



A Study on Clinical Correlation of High-Resolution Computed Tomography–Temporal Bone Findings with Intraoperative Findings in Cholesteatoma.

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Received: 05-07-2026

Revised: 28-07-2026

Accepted: 16-09-2026

Published: 30-09-2026

Abstract

Background: Cholesteatoma is a destructive otological condition that can cause erosion of the ossicles and temporal bone, leading to hearing impairment and potentially serious complications. HRCT (High-Resolution Computed Tomography) of the temporal bone helps determine disease extent, assess bony erosion, and identify complications before surgery. This study aimed to correlate preoperative HRCT findings with intraoperative findings in patients with cholesteatoma. **Methods:** A hospital-based prospective cross-sectional study was conducted in the Department of Otorhinolaryngology at PES Institute of Medical Sciences and Research (PESIMSR), Kuppam, Andhra Pradesh, from January 2018 to June 2019. Thirty patients clinically suspected of having cholesteatoma were included. HRCT scans of the temporal bone were obtained using 1-mm axial sections with coronal reconstructions. The radiological findings were compared with intraoperative findings observed during mastoidectomy. Sensitivity, specificity, positive predictive value, negative predictive value, and Cohen's kappa coefficient were used to evaluate diagnostic accuracy and agreement. **Results:** Ear discharge and hearing loss were present in all 30 patients. Tinnitus and giddiness occurred in 10% each, while earache was reported in 16.6%. HRCT demonstrated high sensitivity (>90%) for detecting disease in the mastoid antrum, aditus ad antrum, epitympanum, mesotympanum, malleus, and incus, as well as mastoid sclerosis. A sensitivity and specificity of 100% were observed for detecting soft-tissue masses in the mastoid antrum. Excellent agreement between HRCT and intraoperative findings was observed for soft-tissue masses in the mastoid antrum, aditus ad antrum, mesotympanum, and external auditory canal, and for malleus erosion. Good agreement was observed for hypotympanum involvement, mastoid sclerosis, and facial canal dehiscence, whereas moderate agreement was noted for epitympanum involvement and incus and stapes erosion. **Conclusion:** HRCT of the temporal bone is a valuable preoperative imaging modality for assessing the extent of cholesteatoma, identifying ossicular erosion and potential complications, and facilitating surgical planning. However, radiological findings should be interpreted alongside clinical and intraoperative assessments.

Keywords: Cholesteatoma, High-Resolution Computed Tomography, Temporal Bone, Intraoperative Findings, Mastoidectomy, Ossicular erosion.



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INTRODUCTION

Chronic otitis media is classified into mucosal disease, squamous disease, and healed chronic otitis media. Squamous COM (Chronic Otitis Media), commonly known as cholesteatoma or unsafe ear, is a significant otological condition characterized by chronic middle ear infection and progressive destruction of the middle ear and mastoid, potentially resulting in serious complications. Despite its name, cholesteatoma contains neither cholesterol nor lipids and is not neoplastic; it consists of keratinizing squamous epithelium and accumulated keratin debris within the tympanomastoid compartment.[1]

Cholesteatoma is classified into congenital and acquired types, with acquired cholesteatoma further subdivided into primary and secondary forms. Approximately 98% of middle ear cholesteatomas are acquired.[2] Primary acquired cholesteatoma commonly develops due to Eustachian tube dysfunction, resulting in persistent negative middle ear pressure, tympanic membrane retraction, and the formation of retraction pockets that accumulate keratin debris.[3-6] Secondary acquired cholesteatoma may arise through migration of squamous epithelium into the middle ear through a tympanic membrane perforation or following surgical implantation.[3-7]. Bone destruction occurs through inflammatory mechanisms, osteoclastic resorption, enzymatic degradation, and pyogenic osteitis.[8] Congenital cholesteatomas commonly occur in the anterosuperior and posterosuperior quadrants of the middle ear.[9]

Clinically, cholesteatoma may present with persistent ear discharge, hearing loss, tympanic membrane retraction pockets, granulation tissue, or a white mass behind the tympanic membrane.[9] Early recognition is essential to prevent progressive disease and associated complications. Children with recurrent or persistent middle ear disease require periodic hearing assessment, as hearing loss may remain unrecognized.[10]. HRCT of the temporal bone is an important imaging modality for evaluating cholesteatoma and determining its extent before surgery. It helps identify ossicular erosion, scutum destruction, mastoid involvement, labyrinthine fistulae, facial canal dehiscence, and other bony complications.[11]

