AMERICAN JOURNAL OF DIAGNOSTIC IMAGING
2026; 12(3): 160-168
10.5455/ajdi.20260202100220

ORIGINAL ARTICLE

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Diagnostic accuracy and agreement of high-resolution computed tomography in detection of temporal bone pathologies at Kilimanjaro Christian Medical Centre, Tanzania

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ABSTRACT

Background: Temporal bone pathologies, including infections, cholesteatoma, and tumors, pose significant diagnostic and surgical challenges. High-resolution computed tomography (HRCT) provides detailed anatomical information, yet its diagnostic accuracy relative to surgical findings in East Africa remains underexplored.

Methods: We conducted a retrospective diagnostic accuracy study of 63 patients at Kilimanjaro Christian Medical Centre (2021–2024), comparing preoperative HRCT findings with intraoperative diagnoses. Sensitivity, specificity, predictive values, and kappa statistics (with 95% confidence intervals) were calculated.

Results: Chronic suppurative otitis media (CSOM) was the most common pathology (76.2%), followed by cholesteatoma (19.0%) and glomus tumors (4.8%). HRCT demonstrated high diagnostic accuracy for CSOM (sensitivity 95.9%, 95% CI 86.0–99.5; specificity 92.9%, 95% CI 66.1–99.8) and cholesteatoma (sensitivity 91.7%, 95% CI 61.5–99.8; specificity 98.0%, 95% CI 86.9–100.0). Agreement was substantial (kappa >0.8) for epitympanum, mesotympanum, hypotympanum, and antrum involvement. Sensitivity was lower for ossicular erosions, particularly the incus (43.8%) and facial nerve canal dehiscence (20.0%).

Conclusion: HRCT is a reliable diagnostic tool for temporal bone pathologies, particularly CSOM and cholesteatoma, showing strong correlation with surgical findings. However, its sensitivity for subtle ossicular and nerve canal erosions is limited. Complementary MRI may be useful, particularly for cholesteatoma and soft-tissue characterization when available. In resource-limited settings, routine HRCT use is recommended for preoperative planning, with surgical confirmation required for fine bony details.

ARTICLE HISTORY

Received April 27, 2026
Revised June 30, 2026
Accepted June 30, 2026
Published September 11, 2026

KEYWORDS

Temporal bone pathologies; chronic suppurative otitis media; cholesteatoma; high-resolution computed tomography; diagnostic accuracy; Tanzania

Background

Temporal bone pathologies, including infections, inflammations, cholesteatoma, trauma, and tumors, pose significant diagnostic and surgical challenges due to the bone's complex anatomy. Accurate preoperative imaging is essential for guiding surgical planning and improving patient outcomes [1,2]. High-resolution computed tomography (HRCT) is widely regarded as the imaging modality of choice for evaluating temporal bone disease, offering detailed visualization of bony structures and disease extent [3].

Globally, chronic suppurative otitis media (CSOM) remains the most common temporal bone pathology, with a prevalence of 2%–4% in developing countries compared to much lower rates in developed nations [4–6]. In Sub-Saharan Africa, CSOM prevalence ranges from 0.4% to 4.2%, making it a leading cause of preventable hearing loss. Cholesteatoma, another destructive pathology, can erode bone and cause serious complications such as facial nerve paralysis, labyrinthine fistula, and intracranial infections [3,7].

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Although HRCT has been extensively studied in high-resource settings, its diagnostic accuracy relative to surgical findings in East Africa remains underexplored. Regional differences, including delayed presentation, limited access to MRI, and referral-center case mix, may influence diagnostic performance [8]. At Kilimanjaro Christian Medical Centre (KCMC), HRCT is the primary imaging modality for temporal bone disease, yet there is limited published data on how well HRCT findings align with intraoperative observations.

This study aimed to evaluate the diagnostic accuracy of HRCT in temporal bone pathologies by comparing preoperative imaging findings with intraoperative surgical results. By providing local data from a Tanzanian tertiary referral hospital, the study seeks to clarify HRCT's strengths and limitations in this context, inform surgical planning, and highlight areas where complementary imaging, such as MRI, may be required.

