Role of computed tomography and magnetic resonance imaging in the assessment of temporal bone pre-cochlear and postcochlear implantation

Tarek M. El-Zayat[a], Mohamed S. Elfeshawy[a], Ahmed H. Khashaba[b], Mohamed E.Abd El-Raouf[a]

Introduction Multidetector computed tomography (CT) and MRI play a critical role in the evaluation and management of different causes of hearing loss, which require many therapeutic techniques including cochlear implantation. Multidetector CT has proven its efficacy in the postoperative imaging of cochlear implant patients. CT confirms the intracochlear position of the implant. It has also been shown that malpositioning and kinking can be detected by CT imaging.

Aim of the work To evaluate the role of various imaging modalities (CT and MRI) in the preoperative and postoperative evaluation of cochlear implant candidates. Patients and methods The study included a total of 20 patients referred to the Radiodiagnosis Department from the ENT Department in Al Galaa Military Hospital. CT and MRI were performed for the assessment of the cochlear state before cochlear implantation operation. Postoperative CT was done to underline the position of the implanted electrode.

Setting and design This study involves prospective, randomized, controlled trials.

Ethics Informed consent from a parent or guardian.

Results This study included 20 patients with bilateral severe to profound sensorineural hearing loss. The study was performed on eight (40%) men and 12 (60%) women. Only 17 (85%) patients underwent cochlear implantation, the other three (15%) cases were diagnosed as Michel deformity, Cochlear hypoplasia, and Labyrinthine ossificans. Full electrode array insertion was reported in all cases who underwent cochlear implantation.

Conclusion Preoperative CT and MRI assessment is critical for determining implant candidacy. Postoperative CT confirms the intracochlear position of the implant.

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Keywords: cochlear implantation, computed tomography, magnetic resonance imaging, petrous, postoperative, preoperative, temporal bone

[a]Department of Radiodiagnosis, Faculty of Medicine (For Boys), Al-Azhar University, [b]Department Otorhinolaryngology, Military Medical Academy and Al Galaa Military Hospital, Cairo, Egypt

Correspondence to Dr. Mohamed Elfeshawy, MD, El Mahalla El Kobra, Gharbyia, Cairo, Egypt. Tel: +20 100 770 0167;
e-mail: mst1200@yahoo.com

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Introduction

The cochlear implant is a highly technological surgical device that is inserted in the cochlea of patients with severe to profound bilateral sensorineural hearing loss (SNHL) and that have not benefited from conventional sound amplification hearing aids [1].

Candidates for the cochlear implant undergo preoperative assessment involving clinical, speech therapeutic, psychological, social criteria, and imaging of the cochlear region to identify the etiology of hearing loss, findings that may contraindicate surgery and helping to select the ear to be implanted [2].

Cochlear implants aim to provide complex sound analysis by stimulating auditory cortex over a wide range of frequencies. To achieve this goal, the implant must be placed well within the cochlear lumen. Therefore, a detailed preoperative and postoperative radiological assessment of the temporal bone has become vital for cochlear implantation [3].

Multidetector computed tomography (MDCT) and MRI play a critical role in the evaluation and management of different causes of hearing loss, which require many therapeutic techniques including cochlear implantation [4].

Multislice CT has proven its efficacy in the postoperative imaging of cochlear implant patients. CT confirms the intracochlear position of the implant. It has also been shown that malpositioning and kinking can be detected by CT imaging [5].

Patients and methods

1. This study including 20 patients (eight men and 12 women) with severe to profound bilateral SNHL during the period from July 2017 to December 2018.

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(2) The age of the total sample ranged from 1 to 45 years, the mean age was 8.05 years.
(3) All patients were referred from the ENT Department of Al Galaa Military Hospital. CT and MRI were performed as part of preoperative assessment in the Radiodiagnosis Department.
(4) CT was done after cochlear implantation to ensure the intracochlear position of inserted electrode.
(5) Written consent was taken from patients to participate in this study. Along with ethical comity approval.
(6) Imaging for the pediatric population was performed under sedation or short-acting general anesthesia. Low-dose pediatric HRCT protocols are used to keep radiation doses to a minimum.

Patient selection (inclusion criteria)

(1) Patients with bilateral, severe to profound, prelinguistic or postlinguistic SNHL and who demonstrate limited benefit from amplification.
(2) Clinical and imaging evaluation were done to select those patients who will benefit the most from implantation.
(3) The decision to operate is made after a thorough evaluation by a multidisciplinary team.

Exclusion criteria

Active, middle ear disease, congenital aural dysplasia, and patients medically unfit for undergoing cochlear implantation.

Patient preparation

(1) Detailed history was taken from the parents/patient.
(2) Preoperative assessment involving clinical, speech therapeutic, psychological, social criteria, and imaging (CT and MRI) of the cochlear region.
(3) Detailed explanation of the procedure to the parents/patient.
(4) Obtaining informed consent from the parents/patient.

