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# Impact of Multimodality Imaging in Pediatric Cochlear Implant Preoperative Workup

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## ABSTRACT
**Background:** Hearing loss is the most common sensory impairment, with SNHL being the most prevalent type. Cochlear implantation is an effective treatment for severe-to-profound hearing loss. Preoperative CT and MRI are essential for anatomical assessment and surgical planning. This study evaluates the roles of CT and MRI, and their combined use, in pediatric cochlear implant candidates.
**Methods:** This ambispective observational study was conducted in the ENT Department of Pacific Medical College and Hospital, Udaipur. It included pediatric patients aged 1–12 years with bilateral severe-to-profound SNHL presenting between May 2024 and November 2025, along with retrospective data from the previous 10 years. A total of 35 patients were included using a convenient sampling of the bones. Imaging findings were evaluated for anatomical variations and inner ear malformations.
**Results:** Most patients were 4–6 years (48.6%), with male predominance (57.1%) and congenital hearing loss (62.9%). CT detected bony abnormalities, while MRI identified neural and soft tissue defects. Combined imaging improved diagnostic yield by up to 20%.
**Conclusion:** Preoperative imaging using HRCT and MRI provides complementary information essential for cochlear implant planning. HRCT is invaluable for assessing bony anatomy and surgical feasibility, whereas MRI is crucial for evaluating cochlear nerve integrity and soft-tissue abnormalities. The combined use of both modalities enhances diagnostic accuracy, aids in surgical planning, and improves overall outcomes in pediatric cochlear implantation.

**Key-words:** Cochlear implant, HRCT temporal bone, MRI brain with inner ear, Preoperative assessment

## INTRODUCTION
Hearing loss is the most common sensory deficit worldwide, affecting over 5% of the global population (approximately 430 million individuals, including 34 million children), according to the World Health Organization. In India, nearly 63 million people suffer from significant hearing impairment. Sensorineural hearing loss (SNHL), resulting from pathology of the cochlea, auditory nerve, or central nervous system, is the most prevalent type and accounts for the majority of permanent hearing loss [1].

Early identification and timely intervention are essential to minimize adverse effects on speech, language, and cognitive development, particularly in children. Cochlear implantation has emerged as an effective treatment for patients with moderate-to-profound SNHL who derive limited benefit from hearing aids [2]. Radiological imaging plays a crucial role in the preoperative evaluation of cochlear implant candidates, especially in children with unexplained SNHL. Computed tomography (CT) is widely used as the initial imaging modality due to its excellent visualisation of osseous anatomy and its ability to detect congenital malformations and middle-ear pathology [3]. However, CT involves ionizing radiation, which is a concern in pediatric patients [4]. Magnetic resonance

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imaging (MRI) provides superior soft-tissue contrast and is the preferred modality for evaluating the cochlear nerve and central causes of SNHL [5]. It also avoids ionizing radiation, making it particularly advantageous in children [2]. Given the complementary strengths of CT and MRI, many centers advocate a combined imaging approach for comprehensive preoperative assessment. Integrated imaging has been shown to improve the safety and effectiveness of cochlear implantation [6].

Preoperative imaging is essential for identifying anatomical variations and cochleovestibular anomalies that may influence surgical planning [7]. Such variations, including an abnormal facial nerve course and vascular anomalies, can significantly impact surgical approach and outcomes [8]. The primary objectives of imaging are to detect anomalies that may preclude implantation, assess cochlear patency and nerve integrity, anticipate surgical challenges, and determine the most suitable ear for implantation [9].

## MATERIALS AND METHODS

**Study Design and Setting-** This ambispective observational study was conducted in the Department of ENT, Pacific Medical College and Hospital, Udaipur.

**Study Population-** The study included 35 pediatric patients diagnosed with severe to profound bilateral sensorineural hearing loss (SNHL). A retrospective review of medical records from the preceding 10 years was also carried out to identify patients who had undergone cochlear implant surgery.

**Inclusion Criteria-** Patients of either gender, aged 1–12 years, with bilateral severe to profound SNHL who did not derive benefit from hearing aids were included.

