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Correlation of Pre-operative High-Resolution Computed Tomography of Temporal Bone Findings with Surgical Findings in Chronic Suppurative Otitis Media: A Prospective Analytical Study

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Abstract
Background: *High-resolution computed tomography (HRCT) has become essential for preoperative evaluation in chronic suppurative otitis media (CSOM), yet correlation studies with surgical findings remain limited. This study evaluated diagnostic accuracy of HRCT and clinical utility of TMC staging.*
Methods: *A prospective analytical observational study was conducted on 34 patients with CSOM requiring surgical intervention from May 2023 to January 2025. HRCT findings were systematically compared with intraoperative observations for anatomical structures including ossicles, facial canal, mastoid involvement, and scutum erosion. TMC staging was performed and correlated with histopathological diagnosis and 30-day postoperative outcomes. Diagnostic accuracy parameters were calculated with 95% confidence intervals.*
Results: *The study population had mean age 42.6±18.5 years with male predominance (76.5%). HRCT demonstrated excellent diagnostic accuracy for facial canal involvement (91.2%), scutum erosion (91.2%), and Prussack's space involvement (91.2%), with area under curve (AUC) values of 0.84, 0.91, and 0.91 respectively. All three ossicles showed good accuracy (88.2%) with AUC values exceeding 0.86. TMC Stage 4 was most common (44.1%), with cholesteatoma found in 73.3% of Stage 4 cases versus 0% in Stage 1 ($p=0.022$). Complete resolution decreased from 87.5% in Stage 1 to 40.0% in Stage 4. Strong correlations existed between TMC stage and cholesteatoma presence ($r=0.61$, $p<0.001$), ossicular erosions ($r=0.58$, $p<0.001$), and clinical outcomes ($r=-0.45$, $p=0.007$).*
Conclusion: *HRCT demonstrates excellent diagnostic accuracy for detecting critical anatomical changes in CSOM. TMC staging provides valuable prognostic information correlating with pathology and clinical outcomes, supporting its integration into routine preoperative evaluation.*
Keywords: *Chronic suppurative otitis media, High-resolution computed tomography, TMC staging, Diagnostic accuracy, Cholesteatoma, Temporal bone imaging*

I. Introduction

Chronic suppurative otitis media (CSOM) represents a persistent inflammatory condition of the middle ear and mastoid characterized by recurrent or continuous otorrhea through a perforated tympanic membrane lasting more than six weeks (1). This condition affects over 65-330 million individuals worldwide, with particularly high prevalence in developing countries where it contributes significantly to preventable hearing loss (2). The complex pathophysiology of CSOM involves bacterial colonization, chronic inflammation, and progressive tissue destruction that can lead to serious complications including ossicular erosion, facial nerve paralysis, labyrinthine fistulae, and intracranial extension (3,4).

The management of CSOM frequently necessitates surgical intervention to eradicate infection, prevent complications, and restore hearing function. Success of these procedures depends heavily on accurate preoperative assessment of disease extent, anatomical variations, and potential complications. Traditional otoscopic examination, while fundamental, provides limited visualization of deeper structures and may underestimate disease severity, particularly in the presence of granulation tissue or debris (5,6).

High-resolution computed tomography (HRCT) of the temporal bone has emerged as the cornerstone imaging modality for preoperative evaluation in CSOM. Unlike conventional radiography, HRCT provides exquisite anatomical detail with submillimeter resolution, enabling visualization of ossicular chain integrity, bony erosions, mastoid involvement, and critical structures such as the facial nerve canal and inner ear (7,8). The ability

to detect subtle abnormalities through multiplanar reconstructions has revolutionized surgical planning, allowing surgeons to anticipate intraoperative findings and modify their approach accordingly.

Despite widespread adoption of HRCT in CSOM evaluation, the correlation between radiological and surgical findings varies across studies, with reported sensitivities ranging from 65% to 95% depending on the anatomical structure evaluated (9,10). These variations may be attributed to differences in imaging protocols, radiologist experience, disease severity, and definition criteria for pathological changes. Understanding these correlations is crucial for optimizing surgical outcomes and minimizing unexpected intraoperative findings that could compromise patient safety.

The pathogenesis of CSOM involves two primary subtypes: tubotympanic (mucosal) and atticoantral (squamous) disease. The latter is frequently associated with cholesteatoma formation, characterized by the presence of keratinizing squamous epithelium within the middle ear space (11). Cholesteatomas exhibit locally aggressive behavior, causing progressive bone erosion through enzymatic activity and mechanical pressure effects. Early and accurate detection of cholesteatoma is paramount, as these lesions require complete surgical excision to prevent recurrence and complications (12).

