
Pictorial Review

Cochlear Implant Failure: Imaging Evaluation of the Electrode Course

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Cochlear implant (CI) is an electronic device used to rehabilitate patients with sensorineural hearing loss. The intent of this review is to demonstrate the normal position of the electrode on computed tomography (CT) and contrast this with various examples of the electrode malpositioning. Post-implantation CT is performed to localize the cause of implant failure in patients in which radiographs suggest an anomalous course of the electrode. A common cause of device failure is extrusion or malpositioning of the electrode. It is important for the radiologists to recognize this important aspect of device failure. Post-implant CT can help identify patients with malpositioned electrode in whom another attempt can be made by correctly re-implanting the electrode. Jain R., Mukherji S. K. (2003). *Clinical Radiology* **58**, 288–293.

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Key words: cochlear implant, CT, complications, hearing loss, implant failure.

INTRODUCTION

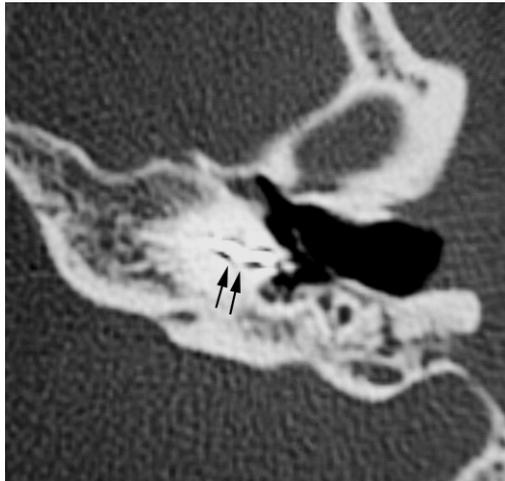
A cochlear implant (CI) is an electronic device used to rehabilitate patients with sensorineural hearing loss. It provides direct stimulation of the residual spiral ganglion cells of the cochlear nerve bypassing the destroyed hair cells. Cochlear implantation is a safe and reliable otosurgical procedure with significant benefit to patients in terms of enhancement of communication skills and quality of life. The reported rate of severe complications is low when compared with other otosurgical procedures [1]. Pre-CI imaging evaluation includes both computed tomography (CT) and magnetic resonance (MR) to determine patients with contraindications for cochlear implantation, as well as to guide the choice of the device and surgical approach. The key point is to identify patients with congenital absence or severe hypoplasia of the cochlear nerve or the cochlea, which is a contraindication for cochlear implant on that particular side. Status of the membranous labyrinth, aeration of the mastoid and the middle ear cavity, course of the

facial nerve and exclusion of a vascular anomaly of the carotid artery or the jugular bulb are other important features of the pre-surgical assessment. Post-surgical radiographic evaluation of the implant is done with plain radiographs (profile and modified Stenver's views) to depict the course and positioning

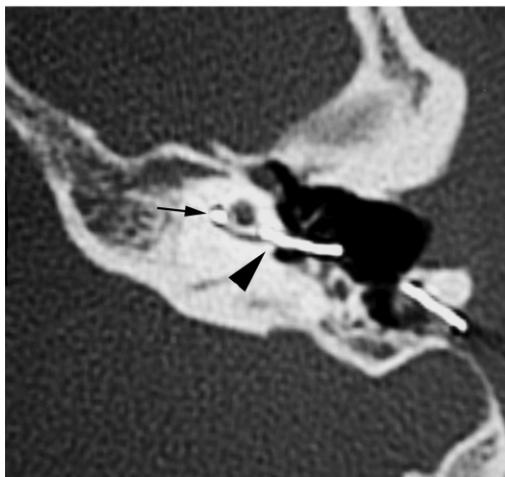


Fig. 1 – Skull radiograph showing the normal implant electrode positioning. Electrode in the basal turn (double black arrows) and its tip in the middle turn of cochlea (single black arrow). Cochlear implant device (single white arrow).

