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St. Paul's Hospital Millennium Medical College**

**St. Paul's Hospital Millennium Medical College**

**Department of radiology and medical radiology technology**

**Graduate study program**

**Assessment of of pre-operative high-resolution computed tomography and  
intra-operative findings in cholesteatoma patients: A retrospective study**

**By Natnael Fikadu (MD, Radiology resident)**

**July 2024**

**Addis Ababa - Ethiopia**



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**By Natnael Fikadu (MD, Radiology resident)**

**Advisors:**

**Dr. Yonas (MD, Neuro-radiology sub-specialist)**

**Dr. Seman K Ousman (PhD, Assistant professor)**

**A Research Paper submitted to St. Paul Hospital Millennium Medical College,  
Department of Radiology and Medical Radiology Technology in Partial  
fulfillment of the Requirements for the speciality certificate in radiology.**

**Addis Ababa, Ethiopia**

**July 2024**

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|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Name of investigator</b>               | <b>Natnael Fikadu (MD, Radiology resident)</b>                                                                                                                                                                                        |
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| <b>Address of investigator</b>            | <b>Cell phone: +251961207881</b>                                                                                                                                                                                                      |
|                                           | <b>P.O. Box: -----</b>                                                                                                                                                                                                                |
|                                           | <b>Email: <a href="mailto:Nhattybira@gmail.com">Nhattybira@gmail.com</a></b>                                                                                                                                                          |
| <b>Name of Advisor(s)</b>                 | <b>1) Dr. Yonas (MD, Neuro-radiology sub-specialist)</b><br><b>2) Dr. Seman K Ousman (PhD)</b>                                                                                                                                        |

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## **Acronyms and Abbreviations**

CT: Computed Tomography

HRCT: High Resolution Computed Tomography

MRI: Magnetic Resonance Imaging

CSOM: Chronic Suppurative Otitis Media

EAC: External Auditory Canal

IAC: Internal Auditory Canal.

LSCC: Lateral Semicircular Canal

FNC: Facial Nerve Canal

PPV: Positive Predictive Value.

NPV: Negative Predictive Value

ENT: Ear Nose Throat

OPD: Outpatient department

SPHMMC: Saint Paul's Hospital Millennium Medical College.

## Abstract

**Background-** Cholesteatoma is a non-neoplastic locally aggressive lesion that commonly occurs within the pneumatized temporal bone that often necessitates surgical intervention due to its potential to cause complications such as hearing loss, dizziness, facial nerve paralysis. High-resolution computed tomography (HRCT) aids in its assessment, guiding surgical planning. This study aim was to evaluate the diagnostic efficacy of HRCT compared to surgical findings at St. Paul's Hospital Millennium Medical College (SPHMMC).

**Objectives:** The aim of this study was to synthesize knowledge on pre-operative high-resolution computed tomography (HRCT) scans in delineating the condition of middle ear structures in our patients diagnosed with cholesteatoma through a retrospective chart review from January 2023 to May 2024

**Methods:** This study involved a retrospective review of 42 high-resolution computed tomography (HRCT) reports, interpreted by senior radiologists, from January 2023 to May 2024 at St. Paul's Hospital Millennium Medical College in Addis Ababa, Ethiopia. The HRCT findings of the temporal bone were compared with intraoperative findings from surgeries for cholesteatoma. Agreement between HRCT and surgical findings was assessed using Cohen's kappa statistic to measure beyond chance agreement. Sensitivity, specificity, positive predictive value, and negative predictive value of HRCT in detecting cholesteatoma were calculated relative to the surgical findings, which served as the gold standard.

**Results:** The study included 42 cholesteatoma patients, aged 14 to 60 years, with a mean age of 30.1 years. The findings demonstrated an excellent correlation between preoperative high-resolution computed tomography (HRCT) scans and intraoperative observations. Consequently, HRCT of the temporal bone is a valuable tool for surgeons in the early detection and surgical planning of cholesteatoma, despite its drawbacks of increased radiation exposure and relatively high cost.

**Key word-**Cholesteatoma, Temporal HRCT, Surgery, Retrospective Chart Review, Validation Study

# **1. Introduction**

## **1.1. Background**

Cholesteatoma defined as lesions primarily originating within pneumatized portions of the temporal bone, including the middle ear and mastoid, and less frequently within the external auditory canal are characterized as non-neoplastic, locally invasive masses, typically presenting as unilateral cystic structures formed by the accumulation of desquamated keratin and squamous debris, surrounded by a fibrous matrix and often accompanied by an inflammatory reaction (1).

