



Original Article

Electrode Misdirection into the Superior Semicircular Canal: Complication of Cochlear Implantation by Round Window Approach

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OBJECTIVE: The purposes of this study were to investigate the misdirection of the electrode into the superior semicircular canal during cochlear implantation and to suggest surgical principles for correct electrode insertion through the round window membrane.

MATERIALS and METHODS: In this retrospective case review, operative records and postoperative images of cochlear implantations performed at a tertiary care facility from 1988 to 2010 were reviewed.

RESULTS: In 3 out of 629 cases, electrode insertion into the superior semicircular canal was found. All 3 cases occurred in cochlear implantations using the round window approach, and none was found when using the cochleostomy approach. Insufficient exposure of the round window membrane and intra-cochlear soft tissue were regarded as the cause of misdirection of the electrode. The electrodes were repositioned appropriately into the cochlea with revision surgery in all 3 cases.

CONCLUSION: In order to prevent electrode misdirection during cochlear implantation through the round window, the round window membrane needs to be clearly visualized by sufficiently drilling bony overhangs and removing soft tissues around the round window.

KEY WORDS: Cochlear implant, superior semicircular canal, electrode misinsertion, round window approach

INTRODUCTION

As the number of cochlear implantations has increased, various complications have occurred in recent years. Overall complication rates requiring revision surgery vary from 3.8% to 5.1%, and a misplaced electrode is reported to be one of the most common major complications, next to device failure^[1,2]. Previous case reports have described misplaced electrodes in the vestibule or semicircular canals. They have suggested inner ear anomalies, cochlear ossification due to otosclerosis or labyrinthitis and inappropriate location of cochleostomy as possible causes of misplaced electrodes^[3,4].

With the greater emphasis on the preservation of residual hearing, minimally invasive procedures have received particular attention in cochlear implantation. Among those methods, electrode insertion through the round window membrane has been commonly used^[5,6]. Compared to the traditional cochleostomy approach, the round window approach is known to achieve more perimodiolar and deeper insertion of the electrode into the cochlea^[6]. Electrode insertion through the round window membrane also reduces the amount of bone drilling and therefore minimizes the risk of structural damage to the inner ear. Previous studies have suggested that insertions through the round window membrane might be more effective and less arbitrary than traditional cochleostomy^[7,8]. In addition, a greater number of spiral ganglion at the basal region of the cochlea can be stimulated by insertion through the round window membrane compared to the conventional cochleostomy approach^[9]. Despite these advantages, the round window approach is not always performed easily. Exposure of the round window membrane is difficult through posterior tympanotomy in some cases, and electrode insertion into the scala tympani is not always achieved successfully, depending on the type of electrode. Therefore, the round window approach should be performed with caution, taking care of some aspects that may interfere with the appropriate insertion of the electrode into the scala tympani and lead to misplacement.

The purposes of this study were to investigate the misdirection of the electrode into the superior semicircular canal in cochlea implantation and to suggest surgical principles for correct electrode insertion through the round window membrane.

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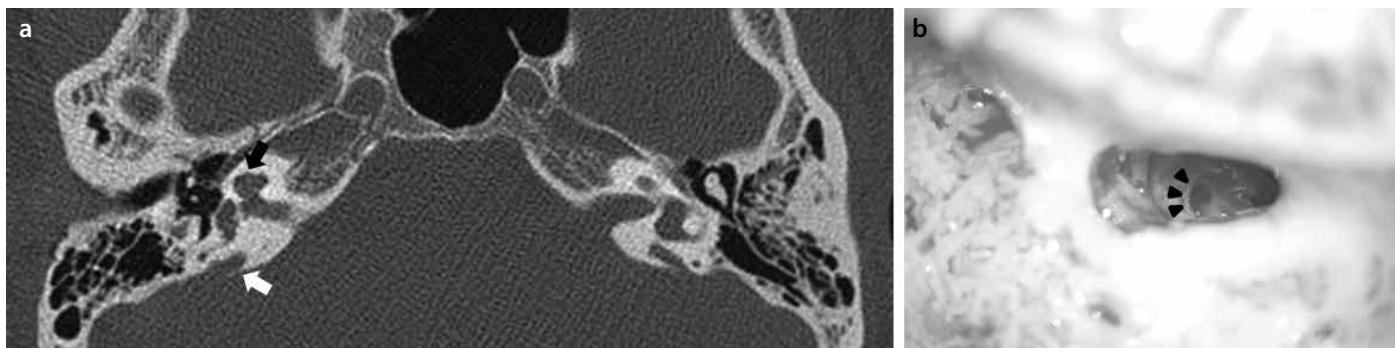


