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Original Research Paper

Radiology

ROLE OF CROSS-SECTIONAL IMAGING IN COCHLEAR MALFORMATION

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ABSTRACT **Background:** Hearing loss is a significant global health concern, affecting millions of individuals, particularly children. The advent of cochlear implants (CIs) has revolutionized treatment options for pediatric patients with severe to profound sensorineural hearing loss (SNHL). This study evaluates the efficacy of high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI) in the preoperative assessment of cochlear implantation candidates. **Materials And Methods:** After approval from IEC, this analytical cross-sectional study was conducted in Department of Radiodiagnosis at SAIMS & PG Institute, Indore and 40 pediatric patients of both sexes referred due to clinical suspicions of hearing loss and the need for cochlear implants were enrolled after taking an informed consent. The diagnostic efficacy of imaging modalities i.e., HRCT and MRI were analyzed to determine their sensitivity, specificity, and overall accuracy in identifying cochlear patency and associated anomalies. **Results:** HRCT demonstrated a sensitivity of 100%, specificity of 93.75%, PPV of 80%, NPV of 100%, and overall accuracy of 95% for cochlear patency. MRI also exhibited a sensitivity of 100%, with a specificity of 96.88%, PPV of 88.89%, NPV of 100%, and overall accuracy of 97.5%. For diagnosing associated anomalies, HRCT showed a sensitivity of 60%, specificity of 100%, PPV of 100%, NPV of 94.59%, and overall accuracy of 95%, while MRI had a sensitivity of 75%, specificity of 100%, PPV of 100%, NPV of 97.30%, and overall accuracy of 97.50%. Statistical analysis revealed no significant differences between HRCT and MRI regarding cochlear capacity and patency (P = 1.000) or in detecting associated anomalies (P = 1.000). **Conclusion:** The study concludes that while both imaging modalities are valuable in preoperative evaluations, HRCT is particularly advantageous for assessing cochlear patency and associated bony anomalies. This facilitates better surgical planning and improves outcomes for pediatric patients undergoing cochlear implantation.

KEYWORDS : Pediatric cochlear implant, temporal bone, cochlear patency, High-Resolution Computed Tomography (HRCT), Magnetic Resonance Imaging (MRI)

INTRODUCTION

Hearing loss is the most common sensory disorder globally, affecting around 5% of the population, including 34 million children [1]. Among children, the prevalence of permanent bilateral sensorineural hearing loss (SNHL) greater than 40 dB HL is estimated to range from 1 to 3 per 1,000 newborns, increasing to 1.62–1.68 per 100 by age 16 [2]. This trend can be attributed to factors such as missed diagnoses in early screenings, postnatal acquisition of hearing loss, late-onset progressive hearing loss, and the influx of children from regions without neonatal hearing screening programs [3]. Among those born with bilateral hearing loss, approximately 25%–30% experience profound hearing loss (greater than 90 dB HL), while 20%–25% have severe hearing loss (71–90 dB HL). Current FDA guidelines indicate that around 45% of children diagnosed with hearing loss may qualify for cochlear implants (CIs) [1].

Cochlear implants are a significant technological advancement that convert auditory signals into electrical impulses, stimulating neurons in the spiral ganglion and enabling sound signal transmission through the cochlear nerve to the auditory cortex. The integrity of the cochlear nerve is vital for auditory-speech performance after implantation, with cochlear nerve aplasia being the only absolute contraindication for receiving a cochlear implant [1].

While MRI is recognized as the gold standard for assessing cochlear nerve integrity, CT scans of the temporal bone are often preferred due to their speed and practicality in clinical settings [4, 5]. Candidates for cochlear implantation undergo comprehensive preoperative evaluations, which include clinical assessments, speech therapy, psychological evaluations, and social considerations. Imaging of the cochlear region is crucial for identifying the cause of hearing loss, assessing factors that may contraindicate surgery, selecting the appropriate ear for implantation, evaluating surgical anatomy, and anticipating potential complications [6].

Understanding the etiology of hearing loss before surgery is essential, with high-resolution computed tomography (HRCT) and MRI being the primary radiological investigations employed [7]. CT scans provide detailed insights into the osseous anatomy of the inner and middle ear, as well as information on mastoid pneumatization and middle-ear aeration, making CT the preferred imaging choice for pediatric candidates [6, 8].

However, CT imaging carries notable drawbacks, particularly the exposure to ionizing radiation, which poses risks to the vulnerable pediatric population. Although low-dose temporal bone CT is an option, achieving high-resolution imaging while minimizing radiation exposure is challenging. Additionally, CT scans visualize the bony channel housing the cochlear nerve but do not provide a direct view of the nerve itself [9].

