Al-Azhar International Medical Journal

Volume 4 | Issue 1 Article 15

1-2023

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How to Cite This Article

Mohamed, Abd Elhamed; El Kheshen, Abdallah Mohamed; Aun, Abdel El Aziz; and Ali, Mahrous (2023) "Role of preoperative Computed Tomography and Magnetic Resonance Imaging in pediatric cochlear implantation," *Al-Azhar International Medical Journal*: Vol. 4: Iss. 1, Article 15.
DOI: https://doi.org/10.58675/2682-339X.1630

ORIGINAL ARTICLE

Role of Preoperative Computed Tomography and MRI in Pediatric Cochlear Implantation

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Abstract

Background: **Cochlear implant is an electronic device that stimulates auditory spiral ganglion cells to give persons with hearing loss a sense of sound. Two primary radiological research studies for cochlear implantation are high-resolution computed tomography and MRI. Poor depiction of aerated or mineralized structures is a major disadvantage of using MRI before cochlear implantation. Furthermore, owing to length of test, sedation is usually needed for MRI in young studied cases. Computed tomography scans can be conducted much more quickly.**

Aim and objectives: **The study's goal was to highlight the role of preoperative imaging in assessment of sensorineural hearing loss in pediatric candidates for cochlear implantation.**

Patients and methods: **This study included 20 studied cases with severe to profound sensorineural hearing loss who were referred to the Radiodiagnosis Department at Al-Azhar University hospitals for imaging evaluation before cochlear implantation. All patients were subjected to high-resolution computed tomography and MRI of temporal bones.**

Results: **In the present study, the vestibular aqueduct was normal in 17 patients bilaterally, enlarged in two patients (four temporal bones), and not visualized in one female patient (one temporal bone). Vascular abnormalities were diagnosed in five patients (25% of total patients, 10 temporal bones) and included high jugular bulb and deep sigmoid sinus.**

Conclusion: **Imaging is indispensable to the preoperative evaluation of patients undergoing cochlear implantation.**

Keywords: Cochlear implantation, Computed tomography, MRI, Pediatric, Preoperative

1. Introduction

Cochlear implant is an electronic device that stimulates auditory spiral ganglion cells to give persons with hearing loss a sense of sound. As of 2005, nearly 85 000 patients worldwide received cochlear implants.[1]

Candidates for cochlear implantation are evaluated preoperatively using clinical, speech therapy, psychological, and social criteria. Imaging of cochlear region is critical throughout this stage in identifying etiology of hearing loss, locating outcomes that may contraindicate surgery, assisting in selection of ear to be implanted, adequately assessing anatomy for surgery, and forecasting difficulties within limits.[1]

It is essential to determine the etiology of hearing loss before surgery. Two primary radiological investigations for cochlear implantation are high-resolution computed tomography (HRCT) and MRI.[2]

Traditionally, CT has been the favored imaging modality for pediatric candidates for cochlear implantation.[1] CT of petrous temporal bones allows for detailed assessment of inner and middle ear osseous anatomy and also evaluates mastoid pneumatization and degree of middle-ear aeration.[3]

Even so, there are some drawbacks to using CT because it patients studied cases to ionizing radiation, which is especially concerning in vulnerable pediatric population. Low-dose temporal bone CT may be done, but due to dense petrous bone and high-resolution requirements in this region, dose decrease may be difficult. Furthermore, CT does not show cochlear nerve directly, only the bone channel that includes it.[4]

Internal auditory canal and inner ear MRI allows for direct visualization of cisternal and intracanalicular vestibulocochlear nerve bundles and poses no radiation risk. This area's dedicated

Accepted 31 August 2022.
Available online 15 May 2023

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https://doi.org/10.58675/2682-339X.1630

MRI employs high-resolution heavily T2-weighted three-dimensional imaging techniques.

Poor depiction of aerated or mineralized structures, as well as degree of mastoid or middle ear pneumatization, is a major disadvantage of using MRI before cochlear implantation. Furthermore, due to length of test, sedation is usually needed for MRI in young studied cases. CT scans can be conducted much more quickly.[3]

The goal of this work was to emphasize role of preoperative imaging in assessment of sensorineural hearing loss in pediatric candidates for cochlear implantation.

2. Patients and methods

The research was conducted on 20 studied cases presented to Al-Azhar University Hospitals with sensorineural hearing loss who are candidates for cochlear implantation from November 2019 to November 2021. The study was done after being approved by the Institutional Ethical Committee, Al-Azhar University. Written consent was taken from patients and/or caregivers before participating in the study.