Figure 1. a, b. Temporal bone computed tomography in Case 1. Enlarged vestibular aqueducts (white arrows) with cochlea dysplasia (black arrow) are observed (a). Surgical findings in the first implantation. The round window is seen through the facial recess, but superior bony overhangs (black arrowheads) of the round window niche prevent visualization of the margin of the round window membrane (b)

MATERIALS and METHODS

Study Design and Patients

This study is a chart review of medical records of 629 cases of cochlear implantation performed at Severance Hospital, Seoul, Korea from 1988 to 2010. Operation notes and images were reviewed to identify patients who had undergone revision cochlear implantation surgery because of a misdirected electrode in the vestibular organ. No ethics committee approval was received as this study was a chart review of case series.

RESULTS

In 3 out of 629 cases (0.5%), electrode misdirection to the superior semicircular canal was identified. All 3 cases were related to the round window approach. Of these cases, 2 cases resulted in electrode misinsertion during the primary implantation surgery using a Nucleus device (Cochlear, Sydney, Australia). In the other case, misdirection occurred during revision implantation after the device failure of a Clarion device (Advanced Bionics, Stäfa, Switzerland).

After revision surgery, electrodes were placed appropriately in all cases. All patients showed favorable audiological performance postoperatively.

Case Studies

Case 1

A 20-year-old female presented with bilateral hearing impairment for more than 15 years. Her parents mentioned that her hearing impairment had developed when she ran a fever at the age of 4. She had no history of medical diseases, and other family members had normal hearing. Hearing aids had been tried until that time, and she was making a living by doing design work after graduating from high school.

Pure tone audiogram revealed hearing thresholds of 110 dB and 105 dB in the right and left ear, respectively, and an air-bone gap of approximately 40 dB was noted at frequencies lower than 1 kHz. Speech discrimination scores were 0 on both sides. She could detect only environmental sounds, which is equivalent to a CAP score of 1. However, her speech production capability was nearly normal for her age. Temporal bone computed tomography (CT) scans showed enlarged vestibular aqueducts on both sides, which could explain the conductive component seen at lower frequencies (Figure 1A). Cochlear implan-

tation (Nucleus CI24R (Cochlear, Sydney, Australia)) was performed in her right ear. After a regular mastoidectomy with posterior tympanotomy, the round window membrane was clearly defined. The electrode was inserted after membrane incision by using a sickle knife without bony drilling (Figure 1B). After implantation, she suffered from vertigo. A postoperative X-ray revealed a misdirected electrode (Figure 2A), and the tip of the electrode was found to be situated in the superior semicircular canal. In the revision surgery, bony drilling around the round window niche was performed until the margin of the round window membrane and the basilar membrane were exposed clearly. The previous electrode was reinserted in the direction from posterior-superior to anterior-inferior. Appropriate insertion of the electrode into the cochlea was confirmed by postoperative X-ray (Figure 2B). A postoperative vestibular function study showed the disappearance of cervical vestibular evoked myogenic potential (cVEMP) (Figure 3), whereas caloric responses remained unchanged. Dizziness subsided in several days with conservative management.

Case 2

A 28-year-old male presented with malfunction of the device for several months. An integrity test showed the failure of a previously implanted Clarion Hires 90K device (Advanced Bionics, Stafa, Switzerland). He had received a cochlear implantation in his left ear 6 years ago due to bilateral idiopathic sudden sensorineural hearing loss, which developed 3 years before the surgery. According to the medical records, the electrode had been inserted directly through the round window without bony drilling in the first surgery. A postoperative X-ray showed appropriate electrode insertion, and the device had worked properly for 5 years.

During the revision surgery, the skin flap was elevated carefully, and the internal device was removed after cutting the electrode instead of pulling it out from the cochlea. After positioning a new internal device, the previously inserted electrode was gently removed. Intracochlear soft tissue was observed. A new electrode was inserted following the path of least resistance. Postoperatively, the patient complained of neither headache nor dizziness. However, a radiographic study showed a misdirected electrode to the superior semicircular canal (Figure 4).

