling cochlear action potentials. The NRT traces obtained before the revision surgery suggested possible overloading of the measurement amplifier due to unoptimized parameters used during the measurements (Ramos de Miguel et al., 2017). Not all electrodes selected for NRT measurements elicited neural responses, only the more apical electrodes exhibited N1 and P1 peaks. The observed amplitudes of the action potentials evoked by these electrodes appeared larger than typical cochlear action potentials and seemed to increase with higher stimulation intensities.

The patient's ability to detect sounds and achieve favourable results in aided tone audiometry also does not necessarily indicate the accurate placement of the electrodes within the cochlea. It is possible that the high stimulation intensity led to the spread of current beyond the vestibule. Past studies have demonstrated that electrical current can spread from cochlear implants to the periphery and the vestibular system (Parkes et al., 2017; Tran et al., 2015). Conversely, it is also possible for current to spread from the vestibule to the cochlea, which could account for why the patient still detected sounds and performed relatively well in aided tone audiometry. The spread of current may also explain why the patient only detected sounds in the Monopolar1+2 and Monopolar2 stimulation modes, but not in the Monopolar1 mode, as different stimulation modes influence the pathway of current within the labyrinthine structure.

There is one additional noteworthy aspect in this case that merits discussion. The patient experienced vibrotactile sensation or occasional subtle jolts in his head as the stimulation intensity increased and crossed a threshold. This sensation is not typically observed in other cochlear implant recipients. One possible explanation for the head jolt could be related to the stimulation of the otoliths. It is known there are otolith projections to the neck muscles, which elicit reflexive head movement (Rosengren and Colebatch, 2018).

Cochlear implant electrode misplacement is a rare but serious and avoidable complication of cochlear implantation. This case study emphasizes the importance of surgeons remaining vigilant to the possibility of electrode array misplacement, even in the presence of normal anatomy or uncomplicated insertions. New techniques offered by implant companies provide real-time feedback on electrode insertion during surgery. Advances in Neural Response Telemetry (NRT) monitoring, such as Transimpedance Matrixes (TIMS), offer a 'heat map' of the electrodes inserted, which may alert the surgeon to potential misplacements. Intra-operative cone-beam CT can confirm electrode placement, but it can be technically challenging to perform and is not widely available in cochlear implant operating rooms. Ultimately, when surgical outcomes are poorer than expected, the surgeon should promptly consider re-evaluating the electrode position.

4. Conclusion

Our case report illustrates the possibility of electrode array misplacement without clear clinical warning signs (e.g., vestibular symptoms). The patient described in this case was found to have otolithic or saccular weakness during vestibular testing, which explained the absence of vestibular symptoms despite the electrode being misplaced in the vestibule. The presence of NRT responses and good-aided tone audiometry do not necessarily indicate correct electrode placement. Clinicians should maintain a high level of suspicion and call for further investigation, such as device integrity testing or a CT scan if patients do not show progress with the device. This is especially crucial when the anatomical structure of the labyrinthine and internal auditory meatus is normal, and the recipients are also motivated to use the device and comply with aural rehabilitation.

Author contribution

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Availability of data and materials

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

Declaration of competing interests

The authors declare that they have no competing interests. This study has no grant of funding.

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