Computed tomographic imaging technique

(1) Imaging for the pediatrics population was performed under sedation or short-acting general anesthesia.
(2) All patients were examined by multiple detector computed tomography (MDCT) in supine with head first and then axial images were obtained from the top of the petrous apex to the inferior tip of the mastoid bone with the patient's neck semiflexed. The images were transferred to a workstation were multiplanar reformation (MPR) images were conducted for image analysis.
(3) All patients were examined by MDCT scanning using CT machines with 128 dual detector rows (Somatom Definition Edge; Siemens, Siemens Healthcare GmbH, Henkestr, Erlangen, Federal Republic of Germany)

The following parameters were used:

Detector	2×Stellar detector
Number of slices	2×128
Rotation time	0.28 s
Temporal resolution	75 ms, heart-rate independent
Generator power	200 kW (2×100 kW)
kV steps	70, 80, 100, 120, 140 kV
Isotropic resolution	0.33 mm
Cross-plane resolution	0.30 mm
Matrix	725×725
Field of view	200 mm
Window level	600
Window width	4000

Technique MRI

(1) All patients were examined by MRI scanning using (1.5 T GE Signa Explorer, 60 cm; GE).
(2) The ideal MRI scan would be short in duration and nonstrenuous for the patient and technician. It provides a high signal-to-nose ratio, and consistent signal intensities throughout the scan.
(3) Imaging for the pediatric population was performed under sedation or short-acting general anesthesia.
(4) For neuro-otologic MRI examinations, a standard head coil is used. Superficial coils that display the temporal bone in detail can also be used, but in order to also include the brain stem and brain it is necessary to switch to a standard head coil. Currently, multichannel coils that enable parallel imaging are used for this purpose.

MRI was performed with the following sequences:

Sequences	Axial T2	Axial and coronal T1	3D fast imaging employing steady-state acquisition (FIESTA)
TR	400 ms	400	8
TE	100 ms	9	4
Slice thickness	3 mm	2 mm	2 mm
Field of view	200×200 mm	160×160 mm	160×160 mm
Matrix	256×256	512×512	512×512

Computed tomography and magnetic resonance image analysis

Each case was assessed for:

1. Different abnormalities requiring cochlear implantation.
2. Congenital versus acquired lesions.
3. Whether cochlear implantation would be useful for the patient or not.

Postoperative multidetector computed tomography

Generation of two-dimensional reformations and three-dimensional reconstruction to visualize the electrode array within the cochlea or not.

Results

This study included 20 patients with bilateral severe to profound SNHL. The study was performed on eight (40%) men and 12 (60%) women. The age of the total sample ranged from 1 to 45 years, the mean age was 8.05 years.

Table 1 shows that in our study:

1. The most common age group is from 1 to 3 years representing 65% of cases.
2. Women were more affected than men representing 60% of the cases.

The patients were divided according to the onset of hearing loss into two main categories (Table 2): prelingual (deafness before the patients begin to speak) and postlingual (deafness after acquisition of speech).

Table 2 shows that:

1. The most common onset is the prelingual representing 60% of cases.

The patients were classified according to etiological factors of SNHL into two groups: congenital and acquired causes (Table 3).

Table 1 Distribution of patients according to their age and sex group

Age group (years)	*n* (%)	Males [*n* (%)]	Females [*n* (%)]
1–3	13 (65)	6 (46.2)	7 (53.8)
4–8	4 (20)	1 (25)	3 (75)
>8	3 (15)	1 (33.3)	2 (66.7)
Total	20 (100)	8 (40)	12 (60)

Table 2 Distribution of patients according to the onset of hearing loss

Onset	*n* (%)
Prelingual	12 (60)
Postlingual	8 (40)

Table 3 shows that:

1. The most common etiological factor for SNHL was congenital (found in 12 patients representing 65% of the total number of patients).

Preoperative multidetector computed tomography and MRI assessment

Most causes of hearing impairment including the external auditory canal, middle ear space, and the

Table 3 Frequency of etiological factors of sensorineural hearing loss among the study group

Etiology	Total of SNHL	Frequency (%)
Congenital	12	60
Acquired	8	40
Total	20	100

SNHL, sensorineural hearing loss.

Table 4 Multidetector computed tomography and MRI findings of the inner ear of the 20 patients

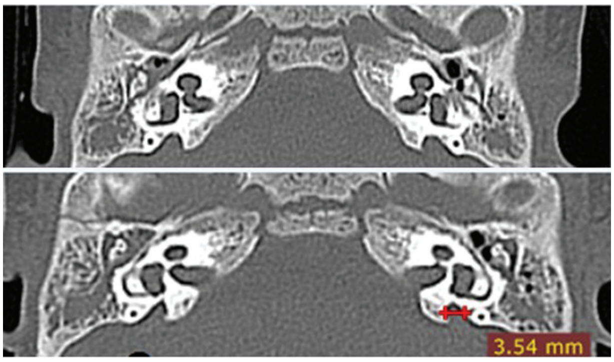
MDCT findings	*n* (%)
Congenital	5
Mondini deformity	2
Vestibular aqueduct syndrome	1 (25)
Michel deformity	1
Cochlear hypoplasia	1
Postmeningitic calcification	1 (5)
Normal	14 (70)
Total	20 (100)

MDCT, multidetector computed tomography.