In the third surgery, an intracochlear obstruction with fibrous tissue was observed after electrode removal. Soft tissue around the round window was removed, and the electrode was reinserted after bony drilling of the posterior-superior portion of the round window niche.

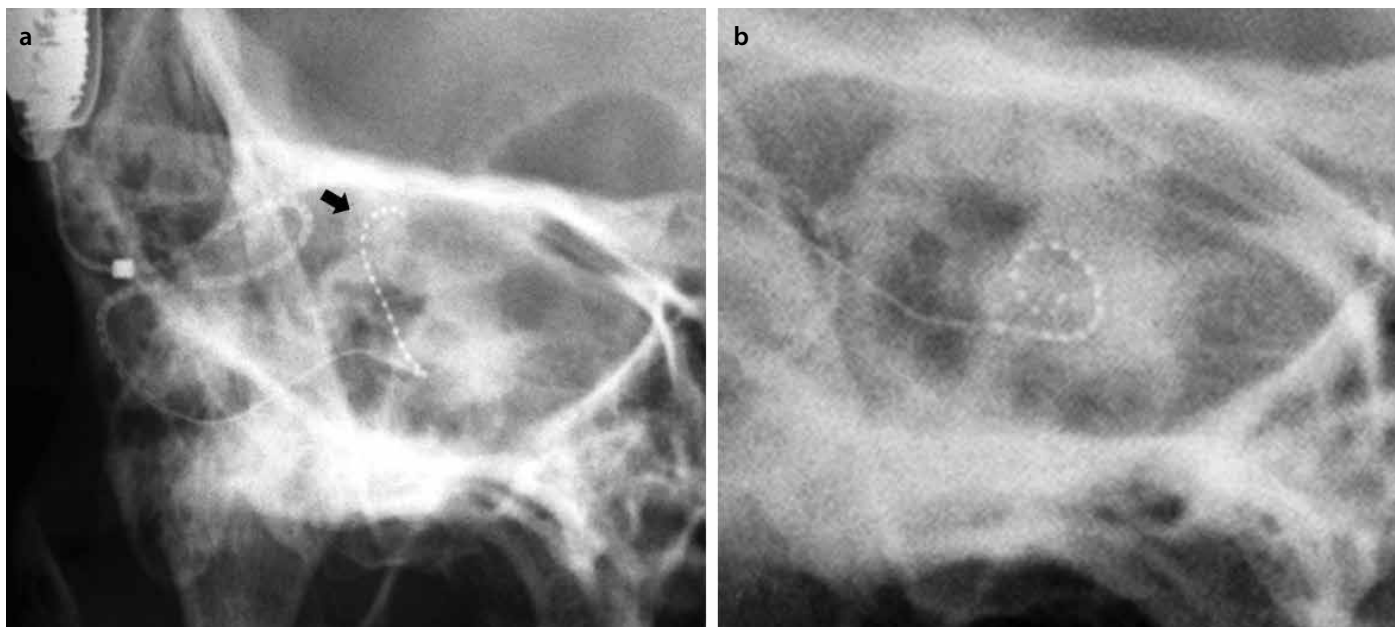


Figure 2. a, b. Modified Stenver's views in Case 1. The electrode is located in the superior semicircular canal after the first implantation (arrow) (a), and it is repositioned into the cochlea after the second operation (b)