**Exclusion Criteria-** Patients aged more than 12 years, those with mild to moderate SNHL, conductive hearing loss, or those unwilling to participate were excluded.

**Imaging Protocol-** All patients underwent preoperative radiological evaluation in the Department of Diagnostic Radiology. High-resolution CT (HRCT) of the temporal bone was performed using 2 mm slice thickness in axial and coronal planes. MRI of the brain with inner ear was performed using T1, T2, FLAIR, diffusion-weighted, and gradient-echo sequences in axial, coronal, and sagittal planes.

**Data Analysis-** Imaging findings were evaluated to identify anatomical variations and inner ear malformations involving bony, soft tissue, and neural structures relevant to cochlear implantation.

**Ethical Considerations:** Ethical approval was obtained from the institutional ethics committee and informed consent was taken from all the patients.

## RESULTS

The age distribution of the study participants showed a predominance of younger children. The largest proportion of patients, 17 out of 35 (48.6%), were aged 4–6 years. Children aged 1–3 years accounted for 8 patients (22.9%), those aged 7–9 years accounted for 6 patients (17.1%), and the smallest group, aged 10–12 years, accounted for 4 patients (11.4%). In the study cohort, males were slightly more predominant than females. Out of 35 patients, 20 were male (57.1%), while 15 were female (42.9%) (Table 1).

**Table 1:** Case distribution according to HRCT Temporal Bone Findings (n = 35 patients / 70 ears)

| Parameter | Right Ear Normal n(%) | Right Ear Abnormal n(%) | Left Ear Normal n(%) | Left Ear Abnormal n(%) |
|---|---|---|---|---|
| External Auditory Canal | 33 (94.3%) | 2 (5.7%) | 35 (100%) | 0 (0%) |
| Tympanic Membrane | 33 (94.3%) | 2 (5.7%) | 31 (88.6%) | 4 (11.4%) |
| Ear Ossicles | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Mastoid Pneumatization | 28 (80.0%) | 7 (20.0%) | 27 (77.1%) | 8 (22.9%) |
| Facial Nerve Canal | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Sigmoid Sinus Position | 34 (97.1%) | 1 (2.9%) | 34 (97.1%) | 1 (2.9%) |

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| | | | | |
|---|---|---|---|---|
| Carotid Canal | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Jugular Bulb | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Bony Labyrinth | 32 (91.4%) | 3 (8.6%) | 30 (85.7%) | 5 (14.3%) |
| Cochlea | 33 (94.3%) | 2 (5.7%) | 31 (88.6%) | 4 (11.4%) |
| Round Window | 34 (97.1%) | 1 (2.9%) | 33 (94.3%) | 2 (5.7%) |
| Oval Window | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Vestibule | 35 (100%) | 0 (0%) | 31 (88.6%) | 4 (11.4%) |
| Internal Auditory Canal | 33 (94.3%) | 2 (5.7%) | 32 (91.4%) | 3 (8.6%) |
| Cochlear Aperture | 34 (97.1%) | 1 (2.9%) | 33 (94.3%) | 2 (5.7%) |
| Semi Circular canal | 34(97.1%) | 1(2.9%%) | 34(97.1%) | 1(2.9%) |

Assessment of temporal bone and inner ear structures revealed that most parameters were normal in both ears, with only a small proportion showing abnormalities. For the right ear, structures such as the ear ossicles, the facial nerve canal, carotid canal, and jugular bulb were entirely normal (100%). In contrast, other parameters, including the external auditory canal, tympanic membrane, cochlea, internal auditory canal, cochlear aperture, semicircular canals, and bony labyrinth, showed normal findings in 91.4–97.1% of cases. Mastoid pneumatization was relatively more frequently abnormal in the right ear (20%). In the left ear, normal findings were similarly predominant, particularly in ear ossicles, facial nerve canal, carotid canal, jugular bulb, and oval window (100%). Slightly higher abnormality rates were observed in the mastoid pneumatization (22.9%), vestibule (11.4%), cochlea (11.4%), and bony labyrinth (14.3%). Overall, the data indicate that computed tomography (CT) was effective in assessing all bony structures of the temporal bone and inner ear, providing a detailed evaluation and identifying even subtle anatomical variations (Table 1, Fig. 1).