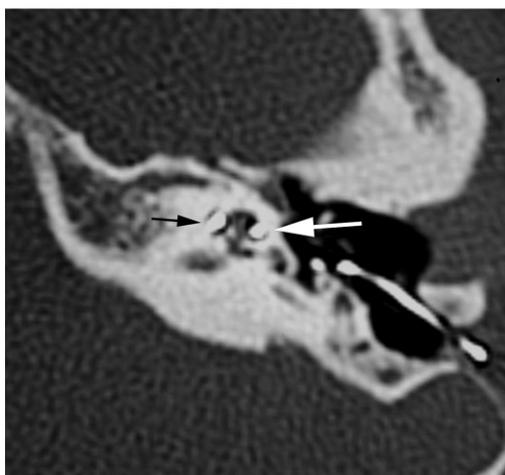
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(a)



(b)



(c)

Fig. 2 – Axial CT showing the normal electrode positioning. (a) Electrode in the basal turn of cochlea (double arrows), (b) electrode entering the round window (arrowhead) and (c) electrode in the proximal part of basal turn (single black arrow) and at the junction of basal and middle turns (single white arrow).

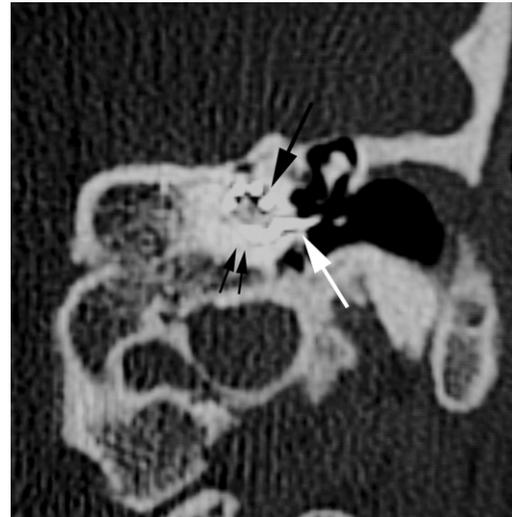


Fig. 3 – Coronal CT showing the normal electrode positioning. Electrode entering the round window (single white arrow), coursing through the basal turn (double black arrows) and its tip in the middle turn of cochlea (single black arrow).

of the electrode array, which also serves as a baseline for further comparisons. High resolution CT (HRCT) is performed to localize the cause of implant failure in patients in which plain radiographs suggest an anomalous course of the electrode. A common cause of device failure is extrusion or malpositioning of the electrode. MR imaging has been contraindicated in patients with cochlear implants due to concerns regarding torque, force, demagnetization, artefacts, induced voltages and heating. However, preliminary experiments with Med-El Combi 40 + cochlear implants in cadavers and patients using a 0.2 T unit have shown some promising results [2].

The intent of this pictorial review is to demonstrate the normal position of the electrode on CT and compare this with various examples of electrode malpositioning. We will demonstrate examples of electrode coiled into the middle ear cavity or mastoid bowl, incomplete or incorrect insertion of the electrode in the cochlea, electrode malpositioned into the cochlear aqueduct, petrous carotid canal, eustachian tube, and electrode abutting the labyrinthine part of the facial nerve.

CASE MATERIAL

The surgical procedure usually performed for cochlear implantation is a canal wall-up mastoidectomy. The facial recess cells are opened into the middle ear cavity, thereby, allowing surgical access to the round window. The electrode is advanced into the basal turn of cochlea either directly through the round window or via a cochleostomy. The electrode is advanced into scala tympani for approximately one and a half turns or for a distance of 20–24 mm (Figs 1–3). Patients functioning with more than 15 active electrodes perform better on auditory tests than patients with fewer active electrodes [3].