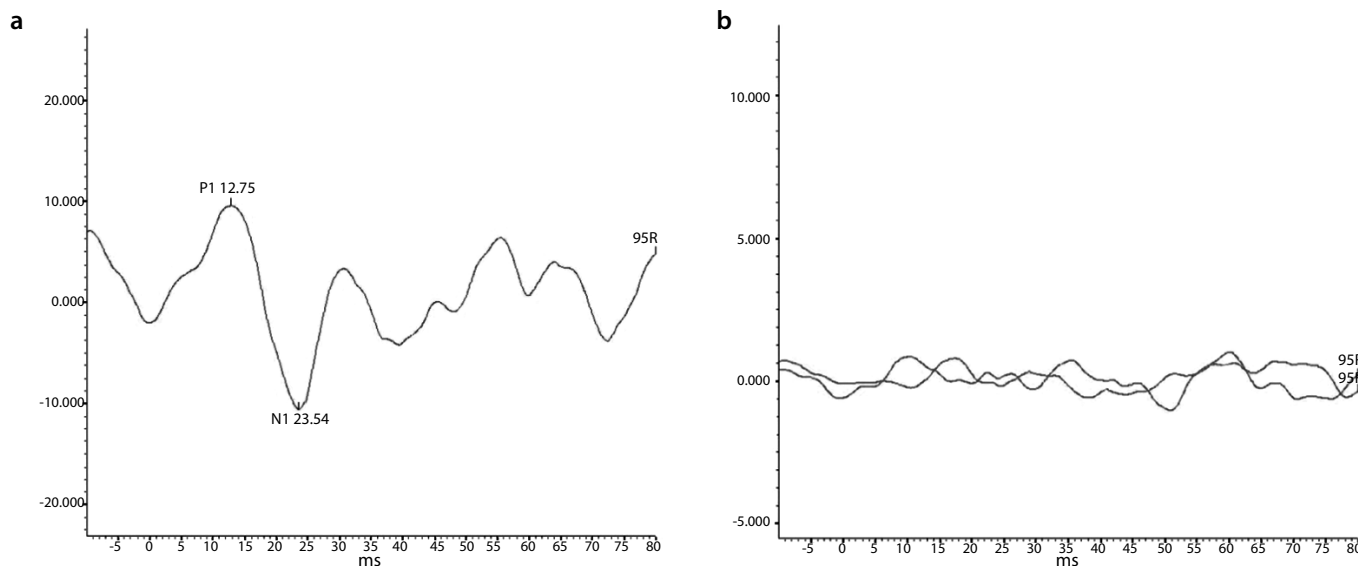


Figure 3. a, b. Preoperative (a) and postoperative (b) cervical vestibular evoked myogenic potential (VEMP) in Case 1. The VEMP response disappeared after the first cochlear implantation

Case 3

A 7-year-old female presented with prelingual deafness. She had been wearing hearing aids on both ears since the age of 2. There were no abnormal inner ear findings on the temporal bone CT. Cochlear implantation was performed with a Nucleus CI24R device (Cochlear, Sydney, Australia). The electrode was fully inserted through the round window without bony drilling. After the operation, we identified the misplaced electrode by radiograph and postoperative CT. Reinsertion of the electrode was done on the following day (Figure 5). In the revision surgery, drilling around the round window niche and identification of the margin of round window were performed antecedently for correct insertion of the electrode. The patient was discharged without any specific complications after 1 week.

DISCUSSION

The round window membrane is surrounded by bony overhangs of the round window niche, which is highly variable in its morphology. It can not be fully exposed without drilling of the bony overhangs, because its size and orientation of the opening vary [10]. One study showed that drilling the niche overhangs increases the visible surface area of the membrane by a factor of 1.5 to 3 times and, on top of that, demonstrated by cadaveric temporal bone dissection that drilling of the antero-inferior margin of the round window membrane provided unrestricted access of the electrode to the scala tympani [11].

In our cases, the electrodes were misdirected at the round window membrane and inserted into the scala vestibuli by piercing the basilar membrane. It eventually entered the vestibule and passed into the