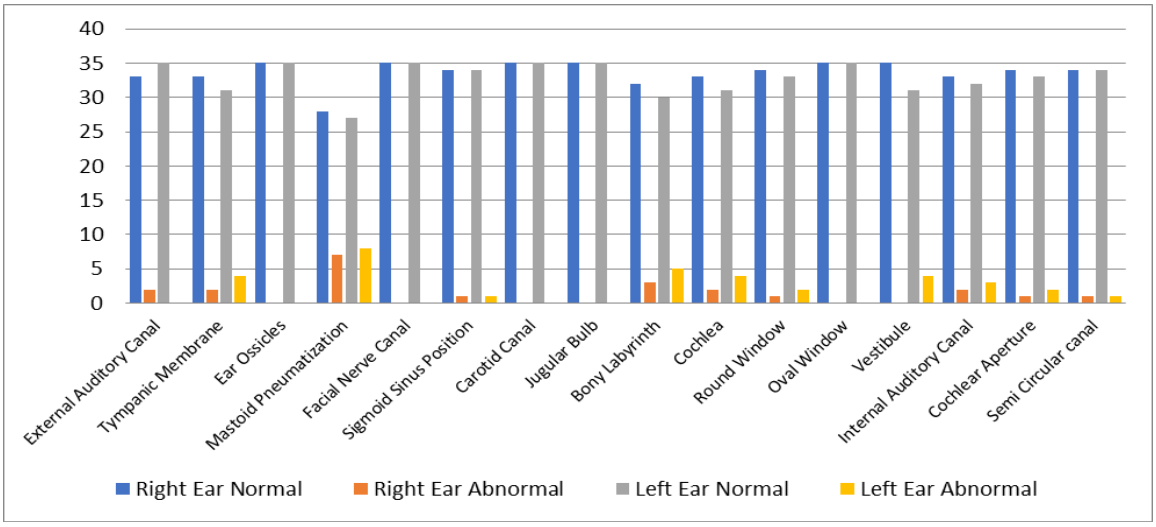


**Fig. 1:** Case distribution according to HRCT Temporal Bone Findings

**Table 2:** Case Distribution of MRI Brain with Inner Ear Findings

| Parameter | Right Ear Normal n (%) | Right Ear Abnormal n (%) | Left Ear Normal n (%) | Left Ear Abnormal n (%) |
|---|---|---|---|---|
| Cochlea | 32 (91.4%) | 3 (8.6%) | 30 (85.7%) | 6 (17.1%) |

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| | | | | |
|---|---|---|---|---|
| Vestibule | 33 (94.3%) | 2 (5.7%) | 31 (88.6%) | 4 (11.4%) |
| SCC | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Labyrinth Fluid Signal | 32 (91.4%) | 3 (8.6.%) | 34 (97.1%) | 1 (2.9%) |
| Spiral Lamina & Modiolus | 31 (88.6%) | 4 (11.4%) | 30 (85.7%) | 5 (14.3%) |
| Symmetry of Scala Tympani & Vestibuli | 33 (94.3%) | 2 (5.7%) | 31 (88.6%) | 4 (11.4%) |
| Internal auditory canal | 33 (94.3%) | 2 (5.7%) | 31 (88.6%) | 4 (11.4%) |
| Pyramids of Temporal Bone | 35 (100%) | 0 (0%) | 35 (100%) | 0 (0%) |
| Sigmoid Sinus Location | 34 (97.1%) | 1 (2.9%) | 34 (97.1%) | 1 (2.9%) |
| Jugular Bulb | 33 (94.3%) | 2 (5.7%) | 31 (88.6%) | 4 (11.4%) |