In contrast, MRI allows direct imaging of the vestibulocochlear nerve bundles in the cisternal and intracanalicular regions, offering the advantage of eliminating radiation exposure. This specialized MRI technique utilizes high-resolution, heavily T2-weighted three-dimensional imaging for detailed anatomical information. However, MRI also has limitations in visualizing aerated or mineralized structures critical for cochlear implantation. The longer duration of MRI procedures often requires sedation for young patients, while CT scans are faster and can provide essential information more efficiently [8].

Radiologists face the challenge of determining the most suitable imaging modality for specific clinical scenarios, leading to questions about the necessity of dual-mode investigations. Both MRI and HRCT are extensively utilized in clinical practice, often complementing each other's strengths. Therefore, this study aims to compare the effectiveness of MRI and HRCT in the preoperative evaluation of pediatric cochlear implantation candidates, assessing which modality provides more valuable insights to guide clinical decision-making.

MATERIAL AND METHODS

An analytical cross-sectional study was conducted after receiving approval from the institutional ethical committee, involving 40 pediatric patients of both sexes referred to the Department of Radiodiagnosis at SAIMS & PG Institute in Indore, due to clinical suspicions of hearing loss and the need for cochlear implants.

The study spanned 15 months, during which patients who met the established inclusion and exclusion criteria were enrolled after obtaining informed consent from the parent/guardian after explaining the study protocol.

Inclusion Criteria

- Patients with clinical suspicion of hearing loss and cochlear implant patient in pediatric age group patients
- *Exclusion Criteria*
- Patients whose parents/guardians did not gave consent for participation in the study
- Patients in whom Magnetic Resonance Imaging and CT are contraindicated.
- Patients on life support systems.

Methodology

After obtaining informed consent, participants were subjected to a thorough preoperative evaluation, which included detailed medical and hearing histories, audiologic assessments, and imaging.

The medical history covered patient characteristics such as age, sex, onset of hearing loss, and relevant family, perinatal, and medical history. Audiologic evaluation involved pure tone audiometry for children aged 4 and above, or auditory brainstem response for younger patients, along with otoacoustic emissions testing and aided threshold testing. Speech discrimination tests were also conducted to determine the lack of benefit from hearing aids.

The imaging protocols, approved by the hospital's ethics committee, involved non-contrast high-resolution computed tomography (HRCT) of the temporal bone using a Siemens 128-slice CT scanner (Somatom Definition AS). Sedation was administered to younger children to minimize movement. The high-resolution imaging technique was carefully calibrated, with the CT scanner angled 20 degrees from the craniocaudal to the orbitomental line for precise scanning. Temporal bone images were taken in axial and coronal sections with slice thicknesses ranging from 0.5 to 1 mm, and targeted imaging was employed. The images were reviewed using the bone algorithm technique, reconstructed, and analyzed for pre-surgical planning purposes.

For the MRI examination, a 1.5 Tesla Magnetom (Siemens) machine was utilized with a fast-moving 3D echo sequence, providing images with a thickness of 0.75-0.85 mm. To assess the inner auditory canal, T2-weighted imaging (T2WI) was employed using two-dimensional oblique sequences, applying a fast-moving echo aligned along the axis from the right side. This approach allowed for detailed visualization of the inner ear structures and cochlear nerve, critical for preoperative evaluation in cochlear implantation candidates. All CT scan and MRI images were analyzed by the first author, who was blinded to the surgical and clinical outcomes. The radiological findings were documented as either positive or negative based on the imaging results. The final step involved matching the radiological findings from HRCT and MRI of the temporal bone with the actual surgical findings to assess their accuracy and correlation.

Statistical Analysis

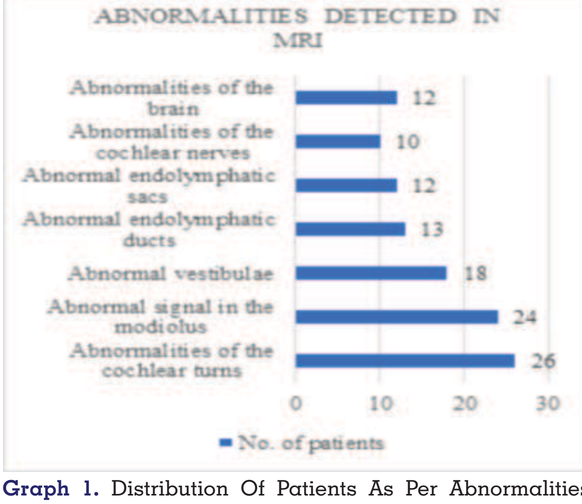
The data was coded and entered into Microsoft Excel 2010, and analyzed using both Excel and SPSS 20.0 for Windows. The study results were organized into tables and subjected to statistical analysis. Descriptive statistics were employed to identify characteristics and features of the collected data, with mean and percentage utilized for representation. A Chi-square test was applied to assess associations between variables, considering a p-value of less than 0.05 as statistically significant. Additionally, sensitivity, specificity, positive predictive value, and negative predictive value were calculated to further evaluate the data.