Table 5 Patients who underwent cochlear implantation

Underwent cochlear implantation	*n* (%)
Underwent cochlear implantation	17 (85)
Not undergone cochlear implantation	3 (15)
Total	20 (100)

Figure 1



Axial CT of Mondini abnormality including: abnormal cochlea. Only 1.5 turns (instead of the normal 2.5 turns). Normal basal turn with a cystic apex in place of the distal 1.5 turns. Vestibular abnormalities: enlarged vestibule. Enlarged vestibular aqueduct (reaches 3.5 mm) containing a dilated endolymphatic sac. Normal semicircular canals. CT, computed tomography.

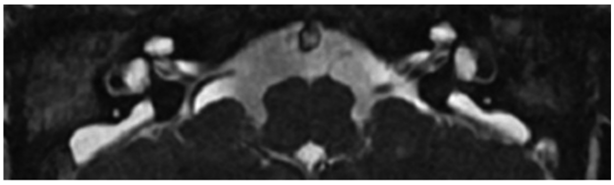
cochlea are best visualized with CT scan and MRI of the temporal bone [4].

Table 4 shows that:

(1) Most of the patients had normal study of the inner ear (14 out of 20 patients).

(2) Congenital malformation of the inner ear was detected in only five cases representing 25% of cases.

Figure 2



Case no. 1: Axial T2 high-resolution MRI features of Mondini abnormality.

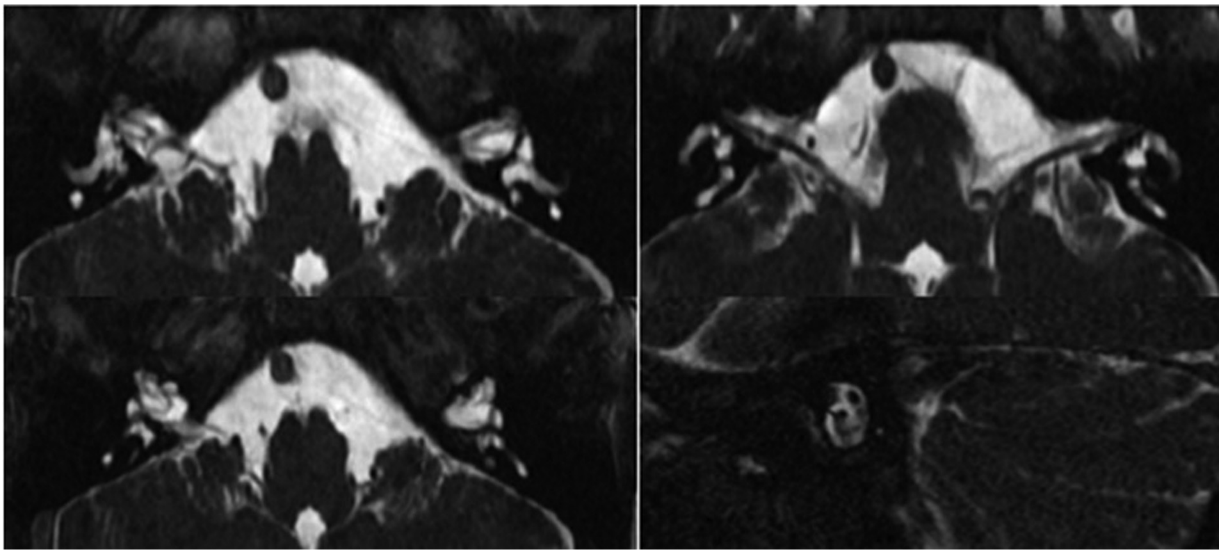
In our study

Only 17 (85%) patients underwent cochlear implantation (Table 5), the other three cases were diagnosed as follows:

(1) Michel deformity: this case has been excluded from undergoing cochlear implantation because of absence of vestibulocochlear structures bilaterally.