HRCT excels in identifying indirect signs of cholesteatoma, including scutum blunting, aditus ad antrum widening, and ossicular erosion patterns. However, differentiation between cholesteatoma and other soft tissue pathologies such as granulation tissue remains challenging on conventional CT imaging alone (13). Recent advances in diffusion-weighted magnetic resonance imaging have shown promise in improving tissue characterization, though HRCT remains the primary modality for surgical planning due to its superior bony detail visualization (14).

The temporal bone's intricate anatomy presents unique challenges for both imaging interpretation and surgical navigation. Critical structures including the facial nerve, inner ear, and dural plates are at risk during surgery, making accurate preoperative mapping essential. Studies have shown that preoperative knowledge of anatomical variations such as low-lying dura, anteriorly positioned sigmoid sinus, or high jugular bulb significantly influences surgical approach and reduces complication rates (15).

Various staging systems have been proposed to standardize CSOM assessment and predict surgical outcomes. The TMC (Tympanic-Mastoid-Complication) staging system incorporates imaging findings to classify disease extent systematically, providing a framework for prognostication and treatment planning. This system evaluates tympanic cavity involvement, mastoid extension, and presence of complications, offering a comprehensive approach to disease assessment that may correlate with surgical complexity and clinical outcomes.

This study aims to evaluate the diagnostic accuracy of HRCT in detecting various pathological changes in CSOM and establish the clinical utility of TMC staging for predicting surgical outcomes. By systematically correlating preoperative imaging findings with intraoperative observations and postoperative results, we seek to validate HRCT as a reliable preoperative tool and demonstrate the prognostic value of structured staging systems in CSOM management.

Aims

The primary objectives of this study were:

1. To compare the soft tissue and osseous changes in chronic suppurative otitis media using HRCT of the temporal bones with intraoperative findings
2. To perform HRCT-based TMC staging and establish correlation between stage and clinical outcome

II. Materials and Methods

Study Design and Setting

This prospective analytical observational study was conducted at M.S. Ramaiah Medical College and Hospitals, Bengaluru, India, from May 2023 to January 2025. The study was approved by the institutional ethics committee and conducted in accordance with the Declaration of Helsinki principles.

Study Population and Sample Size

The study population comprised patients presenting with chronic suppurative otitis media requiring surgical intervention. Based on literature review indicating 55.76% soft tissue involvement detection by HRCT versus 25% during surgery, a sample size of 34 patients was calculated to detect this difference with 80% power and 95% confidence level using standard statistical formulas for comparing two proportions.

Inclusion Criteria

Patients were included if they met the following criteria:

- Clinical and radiological diagnosis of chronic suppurative otitis media
- Age greater than 10 years
- Underwent HRCT temporal bone at our institution followed by surgical intervention

- Available for 30-day postoperative follow-up
- Provided informed consent for participation

Exclusion Criteria

Patients were excluded for:

- Congenital ear abnormalities or malignant pathology
- History of significant temporal bone trauma
- Previous ear surgery on the affected side
- Medical contraindications to surgery or anesthesia
- Inability to provide informed consent or unavailable for follow-up

Imaging Protocol

HRCT imaging was performed using Toshiba Asteion VP single-slice helical CT scanner and Siemens Somatom 128-slice CT scanner. Standard imaging parameters included 2mm slice thickness, 512×512 matrix, 200mm field of view, 120 kV, and 50 mA. Images were acquired in axial and coronal planes with bone algorithm reconstruction. Contrast enhancement was used when clinically indicated.

Surgical Correlation

All surgical procedures were performed by experienced otolaryngologists. Intraoperative findings were systematically documented using standardized forms recording tympanic membrane status, ossicular chain integrity, bony erosions, soft tissue pathology extent, facial canal involvement, and mastoid characteristics. Tissue specimens were obtained for histopathological examination in all cases.

TMC Staging System

The TMC staging system classified disease based on:

T (Tympanic Involvement):

- T0: No involvement
- T1: One side of one region (T1a: epitympanum; T1b: mesotympanum)
- T2: Both sides of one region (T2a: epitympanum; T2b: mesotympanum)
- T3: Extension between regions
- T4: Holotympanic involvement

M (Mastoid Involvement):

- M0: No involvement
- M1: Antrum only
- M2: Entire mastoid cavity

C (Complications):

- C0: Uncomplicated
- C1: Cranial/extracranial complications
- C2: Intracranial complications

Overall stages ranged from 1 (T1M0C0) to 4 (T4M2C0 or any involvement with complications).

