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Value of Imaging in Cochlear Implantation Patients

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ABSTRACT

Background: Cochlear implantation (CI) is an established therapeutic intervention for patients presenting with sensorineural hearing loss of severe degree (70–90 dB HL) and profound degree (> 90 dB HL), facilitating auditory rehabilitation. Preoperative cochlear imaging is critical for identifying the etiology, guiding device selection, determining the appropriate side for implantation, and optimizing surgical timing. This study seeks to evaluate the relationship between radiological evaluations and intraoperative observations in patients undergoing cochlear implantation.

Subjects and methods: This study included 50 participants enrolled in the CI program who underwent CI surgery.

Results: Radiological evaluation of the facial nerve showed anterior displacement in 3 patients (6%), with the remaining 47 patients (94%) demonstrating normal anatomical positioning. In contrast, intraoperative findings revealed anterior displacement in 4 patients (8%), lateral displacement in 6 patients (12%), and normal positioning in 40 patients (80%). Imaging accurately predicted the facial nerve course in 41 cases (82%), while it was inconclusive or incorrect in 9 cases (18%).

Conclusions: CT offers high-resolution imaging of temporal bone microanatomy, mastoid air cell system pneumatization, and cochlear lumen patency. However, it has limitations in assessing neural structures, intracochlear fluid, or fibrosis within the inner ear. In contrast, magnetic resonance imaging offers superior visualization of the inner auditory canal nerves, retrocochlear pathologies, and membranous changes within the inner ear. Despite its advantages, MRI provides limited information on bony structures and is associated with higher costs.

Keywords: Cochlear implant, Semicircular canal, Internal carotid artery, Cerebrospinal fluid.

INTRODUCTION

Cochlear implants (CI) were first developed in France in 1957 by Djourno and Eyries, who pioneered the technique of electrically stimulating the cochlear nerve. The concept of auditory excitation via electrical currents was originally demonstrated by Volta in the late 18th century. Early advancements in cochlear implant technology were limited by the size of electronic components and the weight of power sources [1].

CI is regarded as an efficacious intervention for individuals with profound (> 90 dB) and severe (70 to 90 dB) hearing loss. Recent advancements in speech processing strategies have resulted in enhanced auditory outcomes [2]. As the demand for CI rises, radiologists must be cognizant of the essential factors to evaluate prior to patient implantation [3].

Candidates for cochlear implantation underwent an extensive preoperative assessment that included clinical examination, speech and language evaluation, rehabilitative readiness, psychological profiling, and social considerations. Imaging of the cochlear region constituted a vital aspect of this evaluation, facilitating the identification of etiological factors contributing to hearing loss, informing cochlear device selection, determining the appropriate side for implantation, and planning the timing of surgery [4].

Given the significance of accurate preoperative assessment, an optimal evaluation protocol combined high-resolution CT combined with magnetic resonance imaging (MRI) of the temporal bone. This study aimed to correlate preoperative radiological findings with intraoperative observations in patients undergoing cochlear implantation.

PATIENTS AND METHODS

Fifty patients were enrolled in this study from the CI program who underwent CI surgery, encompassing all ages and both genders. Patients met the criteria for cochlear implantation, inclusion criteria encompassed bilateral profound hearing loss refractory to amplification via hearing aids, as well as absence of auditory brainstem response (ABR) waves and phoniatric criteria for inclusion encompassed an intelligence quotient (IQ) exceeding 80, assessed using the Stanford-Binet Intelligence scale, alongside the absence of any medical, surgical, or radiological contraindications to surgery. Family motivation and commitment to continued audiological and phoniatric follow-up were also essential components of patient selection. The study was conducted between January 2015 and January 2016 following approval by the Research Ethics Committee of the Faculty of Medicine, Sohag University, Sohag, Egypt. Informed written consent was obtained from all participants or their legal guardians prior to enrollment.

Exclusion criteria: Patients who did not fulfill the established indications for cochlear implantation, those lacking complete preoperative evaluation data, and individuals with significant cochlear malformations

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such as common cavity deformity. All participants underwent comprehensive preoperative radiological assessment utilizing high-resolution CT and MRI of the temporal bone.

Radiological images were independently reviewed by both otologic surgeons and radiologists, with anatomical and pathological findings discussed during multi-disciplinary cochlear implant committee meetings and prior to surgical intervention. All surgeries were performed or supervised by a single experienced surgeon. Intraoperative findings were meticulously documented and correlated with preoperative imaging data.