Evaluation of inner ear structures revealed that most ears appeared normal across multiple parameters. For the right ear, normal findings were most frequent in the semicircular canals and pyramids of the temporal bone (100%), followed by the cochlea and labyrinth fluid signal (91.4%), spiral lamina and modiolus (88.6%), and other structures such as the vestibule, internal auditory canal, symmetry of scala tympani and vestibuli, and jugular bulb, which ranged from 94.3% to 88.6% normal. Abnormalities were relatively uncommon, with the highest rates seen in the spiral lamina & modiolus (11.4%) and cochlea (8.6%). For the left ear, normal findings were similarly predominant, with semicircular canals and temporal bone pyramids normal in all cases (100%), and other parameters ranging from 97.1% (labyrinth fluid signal and sigmoid sinus location) to 85.7% (cochlea and spiral lamina & modiolus). Abnormalities were slightly more frequent in the left ear compared to the right, particularly in the cochlea (17.1%) and spiral lamina & modiolus (14.3%). Overall, magnetic resonance imaging (MRI) proved useful for evaluating soft tissue structures, providing superior contrast resolution for detailed visualisation of the membranous labyrinth, cochlear nerve, and associated neural components (Table 2, Fig. 2).

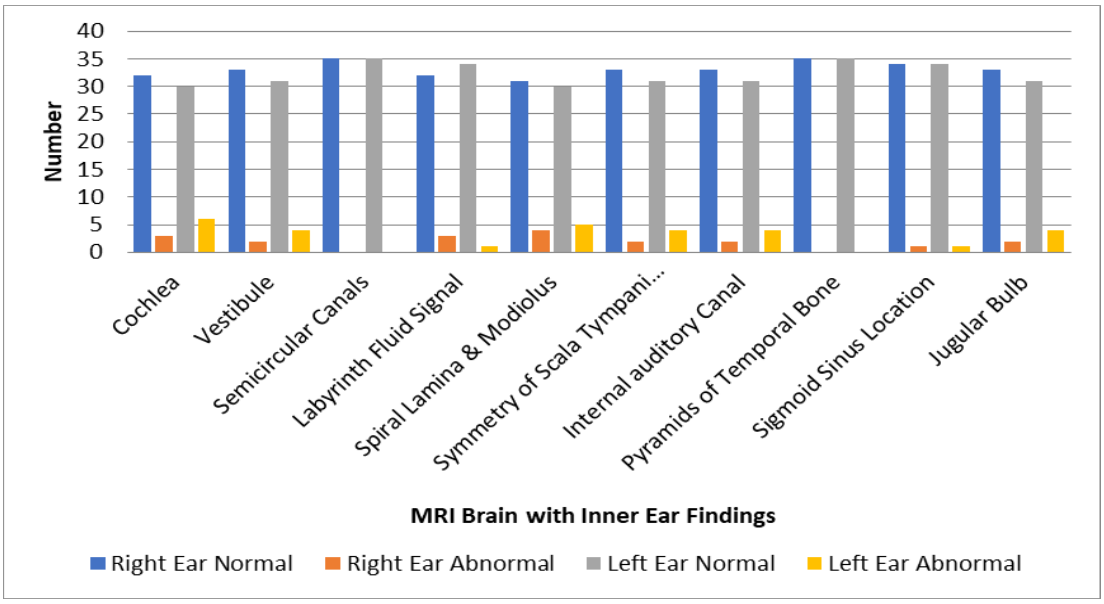


**Fig. 2:** Case Distribution of MRI Brain with Inner Ear Findings

## DISCUSSION

High-resolution CT (HRCT) evaluation in the present study revealed that most temporal bone structures were normal; however, several abnormalities were identified, including poor mastoid pneumatization (22.9%), incomplete partition (10%), and enlarged vestibular aqueduct (6.7%). These findings highlight the role of HRCT in detecting bony abnormalities of the temporal bone. Poor mastoid pneumatization was the most common abnormality, suggesting developmental variations or chronic pathology. HRCT is particularly useful in assessing the bony labyrinth, ossicles, and cochlear architecture, which are critical for surgical planning. Similar findings were reported by Trimble *et al.* [10], who observed temporal bone abnormalities in approximately 20–30% of cochlear implant candidates, predominantly involving bony inner ear structures. Tahir *et al.* [11] reported that HRCT detected structural abnormalities in nearly 25% of patients, emphasizing its importance in identifying cochlear and mastoid variations. Yamazaki *et al.* [12] demonstrated that HRCT plays a crucial role in preoperative assessment by accurately delineating bony anatomy and predicting surgical challenges in cochlear implantation. Fatterpekar *et al.* [13] demonstrated that approximately 20–30% of patients with sensorineural hearing loss show abnormalities on HRCT, particularly involving the bony labyrinth and mastoid air cell system.