Inclusion criteria were patients from age of 1–18 years old and complaining of marked bilateral sensorineural hearing loss who did not obtain acceptable advantage from hearing aids.

2.1. Methods

All patients were subjected to the following: (a) full history taking with complete review of medical and hearing history, including patient characteristics, such as age and sex; onset of hearing loss and wearing of hearing aids; history of consanguinity and similar conditions; relevant perinatal history of possible etiological factors of hearing loss such as drug intake during pregnancy, maternal measles or rubella, and neonatal jaundice; history of meningitis and otologic diseases such as chronic suppurative otitis media; and medical and drug history. (b) Audiologic evaluation: hearing sensitivity testing by pure tone audiometry for ages 4 years and above, or by auditory brainstem response for children less than 4 years. Otoacoustic emission testing to diagnose cases of auditory neuropathy. Aided threshold testing using the patient's hearing aids to determine the lack of benefit from amplification. Speech discrimination testing using his/her hearing aid to verify cochlear implantation candidacy. (c) Imaging: all imaging protocols were approved by our hospital local research ethics committee. Preoperative radiologic assessment included noncontrast HRCT examination of temporal bone. All patients were scanned without contrast administration in axial plane with the use of multislice CT scanner (Toshiba, 16 slices).

The examinations were carried out in the following sequence: (a) sedation was provided for young children. (b) Patients were instructed to reduce motion of head throughout scanning as much as possible to minimize motion artifacts. (c) High-resolution scanning and high-resolution reconstruction filter were used to achieve isotropic and high-quality imaging. Images were captured with slice thickness of 0.625 mm, rotation time of 0.5 s, pitch factor of 0.725, tube voltage of 120 kV, tube current of 125 mA, and scan field of view of 240 mm. Images were reconstructed with 0.3-mm increment, 90-mm reconstruction FOV with individual magnification for right and left temporal bones, 512 × 512 matrix, and high-resolution reconstruction algorithm. The scan time was ~60 s. (d) Window width and level were adjusted until both small anatomic characteristics of inner ear were visible. In bone algorithm images, window level of 600–700 HU and window width of 3000–4000 HU were adequate. (e) With patient supine, axial images were acquired in plane 30 above anthropologic baseline (line intersecting inferior orbital rim and EAC). (f) Axial scans covered all the parts of the temporal bone. (g) When imaging above or below the level of the temporal bone was required, two sets of images were obtained: a soft tissue window and a bone window algorithm. For the display of soft tissues, a window level of 35–45 HU and a window width ranging from 190 to 220 HU were selected. In bone algorithm images, window level of 300–400 HU and window width of 1200–1600 HU were chosen. (h) Images were transmitted to workstation running postprocessing software package.

2.1.1. Postprocessing

This includes generation of 2D reformations and 3D reconstructions as follows: 2D reformats in coronal and sagittal planes. Multiplanar reconstructions through inner ear structures were done as follows: MPRs through the cochlea were made by oblique coronal reconstructions parallel to basal turn of cochlea and perpendicular to modiolus. Second set of MPRs was made perpendicular to basal turn and parallel to modiolus letting simultaneous visualization of all the cochlear turns and cochlear aperture. Oblique sagittal reconstructions in the long axis plane of the SSCC and PSCC, the vestibular aqueduct, facial nerve canal, the round window and double oblique axial

reconstruction of stapes at oval window. 3D reconstructions were made using volume-rendering technique, and minimum intensity projection (MinIP). A pre-implantation CT checklist includes status of inner ear structures, particularly cochlear morphology and patency, size of vestibular aqueduct, size of IAC and BCNC, facial nerve canal, and other pathologies such as otosclerosis, labyrinthitis ossificans, and mastoiditis. Moreover, jugular bulb height and carotid canal were evaluated.

The following indices were used: stenotic BCNC: less than 1.5 mm in width, measured at its midportion; stenotic IAC: less than 2.5 mm in width, measured at its midportion; and large vestibular aqueduct: more than 1.5 mm in diameter, measured at midpoint of postisthmic segment or midway among common crus and its external aperture.