The diagnostic accuracy of radiological assessment was evaluated by comparing imaging findings with intraoperative observations. Concordant results were classified as true positives or true negatives, while discrepancies were designated as false positives (Radiological findings not confirmed surgically) or false negatives (Normal imaging despite intraoperative abnormalities). This analysis aimed to assess the reliability of imaging modalities in preoperative evaluation for cochlear implantation.

The methods for CT and MRI:

CT scans of the temporal bone were performed at radiology department at Sohag university hospital by using an 8-dectors scanner (General Electronic Medical Systems, USA). Scanning is performed using a standard axial plane protocol with a helical acquisition technique set at 135 kV, 230 mAs, a pitch of 0.69, and a slice thickness of 0.5 mm. During imaging, the patient's head is maintained in a neutral position without chin tilt to align approximately with the Reid baseline. The acquired image data are reconstructed over a 230-mm field of view. Utilizing a dedicated workstation. Axial source images are processed to generate coronal and sagittal multiplanar reformatted (MPR) images. Additionally, oblique coronal MPRs are customized to the cochlear axis to visualize the entire cochlear turns within a single image.

MRI was performed using a dedicated head coil with patients positioned supine in a neutral posture. The imaging protocol included axial and coronal balanced turbo field echo (B_TFE) sequences centered on the inner ear, oblique sagittal T2-weighted three-dimensional DRIVE CLEAR sequences targeting the internal auditory canals, and fluid-attenuated inversion recovery (FLAIR) sequences of the brain. Specific imaging parameters were as follows: Axial and coronal B_TFE (TR: 6 ms; TE: 3 ms; field of view [FOV]: 180 mm; slice thickness: 1 mm; interslice gap: 0.5 mm; flip angle: 60°; scan time: 1.43 minutes axial, 1.35 minutes coronal), oblique sagittal T2W 3D DRIVE CLEAR (TR: 1.5 s; TE: 250 ms; FOV: 130 mm; slice thickness: 1.4 mm; interslice gap: 0.7 mm; flip angle: 90°; scan time: 2.26 minutes), and FLAIR (TR: 9 s; TE: 140 ms; FOV: 230 mm; slice thickness: 4 mm; interslice gap: 1 mm; flip angle: 90°; scan time: 3 minutes). Light sedation was administered to uncooperative pediatric patients to minimize motion artifacts during scanning.

Parameters evaluated for statistical analysis included skull bone thickness, mastoid pneumatization, lateral sinus positioning, dura mater level in the middle cranial fossa, jugular bulb position, facial nerve course, lateral semicircular canal (SCC) orientation, alignment of the cochlear basal turn relative to the internal carotid artery (ICA), cochlear duct patency, expected electrode insertion depth, vestibular aqueduct condition, and the relationship of the endolymphatic sac to cerebrospinal fluid (CSF) gusher and round window accessibility.

Statistical analyses

It was conducted using SPSS version 26 (IBM Corp., Armonk, NY, USA). Quantitative data are presented as means ± standard deviations (SD), whereas qualitative variables are expressed as frequencies and percentages (%).

RESULTS

The study cohort had a mean age of ± 3.5 and a median age of 4 years, with an age range spanning from 2 to 26 years. The mean age among female participants was 5.2 years, whereas male participants had a mean age of 3.6 years (Table 1).

Table (1): Participant Distribution According to Age Groups and Gender

Age	Male	Female
< 2	4	3
2	8	4
4	13	16
6	0	0
8	0	0
10	0	0
>10	0	2

Data are presented as numbers.

The overall radiological and surgical study of skull bone thickness, type of mastoid process and lateral sinus position, crosstabulation of radiological and surgical skull bone thickness, type of mastoid process and lateral sinus position assessment were enumerated in **Table 2**

Table (2): The overall radiological and surgical study of skull bone thickness, type of mastoid process and lateral sinus position, cross-tabulation of radiological and surgical skull bone thickness, type of mastoid process and lateral sinus position assessment