The global annual incidence of acquired cholesteatoma ranges from approximately 3 per 100,000 in children and 9.2 per 100,000 in adults, with a male predominance. Incidence varies across ethnicity, with higher rates among Caucasians and Africans, lower among Asians, and least among Eskimos (2).

Cholesteatoma is mainly classified into congenital and acquired types. Acquired cholesteatoma is further divided into primary and secondary categories, based on whether there is a tympanic membrane perforation and whether the epithelium migrates into the middle ear through this perforation. Primary acquired cholesteatoma of the middle ear develops because of tympanic membrane retraction, which accumulates desquamated epithelium and loses its self-cleaning ability. In contrast, secondary acquired cholesteatoma arises from the migration of epithelium through a marginal perforation in the tympanic membrane. Congenital cholesteatoma is defined as a developmental defect where an epithelial rest becomes entrapped in the middle ear cleft during embryogenesis (3).

Symptoms of cholesteatoma vary but may include hearing loss, recurrent ear infection, otorrhea, tinnitus, vertigo, and facial nerve weakness if the facial nerve is involved. These symptoms can have a profound impact on the patient's quality of life and may necessitate surgical intervention to prevent complications and preserve hearing function. Cholesteatoma also poses several potential intra and extracranial complications, extracranial complications including erosion of ossicles leading to conductive hearing loss, erosion of the inner ear structures causing sensorineural hearing loss or vertigo, facial nerve paralysis if the facial nerve canal is involved, and intracranial complications such as meningitis or brain abscess if the infection spreads beyond the temporal bone (4).

Cholesteatoma diagnostic tools include otoscopy, audiometry, and tympanometry; however, these may not always provide definitive information about the presence, size, or extent of cholesteatoma. Otoscopy may not always reveal the full extent of cholesteatoma, especially in cases where lesions are hidden or located deep within the middle ear cleft. In recent years, high-resolution CT (HRCT) imaging has emerged as a valuable tool in the evaluation of cholesteatoma. HRCT offers detailed visualization of temporal bone structures and precise delineation of cholesteatoma-related abnormalities. Its ability to detect subtle bony erosions, soft tissue density within the middle ear cavity, and associated complications makes it a valuable tool for preoperative assessment. HRCT can complement traditional diagnostic methods and has also shown a growing role as a non-invasive imaging modality in providing valuable information to guide surgical planning, optimize treatment strategies, and improve patient outcomes in cholesteatoma management (4).

Temporal high-resolution CT (HRCT) with multiplanar reconstruction is the first-line imaging study. Coronal CT effectively visualizes the Prussak space, attic, and scutum. Small cholesteatomas appear as soft tissue masses in the Prussak space and posterior mesotympanum for pars flaccida and pars tensa cholesteatomas, respectively. HRCT can also detect ossicular erosion or displacement. For larger cholesteatomas, HRCT helps determine local extension and assess potential complications.

Temporal bone Magnetic Resonance Imaging with non-echo planar diffusion-weighted imaging (non-EPI DWI) is the most sensitive and specific tool, complementing HRCT. Non-EPI DWI can confirm or exclude cholesteatoma if CT findings are equivocal. Post-contrast MRI addresses concerns regarding extension and potential complications raised by HRCT(5). Surgical removal is the sole effective treatment of cholesteatoma.

The main objective of cholesteatoma surgery is complete disease eradication and recurrence prevention, with the additional aim of restoring ear function to near normal. Surgical techniques for Cholesteatoma include open cavity (canal wall-down) and closed cavity (canal wall-up) mastoidectomy(4).

## 1.2 Statement of the problem

Cholesteatoma, characterized by its insidious progression and propensity for asymptomatic presentation, poses significant risks due to potential intra- and extra-cranial complications, which can result in considerable morbidity and mortality if left untreated. The gradual expansion of cholesteatoma often evades detection until they attain a critical size, endangering intra-temporal structures and precipitating various complications such as conductive hearing loss from ossicular erosion, sensorineural hearing loss or vertigo from inner ear damage, facial nerve paralysis in cases involving the facial nerve canal, and life-threatening intra-cranial conditions like meningitis or brain abscess if the infection extends beyond the temporal bone (4).

Available evidence suggests a higher prevalence in underdeveloped nations compared to developed ones (2). Despite the apparent burden of cholesteatoma however, a scarcity of data exists regarding its incidence and prevalence in Sub-Saharan African countries, including Ethiopia. Factors such as long-standing untreated chronic otitis media, eustachian tube dysfunction, trauma, anatomical variations of the temporal bone, genetic predisposition, and immune dysfunction have been associated with an increased predisposition to the development of acquired cholesteatoma, emphasizing the necessity for comprehensive epidemiological and risk factors studies in these regions.