MRI examination: studied cases were scanned using 1.5 T MRI scanner. The examinations were carried out in the following steps: (a) screening of the patient for any contraindications to the MRI examination. (b) sedation was provided for young children. (c) Patients were instructed to reduce motion of head throughout scanning as much as possible to minimize motion artifacts. (d) Instructions were also given to remove any prohibited materials such as hairpins or watches before entering the magnet's room. (e) The head coil was used as the receiver coil. (f) Each examination included the following: (a) conventional TSE sequences of the IAC and CPA, which included axial and coronal T1W spin echo (SE) of the IAC, axial and coronal T2W TSE of the IAC, and axial T1 and T2W SE sequences of the brain, and (b) high-resolution 3D heavily T2W FSE sequences, which included axial 3D T2W TSE sequence of the inner ear and oblique sagittal 3D T2W FSE sequence perpendicular to long axis of IAC, starting from CPA to fundus of IAC.

A pre-implantation MRI checklist included status of inner ear structures, particularly cochlear morphology and patency in the form of two and half turns in 3D heavily T2W sequence and caliber and integrity of cochlear nerve (cochlear nerve must be larger or equal in caliber compared with facial nerve in IAC.

Temporal bones of included patients were examined for presence of absolute contraindications to cochlear implantation, which include cochlear nerve aplasia and complete cochlear aplasia; presence of relative contraindications to implantation, such as malformation of inner ear other than cochlear nerve aplasia and absent cochlea (such conditions may require special intervention or modification of the implantation technique), and other coincidental findings that may complicate surgery and need to be managed properly for safe implantation, such as otomastoiditis and high jugular bulb.

3. Results

Age and sex distribution of studied cases are illustrated in Fig. 1.

The patients were divided according to the onset of hearing loss into two main categories: prelingual and postlingual hearing loss. A total of 17 (85%) patients presented with prelingual SNHL, whereas only three (15%) patients presented with postlingual SNHL (Tables 1 and 2).

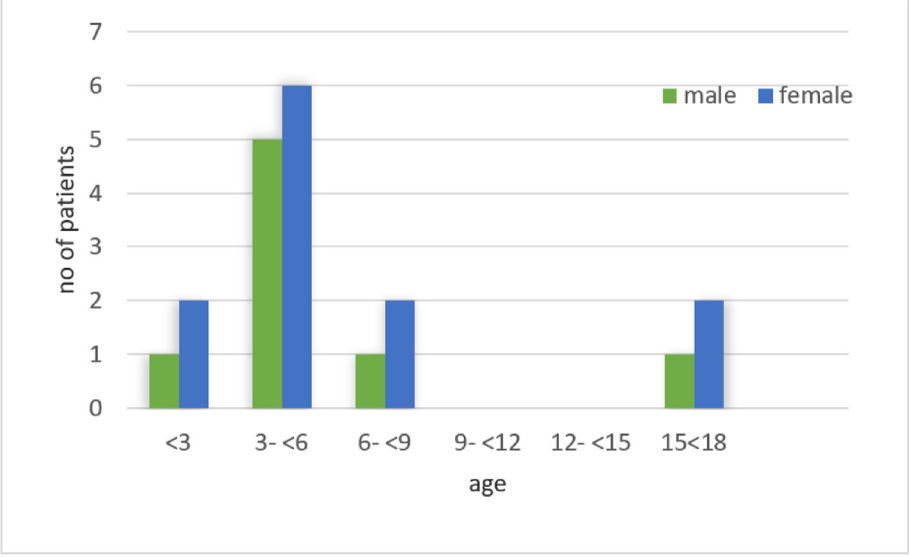

Fig. 1. Age and sex distribution of patients.

Table 1. Distribution of studied cases by age and sex according to onset of hearing loss.

	Prelingual		Postlingual		
Age (in years)	Male	Female	Male	Female	Total
<3	1	2	0	0	3
3 to <6	5	6	0	0	11
6 to <9	1	2	0	0	3
9 to <12	0	0	0	0	0
12 to <15	0	0	0	0	0
15 to <18	0	0	1	2	3
Total	7	10	1	2	20

Table 2. Frequency of presence of radiological abnormalities involving the temporal bones and frequency of affection of inner and middle ears in the studied temporal bones.

Temporal bone abnormality	Number of patients	$N = 20$ (%)
Not present	6	30
Present		
Bilateral	12	60
Unilateral	2	10
Radiological findings	Number of temporal bones	$N = 40$ (%)
Normal	14	35
Isolated inner ear pathology	12	30
Isolated middle ear pathology	13	32.5
Mixed inner and middle ear pathologies	1	2.5

Distribution of studied cases by sex according to the different pathologies of temporal bones (Fig. 2).

Vascular abnormalities were diagnosed in five patients (25% of total patients, 10 temporal bones), and they included high jugular bulb and deep sigmoid sinus (Table 3).