Skull bone thickness	Radiology		Surgery	
Thick	27		23	
Thin	23		27	
Radiology skull bone thickness	Surgery skull bone thickness			
	Thick		Thin	
Thick	18 (true +ve)		9 (false +ve)	
Thin	5 (false -ve)		18 (true -ve)	
Type of mastoid process				
	Radiology		Surgery	
Pneumatic	39		36	
Diploic	6		14	
Sclerotic	3		0	
Mixed	2		0	
Surgery Mastoid process	Radiology Mastoid process			
	Diploic	Mixed	Pneumatic	Sclerotic
Diploic	4	2	5	3
pneumatic	2	0	34	0
Lateral sinus position				
Lateral sinus position	Radiology		Surgery	
Normal	43		38	
Ant. displaced	4		11	
Lat. displaced	3		1	
Radiology Lateral Sinus position	Surgery Lat sinus position			
	Normal	Ant dips	Lat dips	
Normal	33	9	1	
Ant dips	2	2	0	
Lat dips	3	0	0	

Data are presented as numbers.

The radiological evaluation of the facial nerve indicated that three patients (6%) had anterior displacement of the nerve, whereas 47 patients (94%) presented with a normal configuration. Surgical assessment of the patients indicated that four patients (8%) exhibited anterior displacement, six patients (12%) had lateral displacement, whereas 40 patients (80%) presented with normal alignment. Imaging accurately delineated the facial nerve location in 41 patients (82%), while it failed to do so in nine cases (18%) (Table 3).

Table (3): Concordance of radiological and surgical assessments of Middle Cranial Fossa Dura level, Jugular Bulb position, and Facial nerve position

Level of middle cranial fossa dura			
Middle cranial fossa dura	Radiology		Surgery
Normal	38		39
Low	12		11
Radiology Middle cranial fossa dura	Middle cranial fossa dura		
	Normal		Low
Normal	31 (true -ve)		7 (false -ve)
Low	8 (false +ve)		4 (true +ve)
Jugular bulb position			
Jugular bulb position	Radiology		Surgery
Normal	30		48
High	20		2
Radiology Jugular bulb position	Jugular bulb position		
	Normal		High
Normal	29 (true +ve)		1 (false +ve)
High	19 (false -ve)		1 (true -ve)
Facial nerve position			
Facial nerve position	Radiology		Surgery
Normal	47		40
Ant displaced	3		4
Lat displaced	0		6
Radiology Facial nerve position	Facial nerve position		
	Normal	Ant dips	Lat dips
Normal	39	2	6
Ant dips	1	2	0

Data are presented as numbers.

Cross-tabulation of radiological and surgical evaluations was performed for the SCC, alignment of the cochlear basal turn with ICA, vestibular aqueduct, and endolymphatic sac. A detailed analysis specifically addressing the basal turn–ICA alignment, vestibular aqueduct, and endolymphatic sac findings was also conducted and enumerated in table (4).

Table (4): Comparative analysis of radiological and surgical evaluations of the lateral semicircular canal, basal turn–internal carotid artery spatial relationship, vestibular aqueduct morphology, and endolymphatic sac characteristics, including an in-depth assessment of basal turn–ICA alignment, vestibular aqueduct, and endolymphatic sac metrics

<table>
<tr><th rowspan="2">Radiology Lat SCC position</th><th colspan="3">Surgery Lat SCC position</th></tr>
<tr><th colspan="3">normal</th></tr>
<tr><td>Normal</td><td colspan="3">50</td></tr>
<tr><th colspan="4">The overall radiological and surgical study of Basal turn alignment with ICA</th></tr>
<tr><th>Basal turn alignment with ICA</th><th colspan="2">Radiology</th><th>Surgery</th></tr>
<tr><td>No post rotation</td><td colspan="2">47</td><td>45</td></tr>
<tr><td>post rotated cochlea</td><td colspan="2">3</td><td>5</td></tr>
<tr><th rowspan="2">Radiology Basal turn alignment with ICA</th><th colspan="3">Surgery Basal turn alignment with ICA</th></tr>
<tr><th colspan="2">no post rotation</th><th>post rotation</th></tr>
<tr><td>no post rotation</td><td colspan="2">43 (true -ve)</td><td>4 (false -ve)</td></tr>
<tr><td>post rotation</td><td colspan="2">2 (false +ve)</td><td>1 (true +ve)</td></tr>
<tr><th colspan="4">Vestibular aqueduct and endolymphatic sac</th></tr>
<tr><th rowspan="2">Radiology / Surgery</th><th colspan="2">Radiology</th><th rowspan="2">Surgery(CSF gusher)</th></tr>
<tr><th>vestibular aqueduct</th><th>endolymphatic sac</th></tr>
<tr><td>Normal</td><td>46</td><td>47</td><td>47</td></tr>
<tr><td>Dilated</td><td>4</td><td>3</td><td>3</td></tr>
<tr><th rowspan="2">Radiology vestibular aqueduct</th><th colspan="3">Surgery CSF gusher</th></tr>
<tr><th colspan="2">Yes</th><th>No</th></tr>
<tr><td>Normal</td><td colspan="2">1</td><td>45</td></tr>
<tr><td>Dilated</td><td colspan="2">2</td><td>2</td></tr>
<tr><th rowspan="2">Radiology endolymphatic sac</th><th colspan="3">Surgery CSF gusher</th></tr>
<tr><th colspan="2">Yes</th><th>No</th></tr>
<tr><td>Normal</td><td colspan="2">1</td><td>46</td></tr>
<tr><td>Dilated</td><td colspan="2">2</td><td>1</td></tr>
</table>