Outcome Assessment

Clinical outcomes were evaluated at 30 days postoperatively and classified as complete resolution (absence of discharge with intact tympanic membrane), partial improvement (reduced symptoms), or no improvement (persistent symptoms). Histopathological examination results were correlated with imaging and clinical findings.

Statistical Analysis

Descriptive statistics were calculated for demographic and clinical variables. Diagnostic accuracy parameters including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and area under curve (AUC) were calculated with 95% confidence intervals. Chi-square tests and Fisher's exact tests were used for categorical variables. Correlation analysis was performed using Pearson correlation coefficients. Statistical significance was set at $p<0.05$. All analyses were performed using appropriate statistical software.

III. Results

Demographic Characteristics

The study included 34 patients with mean age 42.6±18.5 years (range 10-80 years, median 49.0 years). Age distribution showed bimodal pattern with peaks at 10-20 years (20.6%) and 51-60 years (26.5%). Male predominance was observed with 26 males (76.5%) and 8 females (23.5%), resulting in male-to-female ratio of 3.3:1.

HRCT versus Surgical Findings Distribution

Table 1: Distribution of HRCT and Surgical Findings

Finding	CT Present n (%)	CT Absent n (%)	Surgery Present n (%)	Surgery Absent n (%)
Facial Canal Involvement	6 (17.6)	28 (82.4)	7 (20.6)	27 (79.4)
Mastoid Soft Tissue	27 (79.4)	7 (20.6)	30 (88.2)	4 (11.8)
Mastoid Sclerosis	20 (58.8)	14 (41.2)	19 (55.9)	15 (44.1)
Scutum Erosion	11 (32.4)	23 (67.6)	10 (29.4)	24 (70.6)
Malleus Erosion	11 (32.4)	23 (67.6)	13 (38.2)	21 (61.8)
Incus Erosion	11 (32.4)	23 (67.6)	13 (38.2)	21 (61.8)
Stapes Erosion	13 (38.2)	21 (61.8)	15 (44.1)	19 (55.9)
Prussack's Space Involvement	21 (61.8)	13 (38.2)	22 (64.7)	12 (35.3)

Mastoid soft tissue involvement was most common (CT: 79.4%, surgery: 88.2%), followed by Prussack's space involvement (CT: 61.8%, surgery: 64.7%). Facial canal involvement was least common (CT: 17.6%, surgery: 20.6%).

Diagnostic Accuracy of HRCT

Table 2: Diagnostic Accuracy Parameters

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	AUC	p-value
Facial Canal	71.4	96.3	83.3	92.9	91.2	0.84	0.003*
Mastoid Soft Tissue	86.7	75.0	96.3	42.9	85.3	0.81	0.032*
Mastoid Sclerosis	89.5	80.0	85.0	85.7	85.3	0.85	<0.001*
Scutum Erosion	90.0	91.7	81.8	95.7	91.2	0.91	<0.001*
Malleus Erosion	76.9	95.2	90.9	87.0	88.2	0.86	<0.001*
Incus Erosion	76.9	95.2	90.9	87.0	88.2	0.86	<0.001*
Stapes Erosion	80.0	94.7	92.3	85.7	88.2	0.87	<0.001*
Prussack's Space	90.9	91.7	95.2	84.6	91.2	0.91	<0.001*

*Statistically significant ($p<0.05$)

HRCT achieved highest diagnostic accuracy for facial canal involvement, scutum erosion, and Prussack's space involvement (all 91.2%). All ossicles showed identical accuracy (88.2%) with excellent specificity values exceeding 94%.

TMC Staging Distribution and Correlations

Table 3: TMC Stage Distribution and Pathological Correlation

TMC Stage	n (%)	Cholesteatoma n (%)	Granulation Tissue n (%)	Chronic Inflammation n (%)
Stage 1	8 (23.5)	0 (0)	7 (87.5)	1 (12.5)
Stage 2	6 (17.6)	2 (33.3)	4 (66.7)	0 (0)
Stage 3	5 (14.7)	2 (40.0)	3 (60.0)	0 (0)
Stage 4	15 (44.1)	11 (73.3)	4 (26.7)	0 (0)
Total	34 (100)	15 (44.1)	18 (52.9)	1 (2.9)

Chi-square test: $\chi^2=14.82$, $p=0.022$*

Stage 4 disease was most common (44.1%), with strong association between advanced stage and cholesteatoma presence (73.3% in Stage 4 vs 0% in Stage 1).