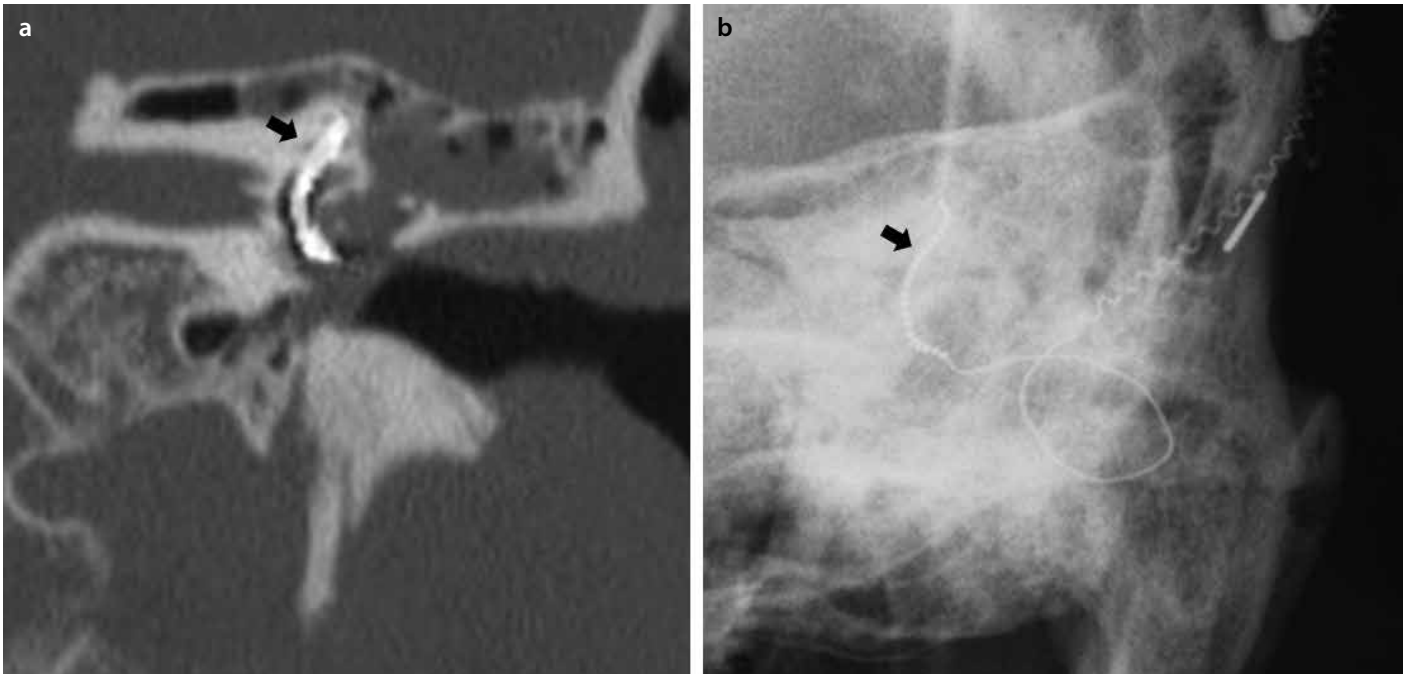


Figure 4. a, b. Postoperative images in Case 2. Electrode malposition in the superior semicircular canal (arrow) is observed in the coronal view of temporal bone computed tomography (a) and in the modified Stenver's view (b)



Figure 5. Postoperative temporal bone computed tomography in Case 3. Electrode is inserted in the superior semicircular canal

superior semicircular canal, which might explain the disappearance of VEMP. The misplacement is thought to be due to the inadequate identification of the round window membrane. The round window varies in size and shape and so does its bony margin^[10,11]. Bony overhangs or intracochlear obstructive structures can result in the misguiding of the electrode toward the basilar membrane and not along the scala tympani, as in our cases. Drilling of the bony overhangs and exposing the whole round window membrane can prevent this mistake.

These findings suggest several surgical principles for correct electrode insertion through the round window membrane. First, this ap-

proach requires a large posterior tympanotomy for sufficient exposure of the round window through the facial recess. Second, any soft tissue, including middle ear mucosa, should be removed around the round window. This allows better visualization of the round window membrane. Third, it is necessary to remove the bony structure of the round window niche. Occasionally, the margin of the round window membrane may be seen clearly; thus, surgeons are tempted to insert electrodes without drilling. However, removal of bony overhangs is helpful in identifying the whole margin of the round window membrane. Furthermore, bony drilling can allow an adequate insertion angle of the electrode, so that it helps the electrode enter the scala tympani correctly from the superior-posterior to inferior-anterior direction. For atraumatic electrode insertion, drilling is necessary not only at the anterior-inferior bony portion but also at the superior bony overhangs of the round window (Figure 6). Fourth, especially in revision cases, intracochlear soft tissue around the round window should be removed so that it does not block the scala tympani and mislead the electrode to the vestibule, as in our second case.

During the round window approach, an improper insertion angle of the electrodes may result in the misdirection of them into vestibule and semicircular canals. Especially, a flexible tip, recently developed for the round window approach, can cause this more easily.^[4] On the other hand, in the cochleostomy approach, inappropriate cochleostomy can lead to the misinsertion of electrodes into the middle ear cavity, Eustachian tube, and hypotympanum, even extending into the internal carotid canal.^[12] However, unless surgical landmarks (i.e., oval window, round window, and promontory) are fully identified before insertion, misplacement of electrodes can occur into various locations, regardless of approach.