Data are presented as numbers, SCC: Semicircular canal, ICA: Internal carotid artery, CSF: Cerebrospinal fluid.

Comprehensive radiological and intraoperative assessment of round window accessibility, accompanied by cross-tabulation analysis comparing radiological findings with surgical observations, were detailed in table (5).

Table (5): Integrated radiological and intraoperative analysis of round window accessibility and cross-tabulation of findings

<table>
<tr><th>Round window accessibility</th><th>Radiology</th><th>Surgery</th></tr>
<tr><td>open accessibility</td><td>41</td><td>37</td></tr>
<tr><td>Difficult exposure</td><td>9</td><td>13</td></tr>
<tr><th rowspan="2">Radiology round window niche</th><th colspan="2">Surgery round window niche</th></tr>
<tr><th>Open accessibility</th><th>Difficult</th></tr>
<tr><td>open accessibility</td><td>34 (true -ve)</td><td>7 (false -ve)</td></tr>
<tr><td>Difficult</td><td>3 (false +ve)</td><td>6 (true +ve)</td></tr>
</table>

Data are presented as numbers.

DISCUSSION

Preoperative imaging of the temporal bone is invaluable for evaluating local anatomical structures and pathological conditions that could potentially complicate surgery or compromise cochlear implant functionality. Consequently, imaging studies are indispensable prior to cochlear implantation. Detecting structural abnormalities within the cochlea, middle ear, and mastoid is critical to devising an optimal surgical plan [5].

In our study, the radiological assessment of skull bone thickness effectively identified the accurate type of skull bone thickness (As an indicator for the probable seat depth for the internal device) in 36 cases (72%) with sensitivity of 66.7%, and specificity of 78%. No similar study published in this subject was found according to our knowledge that may document the correlation between the skull bone thickness and the depth of the intended seat drilling.

In this study, CT imaging accurately identified the true type of mastoid process in 38 patients (76%). This aligns with the work of **Vlastarakos *et al.*** [6] which identified a robust association between radiological evaluations and surgical results in the mastoid air cell complex. We also discovered that the condition of pneumatization of the mastoid process bore no correlation to the degree of accessibility of the round window. Among the 13 patients with challenging round window accessibility during surgery, 11 exhibited pneumatic mastoid conditions. Our result opposes the suggestions made by **Park *et al.*** [7] who demonstrated that poor mastoid pneumatization correlates with increased challenges during cortical mastoidectomy. They evaluated the utility of CT imaging in anticipating potential difficulties throughout the critical stages of cochlear implant surgery.

We found that the radiological assessment of lateral sinus position had succeeded in suggesting its true position in 33 patients (66%). Of 50 CI patients, 12 patients had displaced lateral sinus. This finding aligns with the study by **Vlastarakos *et al.*** [6] study who reported a strong correlation between radiological assessments and intraoperative findings concerning the anatomical position of the lateral sinus. This observation is parallel with the findings of **Ma *et al.*** [8] who also discovered that four instances exhibited considerable sigmoid sinus displacement, complicating the surgical procedure.