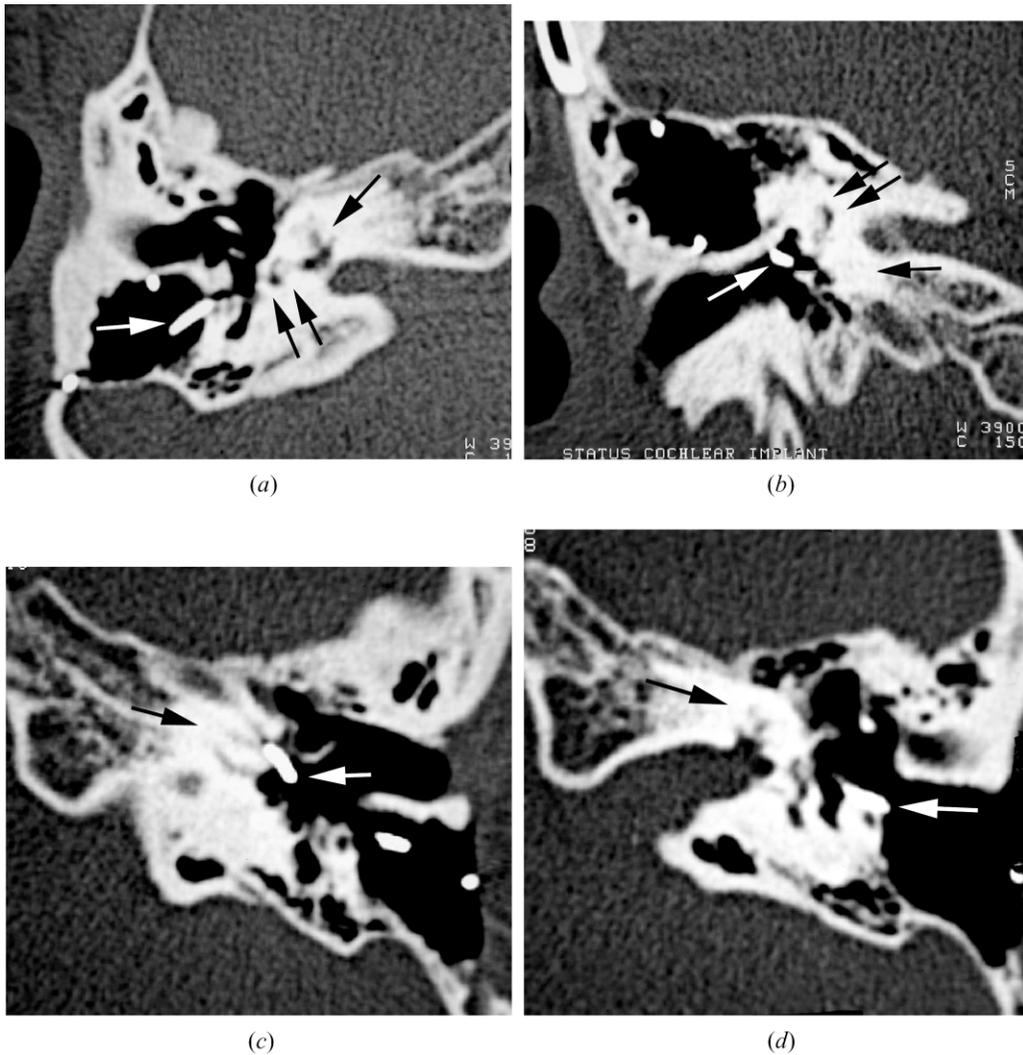


Fig. 4 – Case 1. (a) Axial and (b) coronal CT of right temporal bone showing complete ossification of the cochlea (single black arrow) and the vestibule (double black arrows). The electrode is not entering the basal turn of cochlea and is rather coiled in the middle ear cavity and mastoid bowl (single white arrow). (c) And (d) axial CT of left temporal bone in the same patient showing the electrode (single white arrow) in the middle ear cavity and not entering the ossified cochlea (single black arrow).