Methods

Study design and time

This was a hospital-based retrospective diagnostic accuracy study conducted at Kilimanjaro Christian Medical Centre (KCMC), Moshi, Tanzania, between January 2021 and December 2024. The study compared preoperative HRCT findings with intraoperative surgical observations in patients with temporal bone pathologies.

Study population

Eligible patients were those who underwent both HRCT imaging of the temporal bone and subsequent surgical intervention. Exclusion criteria included incomplete medical records or missing HRCT images. Because only surgical patients were included, the study population may represent more severe or surgically selected disease; this potential verification bias is acknowledged as a limitation.

Sample size and sampling

The minimum required sample size was calculated as 66 patients using a single proportion formula based on an expected CSOM prevalence

$$n = \frac{Z^2 \cdot P(1-P)}{d^2}$$

where:

- Z = Z-score for 95% confidence level (1.96).
- P = expected prevalence of chronic suppurative otitis media (CSOM), taken as 0.78 (78%) based on prior studies [4].
- d = desired precision (margin of error), set at 0.1 (10%).

Substituting values:

$$n = \frac{(1.96)^2 \cdot 0.78(1-0.78)}{(0.1)^2}$$

$$n = \frac{3.84 \cdot 0.78 \cdot 0.22}{0.01} = 65.9.$$

Thus, the minimum required sample size was 66 patients.

A total of 63 patients met the inclusion criteria. Although slightly below the calculated minimum, this shortfall may reduce the precision of diagnostic accuracy estimates, particularly for rare pathologies such as glomus tumors.

Radiological assessment

Preoperative HRCT scans were independently reviewed by two blinded radiologists with more than 5 years of experience in temporal bone imaging. Disagreements were resolved by consensus. Interobserver agreement statistics were not formally calculated and are acknowledged as a limitation.

HRCT PROTOCOL

Scanning was performed using a 128-detector CT scanner (Siemens SOMATOM Definition). Axial images were acquired with 0.6 mm slice thickness, aligned parallel to the infraorbitomeatal line. Coronal and sagittal reformats were generated using a high-resolution bone reconstruction kernel (B70). The field of view was 180 mm, tube voltage 120 kVp, and tube current 200 mAs. Images were transferred to a Syngo-via workstation (Siemens Healthineers) for multiplanar reconstruction and analysis.

Data collection

Demographic data, clinical presentation, HRCT findings, and intraoperative observations were extracted from medical records, CT registers, and surgical notes. HRCT findings included opacification, ossicular erosion, tympanic membrane perforation, and canal dehiscence. Surgical findings served as the reference standard.

Statistical analysis

Data were analyzed using SPSS version 25. Diagnostic accuracy metrics—including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and kappa statistics—were calculated with 95% confidence intervals. McNemar's test was used to assess paired differences between HRCT and surgical findings. Kappa values were interpreted according to Landis and Koch's classification (poor <0.20, fair 0.21–0.40, moderate 0.41–0.60, substantial 0.61–0.80, almost perfect >0.80).

Results

Sociodemographic and clinical characteristics of participants

A total of 63 patients were included. The mean age was 34.2 ± 14.8 years, with the majority (55.6%) aged 20–44 years (Table 1). Females comprised 66.7% of the cohort. Most participants resided in Arusha (42.9%) and Kilimanjaro (36.5%). The most common presenting symptom was ear discharge (88.9%), followed by hearing loss (73.0%). Post-auricular swelling and facial paralysis were not observed.

Laterality characteristics of the patients

Among the study participants, the left side was affected in 54% of cases, while the right side accounted for 46%. This distribution is illustrated in Figure 1, which demonstrates a slightly higher prevalence of left-sided disease but no strong lateral predilection overall. Percentages are displayed within each bar for clarity, and the vertical axis represents the proportion of affected cases (Tables 3 and 5).

