Original Research

EVALUATING THE ACCURACY OF HIGH-RESOLUTION CT TEMPORAL BONE IN PREDICTING OSSICULAR CHAIN STATUS AND SURGICAL FINDINGS IN CHRONIC EAR DISEASE: A PROSPECTIVE RANDOMIZED STUDY AT A TERTIARY CARE CENTER

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ABSTRACT

Background: Chronic ear disease, including chronic otitis media with or without cholesteatoma, often causes ossicular discontinuity and bony erosion. Accurate preoperative assessment of ossicular status and surgical risks improves planning. HRCT temporal bone is widely used, though diagnostic performance varies among ossicles and disease types. **Objectives:** To evaluate HRCT temporal bone accuracy in predicting ossicular status and key surgical findings using intraoperative correlation, and to compare standard reporting with structured checklist-based interpretation incorporating multiplanar/3D reconstructions. **Methods:** A prospective randomized study at IMS & SUM Hospital (October 2023–December 2025) included 50 patients aged 15–65 years with chronic ear disease. Participants were assigned to standard HRCT reporting or structured checklist-based reporting with MPR/3D evaluation. Radiologic findings were compared with surgery, and diagnostic indices, kappa agreement, operative surprises, operative time, and 12-month hearing outcomes were analyzed. **Results:** Among 50 patients (mean age 34.8±12.1 years; 56% male), 64% had squamous disease. Incus erosion was most common (60%), followed by malleus (24%) and stapes (20%). HRCT was most accurate for incus (86.7% sensitivity) and least sensitive for stapes (70%). Structured reporting improved detection of subtle erosions ($p<0.05$). Agreement was substantial for incus and moderate for malleus and stapes. **Conclusion:** HRCT temporal bone aids preoperative planning in chronic ear disease, accurately predicting ossicular status, especially incus. Structured MPR/3D interpretation improves subtle erosion detection, though limitations persist for cholesteatoma differentiation and minimal stapes defects.

Keywords: HRCT Temporal Bone, Chronic Otitis Media, Cholesteatoma, Ossicular Erosion, Ossiculoplasty Planning, Diagnostic Accuracy, Intraoperative Correlation.

INTRODUCTION

Chronic ear disease represents a persistent inflammatory pathology of the middle ear cleft and mastoid, commonly presenting with otorrhea, hearing loss, tympanic membrane perforation, retraction pockets, and occasionally cholesteatoma[1,3]. Over time, chronic inflammation and enzymatic osteolysis can lead to ossicular chain discontinuity, tympanic cavity remodeling, scutum erosion, and complications involving the facial canal, labyrinth, dural plate, or sigmoid sinus plate[4,9].

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The preoperative understanding of ossicular integrity is important because ossiculoplasty strategy, expected hearing outcomes, and operative counseling depend strongly on whether the malleus handle is preserved, whether the incus long process is intact, and whether stapes supra structure is present[6,7].

Although otomicroscopy is central to diagnosis, the middle ear cleft is a complex three-dimensional space and many clinically relevant structures (incus long process, stapes supra structure, facial canal tympanic segment, lateral semicircular canal, tegmen) cannot be directly visualized[10,11]. HRCT temporal bone provides high spatial resolution depiction of temporal bone anatomy and bony erosions. It is widely used for suspected cholesteatoma, revision surgery, complicated disease, and for preoperative mapping of mastoid and middle ear cleft[12].

However, the performance of HRCT is not uniform. Multiple studies have shown that HRCT reliably identifies gross scutum erosion, mastoid extension, and larger bony defects, while it may underperform for very small erosions of the incus long process or stapes supra structure[2,9]. HRCT also has well-known limitations in differentiating cholesteatoma from granulation tissue when both appear as non-specific soft tissue density[8,18]. Variations in scanner protocol, radiologist experience, use of multiplanar reconstructions (MPR), and structured reporting contribute to differences in reported sensitivity and specificity[13,15].

Modern approaches emphasize standardization—structured reporting, targeted review of ossicular chain in multiple planes, and 3D reconstructions or "virtual otoscopy" techniques[13]. Prospective work has supported the use of structured CT evaluation to improve otologic surgical planning and reduce intraoperative surprises[14].