AIMS AND OBJECTIVES

The study aimed to correlate the pre-operative HRCT findings of the temporal bone with the intraoperative findings in patients diagnosed with cholesteatoma. The objectives are to evaluate the extent and location of cholesteatoma, assess the involvement and erosion of the ossicular chain and surrounding bony structures, identify complications and anatomical variations, and determine the diagnostic accuracy of HRCT in predicting intraoperative findings, thereby assessing its role in pre-operative evaluation and surgical planning.

MATERIALS AND METHODS

Study Design

This hospital-based prospective cross-sectional study was conducted in the Department of Otorhinolaryngology (ENT) at PES Institute of Medical Sciences and Research (PESIMSR), Kuppam, over a period of one and a half years, from January 1, 2018, to June 30, 2019.

Inclusion and Exclusion Criteria

The study included all patients who were clinically suspected of having cholesteatoma and were willing to undergo HRCT of the temporal bone and surgical intervention. Patients with clinically suspected mucosal-type chronic otitis media, a history of previous ear surgery or head trauma, congenital ear diseases, or suspected malignant ear pathology were excluded from the study. Patients who were medically unfit to undergo surgery and anaesthesia were also excluded.

Sample Size Calculation

According to the records of the Medical Records Department, an average of 20 patients with cholesteatoma were admitted and underwent mastoidectomy at PESIMSR annually. Based on these records and the study requirements, a total of 30 patients were included in the study.

Data Collection Procedure

Patients attending the ENT outpatient department at PESIMSR, Kuppam, between January 1, 2018, and June 30, 2019, who fulfilled the predefined inclusion and exclusion criteria were enrolled in the study after obtaining written informed consent. A detailed clinical history and thorough otological examination were performed for each patient. All participants underwent HRCT of the temporal bone with 1 mm thin sections in axial and coronal planes.

The images were initially acquired in the axial plane using a 512×512 high-resolution matrix and a field of view of 30° , with scanning extending from the lower margin of the external auditory canal to the arcuate eminence of the superior semicircular canal. Coronal reconstructions were subsequently obtained, and the contralateral temporal bone was included for comparison.

Intravenous contrast was administered when indicated to evaluate suspected intracranial extension of the disease. All patients underwent mastoidectomy through a postaural approach, and the intraoperative findings were documented in a structured proforma. The radiological findings were systematically recorded, tabulated, and correlated with the corresponding intraoperative findings to assess the diagnostic accuracy of HRCT in identifying the extent of cholesteatoma and associated bony changes. All patients were followed up until the completion of the study.

Statistical Analysis

The collected data were analyzed using Microsoft Excel and Epi Info version 7.1. Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as mean $\pm$ standard deviation. Inter-rater agreement between the preoperative HRCT findings and intraoperative surgical findings was assessed using Cohen's kappa coefficient. The diagnostic performance of HRCT was evaluated by calculating sensitivity, specificity, PPV (Positive Predictive Value), and NPV (Negative Predictive Value), with intraoperative surgical findings considered the gold standard.

RESULTS

Table 1: Age and Gender Distribution of the Study Population

Age Groups (in years)	Female n (%)	Male n (%)	Total n (%)
20 to 29	06 (33.3)	07 (58.3)	13 (43.3)
30 to 39	04 (22.2)	03 (25.0)	07 (23.3)
40 to 49	07 (38.9)	01 (8.3)	08 (26.6)
50 to 59	01 (5.5)	01 (8.3)	02 (06.6)
Total	18 (100)	12 (100)	30 (100)
Mean age $\pm$ SD (years)	34.8 $\pm$ 8.7	31.8 $\pm$ 10.6	33.6 $\pm$ 9.4

Table 1 illustrates the age and gender wise distribution of the 30 patients included in the study. Females were the majority, 60% (18 patients), and males were 40% (12 patients). The mean age of the study population was 33.6 $\pm$ 9.4 years, with males having a lower mean age of 31.8 $\pm$ 10.6 years compared to 34.8 $\pm$ 8.7 years for females. Males were higher in the age group 20 to 29 years (58.3%), while females were higher in the age group 40 to 49 years (38.9%).