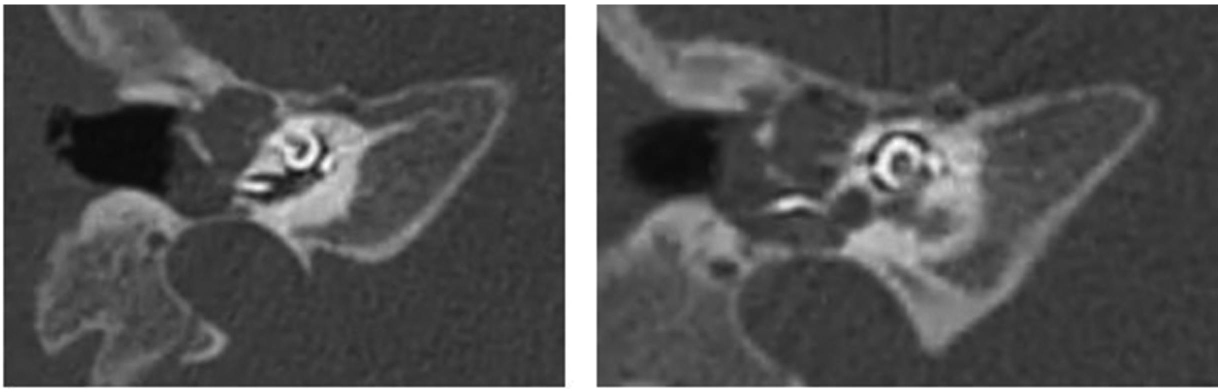
(2) Cochlear hypoplasia: this case has been excluded from undergoing cochlear implantation because it has bilateral cochlear hypoplasia (only one turn or a partial turn is seen) and bilateral hypoplastic cochlear nerves.

Figure 3



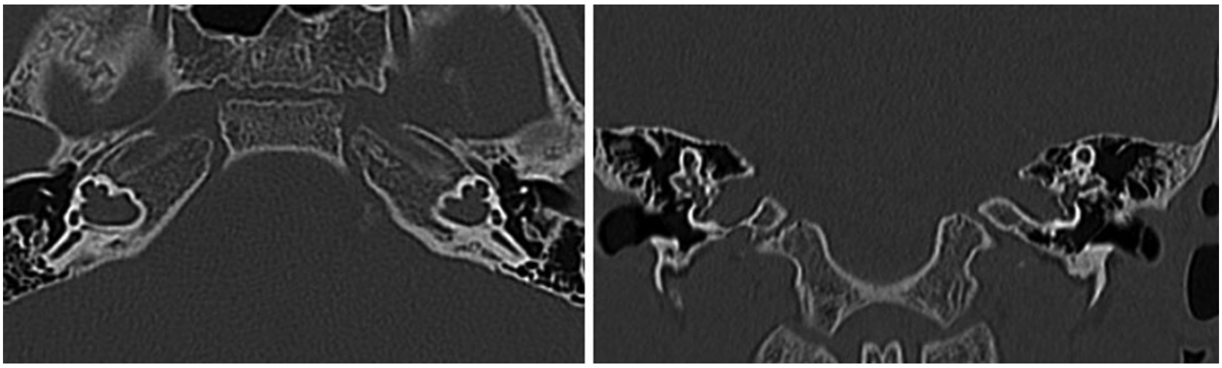
Case no. 1: CT scan images show complete insertion of the electrode and reaching the basal cochlear turn. CT, computed tomography.

Figure 4



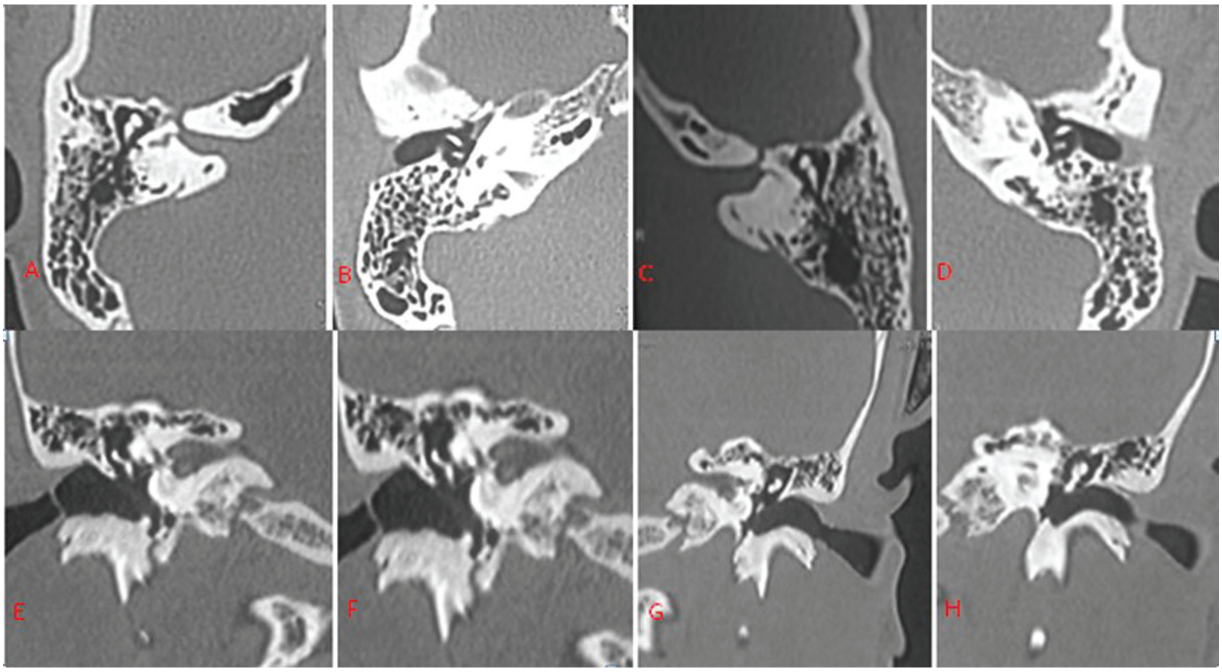
Case no. 2 axial and coronal CT images bilateral cochlear hypoplasia is considered in terms of a small cochlear bud of variable length (usually 1–3 mm). It has only one turn or a partial turn is seen. Vestibule and semicircular canals are malformed with a dilated vestibule. Symmetrically dilated internal auditory canals bilaterally. Dilated cochlear aqueduct. Normal vestibular aqueduct. CT, computed tomography.