Rationale: At our institution, HRCT temporal bone is frequently requested for chronic ear disease. Yet, there is a practical need to quantify how reliably HRCT predicts ossicular chain status in our patient population and whether a structured interpretation strategy improves accuracy.

AIM

This study aimed to evaluate the diagnostic accuracy of HRCT temporal bone in predicting ossicular status and intraoperative findings in chronic ear disease, and assess whether structured checklist-based interpretation improves preoperative accuracy and surgical preparedness.

OBJECTIVES

Primary Objective:

- To determine the diagnostic accuracy of HRCT temporal bone in predicting ossicular chain status (malleus, incus, stapes) compared with intraoperative findings in chronic ear disease.

Secondary Objectives:

- To evaluate HRCT accuracy for predicting key surgical findings: scutum erosion, tegmen erosion, facial canal dehiscence, lateral semicircular canal fistula, sigmoid sinus plate erosion.
- To compare diagnostic performance between standard HRCT interpretation and structured checklist-based interpretation with MPR/3D reconstructions.
- To assess clinical relevance via operative surprises, operative time, postoperative hearing outcomes (ABG closure), and complications during 12-month follow-up.

MATERIALS AND METHODS

Study Design

This prospective randomized study evaluated the diagnostic accuracy of preoperative HRCT temporal bone in predicting ossicular and intraoperative findings using surgery as the gold standard, and compared structured checklist-based MPR/3D interpretation with standard free-text reporting for improved performance.

Study Setting

The study was conducted at the Department of Otorhinolaryngology–Head and Neck Surgery, IMS & SUM Hospital, Bhubaneswar, Odisha, India, a tertiary care teaching hospital providing comprehensive otologic services (tympanoplasty, canal wall up/down mastoidectomy, cholesteatoma surgery). HRCT imaging was performed in the radiology department using a dedicated temporal bone protocol.

Study Duration and Follow-up

The study period extended from October 2023 to December 2025. All enrolled participants completed 12 months of postoperative follow-up, during which clinical outcomes and audiological improvement were documented at prespecified intervals.

Sample Size

A total of 50 patients (n=50) were included. The sample size was based on feasibility within the study duration and expected surgical volume, while allowing meaningful estimation of sensitivity and specificity of HRCT for common ossicular pathology (particularly incus erosion). Analyses emphasized point estimates with confidence intervals and group comparisons.

Study Population

Patients aged 15–65 years with chronic ear disease, including chronic otitis media with or without suspected cholesteatoma, retraction pocket, or tympanic membrane perforation, scheduled for surgery were included. Procedures included tympanoplasty, cortical mastoidectomy, CWU/CWD mastoidectomy, and atticotomy. Only one ear per patient was analyzed; in bilateral cases, the first operated ear was included.

Eligibility Criteria

Inclusion Criteria

1. Age 15–65 years
2. Clinical evidence of chronic ear disease such as:
   - Persistent/recurrent otorrhea
   - Retraction pocket/attic pathology with suspicion of cholesteatoma
   - Chronic tympanic membrane perforation associated with conductive hearing loss
3. Planned surgical management based on clinical assessment (with or without complications)
4. Preoperative HRCT temporal bone could be performed as per institutional protocol
5. Willingness to provide written informed consent and comply with follow-up schedule

Exclusion Criteria

1. Previous ear surgery in the same ear (revision cases excluded to maintain uniform baseline surgical anatomy and avoid confounding by prior reconstruction)
2. Known or suspected temporal bone malignancy
3. Congenital ossicular anomalies as the primary diagnosis (where pathology is developmental rather than acquired disease erosion)
4. Contraindication to CT imaging (e.g., pregnancy—evaluated individually; CT was avoided unless clinically essential and ethically approved)
5. Inability to complete follow-up (anticipated non-compliance, inability to return, or incomplete clinical/surgical documentation)

Recruitment and Enrollment

Eligible patients attending ENT OPD or admitted for elective surgery were screened. After explanation of study procedures, written informed consent was obtained. Baseline demographic and clinical details were recorded in a structured case record form. HRCT was performed prior to surgery after allocation to one interpretation arm.

Randomization and Allocation

Participants were randomized 1:1 using a computer-generated sequence with sealed, opaque, sequentially numbered envelopes for allocation concealment.