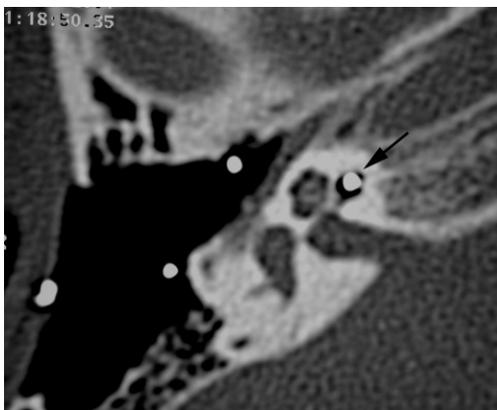
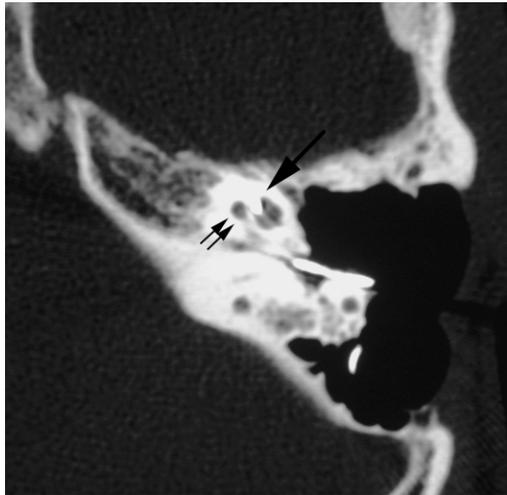


Fig. 5 – Case 2. Axial CT showing incomplete insertion of the electrode with its tip (single arrow) ending in the proximal part of the basal turn rather than in the middle turn.

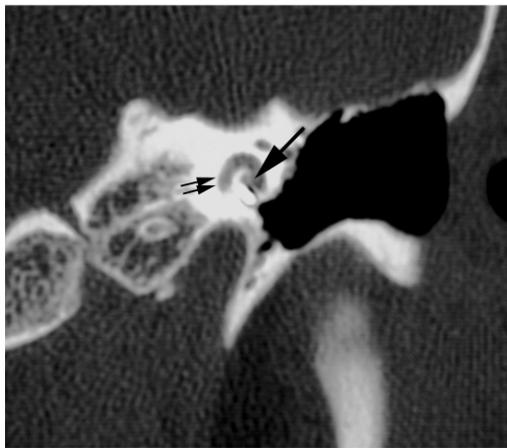
Electrode Coiling into the Middle Ear Cavity and Mastoid Bowl

Case 1

The electrode was seen coiled into the middle ear cavity and mastoid bowl on both the sides (Fig. 4). It could not be advanced into the cochlea on either side. The patient had bilateral post-meningitis ossification of the membranous labyrinth identified on CT. Cochlear ossification is not a true contraindication to implantation as a significant number of spiral ganglion cells survive even in case of severe ossification, however, it complicates electrode insertion. Post-meningitis labyrinthitis ossificans and otosclerosis are the most common causes of device failure related to abnormal electrode insertion apart from the experience of the operating surgeon [3,4]. Multiple



(a)



(b)

Fig. 6 – Case 3. (a) Axial and (b) coronal CT showing the electrode entering the middle turn of cochlea (single arrow) by piercing the bony septum between the basal and the middle turns rather than coursing through the whole of the basal turn (double arrows).

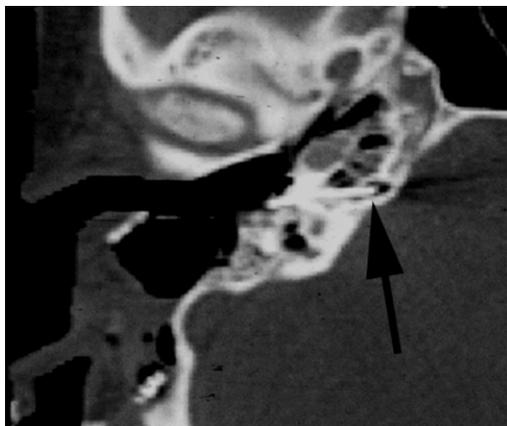
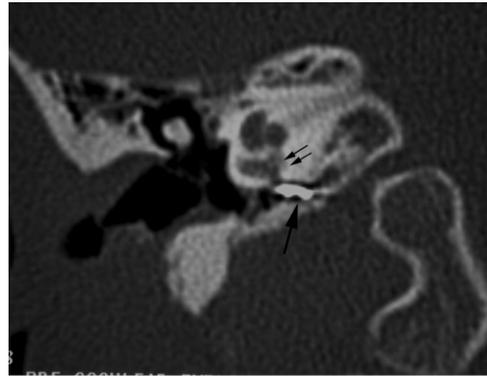