Figure 5



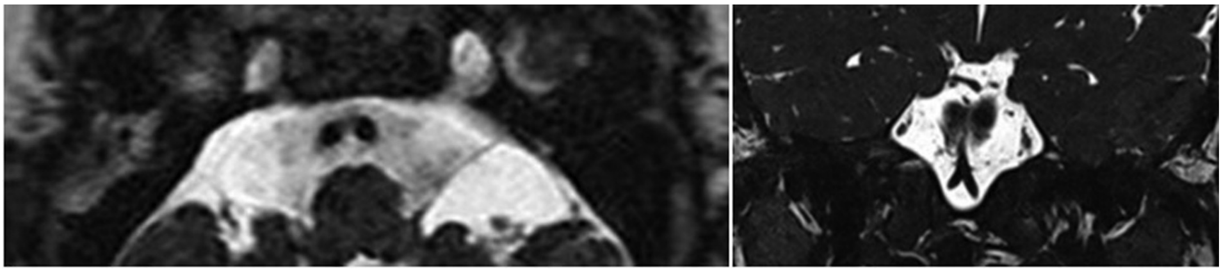
Case no. 2: serial axial T2 high-resolution and sagittal oblique show cochlear hypoplasia, malformed vestibule and semicircular canals, bilateral, dilated internal auditory canals and bilateral hypoplastic cochlear nerves.

Figure 6



Case no. 3: axial and coronal CT scan images show absence of vestibulocochlear structures (Michel deformity). CT, computed tomography.

Figure 7



Case no. 3: axial and coronal T2 and 3D FIESTA images show absence of vestibulocochlear structures and cochlear nerve deficiency. CT, computed tomography; FIESTA, fast imaging employing steady-state acquisition.

(3) Labyrinthine ossificans: this case has been excluded from undergoing cochlear implantation because of bilateral and completely ossified both cochlea which affects insertion

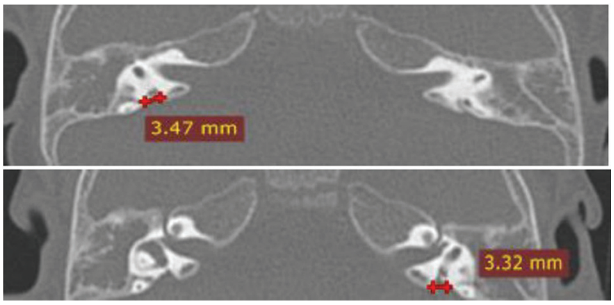
of the wire during cochlear implantation operation.

(4) Table 5 shows that 17 (85%) patients underwent cochlear implantation.

Postoperative multidetector computed tomography assessment

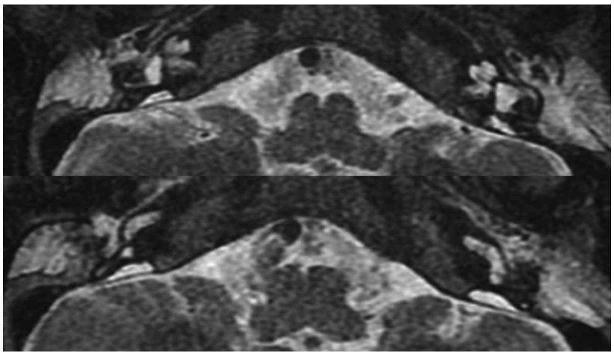
MDCT is necessary to underline the position of the implanted electrode, ensure intracochlear position, and to detect electrode kinking and may serve as a reference.

Figure 8



Case no. 4: axial CT images show bilateral isolated vestibular aqueduct dilatation. CT, computed tomography.

Figure 9



Case no. 4: axial T2 FSE MRI bilateral large endolymphatic sac anomaly.

Full electrode array insertion was reported in all cases that underwent cochlear implantation (Figs 1–18).

Discussion

Cochlear implantation is the standard procedure for managing severe to profound SNHL [6].