In our study, only three patients with lateral sinus displacement observed during surgery experienced difficulty accessing the round window, indicating that the position of the lateral sinus has minimal influence on round window accessibility. Similarly, **Park *et al.*** [7] reported no association between lateral sinus position and difficulty performing cortical mastoidectomy. Evaluation of the middle cranial fossa dura revealed that radiological assessment accurately identified the true dura position in 35 cases (72%), demonstrating a sensitivity of 36.4% and specificity of 79.5% in identifying a low-lying middle cranial fossa dura. This concurs with the findings of **Vlastarakos *et al.*** [6] and **Zhang *et al.*** [9] who reported a strong correlation between radiological assessments and intraoperative observations in evaluating the position of the tegmen. Our analysis indicated that elevation of the middle cranial fossa dura showed minimal correlation with the degree of round window accessibility. Of the 11 patients identified intraoperatively with a low-lying dura mater, only four exhibited challenging access to the circular window. **Park *et al.*** [7] discovered that a low tegmen location correlated with challenges in performing cortical mastoidectomy.

We found also that the radiological assessment of jugular bulb position had succeeded in detecting its true position in 30 patients (60%) with sensitivity of 50% and specificity of 60.4%. This finding contrasts with the study by **Lima Júnior *et al.*** [5], which evaluated the role of imaging modalities in cochlear implant surgery. Their cohort was divided into two groups: Group A, which underwent CT imaging alone, demonstrated an accuracy of 69.69%, sensitivity of 36.36%, and specificity of 86.36%. Conversely, group B, which received both CT and MRI, exhibited improved diagnostic performance with an accuracy of 80.59%, sensitivity of 38.46%, and specificity of 90.74%.

In the present study, all patients underwent both CT and MRI. The radiological parameters were analyzed individually, revealing limited efficacy of imaging in detecting or excluding high jugular bulbs. This discrepancy is attributed to differing criteria: Radiologically, the jugular bulb is considered high if it reaches the level of the cochlea’s basal turn, regardless of whether it obscures the round window niche. However, emphasis is placed only on elevated jugular bulbs that physically impede round window access.

Imaging accurately localized the facial nerve in 41 patients (82%). Notably, the position of the facial nerve exhibited minimal correlation with the degree of round window accessibility. Among the 10 patients demonstrating facial nerve displacement, intraoperatively only three experienced difficulty accessing the round window. To our knowledge, no prior studies have specifically examined this relationship.

The radiographic and surgical evaluation of lateral SCC location showed a sensitivity and specificity of 100%. This is supported by **Vlastarakos *et al.*** [6] and **Zhang *et al.*** [9] who identified a robust association between radiological evaluations and surgical findings for the assessment of lateral SCC. As regards evaluation of basal turn alignment with ICA, the radiological assessment was successful to detect the alignment in 44 cases (88%) with sensitivity of 20% and specificity of 95.6%. We found also among the 50 patients studied, 45 patients (90%) were classified as normal, five patients (10%) were classified as posteriorly rotated.

Our findings also indicated that posterior rotation of the cochlea serves as a predictive factor for challenges in round window accessibility. Of the 50 patients studied, five experienced difficult exposure, with four of these cases demonstrating limited round window accessibility during surgery. This contradicts the findings of the investigation conducted by **Pendem *et al.*** [10] who discovered that in 50 CI candidates evaluated, 38% (n=19) were classified as having normal alignment, while 62% (n=31) were identified as having a rotated basal turn. This discrepancy can be attributed to differences in assessment methods. The referenced study employed a classification system based on quantitative measurements of the spatial interval between the oval window and round window niche derived from preoperative high-resolution CT (HRCT) of the temporal bone. These radiological metrics were then systematically correlated with corresponding intraoperative measurements to assess anatomical congruence. In contrast, our study relied on evaluating the alignment of the basal turn relative to ICA, if it is in line with ICA it is normal in position and if it is not in line with ICA it is post-rotated. Some authors as **Singla *et al.*** [11] reported that in three cases, the carotid canal was located adjacent to the basal turn of the cochlea, while in five cases, the carotid canal impinged upon the anterior cochlear wall. In contrast, our study observed a normal ICA position in all cases. Regarding the spatial alignment with the ICA, five patients demonstrated posterior rotation of the cochlear basal turn.