Diagnostic tools such as otoscopy may have limitations in detecting cholesteatoma, particularly when lesions are concealed or located deep within the middle ear cleft. High-resolution computed tomography (HRCT) imaging has emerged as a valuable tool for evaluating cholesteatoma, offering detailed visualization of temporal bone structures and precise identification of cholesteatoma-related abnormalities. However, HRCT's diagnostic accuracy is not infallible, as it may encounter challenges in differentiating cholesteatoma from other middle ear pathologies with similar radiological features, particularly in cases of small or early-stage lesions and may also face difficulties in distinguishing residual cholesteatoma from postoperative granulation tissue.

Therefore, comprehensive studies are needed to assess the diagnostic accuracy of HRCT in detecting cholesteatoma and guiding surgical management. These studies should involve a meticulous correlation of HRCT findings with intra-operative observations to validate HRCT's

reliability and enhance its role in clinical decision-making. Such research endeavors hold the potential to improve patient outcomes and optimize treatment strategies for cholesteatoma.

Saint Paul's Millennium Medical College serves as a prominent tertiary hospital in Ethiopia, encountering approximately 100-200 cases of cholesteatoma annually, with roughly 30 surgeries performed for this condition. Given the diverse clinical presentations and potential complications associated with cholesteatoma, precise and timely diagnosis is paramount for appropriate treatment. Moreover, there is a notable absence of similar studies conducted in our local setting. Hence, comprehensive investigations are imperative to evaluate the accuracy and usefulness of HRCT in detecting and diagnosing cholesteatoma, along with its correlation with intra-operative findings. Such research endeavours aim to inform clinical decision-making, optimize treatment strategies, and ultimately enhance patient outcomes.

### **1.3 Significance of the Study**

Given the substantial number of cholesteatoma patients attending our hospital's ENT department, it is crucial to study these cases by comparing preoperative HRCT findings with intraoperative observations. This comparison will enable us to refine surgical interventions and minimize intraoperative complications by providing detailed preoperative insights into the extent of the disease. Improving patient care requires accurate and comprehensive preoperative imaging.

Preoperative HRCT imaging is extremely beneficial for surgeons, offering detailed visualization of cholesteatoma extent, bony erosions, and involvement of critical structures. Conducting this study to compare HRCT findings with intraoperative results is essential for effective preoperative planning and complete disease resection.

To the best of my knowledge, similar studies have not been conducted in our local setting, emphasizing the need for localized research to evaluate HRCT's accuracy and utility in detecting and diagnosing cholesteatoma. This study aims to establish the correlation between HRCT and intraoperative findings, thereby enhancing clinical decision-making and treatment strategies. Improved diagnostic accuracy and surgical planning can significantly enhance patient outcomes and reduce complications.

This research will also provide valuable insights for policymakers in developing effective treatment plans, ultimately improving the overall quality of care for cholesteatoma patients. The

findings can serve as a benchmark for future research in this area, contributing to the broader scientific understanding of cholesteatoma management in our setting.

## **2. Literature Review**

The term "cholesteatoma," coined by German physiologist Johannes Müller in 1838, denotes a condition characterized by the presence of keratinized squamous epithelial debris, despite its name not directly reflecting its content of cholesterol (chole) or fat (steat). Schuknecht proposed the term "keratoma" in 1974 as a more apt descriptor, defining the lesion as keratinized exfoliation or "skin in the wrong place." (C. Dornelles et al as cited by Kuo CL et al, (4). The global annual incidence of acquired cholesteatoma ranges from approximately 3 per 100,000 in children and 9.2 per 100,000 in adults, with a male predominance. Among children, incidence varies across ethnicities, with higher rates among Caucasians and Africans, lower among Asians, and least among Eskimos (2).

Cholesteatoma can be broadly categorized as congenital or acquired, with the acquired type further classified based on otomicroscopic appearance and growth pattern extension. Jakler classified growth patterns into attic (posterior epitympanic), tensa (posterior mesotympanic), and anterior epitympanic. Although more commonly found in these sites, cholesteatoma may occur elsewhere in the temporal bone. Cholesteatoma typically induces bone erosion due to factors such as inflammation, local pressure, and enzymatic activity. Clinical examination via otoscopy and binocular microscopy reveals foul-smelling ear discharge, granulation tissue, and polyps, especially in the attic region and over the postero-superior quadrant of the tympanic membrane. Rosito LS et al as cited by Pilakkal AM et al (6).