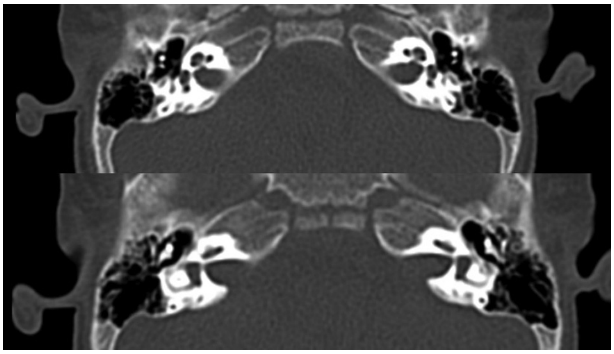
Cochlear implants are recommended for children as young as 12 months and there is no upper age limit [7].

Multiple models of cochlear implant devices are present. All are multichannel intracochlear array devices [8].

The aim of this study was to evaluate the role of various imaging modalities (CT and MRI) in the preoperative and postoperative evaluation of cochlear implant candiates.

All cases (20 cases) underwent preoperative MDCT and MRI of both temporal bones.

Figure 11

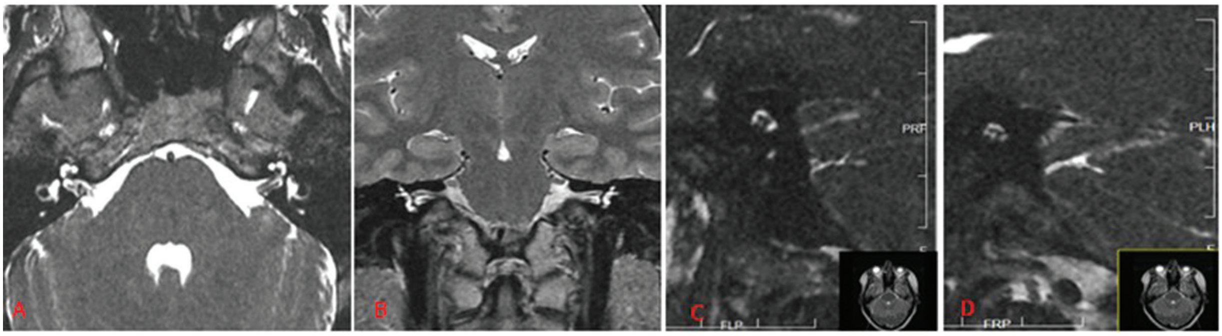


Case no. 5: a 3-year-old girl presented with postlingual severe to profound SNHL. The patient had past history of meningitis. CT scan images show normal inner ear structures, normal bilateral IAC, and both cochlea and normal vestibule on both sides. CT, computed tomography; SNHL, sensorineural hearing loss.

Figure 10

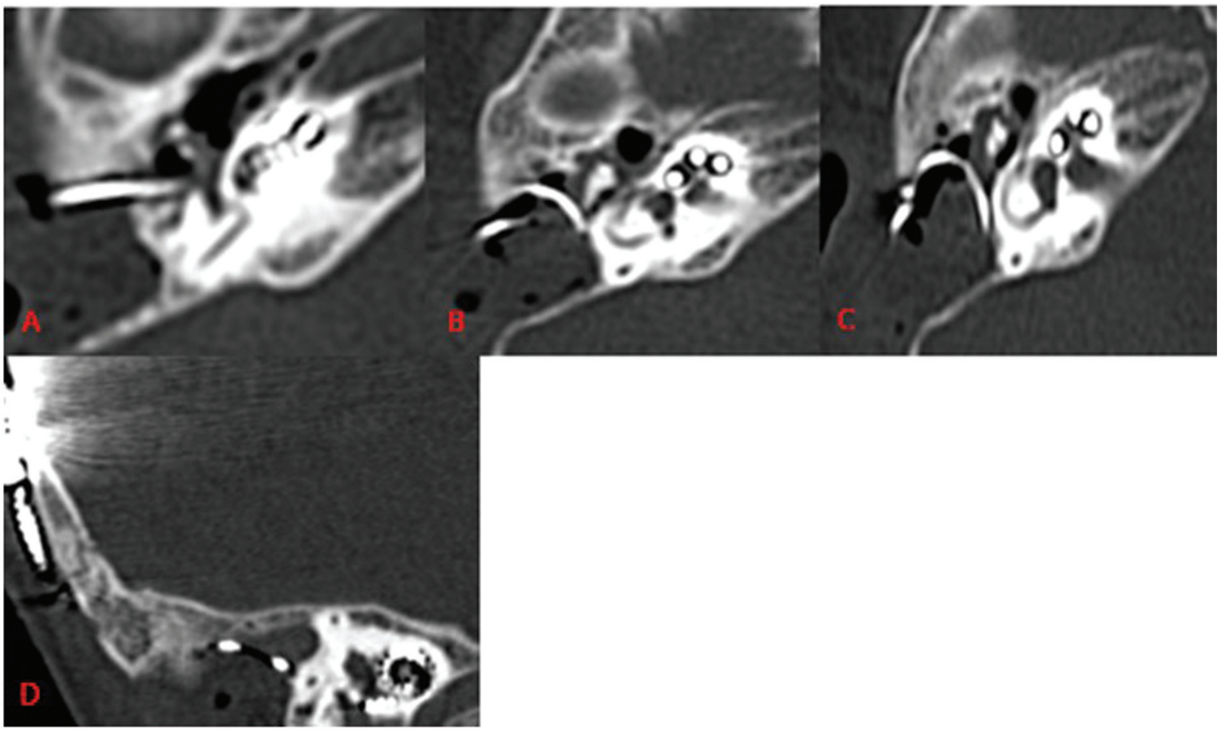
Case no. 4: CT scan images show complete insertion of the electrode and reaching the basal cochlear turn. CT, computed tomography.