Table 2: Clinical Profile: Signs, Symptoms and Ear Examination Findings (N = 30)

Clinical Parameter	Present n	(%)
Signs and Symptoms		
Ear discharge	30	100
Hearing loss	30	100
Tinnitus	03	10
Ear ache	05	16.6
Giddiness	03	10
Others	0	0
Ear Examination Findings		
Attic perforation	12	40
Tympanic membrane retraction	11	36.6
Small pars tensa perforation	03	10
Medium pars tensa perforation	06	20
Large pars tensa perforation	10	33.3

Table 2 observes the clinical presentation of the patients. Ear discharge and hearing loss were seen in all the patients (100%). Tinnitus and giddiness were each present in 10% of the patients and ear ache in 16.6%; no other ear complaints were reported. On ear examination, attic perforation was present in 12 patients (40%) and tympanic membrane retraction in 11 patients (36.6%). Perforation involving only the posterosuperior quadrant of the pars tensa was seen in 3 patients (10%), while 6 patients (20%) had a concurrent medium sized and 10 patients (33.3%) a concurrent large perforation of the pars tensa. Examination of the pinna, pre-auricular and post-auricular areas, facial nerve, fistula test and vestibular function were normal in all patients; 3 patients had mastoid tenderness over the diseased ear.

Table 3: Correlation of HRCT and Intraoperative Findings of Soft Tissue Mass in the External Auditory Canal and Middle Ear Subsites.

HRCT Finding	True Positive	False Positive	False Negative	True Negative	Sensitivity	Specificity	PPV	NPV	Kappa (κ)
Soft tissue mass in EAC	12	0	3	15	80.0%	100.0%	100.0%	83.3%	0.800
Soft tissue mass in Epitympanum	18	4	2	6	90.0%	60.0%	81.8%	75.0%	0.526
Soft tissue mass in Mesotympanum	18	1	1	10	94.7%	90.9%	94.7%	90.9%	0.856
Soft tissue mass in Hypotympanum	4	1	2	23	66.7%	95.8%	80.0%	92.0%	0.666
Soft tissue mass in Mastoid antrum	24	0	0	6	100.0%	100.0%	100.0%	100.0%	1.000
Soft tissue mass in Aditus ad Antrum	22	0	1	7	95.7%	100.0%	100.0%	87.5%	0.911

Table 3 illustrates the correlation of HRCT with intraoperative findings for soft tissue mass in the EAC (External Auditory Canal) and the middle ear and mastoid subsites. Soft tissue mass in the mastoid antrum showed perfect results (100% sensitivity, specificity, PPV and NPV; Kappa 1.000). Soft tissue mass in the aditus ad antrum (Kappa 0.911), mesotympanum (Kappa 0.856) and EAC (Kappa 0.800) showed excellent agreement. In the EAC, sensitivity was 80.0% with 100% specificity and 100% PPV. The epitympanum had 90% sensitivity but the lowest specificity (60%) with Kappa 0.526, and the hypotympanum had 66.7% sensitivity with 95.8% specificity and Kappa 0.666.

Table 4: Correlation of HRCT and Intraoperative Findings of Ossicular Erosion.

HRCT Finding	True Positive	False Positive	False Negative	True Negative	Sensitivity	Specificity	PPV	NPV	Kappa (κ)
Malleus erosion	18	0	1	11	94.7%	100.0%	100.0%	91.7%	0.929
Incus erosion	27	0	2	1	93.1%	100.0%	100.0%	33.3%	0.473
Stapes erosion	15	1	6	8	71.4%	88.9%	93.8%	57.1%	0.520

Table 4 observes the ability of HRCT to detect erosion of the ossicles. Malleus erosion was detected with 94.7% sensitivity, 100% specificity and excellent agreement (Kappa 0.929). Incus erosion had 93.1% sensitivity and 100% specificity, but a low NPV of 33.3% and moderate agreement (Kappa 0.473). Stapes erosion had the lowest sensitivity (71.4%) among the ossicles, with 88.9% specificity, 93.8% PPV, 57.1% NPV and moderate agreement (Kappa 0.520).