Cholesteatoma diagnosis predominantly relies on otological examination, yet imaging modalities play a crucial role in comprehensive evaluation. High-resolution computed tomography (HRCT) serves as a cornerstone in accurately diagnosing cholesteatoma. Key radiological features include the identification of a non-dependent soft tissue mass density within the middle ear cleft, coupled with ossicular erosions and smooth erosions of middle ear borders and adjacent structures. These findings, especially when accompanied by bony expansions of the middle ear cavity and aditus-ad-antrum, strongly indicate the presence of cholesteatoma (6, 7).

High-resolution computed tomography (HRCT) offers comprehensive visualization of temporal bone structures, aiding in the assessment of middle ear pathologies. Axial projections enable detailed depiction of key anatomical features including the sinus tympani, facial recess, lateral semicircular canal, Korner's septum, horizontal segment of the facial nerve canal, internal auditory canal, vestibular aqueduct, oval and round windows, and various temporal ear pathologies. Conversely, coronal scans are instrumental in evaluating specific structures such as the scutum, Prussak's space, tegmen, geniculate ganglion, stapes, jugular fossa, vestibule, and vertical segment of the facial nerve canal.

Optimal imaging protocols dictate that axial images should encompass the petrous apex to the inferior mastoid tip, while coronal images should span from the anterior to posterior margins of the petrous apex to the mastoid. The advent of HRCT with enhanced spatial resolution has revolutionized preoperative imaging, offering intricate anatomical delineation, precise disease extent assessment, and detection of potential complications. Notably, HRCT excels in identifying lateral semicircular canal fistulae, exposed dura, facial canal dehiscence, and delineating the ossicular chain with remarkable detail. (8, 9).

### **Soft tissue mass**

High-resolution computed tomography (HRCT) plays a crucial role in assessing cholesteatoma, particularly in detecting presence of soft tissue masses & defining the location and extent of cholesteatoma involvement which may provide crucial information regarding the most suitable surgical approach considering the given anatomy of the middle ear and mastoid (10, 11). Despite its limitations in differentiating cholesteatomatous soft tissue from other pathologies such as granulation tissue, scar tissue, and wax, HRCT remains superior to other imaging modalities due to its accessibility, cost-effectiveness, and comprehensive depiction of middle ear anatomy. However, its ability to differentiate soft tissue masses is still limited. (10, 11).

Soft tissue density lesions are often found in non-dependent locations such as the epitympanum/Prussak space, aditus ad antrum, mesotympanum, and mastoid antrum (6, 10, 11). While HRCT demonstrates high sensitivity (90-94%) and accuracy in detecting soft tissue

masses within the middle ear cleft, challenges persist in consistently differentiating cholesteatoma from other soft tissue masses. Some studies suggest the possibility of identifying cholesteatoma based on low attenuation values, while others emphasize the importance of a well-differentiated edge in the mass as a reliable indication of cholesteatoma (Mafee et al as cited by sreedhar et al (11). In summary, while HRCT is valuable in detecting soft tissue masses associated with cholesteatoma, further research is needed to elucidate variations in sensitivity and specificity. Addressing these challenges will enhance HRCT's diagnostic accuracy and improve its utility in cholesteatoma diagnosis and management.

### **Blunting/erosion of scutum**

Blunting of the scutum, characterized by the loss of its normally sharp tip, emerges as the earliest identifiable sign of attic cholesteatoma (12). This sign was consistently detected in all cases studied. Pilakkal AM et al (6) noted 100% correlation between CT findings and intra-operative findings with regard to scutum blunting/erosion. Abdulmonaem et al. (8) also emphasized the effectiveness of HRCT in visualizing scutum erosion, particularly on coronal scans. Their study, which included surgically confirmed cases, demonstrated HRCT's capability to accurately detect both blunted and preserved scutum. Specifically, all cases with surgically confirmed blunted scutum were detected by HRCT, while HRCT correctly predicted the preservation of the scutum in all corresponding cases. In a study by Sagar et al. (2017) (13), which evaluated bony erosions in various parts of the temporal bone, scutum involvement was prevalent, affecting 60% of cases. HRCT exhibited a high detection rate (91.67%) for scutum involvement, further underscoring its efficacy in identifying temporal bone pathologies.