Figure 12



Case no. 5: MRI scan images (a) axial T2 high resolution, (b) coronal T2 high resolution, (c) right sagittal oblique T2 high resolution, (d) left sagittal oblique T2 high resolution show normal inner ear structures.

Figure 13



Case no. 5: postcochlear implant. Serial axial cuts (a, b, and c) and coronal cut (d) show complete insertion of the electrode and reaching the basal cochlear turn.

Only 17 cases underwent postoperative MDCT.

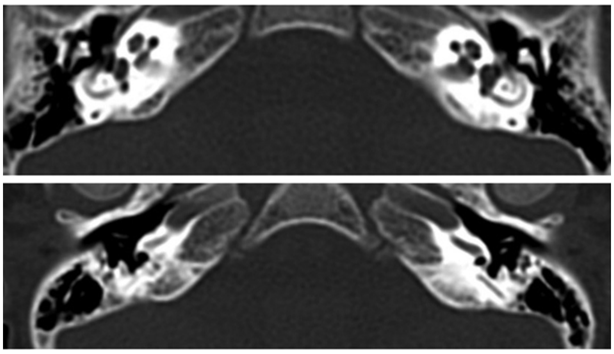
In our study, we agree with Lane and colleagues, who found that the use of oblique sagittal reconstructions with different angles had solved the problem with volume-averaging effect at SCC imaging and diagnosis of dilated vestibular aqueduct. Moreover, oblique sagittal reconstruction can depict the entire length of the tympanic and mastoid segments of the facial nerve [9].

In our study, we agree with Chavhan and colleagues that CISS/FIESTA-C has become a sequence of choice for evaluating the cranial nerves. Cerebellopontine angle cistern lesions and cranial nerves VII and VIII in the internal auditory canal and labyrinth are best evaluated with CISS/FIESTA-C [10].

In our study, most children with congenital SNHL showed normal inner ear morphology with congenital inner ear anomalies reported in 41.6%. This findings agree with Haung *et al.* [11], who explained that the hearing loss is often at the microscopic level and does not affect the appearance of the bony otic capsule or membranous inner ear.

In our study, we agree with Morzaria *et al.* [12] who reported that meningitis is the most common postnatal cause of acquired bilateral SNHL, as the eight patients presented to us with postlingual hearing loss, all of them were postmeningitic.

Figure 14



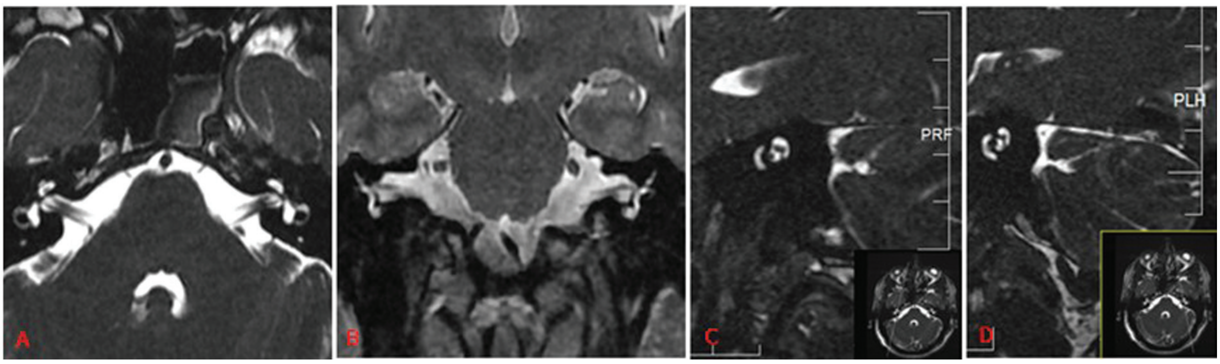
Case no. 6: a 2-year-old male child presented with prelingual severe to profound SNHL. The patient had past history of meningitis. CT scan images show normal inner ear structures, normal bilateral IAC, and both cochlea and normal vestibule on both sides. CT, computed tomography; SNHL, sensorineural hearing loss.