RESULTS

A total of 40 patients (a total of 80 temporal bones/cases) were included over 2½ years of time. Each temporal bone was analyzed separately. There were 25 male patients and 15 female patients. The majority of the patients (33) were mute at the time of attending the ENT surgeon. All patients were between the ages of 6 months and 18 years. Most of the patients belonged to the age group of 1-5 years, with 10 patients being 3 years old and 8 being 2 years old.

Of the 80 temporal bones imaged with MRI, the following abnormalities were encountered: 32% (26/80) had abnormalities of the cochlear turns, 30% (24/80) had abnormal signal in the modiolus, 23% (18/80) had abnormal vestibulae, 16% (13/80) had abnormal endolymphatic ducts, 15% (12/80) had abnormal endolymphatic sacs, 12% (10/80) had abnormalities of the cochlear nerves, and 29% (12/40) had abnormalities of the brain. (Graph 1)

The results for the capacity of cochlear patency and associated anomalies, confirmed during surgery, revealed that out of 40 patients, obstruction of cochlear patency was identified in 8 patients. Additionally, associated anomalies were observed in 5 patients, as shown in Table 1.



Graph 1. Distribution Of Patients As Per Abnormalities Detected In MRI

Cochlear Patency And Associated Anomalies

Table-1: The Final Results Proved During Surgery

No of patients	Cochlear Patency		Anomalies	
	Open	Closed	No	Yes
40	32 (80%)	8 (20%)	35 (87.5%)	5 (12.5%)

For Cochlear Patency

Results as reported in HRCT: The HRCT results of the temporal bone, showing the capacity and cochlear patency in candidate patients for cochlear implantation, are presented in Table 2. Out of 40 patients studied, HRCT results were in good agreement with surgical findings in 38 cases. In 30 cases, a patent cochlea (Figure 1a) was operated on in the usual manner, while 8 cases showed cochlear obstruction in both HRCT and during surgery (Figure 1b), and these were operated on via a cochleostomy. These findings were confirmed during surgery. In 2 cases, HRCT findings mistakenly reported cochlear bone canal obstruction (false positives), which was not verified during surgery. In these cases, the cochlear implant was performed in the usual manner. No case of patent cochlea found on HRCT was disproven during surgery.

HRCT demonstrates exceptional diagnostic performance in predicting cochlear patency, with a sensitivity of 100% and specificity of 93.75%. It effectively identifies open and obstructed cochleas, achieving a positive predictive value of 80% and a negative predictive value of 100%. With an overall accuracy of 95% and a statistically significant p-value of 0.000, these results confirm HRCT's reliability in evaluating cochlear patency for cochlear implant candidates

Table 2. The HRCT Results Of Temporal Bone Showing The Capacity Of Cochlear Patency

Variable		During Surgery		Total	P value
		Closed	Open		
HRCT	Close	8	2	10	0.000 * Sig
	Open	0	30	30	
	Total	8	32	40	
Sensitivity	100%				
Specificity	93.75%				
PPV	80%				
NPV	100%				
Accuracy	95%				

Results as reported in MRI: The MRI findings regarding the temporal bone, which assess cochlear capacity and patency in candidates for cochlear implantation, are summarized in Table 3. Among the 40 patients, 39 were correctly diagnosed through MRI, comprising 8 positive cases that revealed patent cochlea (Figure 2a) and 31 negative cases indicating cochlear obstruction (Figure 2b). However, one case was inaccurately reported as closed (false positive) in the MRI evaluation compared to the surgical results. As a result, the patients proceeded with cochlear implantation as planned.

The MRI analysis demonstrated strong diagnostic effectiveness in evaluating cochlear patency for surgical outcomes, with a sensitivity of 100% and a specificity of 96.88%. It achieved a positive predictive value of 88.89% and a negative predictive value of 100%, indicating high reliability in matching surgical findings. Overall accuracy was 97.50%, and a p-value of 0.000 highlights significant statistical reliability, confirming MRI's effectiveness in preoperative assessments for cochlear implantation.