### **Ossicular erosion:**

Cholesteatoma, characterized by the abnormal proliferation of keratinizing squamous epithelium within the middle ear, often leads to erosions of the ossicular chain, predominantly affecting the incus and stapes. The most widely damaged part of the incus was its long process (25.9%) and the second most common site of damage to the incus was its body (4.8%). Damage to the stapes was the second most common type of damage observed, and mostly involved its superstructure. Erosion of the stapes superstructure was more common than total loss of the bone (40.9% vs.

25.9%, respectively). Even though damage to the malleus was least common, the number of cases where the stapes superstructure was intact was greater than the number of cases of an intact malleus (59% vs. 56%).

These erosions, especially prevalent in advanced cases, significantly contribute to hearing impairment (14). CT scans have demonstrated promising sensitivity in detecting ossicular destruction, particularly involving the incus and malleus, although challenges persist in visualizing stapes erosions (7, 8, 10, 11). In some studies stapes was not consistently visualized in HRCT but appeared as a soft tissue density around oval window niche, for this reason it was not possible distinguished between destruction of stapes and its envelopment by soft tissue (10). Notably, high-resolution CT (HRCT) imaging has been pivotal in characterizing the ossicular chain, with successful characterization achieved in the majority of cases.

A recent study by Shah et al (12) observed ossicular erosion as the most common complication, with varying degrees of involvement observed in the incus, malleus, and stapes. However, the sensitivity of CT scans in predicting ossicular involvement fluctuates across studies, highlighting the imperative for further investigation and refinement of imaging techniques.

### **Lateral semicircular canal (LSCC) Erosion:**

Erosion of the lateral semicircular canal (LSCC) is a common occurrence due to its proximity to the attic's medial wall. However, HRCT imaging may occasionally present challenges, potentially leading to a false impression of canal fistula. Different studies indicate variable sensitivity in detecting LSCC erosion via HRCT (Gaurano et al as cited by Khavasi et al (10). Correlation between lateral semicircular canal fistula observed on HRCT and during surgery demonstrated favourable sensitivity and specificity, as evidenced by studies conducted by Pilakkal AM et al. (2021) (6) and Ashutosh Roy et al. (2023) (15).

In a study by Abdulmonaem et al. (2015) (8), which included surgically confirmed cases of labyrinthine fistula, 14 out of 16 cases involved the lateral semicircular canal. Notably, HRCT successfully visualized 14 of these cases, while the remaining two cases exhibited thinning of the lateral semicircular canal wall without a discernible fistula. The authors highlighted the importance of axial scans for detecting LSCC fistula, emphasizing their ability to depict the

canal comprehensively and minimize false results. While coronal scans also provided valuable information, accurate assessment of fistula necessitates examination of both coronal and axial images.

### **Tegmen tympani erosion:**

a significant concern in otologic pathology, presents challenges in radiological interpretation despite its visualization on coronal scans as a thin bony plate covering the epitympanum and antrum. While coronal imaging aids tegmen visualization, misinterpretations may arise due to volume averaging effects (Abdulmonaem et al., 2015) (8). Discrepancies between radiological findings and surgical outcomes have been noted, with scans suggesting tegmen breach despite surgical confirmation of its integrity. Conversely, radiologically intact areas may exhibit dehiscence upon surgery, as observed in three cases in our study.

Studies have reported variable radio surgical correlation for tegmen erosion. Pilakkal AM et al. (6) observed tegmen plate erosion on HRCT in 12 patients, slightly fewer than during mastoid exploration surgery (10 patients), with high sensitivity (100%) and specificity (96.9%). Similarly, Ashutosh Roy et al. (15) reported HRCT-detected eroded tegmen in 11 cases, matched by intra-operative findings in 9 cases, with sensitivity and specificity both reaching 100% and 95.5%, respectively. In another study by Prabhu Khavasi et al. (10), preoperative HRCT identified dural plate erosions in 6 cases, slightly more than intra-operative findings (4 cases), indicating the importance of meticulous radiological interpretation and intra-operative verification in tegmen tympani assessment.

### **Facial Nerve canal**

Preoperative assessment of facial nerve canal involvement via HRCT poses challenges due to its small size, oblique orientation, and the presence of developmental dehiscence, often exacerbated by volume averaging artifacts (10). In their study, Khavasi et al. (10) identified facial nerve canal erosion in 6 cases via HRCT, while intra-operative findings revealed erosions in 8 cases, primarily affecting the tympanic part in 2 cases and both the tympanic and vertical parts in 6 cases.