Table 5: Correlation of HRCT and Intraoperative Findings of Bony Dehiscence and Mastoid Sclerosis

HRCT Finding	True Positive	False Positive	False Negative	True Negative	Sensitivity	Specificity	PPV	NPV	Kappa (κ)
Facial canal dehiscence	2	0	2	26	50.0%	100.0%	100.0%	92.9%	0.634
Dural plate dehiscence	0	5	0	25	NA	83.3%	NA	100.0%	NA
Sinus plate dehiscence	0	0	0	30	NA	100.0%	NA	100.0%	NA
Lateral semicircular canal dehiscence	0	1	0	29	NA	96.6%	NA	100.0%	NA
Mastoid sclerosis	28	0	1	1	96.6%	100.0%	100.0%	50.0%	0.651

Table 5 depicts the correlation of HRCT with intraoperative findings for facial canal, dural plate, sinus plate and lateral semicircular canal dehiscence, and for mastoid sclerosis. Mastoid sclerosis was identified with 96.6% sensitivity, 100% specificity and Kappa 0.651.

Facial canal dehiscence had 50% sensitivity with 100% specificity and Kappa 0.634. For dural plate, sinus plate and lateral semicircular canal dehiscence there were no true positive cases, so sensitivity, PPV and Kappa could not be calculated (NA); specificity was 83.3%, 100% and 96.6% respectively, with an NPV of 100% for all three.

Table 6 illustrates the cumulative predictive power of HRCT for all fourteen abnormalities. Sensitivity was highest for soft tissue mass in the mastoid antrum (100%) and lowest for facial canal dehiscence (50%). Specificity was 100% for most parameters, the lowest being soft tissue mass in the epitympanum (60%).

PPV was 100% for the majority of parameters, whereas NPV was lowest for incus erosion (33.3%). Sensitivity, PPV and Kappa could not be calculated (NA) for dural plate, sinus plate and lateral semicircular canal dehiscence.

Table 6: Cumulative Predictive Power of HRCT

Abnormality	Sensitivity	Specificity	PPV	NPV	Kappa
Soft tissue mass in EAC	80%	100%	100%	83.3%	0.800
Malleus erosion	94.7%	100%	100%	91.7%	0.929
Incus erosion	93.1%	100%	100%	33.3%	0.473
Stapes erosion	71.4%	88.9%	93.8%	57.1%	0.520
Soft tissue mass in Epitympanum	90%	60%	81.8%	75%	0.526
Soft tissue mass in Mesotympanum	94.7%	90.9%	94.7%	90.9%	0.856
Soft tissue mass in Hypotympanum	66.7%	95.8%	80%	92%	0.666
Soft tissue mass in Mastoid antrum	100%	100%	100%	100%	1.000
Soft tissue mass in Aditus ad Antrum	95.7%	100%	100%	87.5%	0.911
Facial canal dehiscence	50%	100%	100%	92.9%	0.634
Dural plate dehiscence	NA	83.3%	NA	100%	NA
Sinus plate dehiscence	NA	100%	NA	100%	NA
Lateral semicircular canal dehiscence	NA	96.6%	NA	100%	NA
Mastoid sclerosis	96.6%	100%	100%	50%	0.651

Table 7: Level of Agreement (Kappa) between HRCT and Intraoperative Findings

Level of Agreement	Kappa Range	Parameters (Kappa value)
No agreement	≤ 0	No parameters
Poor agreement	0.00 to 0.40	No parameters
Moderate agreement	0.40 to 0.60	Incus erosion (0.473), Stapes erosion (0.520), Soft tissue mass in Epitympanum (0.526)
Good agreement	0.60 to 0.80	Soft tissue mass in Hypotympanum (0.666), Facial canal dehiscence (0.634), Mastoid sclerosis (0.651)
Excellent agreement	0.80 to 1.00	Soft tissue mass in EAC (0.800), Malleus erosion (0.929), Soft tissue mass in Mesotympanum (0.856), Soft tissue mass in Mastoid antrum (1.000), Soft tissue mass in Aditus ad Antrum (0.911)

Table 7 observes the level of agreement between HRCT and intraoperative findings based on the Kappa ranges. No parameter showed no agreement or poor agreement. Three parameters (incus erosion, stapes erosion and soft tissue mass in the epitympanum) showed moderate agreement, three (soft tissue mass in the hypotympanum, facial canal dehiscence and mastoid sclerosis) showed good agreement, and five (soft tissue mass in the EAC, malleus erosion, soft tissue mass in the mesotympanum, mastoid antrum and aditus ad antrum) showed excellent agreement.