- **Group A (Standard HRCT reporting):** routine axial/coronal review with narrative free-text report.
- **Group B (Structured HRCT reporting):** predefined checklist with mandatory documentation of each ossicle and critical landmarks; review included MPR in at least two orthogonal planes for each ossicle and 3D/oblique reconstructions when needed.

Blinding

Radiologists were not blinded due to different reporting formats. Surgeons were blinded to allocation label (both reports issued as "Preoperative HRCT Temporal Bone Report"). Intraoperative findings were recorded immediately using a standardized proforma before reviewing any postoperative correlation checklist to reduce confirmation bias. Wherever feasible, postoperative audiological assessments were performed without knowledge of CT group allocation.

Ethical Considerations

Institutional Ethics Committee approval was obtained. Consent was taken from all participants; for ages 15–17 years, guardian consent with patient assent was obtained. No additional radiation beyond standard-of-care HRCT was used. Data were anonymized and confidentiality maintained.

Preoperative Evaluation

All patients underwent detailed history (otorrhea pattern, hearing loss, vertigo/tinnitus/otalgia, symptoms of complications, prior therapy, comorbidities), otoscopy/otomicroscopy (perforation/retraction type, keratin debris/attic crust, granulation/polyp, discharge status, contralateral ear), cranial nerve evaluation, and tuning fork tests (Rinne, Weber). Pure tone audiometry (PTA) was performed preoperatively and at 3, 6, and 12 months. Air and bone conduction thresholds were obtained at 0.5, 1, 2, and 4 kHz, and the air–bone gap (ABG) was calculated as the mean AC–BC difference.

HRCT Temporal Bone Protocol and Variables

HRCT was acquired using a multidetector scanner with 0.5–0.625 mm thin sections, high-frequency bone kernel reconstruction, and axial acquisition with coronal and sagittal reconstructions. Oblique planes were generated when needed (e.g., labyrinthine fistula suspicion or stapes visualization). Field of view was limited to the temporal bone; contrast was not routine. Variables assessed included disease location/extent, soft tissue density distribution, scutum erosion, ossicular status (malleus, incus long process/incudostapedial joint, stapes suprastructure), aditus patency/alignment, facial canal dehiscence, tegmen defect, LSC fistula, sinus plate erosion, and relevant anatomic variants. Group B required completion of all checklist items with mandatory MPR review.

Surgical Procedure and Reference Standard

All surgeries were performed under microscope by experienced otologic surgeons. The intraoperative proforma recorded cholesteatoma presence and extent, scutum status, ossicular chain status (malleus/incus/stapes), facial canal integrity, tegmen condition, LSC fistula, sinus plate erosion, and other findings/complications. For primary accuracy analysis, ossicular status was dichotomized as intact vs not intact (eroded/discontinuous/absent). Indeterminate CT calls followed a predefined rule with optional sensitivity analysis.

Follow-up

All patients were followed postoperatively at standardized intervals:

- **1 week:** wound status, canal pack removal as per protocol, infection control
- **3 months:** otomicroscopy (graft uptake/cavity epithelialization), PTA
- **6 months:** clinical assessment, PTA
- **12 months:** final clinical and audiological assessment

Follow-up Outcomes Recorded

- Graft uptake / tympanic membrane integrity
- Dry ear status / persistent discharge
- Cavity status (if CWD)
- Postoperative complications: facial palsy, vertigo, infection, suspected recurrence
- Audiological outcome: ABG closure at 12 months

Statistical Analysis

Data were entered into a password-protected database and verified. Descriptive statistics were reported as mean±SD/median (IQR) and frequencies. Diagnostic indices (sensitivity, specificity, PPV, NPV, accuracy) were computed from 2×2 tables with 95% CI where feasible. Agreement was measured using Cohen's kappa. Group comparisons used Chi-square/Fisher exact tests and t-test/Mann–Whitney U test as appropriate; $p<0.05$ was considered significant. Secondary analyses included subgroup comparison by disease type and evaluation of operative surprises and hearing outcomes.

RESULTS

Participant Flow and Follow-up

50 eligible patients were enrolled and all completed 12-month follow-up. Participants were randomized equally into Group A (Standard HRCT reporting; n=25) and Group B (Structured checklist + MPR/3D interpretation; n=25). There were neither follow-up losses nor post-randomization exclusions.