The tympanic part showed greater susceptibility to erosion. HRCT demonstrated a sensitivity of 42% and specificity of 48% in detecting facial nerve canal erosion. Similarly, Stefanescu et al. (16) reported a sensitivity of 50% and specificity of 92.1% in their study, with a moderate-to-poor correlation between imaging and surgery ( $\kappa = 0.42$ ). Çakan et al. (17) found a sensitivity of 100% in diagnosing facial nerve canal involvement, possibly attributed to the expertise of their radiology department in neuroradiology.

**Mastoid Cavity:** Chronic suppurative otitis media (CSOM) typically involves the mastoids, and preoperative high-resolution computed tomography (HRCT) plays a crucial role in its evaluation. In a study by Khavasi et al. (10), all mastoids exhibited sclerosis on preoperative HRCT, a finding consistently confirmed intra-operatively. Moreover, HRCT provided detailed delineation of the mastoid antrum and aditus ad antrum in both coronal and axial planes. Similarly, Payal et al (18) reported 100% sensitivity in identifying sclerotic mastoids, with cellular mastoids exhibiting a specificity of 66%.

**Lateral Mastoid Cortex:** Erosion of the lateral mastoid cortex is a significant aspect of chronic suppurative otitis media. In the study by Khavasi et al. (10), erosion of the lateral mastoid cortex was identified in 6 cases on preoperative HRCT, all of which were confirmed during surgery. HRCT demonstrated excellent accuracy in identifying the destruction of the lateral cortical wall of the mastoid, with 100% sensitivity and specificity. These findings align with studies by various authors, consistently reporting high sensitivity and specificity in identifying lateral mastoid cortex erosion.

### **3. Objectives**

#### **3.1 General objectives**

- To synthesize knowledge on pre-operative high-resolution computed tomography (HRCT) scans in delineating the condition of middle ear structures in our patients diagnosed with cholesteatoma from January 2023 to May 2024

#### **3.2 Specific objectives**

- To assess the efficacy of a pre-operative high-resolution CT scan in depicting the status of the middle ear structures in the presence of cholesteatoma
- To compare the preoperative findings of the HRCT with the intraoperative findings

## 4. Methodology

### 4.1. Study setting.

St. Paul's Hospital Millennium Medical college (SPHMMC) in Addis Ababa, Ethiopia, is a renowned medical institution established through a decree of the council of ministers in 2010, building upon the legacy of the medical school, which opened in 2007, and the hospital established in 1968 by the late Emperor Haile Selassie. Governed by a board under the Federal Ministry of Health, SPHMMC is a pioneer in medical education, initiating Ethiopia's first integrated modular and hybrid problem-based curriculum for undergraduate medical education and expanding to postgraduate programs.

With rapid growth from 3 to 250 faculty members in the last six years, SPHMMC is committed to building capacity and diversifying its program offerings. The hospital, with more than 2800 clinical, academic and administrative staff, provides medical speciality services to patients from across the country, with an inpatient capacity of over 700 beds and serving an average of 1200 emergency and outpatients clients daily (St. Paul's Millennium Medical College. (n.d.). About Us. Retrieved April 28, 2024, from <https://sphmmc.edu.et/about/>)).

The radiology department since its establishment has evolved into a state-of-the-art facility equipped with modern imaging technologies and staffed by skilled radiologists, technologists, and support personnel. The radiology department has played a pivotal role in advancing diagnostic imaging services in Ethiopia, pioneering the adoption of innovating imaging techniques and protocols to enhance patient care and outcome

The radiology department is equipped with comprehensive range of imaging modalities including HRCT, MRI, Ultrasonography & Digital Radiography which enabled the department to perform wide variety of diagnostic studies ranging from routine radiography to complex interventional procedures. Led by experienced radiologists, the department provides comprehensive diagnostic imaging services to a diverse patient population from urban and rural areas across Ethiopia. Beyond clinical services, the department actively engages in research initiatives aimed at advancing the field of diagnostic imaging and contributes to medical education through training programs for radiology residents, technologists, and medical students.

## 4.2 Study period

Data collection for this study encompassed a retrospective chart review of all patients who have been diagnosed with cholesteatoma and have undergone both HRCT and surgical intervention at Saint Paul Hospital Millennium Medical College (SPHMMC) in Addis Ababa, Ethiopia, spanning from January 2023 to May 2024.