As regards assessment of cochlear duct patency, we found that surgical and radiological findings were consistent regarding cochlear duct patency in 47 cases and full electrode insertion, while 2 cases needed compressed MEDEL electrode insertion (short 15 mm) and one case was not fully inserted. This is in accordance with **Dinarvand *et al.*** [12] who found that the surgical outcomes and HRCT findings in 37 cases were consistent with cochlear duct patency, although cochlear duct closure was observed in 3 cases, as validated during surgery using HRCT data. In one case, HRCT suggested ossification of the cochlear duct. However, this finding was not confirmed intraoperatively, and cochlear implantation proceeded according to the standard protocol.

In assessing the vestibular aqueduct and endolymphatic sac, and their association with CSF gusher occurrence, two patients presenting with radiologically dilated vestibular aqueducts experienced CSF gushers during surgery. Conversely, two additional patients with comparable imaging findings did not exhibit a gusher. This yielded a sensitivity of 66.7% and a specificity of 95.7% for the prediction of CSF gusher presence in cases of vestibular aqueduct dilation. Therefore, radiological assessment of the vestibular aqueduct serves as a reliable negative predictive tool for ruling out CSF gusher in cases with a normal duct.

Regarding the endolymphatic sac, two patients with a dilated sac also experienced a gusher, while one patient with a dilated sac did not. These findings suggest that the presence of a widened vestibular aqueduct or dilated endolymphatic sac alone does not definitively predict the occurrence of a gusher during surgery. This is corroborated by other authors, among them **Lima Júnior *et al.*** [5] who categorized the patients into two groups. Group A (CT only) exhibited an accuracy of 69.69%, a sensitivity of 36.36%, and a specificity of 86.36%. In contrast, group B (CT and MRI) demonstrated an accuracy of 80.59%, a sensitivity of 38.46%, and a specificity of 90.74%. In our study, all patients did both CT and MRI.

Assessment of round window accessibility revealed that, among the 50 patients, HRCT findings and surgical outcomes were congruent in 34 instances with the observation and natural appearance of the round window, but in 6 cases, the round windows were challenging to visualize on HRCT. The surgical findings corroborated these results, with a sensitivity of 46.15%, a specificity of 91.89% in predicting limited accessibility, and a negative predictive value of 82.93%. This is in accordance with the study conducted by **Dinarvand *et al.*** [12] who found in their referenced study that that among 41 patients, high-resolution computed tomography (HRCT) and surgical findings were consistent in 28 cases regarding the visibility and integrity of the round window. In four patients, the round window was not visualized on HRCT, and this was confirmed intraoperatively, necessitating cochleostomy for electrode insertion. Additionally, in 9 patients, HRCT suggested a normal round window, but it could not be identified during surgery, and cochleostomy was also performed in these cases. The diagnostic performance of HRCT in assessing the round window demonstrated an accuracy of 78.1%, a sensitivity of 30.8%, and a specificity of 100%. This is further supported by a study that assessed the accuracy of preoperative radiological evaluation of ten middle ear structures in patients with chronic otitis media.

The study revealed a generally poor correlation between radiological reports and surgical findings concerning the round window niche, with agreement improving only in anatomically normal cases (Sensitivity of 0% and specificity of 96%). Thus, while preoperative imaging is a highly specific tool for excluding difficult accessibility, it is limited in detecting obliterated round window niches, which likely accounts for the low sensitivity.

Our study identified posterior cochlear rotation as a significant predictor of difficulty in accessing the round window intraoperatively. Therefore, patients who meet the established criteria for cochlear implantation

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and present with no medical, surgical, or radiological contraindications, should proceed with cochlear implantation. All patients did both CT and MRI and postoperative x-ray to confirm the normal position of the electrode. Short (compressed) electrode should be ready at the time of surgery in case failure to insert long (full) electrode.

CONCLUSION

Although preoperative imaging for CI has certain limitations, it remains essential especially when performed to optimal standards. This imaging plays a crucial role not only in identifying suitable candidates for CI surgery but also in equipping surgeons to anticipate anatomical variations and minimize the risk of intraoperative complications that could affect surgical outcomes. CT and MRI offer distinct yet complementary insights: CT provides excellent visualization of the osseous structures of the temporal bone, mastoid pneumatization, and cochlear patency. However, its utility is limited in evaluating neural elements, intracochlear fluid, or fibrotic changes. In contrast, MRI offers superior assessment of the cranial nerves within the internal auditory canal, retrocochlear pathology, and membranous labyrinth anomalies, though it lacks detailed depiction of bony anatomy and is typically associated with higher costs.

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