The common temporal bone pathologies among patients

As shown in Table 2, CSOM was the most frequent diagnosis, identified in 77.8% of HRCT scans and 76.2% of surgical explorations. Cholesteatoma was present in 19.0% of cases, while glomus tumors were rare (HRCT: 2 cases; surgery: 3 cases). Representative HRCT findings of cholesteatoma with scutum erosion are shown in Figure 2, where intraoperative confirmation demonstrated cholesteatoma occupying the attic region. An example of HRCT demonstrating mastoid opacification in CSOM is presented in Figure 3, with surgical exploration revealing granulation tissue and purulent material.

Table 1. Sociodemographic and clinical characteristics of participants (*N* = 63).

Variable	Category	*n*	%
Age (years)	Mean ± SD	34.2 ± 14.8	
	3–19	12	19.0
	20–44	35	55.6
	45–65	16	25.4
Sex	Male	21	33.3
	Female	42	66.7
Residence	Kilimanjaro	23	36.5
	Arusha	27	42.9
	Manyara	4	6.3
	Other	9	14.3
Symptoms		**Yes *n* (%)**	**No *n* (%)**
	Ear discharge	56 (88.9)	7 (11.1)
	Ear ache	16 (25.4)	47 (74.6)
	Hearing loss	46 (73.0)	17 (27.0)
	Tinnitus	13 (20.6)	50 (79.4)
	Vertigo	5 (7.9)	58 (92.1)
	Post-auricular swelling	0 (0.0)	63 (100.0)
	Headache	12 (19.0)	51 (81.0)
	Ear fullness	13 (20.6)	50 (79.4)
	Facial paralysis	0 (0.0)	63 (100.0)
	Fever	5 (7.9)	58 (92.1)

Table 2. Temporal bone diagnoses based on HRCT and surgical findings (*N* = 63).

Diagnosis	HRCT *n* (%)	Surgical *n* (%)
CSOM	49 (77.8)	48 (76.2)
Cholesteatoma	12 (19.0)	12 (19.0)
Glomus tumor	2 (3.2)	3 (4.8)

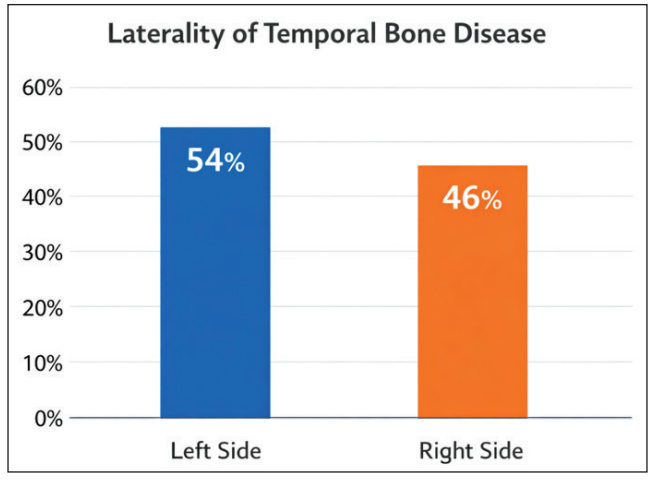


Figure 1. Laterality characteristics of patients with temporal bone pathologies (*N* = 63).