## 4.3 Study design

The study involved a retrospective review of 42 high-resolution computed tomography (HRCT) reports, interpreted by senior radiologists, from January 2023 to May 2024 at St. Paul's Hospital Millennium Medical College in Addis Ababa, Ethiopia. The HRCT findings of the temporal bone were compared with intraoperative findings from surgeries for cholesteatoma. Agreement between HRCT and surgical findings was assessed using Cohen's kappa statistic to measure beyond chance agreement. Sensitivity, specificity, positive predictive value, and negative predictive value of HRCT in detecting cholesteatoma were calculated relative to the surgical findings, which served as the gold standard(4).

## 4.4 Study Population

- **Source Population:** All patients who have been seen at the ENT department in collaboration with the department of radiology in SPHMMC during the study period.
- **Study Population:** All patients who have been diagnosed with cholesteatoma and have undergone both high-resolution CT imaging and surgical intervention in SPHMMC during the study period.

### **Inclusion Criteria:**

- Inclusion criteria were patients diagnosed with cholesteatoma based on clinical evaluation and/or imaging findings, Patients who underwent high-resolution CT (HRCT) imaging of the temporal bone as part of their preoperative assessment, patients who underwent surgical intervention for cholesteatoma at SPHMMC and availability of complete medical records and imaging reports for analysis

**Exclusion criteria:**

- Exclusion criteria were patients with a history of previous ear surgery or treatment for cholesteatoma, patients with contraindication to undergoing HRCT imaging, such as pregnancy or severe claustrophobia, patients with other concurrent middle ear pathologies that could confound the interpretation of HRCT findings and patients with cholesteatoma secondary to congenital syndromes or other underlying conditions not related to chronic otitis media.

**4.5 Sample Size determination**

All patients diagnosed with cholesteatoma who underwent both high-resolution computed tomography (HRCT) imaging and surgical intervention whose case notes are available in the hospital registration archive were eligible for participation. A total of 78 cholesteatoma surgeries were done in the study period, out of which 42 cases fulfilled the inclusion criteria.

**4.6. Measurement****4.6.1. Variables****Independent variables:**

- The HRCT findings
- Patient Demographics: Age, gender
- Disease characteristics: Clinical presentation, chief complaints, duration of illness, location,
- Radiologist experience

**Dependent variable:**

- The surgical findings (Presence or absence of cholesteatoma characteristics, confirmed by surgery)

#### **4.7. Data Collection tools, methods, and procedure:**

- All Operated cholesteatoma cases over the study period were collected from ENT operation registration book. Relevant socio-demographic, clinical data's as well as Operative and radiologic reports regarding cholesteatoma characteristics were systematically extracted from record review.

#### **4.8. Data management and Analysis**

- Once data set is prepared, it was exported from Epi and imported into Statistical Package for Social Science, Version 26 (SPSS v26) for statistical analysis.
- In SPSS, descriptive statistics were generated to summarize the characteristics of the study population and provide an overview of the data.
- Comparison of HRCT findings with surgical findings for cholesteatoma diagnosis was assessed using Cohen's kappa statistic, which measures the agreement beyond chance between the two modalities. Additionally, sensitivity, specificity, positive predicting value and negative predicting value of HRCT in detecting cholesteatoma were calculated based on comparison with the gold standard of surgical findings.

As a general guide [7], kappa values of 0.01–0.20 represent slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, 0.81–0.99 almost perfect agreement, and 1 perfect agreement (19, 20).

#### **4.9. Ethical clearance**

Ethical clearance was obtained from SPHMMC's research review board. The retrospective chart review adhered to the highest ethical standards, ensuring patient confidentiality and data security. Given the retrospective nature of the study, informed consent was not required from individual patients, but all data was anonymized to protect patient privacy. The study followed SPHMMC's ethical guidelines to ensure the integrity and ethical conduct of the research.

#### 4.10. Results.

A total of 42 patients were included in the final analysis in which 24 (57.1%) were male patients and 18 (42.9%) were female patients undergone surgery belonging to the age range of 14 to 60 years. The mean age of the patients was 30.1 years. The peak case of cholesteatoma was observed in the third decade of life, with 42.9 % of cases occurring between ages 20 and 35. The socio-demographic data of the included patient are summarized in Table 1 and Figure 1.