Table 4: TMC Stage versus Clinical Outcomes

TMC Stage	Complete Resolution n (%)	Partial Improvement n (%)	No Improvement n (%)
Stage 1	7 (87.5)	1 (12.5)	0 (0)
Stage 2	5 (83.3)	1 (16.7)	0 (0)
Stage 3	3 (60.0)	2 (40.0)	0 (0)

TMC Stage	Complete Resolution n (%)	Partial Improvement n (%)	No Improvement n (%)
Stage 4	6 (40.0)	7 (46.7)	2 (13.3)
Total	21 (61.8)	11 (32.4)	2 (5.9)

Clinical outcomes demonstrated stage-dependent deterioration, with complete resolution rates declining from 87.5% in Stage 1 to 40.0% in Stage 4. All treatment failures occurred in Stage 4 patients.

Table 5: Correlation Analysis

Variables	Correlation Coefficient (r)	p-value
TMC Stage vs Cholesteatoma Presence	0.61	<0.001*
TMC Stage vs Ossicular Erosions	0.58	<0.001*
TMC Stage vs Prussack's Space	0.54	0.001*
TMC Stage vs Scutum Erosion	0.52	0.002*
TMC Stage vs Clinical Outcome	-0.45	0.007*

*Statistically significant ($p<0.05$)

Strong positive correlations existed between TMC stage and disease severity markers, with significant negative correlation between stage and clinical outcomes.

Tympanic Cavity Involvement Patterns

Holotympanic involvement was most common pattern (CT: 58.8%, surgery: 50.0%), followed by combined epitympanic and mesotympanic involvement (CT: 20.6%, surgery: 23.5%). McNemar's test showed no significant difference between CT and surgical findings ($\chi^2=2.67$, $p=0.45$), indicating excellent agreement.

IV. Discussion

This prospective study demonstrates that HRCT is a highly reliable imaging modality for preoperative evaluation of CSOM, with excellent diagnostic performance across multiple anatomical parameters critical for surgical planning. Our findings validate the clinical utility of systematic HRCT evaluation and establish the prognostic value of TMC staging in predicting surgical outcomes.

Diagnostic Accuracy of HRCT

Our study revealed outstanding diagnostic accuracy for detecting bony erosions, with scutum erosion and Prussack's space involvement achieving 91.2% accuracy (AUC=0.91). These results exceed those reported by Walshe et al., who found 82% sensitivity and 87% specificity for scutum erosion in their systematic review (9). The improved performance in our study may reflect advances in CT technology and standardized interpretation protocols.

The excellent specificity values across all parameters (ranging from 75.0% to 96.3%) indicate that HRCT is particularly valuable for ruling out pathological changes when structures appear normal. However, variable sensitivity rates (71.4% to 90.9%) necessitate continued intraoperative vigilance, as subtle changes may escape radiological detection. This finding aligns with studies by Chatterjee et al., who reported similar sensitivity limitations for facial canal dehiscence (10).

For ossicular chain evaluation, our study demonstrated good diagnostic accuracy (88.2%) for all three ossicles, with stapes showing slightly superior performance (AUC=0.87). These results are comparable to Zhang et al., who reported 89% sensitivity for incus erosion and 83% for stapes evaluation (11). The high positive predictive values (>90% for all ossicles) indicate that detected erosions are highly likely to be confirmed intraoperatively, supporting reliable surgical planning.

Facial canal involvement showed excellent specificity (96.3%) but moderate sensitivity (71.4%), similar to findings by Fuse et al. (75% sensitivity, 94% specificity) (12). The high specificity suggests HRCT reliably rules out involvement when the canal appears intact, though subtle dehiscences may be missed. This limitation emphasizes the importance of surgical vigilance regardless of imaging findings.

TMC Staging System Validation

Our study is among the first to systematically validate the TMC staging system's prognostic utility. The strong correlation between advancing TMC stage and cholesteatoma presence (73.3% in Stage 4 vs 0% in Stage 1, $p=0.022$) provides objective evidence for the staging system's clinical relevance. This gradient exceeds that reported by Saleh and Mills, who found cholesteatoma in 58% of advanced-stage cases (13).