Furthermore, Mafee MF *et al.* [14] reported that HRCT accurately delineates temporal bone anatomy in nearly 90–95% of cases and is highly effective in identifying variations in mastoid pneumatization, facial nerve canal, and cochlear patency, which are essential for surgical planning. Alam-Eldeen MH *et al.* [9] also emphasised that HRCT plays a critical role in detecting anatomical variations, such as mastoid pneumatization patterns, sigmoid sinus position, and jugular bulb location, which may influence the surgical approach in cochlear implantation. The present study findings are consistent with these observations, reinforcing the importance of HRCT in preoperative evaluation.

MRI in the present study demonstrated abnormalities in cochlear, vestibular, and neural structures, with incomplete partition, enlarged vestibular aqueduct, and high-riding jugular bulb (11.4% each) being the most frequently observed findings. Importantly, MRI uniquely identified neural abnormalities, including cochlear nerve hypoplasia (6.7%) and aplasia (3.3%), which cannot be reliably detected on HRCT. Additionally, soft-tissue changes, such as labyrinthitis fibrosis, were identified. These findings highlight MRI's superiority for evaluating the neural and soft-tissue components of the inner ear. Similar observations were reported by Adunka *et al.* [15], who identified inner-ear and cochlear-nerve abnormalities in approximately 15–25% of cochlear implant candidates. Roche *et al.* [16] demonstrated that MRI is superior for detecting cochlear nerve deficiencies and soft-tissue abnormalities. Additionally, Young *et al.* [17] reported that MRI plays a critical role in identifying cases of cochlear nerve aplasia and fibrosis. Additionally, similar findings were reported by Casselman *et al.* [3] who demonstrated that MRI detects inner ear abnormalities in approximately 15–25% of patients and is particularly effective in identifying cochlear nerve deficiencies that cannot be visualized on CT.

Furthermore, Burzyńska-Makuch *et al.* [7] reported that MRI changes influenced clinical decision-making in nearly 30% of cochlear implant candidates. Daqqaq *et al.* [5] emphasized that MRI is superior in detecting cochlear nerve pathology, labyrinthine fibrosis, and central causes of hearing loss, thereby complementing HRCT in comprehensive preoperative evaluation. The combined study demonstrated that HRCT and MRI are complementary. HRCT was superior for bony abnormalities, while MRI was superior for neural and soft-tissue evaluation. Some abnormalities were detected by both modalities, showing good agreement.

## CONCLUSIONS

The present study comprehensively evaluated the radiological profile of paediatric patients undergoing cochlear implantation. Radiological evaluation played a pivotal role in preoperative planning. HRCT effectively delineated bony anatomy, identifying abnormalities such as poor mastoid pneumatization, inner ear bony malformations, narrow facial recesses, and variations in critical surgical landmarks. MRI was essential for assessing soft-tissue structures, particularly cochlear nerve integrity and central auditory pathways, and for detecting abnormalities that HRCT could not reveal. Combined HRCT and MRI provided complementary information, enhancing the surgeon’s ability to anticipate potential challenges and plan the approach**.** Early diagnosis, appropriate patient selection, and thorough

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preoperative planning, using both HRCT and MRI, are crucial for optimising surgical outcomes.

## CONTRIBUTION OF AUTHORS

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**Data collection-** Shubhangi Singh, Tvarita Bharsakale, Raj Kumar Verma
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**Literature search-** Tvarita Bharsakale, Raj Kumar Verma
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**Critical review-** Richa Gupta, Shiv Shanker Kaushik
**Article editing-** Shubhangi Singh, Tvarita Bharsakale
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