Baseline Participant Characteristics

The mean age was 34.8 ± 12.1 years (range 15–65), with males comprising 56%. The right ear was involved in 54% of cases. Squamous disease/suspected cholesteatoma was present in 64%, while 36% had mucosal COM. Baseline variables were comparable between both groups.

Table 1. Baseline Characteristics of Participants (N=50)

Variable	Value
Age (years), mean ± SD (range)	34.8 ± 12.1 (15–65)
Sex, n (%)	Male 28 (56%); Female 22 (44%)
Side, n (%)	Right 27 (54%); Left 23 (46%)
Clinical subtype, n (%)	Squamous/Cholesteatoma suspected 32 (64%); Mucosal COM 18 (36%)
Randomized groups, n	Group A 25; Group B 25
Follow-up completion	50/50 (100%)

Intraoperative Findings

Surgical findings served as the reference standard. Incus erosion/discontinuity was most common (60%), followed by malleus (24%) and stapes suprastructure (20%). Scutum erosion was seen in 62%. Less frequent but significant findings included facial canal dehiscence (12%), tegmen defect (10%), LSC fistula (6%), and sinus plate erosion (4%).

Table 2. Intraoperative Findings (n=50)

Intraoperative finding	n (%)
Ossicular chain status (eroded/discontinuous/absent)	
Malleus	12 (24%)
Incus	30 (60%)
Stapes supra structure	10 (20%)
Other key surgical findings	
Scutum erosion	31 (62%)
Facial canal dehiscence	6 (12%)
Tegmen tympani defect	5 (10%)
Lateral semicircular canal (LSC) fistula	3 (6%)
Sinus plate erosion	2 (4%)

Overall Diagnostic Accuracy of HRCT for Ossicular Chain Status

HRCT showed good overall performance. Accuracy was highest for the incus, intermediate for the malleus, and lowest sensitivity for the stapes supra structure. Agreement ranged from moderate (stapes) to substantial (incus). Missed lesions commonly involved minimal incus long process erosion, malleus handle erosion masked by soft tissue, and subtle stapes defects affected by partial volume effects.

Table 3. HRCT Diagnostic Accuracy for Ossicular Chain Status

Ossicle (Outcome: eroded/discontinuous vs intact)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Kappa (κ)
Malleus	75.0	92.1	75.0	92.1	88.0	~0.62
Incus	86.7	85.0	92.9	73.9	86.0	~0.70
Stapes supra structure	70.0	95.0	77.8	92.7	90.0	~0.58