In our study, the most common cause of the SNHL was congenital causes (representing 60% of cases) and then acquired causes (representing 40% of cases). This slightly differs from McClay *et al.* [13] who reported that the SNHL described in children was due to genetic cause in 50% of their sample while acquired and unknown causes represented 50%.

In our study, we agree with Mackeith *et al.* [14] that combined MDCT and MRI is better as MRI can assess the cochlear nerve anomalies like nerve absence and early stages of postmeningitic labyrinthine fibrosis.

In the current study, out of the 12 patients with congenital SNHL only five (41.6%) patients showed congenital malformation of their inner ears ranged from IP II, dilated vestibular aqueducts, Michel deformity, and cochlear hypoplasia. This result differs from that of Gupta *et al.* [15] who reported that congenital malformations of the inner ear are rare anomalies. So they can be identified on imaging in about 20% of patients with congenital SNHL.In our study, we agree

Figure 15

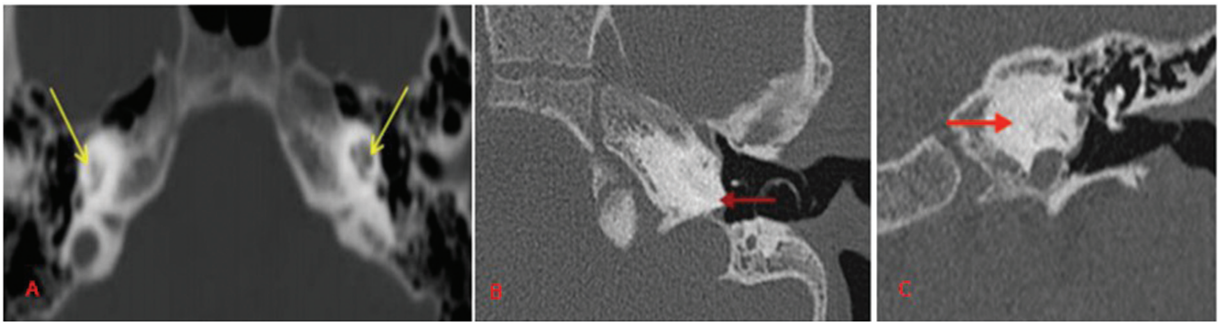


Case no. 6: MRI scan images (a) axial T2 high resolution, (b) coronal T2 high resolution, (c) right sagittal oblique T2 high resolution, (d) left sagittal oblique T2 high resolution show normal inner ear structures.

Figure 16

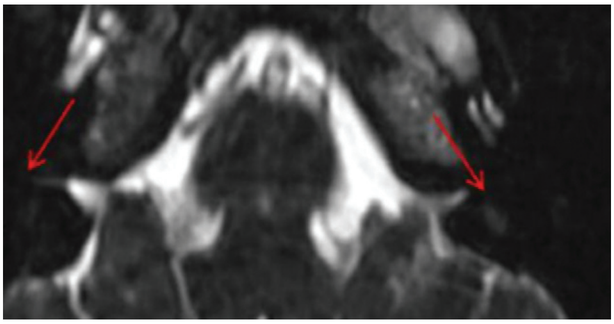
Case no. 6: postcochlear implant. Selected coronal cut (a) and serial axial cuts (b and c) show complete insertion of the electrode and reaching the basal cochlear turn.

Figure 17



Case no. 7: a 16-year- old male patient presented with postlingual severe to profound SNHL. Axial (a and b) and coronal (c) CT scan images show complete ossification of both cochlea. CT, computed tomography; SNHL, sensorineural hearing loss.

Figure 18



Case no. 7: axial T2 high resolution show loss of normal fluid filled spaces of membranous labyrinth on both sides.

with Broomfield and colleagues that certain abnormalities of the inner ear are better depicted on CT, while others are better seen on MRI. Hence, neither MDCT nor MRI of the brain and temporal bones appears to be adequate as a single imaging modality but they are complementary to each other for preoperative imaging of cochlear implantation [16].

In our study, we agree with Arweiler-Harbeck and colleagues that MDCT has proven its efficacy in the postoperative imaging of cochlear implant patients. CT confirms the intracochlear position of the implant. It has also been shown that malpositioning and kinking can be detected by CT imaging [17].

In our study, full electrode array insertion was reported in all cases who underwent cochlear implantation which agrees with Ying *et al.* [18] who reported that misplacement of the electrode is rarely occur.

Conclusion

Preoperative CT and MRI assessment of children with severe or profound SNHL is critical for determining implant candidacy. Both have their proponents. MDCT demonstrates the bony architecture of the temporal bone, while MRI is helpful for identifying membranous labyrinth and soft tissue abnormalities.

MDCT has proven its efficacy in the postoperative imaging of cochlear implant patients. CT confirms the intracochlear position of the implant. It has also been shown that malpositioning and kinking can be detected by CT imaging.

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Place: Al Hussein Univeristy Hospital.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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