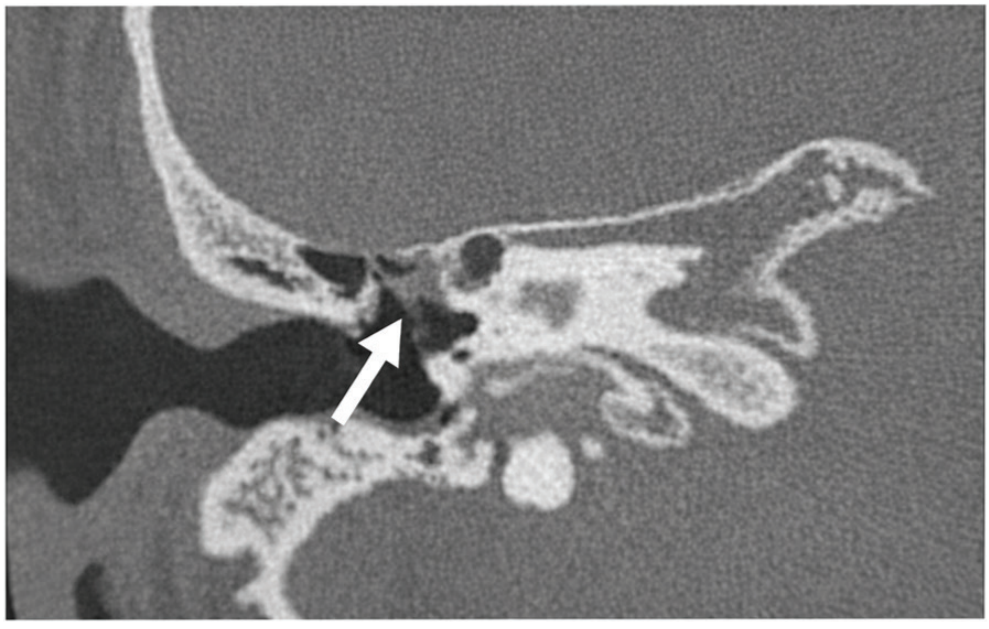


Figure 2. HRCT of Cholesteatoma with scutum erosion, axial HRCT image demonstrating a soft-tissue mass in the epitympanum with erosion of the scutum (arrow). Intraoperative findings confirmed cholesteatoma occupying the attic region.



Figure 3. HRCT of chronic suppurative otitis media (CSOM) with mastoid opacification. Coronal HRCT image showing opacification of the left mastoid air cells (arrows) in a patient with CSOM. Surgical exploration revealed granulation tissue and purulent material within the mastoid cavity.

Anatomical involvement

HRCT and surgical findings showed strong agreement for epitympanum and mastoid air-cell involvement (90.5% each). The mastoid antrum was affected in 65.1% of cases, and aditus widening in 28.6%. Ossicular erosions were less consistently detected: incus erosion was identified in 11.1% of HRCT scans versus 25.4% during surgery. Facial