DISCUSSION

Age and Gender Distribution

The mean age of our patients was 33.6 ± 9.4 years; males were younger (31.8 ± 10.6 years) than females (34.8 ± 8.7 years). Kanotra et al. reported a similar mean age (36.38 years).[12] Females predominated in our study (60%, 18 patients; males 40%, 12 patients), as in Aljehani et al.[13] (61.1%) and Datta et al.[14] (56%). Males were more frequent in the 20 to 29 year group (58.3%) and females in the 40 to 49 year group (38.9%).

History and Clinical Examination

Ear discharge and hearing loss were present in all patients (100%). Tinnitus (10%), earache (16.6%), giddiness (10%) and mastoid tenderness (10%) were less common, and no patient had facial palsy, fever or headache. Prakash et al. reported otorrhoea in 90%, hearing loss in 66.6%, tinnitus in 13.3%, earache in 16.6%, vertigo in 6.6% and facial paralysis in 3.3%.[15] Thukral et al. found ear discharge in 96%, hearing loss in 58% and earache in 62%.[16] while Nanjaraj et al. (2012-13) found otorrhoea in 100%, hearing loss in 62%, earache in 32%, tinnitus in 10%, giddiness in 12%, fever in 10%, headache in 6%, facial palsy in 6% and mastoid tenderness in 12%.[17] These studies agree that otorrhoea is the chief complaint, which probably indicates that patients present late and are often reluctant to seek initial treatment.

Soft Tissue Mass in the External Auditory Canal and Middle Ear Cleft

HRCT diagnoses cholesteatoma by a non-dependent soft tissue mass in the middle ear cleft, ossicular erosion and smooth erosion of the middle ear borders, particularly with bony expansion of the middle ear cavity and aditus ad antrum. Khavasi et al. found HRCT 100% sensitive with 95% accuracy for soft tissue mass in the middle ear cleft;[17] Payal et al. reported 89% sensitivity;[18] Prata et al. reported 72.7% sensitivity, 82.5% specificity, PPV 69.5% and NPV 84.62%;[19] Reddy et al. reported 92%;[20] and Shah et al. 92.5%.[21]

In the present study, soft tissue mass in the EAC was detected with 80% sensitivity, 100% specificity, PPV 100%, NPV 83.3% and excellent agreement ($K = 0.800$), compared with 87.5% sensitivity, 88.57% specificity and $K = 0.665$ in Jose et al.[22] Prakash et al. reported 100% sensitivity and specificity for erosion of the bony EAC.

In Thukral et al.[16] 20 of 23 patients with epitympanic soft tissue density on HRCT had cholesteatoma, and 8 patients (16%) had soft tissue density in the epitympanum, mesotympanum, hypotympanum, aditus and antrum. Prakash et al.[15] found soft tissue involvement of the epitympanum in 83.3%, mesotympanum in 43.3%, hypotympanum in 6.6%, aditus ad antrum in 83.3% and mastoid antrum in 76.6%, with 100% specificity in the epitympanum, mesotympanum and hypotympanum but lower specificity in the antrum and aditus. Jose et al. found good agreement for the epitympanum, mesotympanum and hypotympanum ($K = 0.636, 0.634$ and 0.772) and excellent agreement for the mastoid antrum and aditus ad antrum ($K = 0.813$ for both).[22]

In our study, the epitympanum showed 90% sensitivity, PPV 81.8% and moderate agreement ($K = 0.526$), but specificity was only 60%. The mesotympanum showed excellent agreement ($K = 0.856$) with 94.7% sensitivity and PPV and 90.9% specificity and NPV. In the hypotympanum, sensitivity was only 66.7%, although specificity was 95.8%, PPV 80%, NPV 92% and agreement good ($K = 0.666$). The mastoid antrum was the best-detected site, with 100% sensitivity, specificity, PPV and NPV and $K = 1$, similar to Sreedhar et al.;[23] the aditus ad antrum also showed excellent results (sensitivity 95.7%, specificity 100%, PPV 100%, NPV 87.5%, $K = 0.911$).