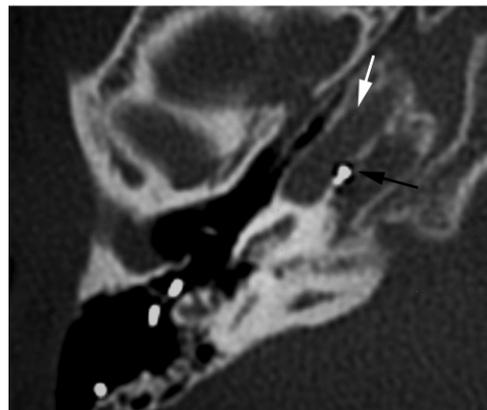
Fig. 7 – Case 4. Axial CT showing the electrode malpositioned into the cochlear aqueduct (single arrow).



(a)



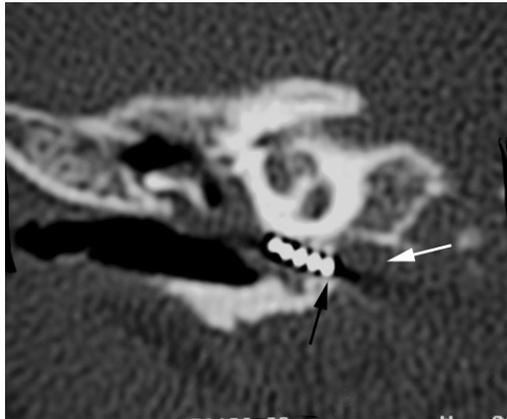
(b)



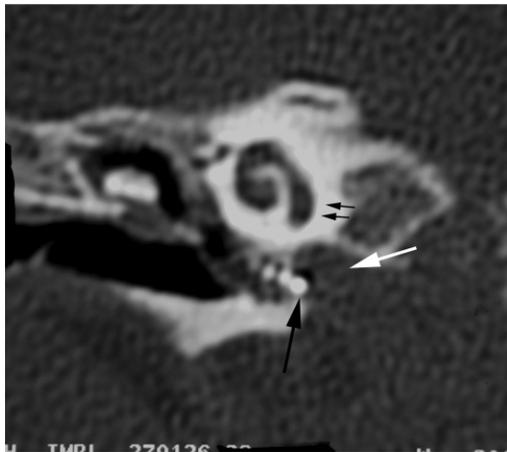
(c)

Fig. 8 – Case 5. (a) Coronal CT showing the electrode (single black arrow) missing the basal turn of cochlea (double black arrows). (b) And (c) axial CT showing the electrode (double black arrows) coursing postero-medial to the petrous carotid canal (single white arrow) before piercing the medial wall of carotid canal (single black arrow).

electrodes can be inserted by antero-inferior transpromontory cochleostomies in these patients. However, pre-implant plain films and HRCT cannot detect ossification in all patients. In one series, the ossification was found surgically in 40% of the cases and plain films were falsely negative in 27% while CT was falsely negative in 22% [5]. Therefore, many authors recommend pre-implant evaluation



(a)



(b)

Fig. 9 – Case 6. (a) And (b) coronal CT showing the electrode (single black arrow) lying inferior to the basal turn of cochlea (double black arrows) and directly abutting the junction of the vertical and horizontal segments of the petrous carotid artery (single white arrow) after piercing the bony septum.

with heavily T2-weighted MR images to detect any fibrosis or ossification not identified on CT in patients with post-meningitis deafness.