Frequency of different inflammatory conditions of temporal bones, frequency of cochlear affection by different pathologies in the study population, frequency of different radiologic features of the vestibule, frequency of different radiologic features of the vestibular aqueduct, frequency of different radiologic features of the IAC, frequency of different radiologic features of the BCNC, and frequency of different radiologic features of the cochlear nerve are illustrated in Table 4.

Classification of research population according to operative feasibility on radiological basis is shown in Table 5.

4. Discussion

In the current study, one patient with bilateral cystic cochleovestibular malformation had dilated both IACs, unilateral cochlear nerve aplasia, and contralateral hypoplasia (as confirmed by MRI), whereas both BCNCs were stenotic on HRCT. Such findings declared him as contraindicated for cochlear implantation. Another patient with unilateral complete labyrinthine aplasia (Michel deformity) showed stenotic IAC and absent vestibulocochlear nerve (as confirmed by MRI showing only facial nerve within IAC). The BCNC was absent on HRCT. The opposite inner ear was normal. She was contraindicated for cochlear implantation on the diseased side and allowed on the opposite radiologically normal side. The study population also included another case with acquired cochlear nerve hypoplasia bilaterally (in the presence of bilaterally normal sized IACs), thus was judged relatively contraindicated for implantation.

Our findings agree with those of Jackler et al.[5] and Shelton et al.,[6] who stated that occurrence of IAC stenosis (as exposed by HRCT) is indicative of cochlear nerve aplasia and poor performance with cochlear implant and that IAC stenosis could be considered as absolute contraindication to cochlear implantation. However,[7] according to other researchers, determining cochlear nerve status in cases of small and

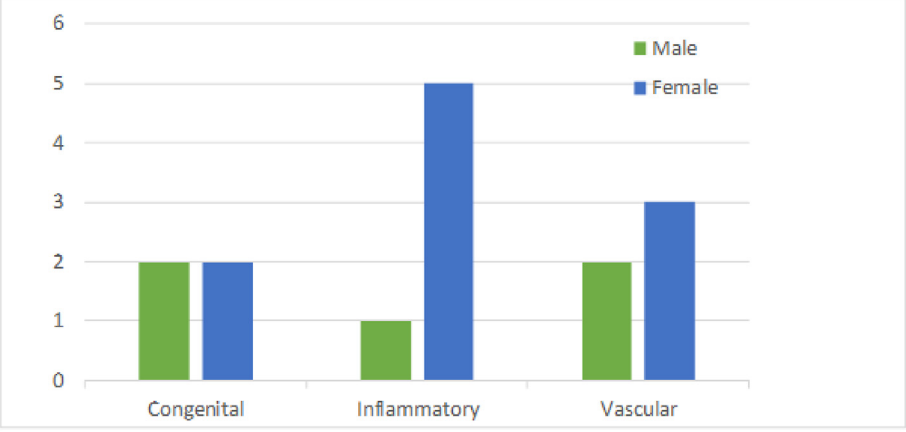

Fig. 2. Distribution of patients by sex according to the different pathologies of temporal bones.

Table 3. Frequency of different vascular abnormalities of temporal bones.

Vascular abnormalities	Total number of temporal bones	$N = 40$ (%)
Jugular bulb		
Normal	30	75
High	8	20
Absent	0	0
Deep sigmoid Sinus	2	5

Table 4. Frequency of different inflammatory conditions of temporal bones, frequency of cochlear affection by different pathologies in the study population, frequency of different radiologic features of the vestibule, frequency of different radiologic features of the vestibular aqueduct, frequency of different radiologic features of the IAC, frequency of different radiologic features of the BCNC, and frequency of different radiologic features of the cochlear nerve.

Inflammatory conditions	Total number of temporal bones	$N = 40$ (%)
Inner ear		
Labyrinthitis ossificans	4	10
Acquired cochlear nerve hypoplasia	2	5
Middle ear		
Otomastoiditis	4	10
Bony erosions	0	0
Cochlear pathology	Total number of temporal bones	$N = 40$ (%)
Normal	33	82.5
Absent	1	2.5
Dysplastic	2	5
Ossified	4	10
Pathology of the vestibule	Total number of temporal bones	$N = 40$ (%)
Normal	33	82.5
Absent	1	2.5
Dilated	2	5
Ossified	4	10
Pathology of the vestibular aqueduct	Total number of temporal bones	$N = 40$ (%)
Normal	35	87.5
Enlarged	4	10
Not visualized	1	2.5
Pathology of the IAC	Total number of temporal bones	$N = 40$ (%)
Normal	37	92.5
Stenotic	1	2.5
Dilated	2	5
Pathology of the BCNC	Total number of temporal bones	$N = 40$ (%)
Normal	37	92.5
Absent	1	2.5
Stenotic	2	5
Pathology of the cochlear nerve	Total number of temporal bones	$N = 40$ (%)
Normal	35	87.5
Aplastic	2	5
Hypoplastic	3	7.5

Table 5. Classification of study population according to operative feasibility on radiological basis.