We experienced 3 cases of electrode malposition in the semicircular canal. Even though cochlear implantation through the round window is potentially less traumatic than the traditional cochleostomy approach, it requires careful confirmation of the round win-

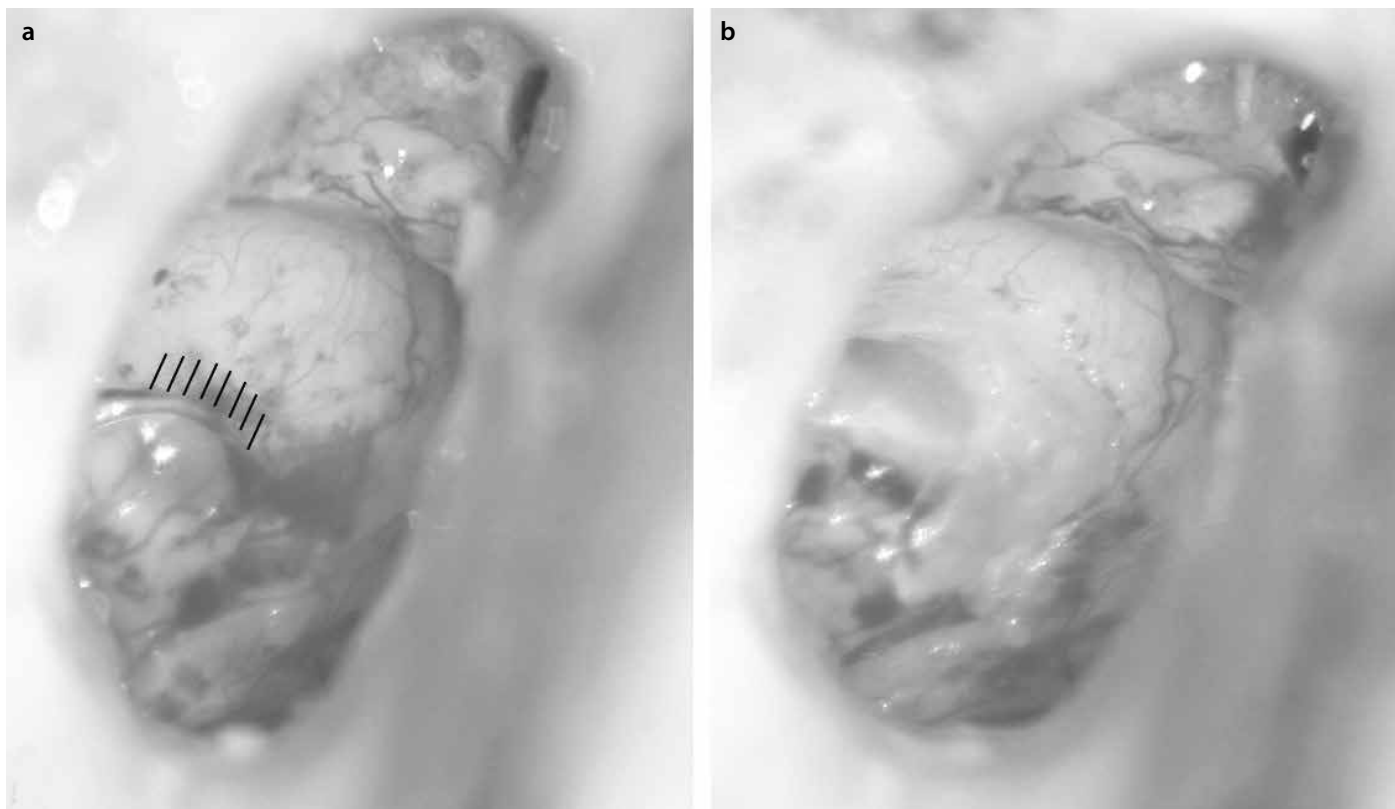


Figure 6. a, b. Exposure of the round window membrane before (a) and after (b) removing the superior and posterior bony overhangs around the round window niche (lined area)

dow membrane for correct insertion of the electrode into the scala tympani. By sufficiently drilling away the bony overhangs around the round window and removing soft tissues formed by previous implantation, surgeons can identify the exact margin of the round window and obtain an adequate insertion angle for the electrode.

Ethics Committee Approval: No approval was received as this study was a chart review of case series.

Peer-review: Externally peer-reviewed.

Informed Consent: No written informed consent was obtained as this was a case series without recognizable photographs of patient.

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