Incomplete Insertion of the Electrode

Case 2

The electrode was inserted through the round window, however, it could not be advanced completely (Fig. 5) due to surgically confirmed ossification in the proximal part of the basal turn. The patient presented with device failure, as the length of the electrode in the scala tympani was insufficient to obtain a properly functioning CI. The ossification was not detected on pre-implant CT.

Electrode Piercing the Interscalar Septum

Case 3

CT evaluation performed for device failure revealed that the

electrode entered the round window and directly extruded through the interscalar septum into the middle turn of cochlea rather than coursing the whole length of the basal turn (Fig. 6). The length of the electrode in the scala tympani was less than what is normally required for an active CI.

Electrode in the Cochlear Aqueduct

Case 4

The tip of the electrode was seen extending directly into the cochlear aqueduct (Fig. 7). The surgeon attempted to place the electrode directly through the round window rather than through a cochleostomy. The implant was removed without complications though the patient was at risk for developing cerebrospinal fluid (CSF) gusher syndrome. A “gusher” or rapid, profuse flow of CSF immediately upon entering the vestibule may be encountered occasionally, particularly in patients with anomalies such as enlarged vestibular aqueduct syndrome, common cavity, and wide internal auditory canal syndrome. These complications are best managed by packing the round window with fascia after implant insertion.

Electrode in the Carotid Canal

Cases 5 and 6

The tip of the electrode was identified in the petrous carotid canal in both patients. The petrous carotid artery is the closest to the cochlea at the junction of its vertical and horizontal segments. The bony septum between the cochlea and the carotid canal has been reported to be as thin as 0.2 mm [6,7]. This close proximity of the carotid artery to the basal turn becomes critical in cochlear drill-out procedure in patients with labyrinthitis ossificans. The carotid canal has a potential space as it also contains areolar tissue, venous plexus and parasympathetic nerves apart from the carotid artery, which can give a false sense of lack of resistance similar to the cochlea [8,9]. In case 5, the electrode travelled approximately 6–7 mm on the outside of the medial wall of carotid canal before piercing the medial bony wall (Fig. 8). In case 6, the electrode was seen tangentially missing the basal turn and pierce the bony septum close to the junction of vertical and horizontal segments of the petrous carotid artery (Fig. 9).

Electrode Entering the Eustachian Tube

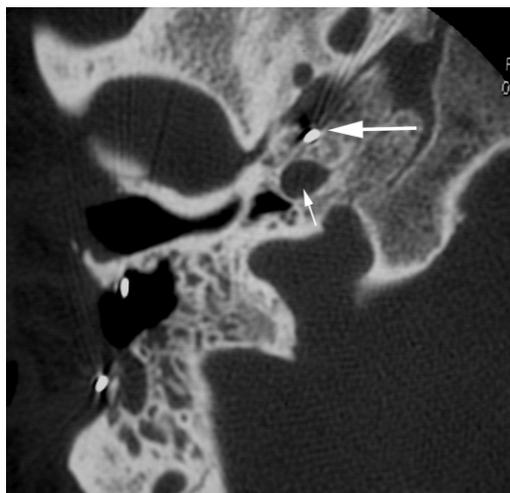
Case 7

The electrode was seen entering the opening of the eustachian tube in the antero-inferior portion of the middle ear cavity (pro-tympanum). The electrode coursed through the eustachian tube and its tip was seen below the skull base in the nasopharynx (Fig. 10).

Electrode Abutting the Facial Nerve

Case 8

The tip of the electrode was seen abutting the labyrinthine part of the facial nerve. The patient complained of facial



(a)



(b)

Fig. 10 – Case 7. (a) Axial CT showing the electrode in the eustachian tube (large white arrow) anterior to the carotid canal (small white arrow). (b) Coronal CT showing the tip of the electrode projecting into the nasopharynx (white arrow) through the eustachian tube.

twitching after cochlear device implantation. The distance between the basal turn of cochlea and the facial nerve is less than 0.5 mm and because of this close proximity the facial nerve trunk can be stimulated by electric signals from the implanted electrode [7]. In our case, however, the electrode was directly abutting the labyrinthine part rather than just stimulating the facial nerve due to the close proximity (Fig. 11). Facial nerve stimulation was seen in 3% of children in one study, most of who had post-meningitis deafness [1]. In adults this phenomenon occurs mainly in patients with otosclerosis or otospongiosis and is thought to be due to bone demineralization [10,11].