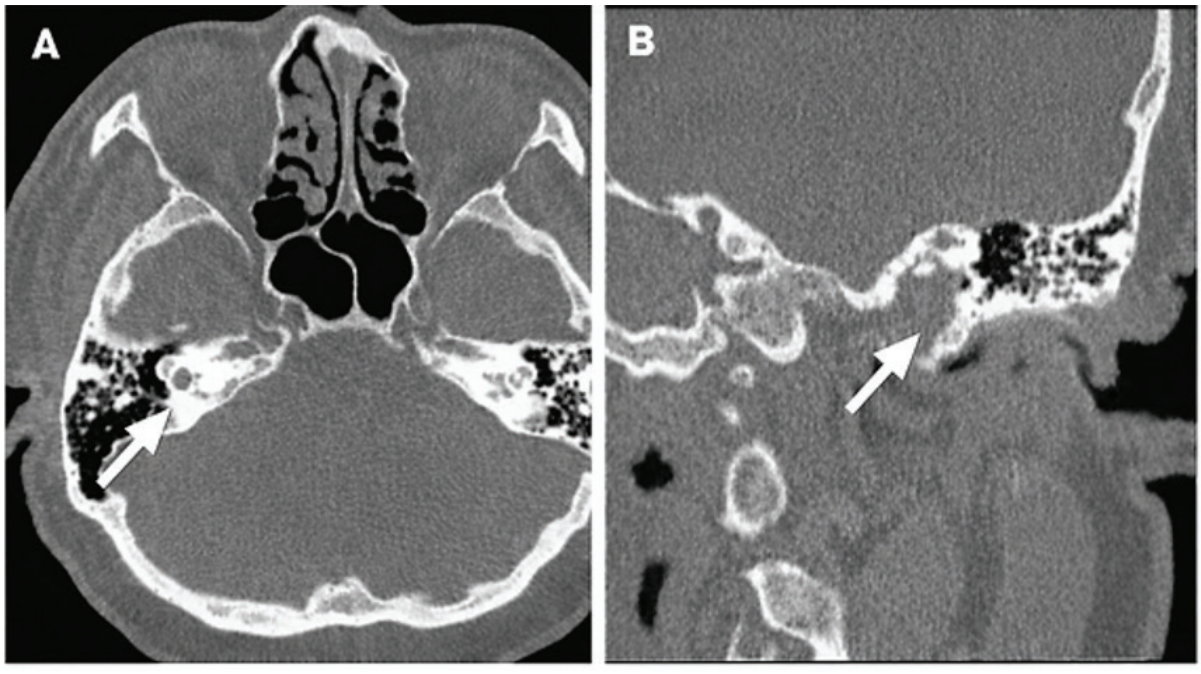


Figure 4. HRCT of a glomus tumor of the temporal bone. (A) Axial HRCT showing a soft-tissue mass in the hypotympanum (arrow) with erosion of the jugular bulb. (B) Coronal HRCT demonstrating a glomus tumor (arrow) with destruction of adjacent bone. Intraoperative findings confirmed glomus tympanicum.

Table 3. Temporal bone pathologies: HRCT versus surgical findings (*N* = 63).

Anatomical site	HRCT *n* (%)	Surgical *n* (%)
Epitympanum (opacification)	57 (90.5)	57 (90.5)
Mastoid air cells	57 (90.5)	57 (90.5)
Mesotympanum	20 (31.7)	21 (33.3)
Hypotympanum	19 (30.2)	18 (28.6)
Mastoid antrum	41 (65.1)	41 (65.1)
Aditus ad antrum (widening)	18 (28.6)	18 (28.6)
Malleus erosion	9 (14.3)	12 (19.0)
Incus erosion	7 (11.1)	16 (25.4)
Stapes erosion	6 (9.5)	8 (12.7)
Scutum erosion	8 (12.7)	7 (11.1)
Tegmen erosion	7 (11.1)	4 (6.3)
Facial nerve canal dehiscence	1 (1.6)	5 (7.9)
Lateral semicircular canal	0 (0.0)	3 (4.8)
Tympanic membrane perforation	42 (66.7)	50 (79.4)
Sigmoid plate dehiscence	1 (1.6)	2 (3.2)

nerve canal dehiscence was underdetected by HRCT (1.6% vs. 7.9%). HRCT findings of a glomus tumor in the hypotympanum with jugular bulb erosion are illustrated in Figure 4, which was confirmed intraoperatively as glomus tympanicum.

Mastoid air cells involvement

Figure 5 presents a side-by-side comparison of mastoid air-cell conditions as detected by HRCT and confirmed during surgery. Four categories are shown: normal, opacified, sclerotic, and erosion. Both HRCT and surgical findings revealed similar distributions, with opacification being the most frequent abnormality (HRCT 63.5%, surgery 66.7%). Normal mastoids were observed in 9.5% of cases by both methods, while sclerotic changes accounted for 19.0%. Erosive changes were less common, identified in 7.9% of HRCT scans compared to 4.8% intraoperatively. The close alignment between HRCT and surgical observations highlights strong agreement in detecting mastoid pathology.

Diagnostic accuracy

As depicted in Table 4, HRCT demonstrated excellent diagnostic performance for the most common temporal bone pathologies. For CSOM, HRCT achieved a sensitivity of 95.9% (95% CI 86.0–99.5) and specificity of 92.9% (95% CI 66.1–99.8), with a positive predictive value (PPV) of 97.9% and a negative predictive value (NPV) of 86.7% (95% CI 59.5–98.3). Similarly, for cholesteatoma, HRCT showed robust accuracy, with sensitivity of 91.7% (95% CI 61.5–99.8) and specificity of 98.0% (95% CI 86.9–100.0). On the contrary, diagnostic performance for glomus