Table 3. The MRI Results Of Temporal Bone Showing The Capacity Of Cochlear Patency

Variable		During Surgery		Total	P value
		Closed	Open		
MRI	Close	8	1	9	0.000 * Sig
	Open	0	31	31	
	Total	8	32	40	
Sensitivity	100%				
Specificity	96.88%				
PPV	88.89%				
NPV	100%				
Accuracy	97.50%				

For Associated Anomalies

Results as reported in HRCT: The HRCT results of the temporal bone, highlighting associated anomalies in candidates for cochlear implantation, are summarized in Table 4.

Among the 40 patients studied, HRCT findings for 38 patients aligned well with the identification of associated anomalies. Specifically, 35 cases were reported as having normal inner and middle ear structures, while abnormalities were noted in 3 cases (Figure 1c). When comparing HRCT results to surgical findings, 2 cases were incorrectly identified as normal, leading to false negatives. However, there were no instances of false positives, as all reported abnormalities in the HRCT were confirmed during surgery.

The analysis of HRCT data shows strong diagnostic efficacy in detecting associated anomalies in cochlear implantation candidates, with a sensitivity of 60% and a specificity of 100%. It achieved a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 94.59%, indicating high reliability in results.

The overall accuracy was 95%, and the statistically significant p-value of 0.000 highlights HRCT's effectiveness in preoperative evaluations for diagnosing associated anomalies.

Table 4. The HRCT Results Of Temporal Bone For Detecting Associated Anomalies

Variable		During Surgery		Total	P value
		Yes	No		
HRCT	Yes	3	0	3	0.000 * Sig
	No	2	35	37	
	Total	5	35	40	
Sensitivity	60%				
Specificity	100%				
PPV	100%				
NPV	94.59%				
Accuracy	95%				

Results as reported in MRI: The MRI results of the temporal bone for detecting associated anomalies in the candidates for cochlear implantation are presented in Table 5. Among the 40 patients under study, 39 were diagnosed by MRI, which indicated no anomaly. This group underwent similar surgery for assessing associated anomalies, resulting in 3 positive cases that showed associated anomalies (Figure 2c) and 36 negative cases. Conversely, the MRI results did not include any false negatives compared to the surgical findings.

The MRI exhibited a sensitivity of 75% and a specificity of 100%, with a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 97.30%. Overall, the accuracy was 97.50%, and the findings were statistically significant (p-value of 0.000), demonstrating MRI's effectiveness in identifying associated anomalies in this patient population.

Table-5: The MRI Results Of Temporal Bone For Detecting Associated Anomalies.

Variable		During Surgery		Total	P value
		Yes	No		
MRI	Yes	3	0	3	0.000 * Sig
	No	1	36	37	
	Total	4	36	40	
Sensitivity	75%				
Specificity	100%				
PPV	100%				
NPV	97.30%				
Accuracy	97.50%				

Comparison Of The Diagnostic Value Of HRCT and MRI Of Temporal Bone In The Candidates For Cochlear Implantation

The comparison of high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI) for assessing the temporal bone in cochlear implant candidates shows that both methods offer comparable diagnostic performance. Statistical analysis indicated no significant differences between HRCT and MRI in terms of their effectiveness in determining cochlear capacity and patency (P = 1.000) or in detecting associated anomalies (P = 1.000). These results affirm the reliability of both imaging techniques for the preoperative evaluation of cochlear implant candidates, demonstrating that either modality can be utilized effectively in clinical practice.

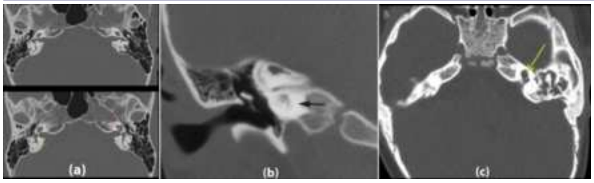


Fig.1: The temporal bone HRCT demonstrating (a) patent cochlea, (b) obstructed cochlea, and (C) Cochlear anomaly (common cavity).

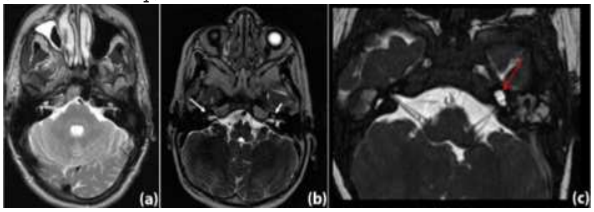


Fig.2: The temporal bone MRI demonstrating(a) patent cochlea, (b) obstructed cochlea, and (c) Cochlear anomaly (common cavity).