The stage-dependent clinical outcomes, with complete resolution rates declining from 87.5% in Stage 1 to 40.0% in Stage 4, establish evidence-based probabilities for patient counseling. The fact that all treatment failures occurred in Stage 4 patients provides particularly valuable prognostic information. These findings support the utility of systematic staging for preoperative planning and outcome prediction.

Strong correlations between TMC stage and disease severity markers (r=0.61 for cholesteatoma, r=0.58 for ossicular erosions) validate the staging system's ability to capture disease complexity. The negative correlation with clinical outcomes (r=-0.45, p=0.007) confirms the prognostic value and supports integration into routine clinical practice.

Comparison with Previous Studies

Our demographic findings, with male predominance (76.5%) and bimodal age distribution, differ from some studies reporting equal gender distribution (14). This variation may reflect regional differences or referral patterns to our tertiary center. The higher male-to-female ratio (3.3:1) compared to Prakash et al.'s 1.5:1 suggests population-specific factors or healthcare access patterns (15).

Our ossicular erosion patterns (incus 38.2%, stapes 44.1%, malleus 38.2%) differ from classical teaching emphasizing incus predominance due to tenuous blood supply. This finding may reflect the high prevalence of advanced disease where multiple ossicles are simultaneously affected, as noted in cholesteatomatous CSOM.

Clinical Implications

The excellent diagnostic accuracy for critical structures supports routine HRCT use in CSOM preoperative evaluation. The particularly high performance for Prussack's space involvement (91.2% accuracy) addresses a previously understudied area with significant pathophysiological importance in cholesteatoma development.

TMC staging's correlation with both pathological findings and clinical outcomes enables evidence-based patient counseling. Stage-specific outcome probabilities allow realistic preoperative discussions, with Stage 4 patients requiring counseling about lower complete resolution rates (40.0%) and potential treatment failure risk (13.3%).

The strong association between advanced TMC stage and cholesteatoma (73.3% in Stage 4) can guide surgical planning, with higher stages potentially requiring more extensive procedures. Stage 1-2 disease may be amenable to more conservative approaches, while Stage 4 often necessitates comprehensive mastoidectomy.

Study Limitations

Several limitations warrant acknowledgment. The relatively small sample size (34 patients) limits generalizability, particularly for subgroup analyses. The single-center design may introduce selection bias toward complex cases typical of tertiary referral centers. The 30-day follow-up period, while adequate for acute outcomes, may not capture long-term recurrence or hearing results.

Lack of inter-observer variability assessment represents another limitation, as interpretation differences could affect diagnostic accuracy in real-world settings. The exclusion of revision cases eliminates an important CSOM subset that often presents diagnostic challenges.

Future Directions

Larger multicenter studies could validate TMC staging across diverse populations and practice settings. Long-term outcome studies would provide more complete prognostic information. Investigation of advanced imaging techniques, including diffusion-weighted MRI and artificial intelligence applications, might further improve diagnostic accuracy.

Cost-effectiveness studies of routine preoperative HRCT would inform policy decisions, particularly in resource-limited settings. Development of standardized reporting templates and training programs could optimize diagnostic consistency and clinical utility.

V. Conclusion

This prospective study establishes HRCT as an excellent diagnostic tool for preoperative evaluation of chronic suppurative otitis media, with outstanding accuracy for detecting critical anatomical changes including bony erosions, ossicular damage, and Prussack's space involvement. The consistently high specificity values across all parameters confirm HRCT's reliability for surgical planning, while acknowledging sensitivity limitations that necessitate continued intraoperative vigilance.

The TMC staging system demonstrates significant clinical utility, with strong correlations between advancing stage and both pathological severity and clinical outcomes. The stage-dependent distribution of cholesteatoma (0% in Stage 1 to 73.3% in Stage 4) and gradient of clinical outcomes provide evidence-based prognostic information valuable for patient counseling and surgical planning.

Integration of systematic HRCT evaluation with TMC staging offers a comprehensive approach to CSOM assessment that enhances surgical planning, optimizes patient selection, and improves outcome prediction. The excellent correlation between imaging and surgical findings validates current diagnostic approaches while highlighting areas for continued vigilance.

These findings support routine implementation of HRCT-based preoperative evaluation and TMC staging in CSOM management. Future research should focus on multicenter validation, long-term outcome assessment, and integration of emerging technologies to further optimize diagnostic accuracy and clinical utility in this common but complex otological condition.

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