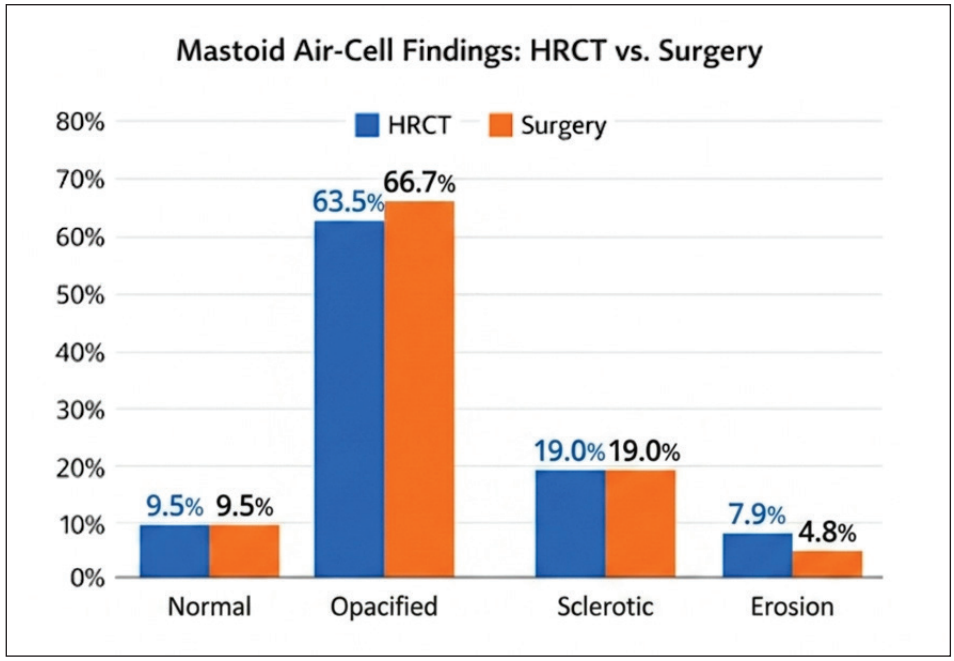


Figure 5. Comparison of mastoid air-cell findings on HRCT and intraoperative assessment.

Table 4. Diagnostic accuracy of HRCT compared with surgical findings.

Disease	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV %	NPV %
CSOM	95.9 (86.0–99.5)	92.9 (66.1–99.8)	97.9	86.7
Cholesteatoma	91.7 (61.5–99.8)	98.0 (86.9–100.0)	91.7	98.0
Glomus tumor	66.7 (12.5–98.2)	98.4 (91.2–100.0)	66.7	98.4

Table 5. 2×2 Contingency tables for HRCT versus surgical findings (*N* = 63).

Disease	TP	FP	FN	TN
CSOM	47	1	2	13
Cholesteatoma	11	1	1	50
Glomus tumor	2	1	1	59

Note: TP = true positive; FP = false positive; FN = false negative; TN = true negative.

tumors was more limited: HRCT detected 2 of 3 surgically confirmed cases, yielding a sensitivity of 66.7% and specificity of 98.4%. Agreement between HRCT and surgical findings was substantial (kappa >0.8) for epitympanum, mesotympanum, hypotympanum, and mastoid antrum involvement, underscoring HRCT's reliability in identifying soft-tissue disease and larger anatomical changes. However, sensitivity was notably lower for subtle bony erosions, particularly of the incus (43.8%), stapes (62.5%), and facial nerve canal dehiscence (20.0%).

To illustrate diagnostic performance, 2×2 contingency tables were constructed for each major pathology, summarizing true positive (TP), false positive (FP), false negative (FN), and true negative (TN) counts. These tables provide the raw data underlying sensitivity, specificity, and predictive value calculations.