DISCUSSION

This study aimed to assess the diagnostic efficacy of high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI) of the temporal bone in patients eligible for cochlear implantation, comparing the imaging findings with surgical outcomes. The results demonstrated that both HRCT and MRI possess significant diagnostic value in this patient population. Roberts et al. [10] reported HRCT's accuracy, sensitivity, specificity, positive predictive value, and negative predictive value as 94.91%, 93.39%, 82.35%, 100%, and 93.33%, respectively. While these results align closely with the current study's findings, a difference in sensitivity may stem from variations in the types of abnormalities evaluated.

Dinarwand et al. [11] indicated that HRCT's diagnostic value for assessing cochlear duct patency yielded an accuracy of 97.5%, with sensitivity, specificity, positive predictive value, and negative predictive value recorded at 100%, 97.4%, 75%, and 100%, respectively. Although these values surpass those found in the current study for HRCT, they show some similarity to the MRI results regarding cochlear duct patency. Furthermore, Dinarwand et al. [11] noted an accuracy of 95.1% for HRCT in identifying associated anomalies, with sensitivity at 60%, specificity at 100%, positive predictive value at 100%, and negative predictive value at 94.7%.

The current study's results align with previous research, confirming HRCT's comparable diagnostic value in detecting anomalies. Ajalloueyan et al. [12] found that the agreement between preoperative CT findings and surgical outcomes exceeded 80%, although limitations in CT imaging were noted in areas such as the attic, middle ear, pyramid, and jugular bulb.

While some studies report no significant differences in sensitivity or specificity between MRI and CT for identifying cochlear implantation-related abnormalities, others suggest that MRI often provides greater sensitivity, particularly for critical conditions influencing treatment decisions, such as cochlear fibrosis, hypoplasia or aplasia of the cochlear nerve, and various brain abnormalities. In this study, MRI had one incorrect diagnosis regarding cochlear capacity and patency, while HRCT had two erroneous findings. Both modalities demonstrated the ability to individually identify abnormalities.

Mackeith et al. [13] emphasized that MRI could identify all critical abnormalities informing surgical decisions, showcasing greater sensitivity than CT. Significant MRI findings, such as cochlear fibrosis and hypoplastic hearing impairment, are frequently not detected by CT. This reinforces the need for a comprehensive evaluation using both imaging modalities to ensure accurate diagnosis and effective treatment planning.

The findings are consistent with previous research, highlighting MRI's strengths in diagnosing soft tissue issues in the middle ear, as Parry et al. [14] indicated it is a superior diagnostic tool for cochlear implantation candidates. In contrast, Al-Rawy et al. [15] found that while CT deemed all patients suitable for surgery, MRI identified that 96.5% were eligible, with only one patient disqualified due to the absence of a bilateral vestibulocochlear nerve.

Al-Rawy et al. [15] reported CT's sensitivity, specificity, positive predictive value, and negative predictive value as 98%, 25%, 94.7%, and 50%, respectively, finding no significant differences between the two imaging modalities. Bettman et al. [16] similarly found comparable sensitivity and specificity for MRI and CT when evaluating cochlear patency, reinforcing the conclusions drawn in this study.

Both MRI and CT effectively identify significant abnormalities; however, certain bone-related issues are better defined by CT due to its superior resolution. Thus, CT remains a valuable tool for detecting bony abnormalities, complementing MRI's strengths in soft tissue assessment. This suggests that a combined approach utilizing both imaging modalities may offer a more comprehensive evaluation for cochlear implantation candidates.

Limitations of the study include a small sample size of 40 patients, which may impact the generalizability of the findings. Additionally, variations in imaging protocols and a lack of long-term follow-up may restrict the correlation of imaging findings with surgical outcomes. Future research should address these limitations for a more comprehensive understanding of HRCT and MRI's roles in cochlear implantation.

CONCLUSION

This study demonstrates that both high-resolution computed tomography (HRCT) and magnetic resonance imaging (MRI) are effective for evaluating cochlear implantation candidates, each with unique advantages. HRCT is superior in detecting bony abnormalities and is more cost-effective, while MRI provides greater sensitivity for soft tissue conditions. Both imaging modalities show high diagnostic accuracy with no significant differences in assessing cochlear patency or identifying associated anomalies. The study recommends starting with HRCT and using MRI when initial findings are unclear. Combining both methods may enhance evaluation and surgical planning, ultimately improving patient outcomes.

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