Ossicular Erosion

Ossicular erosion is very common in cholesteatoma as it enlarges and meets adjoining structures. 24 HRCT showed very good sensitivity and excellent specificity and PPV for ossicular erosion in our study. Malleus erosion was identified with 94.7% sensitivity, 100% specificity, 100% PPV and excellent agreement ($K = 0.929$); incus erosion with 93.1% sensitivity, 100% specificity, 100% PPV and moderate agreement ($K = 0.473$); and stapes erosion with 71.4% sensitivity, 88.9% specificity, 93.8% PPV and moderate agreement ($K = 0.520$). These values resemble those of Datta et al.[14] where sensitivity exceeded 90% with 100% specificity and PPV. The incus was the most commonly eroded ossicle (29 of 30 subjects, 27 detected on HRCT). Datta et al. likewise found incus erosion most common (23 of 25 subjects), with 89% sensitivity and 85% accuracy for ossicular destruction.[14]

Facial Canal Dehiscence

Preoperative knowledge of facial nerve anatomy and dehiscence is crucial to prevent postoperative morbidity, but HRCT demonstration is difficult because of the small size, oblique orientation and developmental dehiscence, particularly when abutted by soft tissue.[24] Datta et al. found the tympanic segment most susceptible to erosion.[14] Khavasi et al. in 6 patients on HRCT versus 8 intraoperatively.[17] Similarly, in our study HRCT detected facial canal dehiscence in only 2 patients versus 4 intraoperatively, giving 50% sensitivity, 100% specificity and PPV, 92.9% NPV and good agreement ($K = 0.634$).

Dural Plate, Sinus Plate and Lateral Semicircular Canal Dehiscence

The dural plate is best seen in the coronal plane. Aljehani et al. reported dural plate dehiscence in 3 patients (7.7%) on both CT and surgery,[13] whereas Khavasi et al. found erosion in 6 cases (15%) on HRCT but 4 (10%) intraoperatively.[17] Sinus plate or tegmen erosion requires the radiologist to look for intracranial complications.[21] Aljehani et al. found sinus plate dehiscence in 6 patients (15.4%) on both CT and surgery, with 100% sensitivity, specificity, PPV and NPV,[13] while Khavasi et al. found erosion in 16 cases (40%) on HRCT but only 8 (20%) intraoperatively.[17]. The lateral semicircular canal (LSCC) lies close to the medial attic wall and is frequently eroded. Thukral et al. reported 100% sensitivity, 97.73% specificity, PPV 66.67% and NPV 100%,[16] and Prata et al. 100% sensitivity, 96.67% specificity, PPV 50% and NPV 100%.[19] Shah et al. 85% sensitivity and 96% specificity,[21] and Payal et al. 66% sensitivity and 83% specificity, concluding that sensitivity was moderate.[18] In our study, no patient had dural plate, sinus plate or LSCC dehiscence intraoperatively, so sensitivity, PPV and Kappa could not be calculated. All three, however, had an excellent NPV of 100%, similar to other studies, with specificity of 83.3%, 100% and 96.6% respectively.

Mastoid Sclerosis

Nanjaraj et al. found HRCT 100% sensitive and specific for the type of pneumatization,[17] and in Khavasi et al. all patients had sclerosis on HRCT confirmed intraoperatively.[17] Kanotra et al. reported 100% sensitivity and PPV,[12] and Datta et al.[14] also found strong agreement. In our study, mastoid sclerosis was detected with 96.6% sensitivity, 100% specificity, 100% PPV, NPV 50% and good agreement ($K = 0.651$).

CONCLUSION

HRCT of the temporal bone is a valuable imaging modality for the preoperative evaluation of cholesteatoma, providing important information regarding the extent of the disease, ossicular erosion, bony changes, anatomical variations, and

potential complications. The present study demonstrated excellent radiological-surgical correlation, with high sensitivity, specificity, predictive values, and Kappa agreement for several anatomical structures, particularly the mastoid antrum and malleus erosion. However, comparatively lower diagnostic accuracy was observed for stapes erosion, and the absence of certain intraoperative findings limited the assessment of their diagnostic performance. Despite the possibility of false-positive and false-negative results, HRCT remains an important tool for surgical planning and anticipating potential complications. Therefore, HRCT findings should be interpreted in conjunction with clinical evaluation and intraoperative findings to ensure optimal management of cholesteatoma.

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