The diagnostic accuracy of CT imaging patterns and the surgical management of temporal bone pathologies

Table 6 summarizes the diagnostic agreement between HRCT and intraoperative findings across key anatomical structures of the temporal bone. Agreement was almost perfect ($\kappa > 0.8$) for epitympanum, mesotympanum, hypotympanum, antrum, and scutum involvement, indicating excellent correlation between imaging and surgical observations. Substantial agreement (κ 0.61–0.80) was observed for malleus, stapes, tegmen, and tympanic membrane perforation. Moderate to fair agreement was noted for incus erosion (κ 0.537) and facial nerve canal dehiscence (κ 0.315), reflecting HRCT's limited sensitivity for subtle ossicular and canal changes. Lateral semicircular canal (LSCC)

Table 6. Agreement between HRCT and intraoperative findings in temporal bone pathologies (*N* = 63).

Finding	Sensitivity %	Specificity %	PPV %	NPV %	Kappa	Agreement level
Opacified epitympanum	98.2	83.3	98.2	83.3	0.816	Substantial
Mastoid air cells	98.2	83.3	98.2	83.3	0.816	Substantial
Opacified mesotympanum	95.2	100.0	100.0	97.7	0.964	Almost perfect
Opacified hypotympanum	94.4	95.6	89.5	97.7	0.885	Almost perfect
Opacified antrum	95.1	90.9	95.1	90.9	0.860	Almost perfect
Widened aditus ad antrum	88.9	95.6	88.9	95.6	0.844	Substantial
Eroded malleus	66.7	98.0	88.9	92.6	0.715	Substantial
Eroded incus	43.8	100.0	100.0	83.9	0.537	Moderate
Eroded stapes	62.5	98.1	83.3	94.6	0.679	Substantial
Eroded scutum	100.0	98.2	87.5	100.0	0.924	Almost perfect
Eroded tegmen	100.0	94.9	57.1	100.0	0.703	Substantial
Facial nerve canal dehiscence	20.0	100.0	100.0	93.5	0.315	Fair
Tympanic membrane perforation	84.0	100.0	100.0	61.9	0.684	Substantial
Sigmoid plate dehiscence	50.0	100.0	100.0	98.4	0.659	Substantial

involvement was observed intraoperatively in three cases but not detected on HRCT. Due to the very small number of positive cases, LSCC was excluded from the diagnostic accuracy table to avoid unstable sensitivity/specificity estimates.

Overall, HRCT demonstrated high reliability for detecting major disease patterns but reduced accuracy for fine bony erosions.

Discussion

This study demonstrates that HRCT provides high diagnostic accuracy for soft-tissue diseases such as CSOM and cholesteatoma, but lower performance for subtle bony erosions. The difference arises from both technical and anatomical factors. HRCT readily detects opacification and larger structural changes due to its high spatial resolution and clear air–soft tissue contrast. On the contrary, ossicular structures, particularly the incus, are small, thin, and obliquely oriented, making them prone to partial volume averaging and beam-hardening artifacts. Dense inflammatory tissue may further obscure fine erosions, explaining discrepancies between CT and surgical findings in "total erosion" cases. The main limitation observed was low sensitivity with generally high specificity, particularly for incus erosion and facial nerve canal dehiscence. HRCT reliably confirms disease when detected but may miss subtle lesions due to partial-volume averaging and inflammatory tissue masking. Similar findings have been reported by Sharma et al., who noted that HRCT often underestimates ossicular erosion compared with intraoperative findings [9].

The high prevalence of CSOM in this cohort compared with international reports likely reflects regional epidemiology. Studies have documented higher CSOM rates in sub-Saharan Africa than in developed countries, attributing this to limited access to early medical care, higher rates of untreated otitis media, and socioeconomic determinants of health [4,10,11]. This emphasizes the importance of local data to guide surgical planning and resource allocation.

While HRCT demonstrated "perfect specificity" for tegmen tympani and sigmoid plate findings, this should be interpreted cautiously. The small number of positive cases limits the reliability of specificity estimates, and similar caution has been advised in studies by Jackler and Swartz et al., who highlighted that specificity values based on few events are inherently unstable [12,13].

Clinically, missed facial nerve canal dehiscence or ossicular erosions carry significant implications. Failure to detect these abnormalities preoperatively increases the risk of iatrogenic injury during mastoidectomy or tympanoplasty and may compromise postoperative hearing outcomes. Ocak et al. [14] emphasized that HRCT underreporting of facial canal dehiscence can predispose to intraoperative nerve injury [14]. Technical factors most likely contributing to missed ossicular erosions include slice thickness, reconstruction algorithms, and inflammatory tissue masking.