Operative decision	Number of patients	$N = 20$ (%)
Absolutely contraindicated	2	10
Relatively contraindicated	2	10
Accepted	16	80

narrow IACs frequently necessitates a range of anatomic (CT and MRI) and functional (auditory brainstem response, otoacoustic emissions, behavioral audiometry, and physical examination) tests.[8]

Our findings, although limited by a small sample of patients, agree with Adunka et al.[8] in that stenotic BCNC is associated with at least cochlear nerve hypoplasia (as in our case of Michel deformity) and that normal size IAC is not guarantee for cochlear nerve integrity (as in our case with IP-I). Their stress upon the role of MRI evaluation justifies our protocol of a combined CT and MRI protocol to evaluate all patient and set the main value of MRI as a tool for valuation of cochlear nerve in normal BCNC to predict outcome after implantation and avoid improper implantation.

In the present study, the vestibular aqueduct was normal in 17 patients bilaterally, enlarged in two patients (four temporal bones), and not visualized in one female patient (one temporal bone). The vestibular aqueduct showed bilateral symmetric affection on both sides in the patients of our series except for a single patient who had unilateral non-visualization of vestibular aqueduct in association with Michel deformity, with normal caliber of the contralateral canal exhibited in the radiologically free ear. Such unilateral affection has been previously reported in the literature but in the context of unilateral enlargement.[9] On the contrary, our two cases of bilateral enlargement came without other depicted abnormalities, establishing a diagnosis of isolated LVA, an allowable clinical entity after its first description by Valvassori and Clemis[10] as an isolated finding.

It was previously considered to be a contraindication for implantation.[11] Nowadays, to judge the feasibility of cochlear implantation in a setting of labyrinthine ossification with luminal obstruction, preoperative identification of certain factors should be met, including whether affection is bilateral, and whether the cochlea is involved, as well as the location and severity of labyrinthine ossification. Such judgment is of great importance to the surgeon, as it may complicate insertion of the electrode array, thus calling for implantation technique modifications or making the procedure contraindicated (only if

there is total or near-total bilateral labyrinthine ossification).[12]

Despite the effect of preoperative radiologic evaluation, the decision still depends on the actual pattern of ossification found during surgery.[13]

In our study, two cases of labyrinthine ossification were detected. One of them had manifest extracochlear ossification evident on HRCT with subtle affection of the cochlea in the form of prominent modiolus and interscalar septa bilaterally. With such findings and with subsequent MRI showing non-ossific fibrotic obliteration of the cochlear lumen, the patient was judged as relatively contraindicated.

The other patient was absolutely contraindicated for implantation based on HRCT-detected severe bilateral cochlear ossification, together with most of the vestibule and SCCs. On MRI images, the extent of loss of normal signal intensities (cerebrospinal fluid-parallel intensities on T1 and T2, deterministic of patency)[11] exceeded CT-depicted ossifications, reflecting associated fibrous obliteration. This well demonstrates the reported added MRI value, specifically T2W sequences, over CT in detection of early labyrinthine fibrous obliteration which could be missed on CT due to lack of the typically detected high-density bone.[14]

Our findings agree with those of literature, where high jugular bulb was reported to be most common vascular anomaly of petrous bone. It has been described in up to 6% of temporal bones tested histologically.[15]

The application of dual-modality imaging with HRCT and MR of petrous bone and MR brain in all patients of our series detected abnormalities connected to deafness, which would not else be shown using either modality alone. For example, in the present study, the patient with bilateral cochlear nerve aplasia suspected on MRI could not be strongly suggested without the reported absent BCNC on HRCT in a patient with bilateral cystic cochleovestibular malformation.

5. Conclusion

High-resolution heavy T2W MRI obtained by FSE technique is sensitive in detection of congenital inner ear anomalies and result in better assessment of IAC and inner ear, increased capacity to obtain MRI in multiple planes with thin sections, and excellent contrast in an acceptably short time. HRCT was superior to MRI in detection of vascular abnormalities such as great jugular bulb and course of facial nerve canal.

Conflict of interest

There are no conflicts of interest.

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