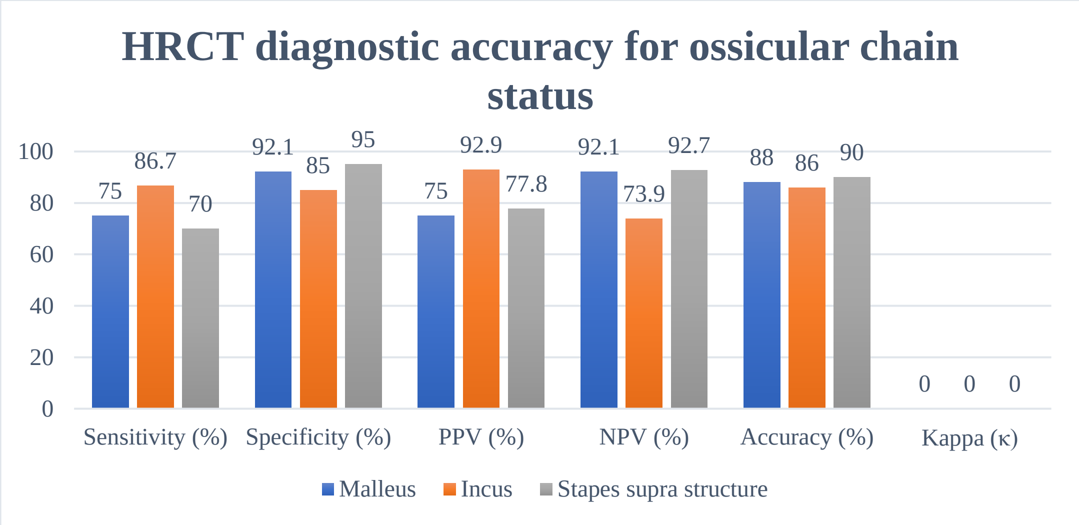

Figure 1: HRCT Diagnostic Accuracy for Ossicular Chain Status

HRCT Accuracy for Other Surgical Findings
HRCT demonstrated high sensitivity for scutum erosion and high specificity for major bony defects such as tegmen erosion, LSC fistula, and sinus plate erosion. Sensitivity was comparatively lower for small dehiscence's, particularly facial canal and tegmen defects.

Table 4. HRCT Diagnostic Accuracy for Additional Surgical Findings

Surgical finding (CT prediction vs surgery)	Sensitivity (%)	Specificity (%)
Scutum erosion	90.3	84.2
Facial canal dehiscence	66.7	95.5
Tegmen tympani defect	60.0	97.8
LSC fistula	66.7	100
Sinus plate erosion	50.0	100

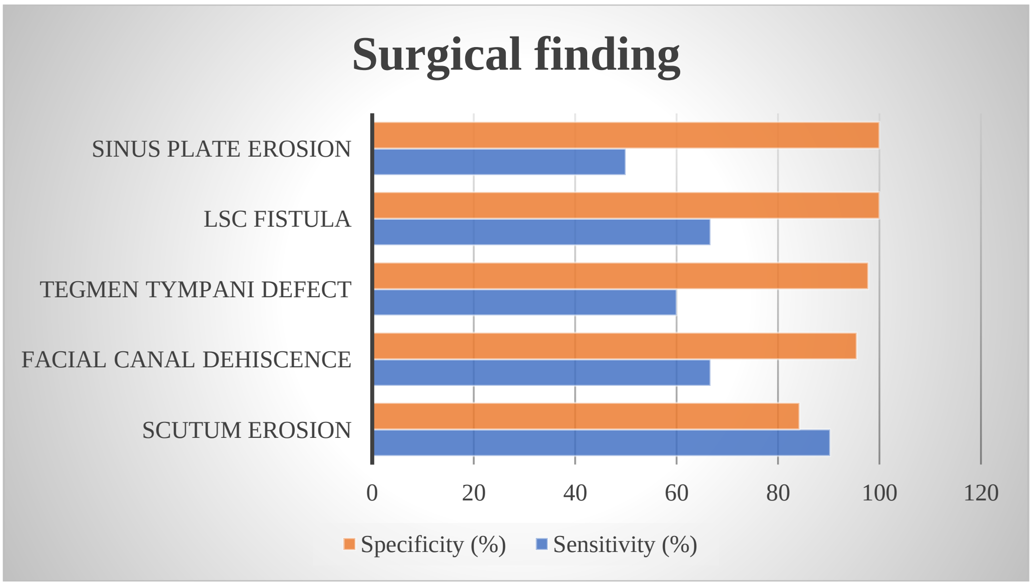

Figure 2: HRCT Diagnostic Accuracy for Additional Surgical Findings

Comparison between Groups: Standard vs Structured Interpretation
Structured reporting with MPR/3D (Group B) improved detection of subtle ossicular erosions. Sensitivity for incus and stapes was significantly higher in Group B ($p<0.05$). Unexpected intraoperative ossicular discontinuity was reduced in

Group B, and operative time showed a modest decrease.

Table 5. Group Comparison of HRCT Interpretation Strategies

Outcome	Group A: Standard report	Group B: Structured + MPR/3D	Statistical note
Incus sensitivity	80%	93%	$p < 0.05$
Stapes sensitivity	60%	80%	$p < 0.05$
Unexpected ossicular discontinuity at surgery	Higher	Lower	$p < 0.05$
Operative time	Longer	Shorter	Trend toward significance

Postoperative Outcomes and Hearing Results
At 12 months, graft uptake was 92%. Mean preoperative ABG improved from 28.5 ± 8.2 dB to 14.2 ± 7.6 dB, with a mean closure of ~14 db. better hearing outcomes were observed in patients with preserved stapes supra structure.