CONCLUSION

In summary, cochlear implantation is a safe surgical

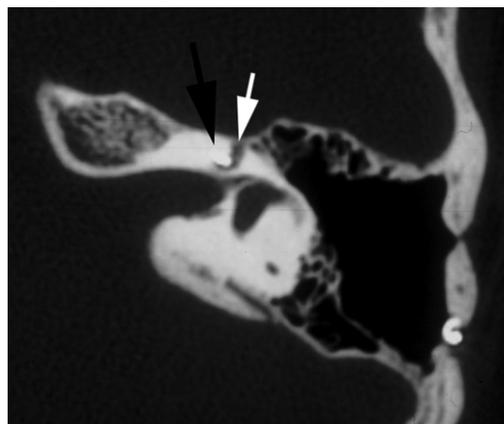


Fig. 11 – Case 8. Axial CT showing the electrode (black arrow) abutting the labyrinthine part of the facial nerve (white arrow).

procedure with good results in terms of overall hearing improvement. However, due to very small distances between the cochlea and the adjacent structures, malpositioning of the electrode may occur. It is important for the radiologists to recognize this important aspect of device failure. Post-implant CT can help differentiate patients with irreversible or refractory hearing loss, who do not improve despite the normally positioned electrode, from those with malpositioned electrode. In the latter group of patients another attempt can be made by correctly re-implanting the electrode.

REFERENCES

- 1 Kempf HG, Johann K, Lenarz T. Complications in pediatric cochlear implant surgery. *Eur Arch Otorhinolaryngol* 1999;256:128–132.
- 2 Smith WMM, Banks PA, Prost KL, Firszt RW, Jill B. Effect of MR imaging on internal magnetic strength in patients with Med-El cochlear implants. Presented at 36th annual meeting ASHNR 2002 Cleveland, Ohio, 11–15 September; 2002.
- 3 Proops DW, Stoddart RL, Donaldson I. Medical, surgical and audiological complications of the first 100 adult cochlear implant patients in Birmingham. *J Laryngol Otol* 1999;24(Suppl):14–17.
- 4 Marsot-Dupuch K, Meyer B. Cochlear implant assessment: imaging issues. *Eur J Radiol* 2001;40:119–132.
- 5 Luetje CM, Jackson K. Cochlear implants in children: what constitutes a complication? *Otolaryngol Head Neck Surg* 1997;117:243–247.
- 6 Muren C, Wadin K, Wilbrand HF. The cochlea and the carotid canal. *Acta Radiol* 1990;20:267–271.
- 7 Wysocki J, Skarzynski H. Distances between the cochlea and adjacent structures related to cochlear implant surgery. *Surg Radiol Anat* 1998; 20:267–271.
- 8 Gastman BR, Hirsch BE, Sando I, Fukui MB, Wargo ML. The potential risk of carotid injury in cochlear implant surgery. *Laryngoscope* 2002; 112:262–266.
- 9 Paullus WS, Pait TG, Rhoton AI, Jr. Microsurgical exposure of the petrous portion of the carotid artery. *J Neurosurg* 1977;47:713–726.
- 10 Muckle RP, Levine SC. Facial nerve stimulation produced by cochlear implants in patients with cochlear otosclerosis. *Am J Otol* 1994;15: 394–398.
- 11 Weber BP, Lenarz T, Battmer RD, Hartrampf R, Dahm M, Dietrich B. Otosclerosis and facial nerve stimulation. *Ann Otol Rhinol Laryngol* 1995;104:445–447.