While HRCT remains the cornerstone for evaluating bony anatomy and disease extent, complementary MRI may be useful, particularly for

cholesteatoma and soft-tissue characterization when available. HRCT excels at detecting opacification, scutum erosion, and mastoid involvement, but its ability to differentiate cholesteatoma from other soft tissue (e.g., granulation tissue) is limited. MRI, especially diffusion-weighted imaging (DWI), provides superior sensitivity and specificity for cholesteatoma by exploiting restricted diffusion within keratin debris. Several studies have shown that non-echo-planar DWI can detect even small residual or recurrent cholesteatomas, which HRCT may miss. In resource-limited settings, HRCT should be prioritized for preoperative planning, but where available, complementary MRI may improve soft-tissue characterization, while ultra-high-resolution CT could enhance ossicular detail.

Lateral semicircular canal (LSCC) involvement was observed intraoperatively in three cases but was not detected on HRCT. Because of the very small number of positive cases, LSCC was not included in the diagnostic accuracy table to avoid unstable sensitivity/specificity estimates. This exclusion should be interpreted cautiously, as it highlights HRCT's limitation in detecting rare but clinically significant labyrinthine erosions. In practice, LSCC fistulae are better characterized with complementary MRI or intraoperative confirmation. Future studies with larger cohorts are needed to more reliably assess HRCT's performance for LSCC involvement.

Although postoperative evaluation was mentioned in the background, this study was limited to preoperative HRCT and intraoperative findings. Postoperative outcomes were not assessed and should be clarified as beyond the scope of this design. Future prospective studies incorporating postoperative imaging would provide valuable insights into HRCT's role in monitoring surgical outcomes.

Finally, intracranial complications were not observed in this cohort, despite their mention in the background. This may reflect earlier surgical intervention or exclusion of non-surgical cases. Previous studies, such as Osma et al., have documented intracranial complications in advanced CSOM, underscoring the importance of vigilance in larger cohorts [15]. Future studies should specifically evaluate HRCT's role in detecting intracranial complications to provide a more comprehensive assessment.

Clinical implications

The findings of this study underscore HRCT's critical role in surgical planning for temporal bone disease in resource-limited settings. Reliable detection of CSOM and cholesteatoma allows surgeons to anticipate disease extent and tailor operative approaches, while awareness of HRCT's limitations in identifying subtle ossicular erosions and facial nerve canal dehiscence highlights the need for intraoperative vigilance. Missed detection of these fine structures may increase the risk of iatrogenic injury and compromise postoperative hearing outcomes. Incorporating HRCT into routine preoperative evaluation, complemented by MRI when available, ensures safer surgery and optimizes patient outcomes in environments where advanced imaging resources are scarce.

Conclusion

HRCT demonstrates high diagnostic accuracy and strong agreement with surgical findings for common temporal bone pathologies, particularly CSOM and cholesteatoma. Its limitations in detecting subtle ossicular erosions and facial nerve canal dehiscence highlight the need for careful intraoperative correlation and, where available, complementary MRI. Despite these limitations, HRCT remains the cornerstone of preoperative evaluation in resource-constrained environments, offering reliable guidance for surgical planning and improving patient outcomes.

Limitations

Several limitations should be acknowledged. First, the retrospective design may introduce selection bias, as only patients who underwent surgery were included. This verification bias likely enriched the sample with more severe disease. Second, the relatively small sample size, particularly for rare pathologies such as glomus tumors, limits the precision of diagnostic accuracy estimates. Third, interobserver variability was not formally assessed, although radiologists reviewed scans independently and resolved disagreements by consensus. Finally, the absence of MRI correlation restricts the evaluation of HRCT's performance in soft tissue characterization. Future prospective studies with larger cohorts, inclusion of non-surgical cases, and multimodal imaging comparisons are recommended to strengthen these findings.

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