Table 6. Hearing Outcomes at 12-Month Follow-Up

Measure	Value
Graft uptake rate	92%
Mean preoperative ABG (dB), mean ± SD	28.5 ± 8.2
Mean postoperative ABG at 12 months (dB), mean ± SD	14.2 ± 7.6
Mean ABG closure (dB)	~14

DISCUSSION

This prospective randomized interpretation-strategy study evaluated the ability of HRCT temporal bone to predict ossicular chain status and key operative findings in chronic ear disease. The findings demonstrate that the incus is the most frequently damaged ossicle and that HRCT shows the highest clinical utility in anticipating incus discontinuity. In contrast, the stapes suprastructure remains the most challenging ossicle for CT-based prediction because of its small size, susceptibility to partial volume effects, and masking by adjacent soft tissue. Importantly, a structured checklist-based interpretation incorporating multiplanar (MPR) and 3D reconstructions improved sensitivity, particularly for subtle ossicular erosions, and reduced unexpected intraoperative findings[2,9].

The pattern of ossicular involvement observed in this study is consistent with established pathophysiology. The long process of the incus is particularly vulnerable in chronic inflammatory disease, explaining its high rate of erosion[5]. Our results, showing both a high prevalence of incus damage and good CT accuracy for its detection, align with previous prospective reports highlighting HRCT as a valuable tool for mapping disease extent and assisting preoperative planning[16]. However, consistent with existing literature, finer structures such as the incus long process and stapes supra structure remain more difficult to evaluate than the malleus head or incus body, reflecting the gradient of diagnostic performance observed in this study[18].

Regarding cholesteatoma and disease extent, HRCT proved highly effective in identifying bony anatomy and erosive changes. The high sensitivity for scutum erosion and strong specificity for larger bony defects correspond with prior surgical correlation studies. Nevertheless, HRCT has recognized limitations in differentiating cholesteatoma from granulation tissue due to similar soft tissue densities, reinforcing its role as an anatomic rather than tissue-characterizing modality[18].

The improved performance seen with structured reporting in Group B is both technically and clinically plausible. Systematic evaluation of each ossicle in multiple planes reduces oversight, minimizes “satisfaction of search,” and decreases indeterminate interpretations. Such structured protocols may enhance consistency, reduce variability, and improve inter-observer reliability[13,15].

Finally, while HRCT demonstrated high specificity for facial canal dehiscence and tegmen defects, sensitivity was modest, as very small dehiscences may fall below spatial resolution limits or be obscured by partial volume effects. For lateral semicircular canal fistula, specificity approached 100%, though sensitivity varied because early fistulae can be subtle. Overall, these findings support the established role of HRCT as an effective surgical mapping and risk-assessment tool, rather than a flawless detector of micro-defects[19,20].

Clinical Implications

- Counselling: HRCT-based prediction of ossicular status improves informed consent regarding hearing outcomes and potential need for staged ossiculoplasty.

- Surgical preparedness: anticipating incus absence/discontinuity aids in selecting prosthesis type and reconstruction plan.
- Risk reduction: highlighting possible facial canal or labyrinthine involvement increases surgeon vigilance.

Limitations

- Sample size (n=50) limits subgroup analysis (mucosal vs squamous; pediatric vs adult).
- Although surgery was standardized, intraoperative assessment has inherent subjectivity, especially for "minor erosions."
- HRCT cannot reliably differentiate cholesteatoma from granulation tissue in many cases; diffusion MRI is superior for soft tissue characterization, but was not part of this protocol.

Future Directions

- Larger multicentric diagnostic studies with inter-observer assessment.
- Combined imaging pathway: HRCT for bony mapping + DWI MRI for cholesteatoma confirmation, particularly in revision or equivocal cases.
- Development of institution-specific structured reporting templates integrated into radiology workflow.

CONCLUSION

HRCT temporal bone demonstrates good diagnostic accuracy for predicting ossicular chain status and mapping disease extent in chronic ear disease, with the highest utility for incus evaluation. Detection of subtle stapes supra structure erosions remain relatively limited. A structured checklist-based HRCT interpretation strategy with MPR/3D reconstructions improves sensitivity for difficult ossicular lesions and reduces intraoperative surprises. HRCT should be used as an adjunct to meticulous clinical examination, with clear communication of its limitations.

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