**Table 1: Sociodemographic characteristics of the study population**

| Age in years | Number of Patients | Percentage |
|--------------|--------------------|------------|
| 13-19        | 12                 | 28.6       |
| 20-35        | 18                 | 42.9       |
| 36-60        | 12                 | 28.6       |
| <b>Sex</b>   |                    |            |
| Male         | 24                 | 57.1       |
| Female       | 18                 | 42.9       |

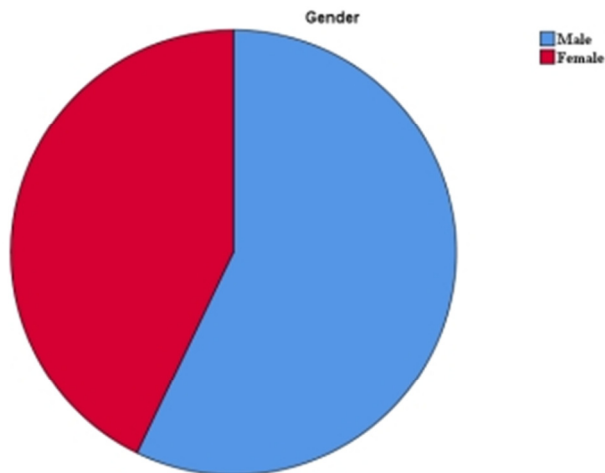


**Fig 1. The Sex distribution of the study participants**

## Clinical symptoms

The common symptoms observed included ear discharge (100%), hearing loss (81%), ear pain (31%), tinnitus (7.1%), and vertigo (7.1%) (Table 2).

**Table 2. Clinical symptoms observed in patients with cholesteatoma**

| <b>Symptoms</b>   |                      |                     |                 |                 |                |
|-------------------|----------------------|---------------------|-----------------|-----------------|----------------|
|                   | <b>Ear discharge</b> | <b>Hearing loss</b> | <b>Ear pain</b> | <b>Tinnitus</b> | <b>vertigo</b> |
| <b>Frequency</b>  | 42                   | 34                  | 13              | 3               | 3              |
| <b>Percentage</b> | 100                  | 81                  | 31              | 7.1             | 7.1            |

## HRCT cholesteatoma Characteristics

In this study of 42 patients with cholesteatoma evaluated by HRCT, characteristic radiological findings were identified. Soft tissue masses were prevalent in all cases 42 (100%), along with mastoid opacification (100%) and scutum erosion in (38) 90.5% of cases. Ossicular chain involvement was noted in (35) 83.3% of patients, while lateral semicircular canal (LSCC) erosion and facial nerve canal (FNC) erosion were observed in (13) 31% and (10) 23.8% of cases, respectively. Tegmen erosion was present in (9) 21.4% of patients, and epidural abscess was detected in (4) 9.5% of cases (Table 3)

**Table 3. The HRCT cholesteatoma characteristics of the study patients**

|                   | <b>Soft tissue mass</b> | <b>Mastoid opacification</b> | <b>Scutum erosion</b> | <b>Ossicular chain involvement</b> | <b>LSCC erosion</b> | <b>FNC erosion</b> | <b>Tegmen erosion</b> | <b>Epidural Abscess</b> |
|-------------------|-------------------------|------------------------------|-----------------------|------------------------------------|---------------------|--------------------|-----------------------|-------------------------|
| <b>Frequency</b>  | 42                      | 42                           | 38                    | 35                                 | 13                  | 10                 | 9                     | 4                       |
| <b>Percentage</b> | 100                     | 100                          | 90.5                  | 83.3                               | 31                  | 23.8               | 21.4                  | 9.5                     |

NB: LSCC = Lateral Semicircular Canal; FNC = Facial Nerve Canal

## **Comparison of the HRCT and Intraoperative findings**

On HRCT of temporal bone, all patients (100%) had extensive involvement of the middle ear and mastoid (holotympanic), where in the intraoperative report showed 3 (11%) of patients - attic and antral involvement with the remaining 39 (89%) involving the mastoid – holotympanic (result not shown).

In the evaluation of 42 cases for Sclerosing type of mastoid opacification and soft tissue mass presence, HRCT demonstrated perfect correlation ( $\kappa = 1.00$ ), accurately identifying these features in all cases. Ossicular chain erosion assessment showed substantial agreement ( $\kappa = 0.70$ ), with HRCT demonstrating 100% specificity and 92.1% sensitivity, while resulting in false positives in 7.9% of cases. Lateral semicircular canal (LSSC) erosion assessment demonstrated substantial agreement ( $\kappa = 0.75$ ), with HRCT correctly identifying no erosion in 24 cases (100% specificity) but missing erosion in 5 cases, resulting in false negatives in 27.8% of cases. Facial nerve canal (FNC) erosion demonstrated fair agreement ( $\kappa = 0.35$ ), with HRCT detecting 10 cases out of 19 confirmed intraoperatively, resulting in false negatives in 57.9% of cases.

Tegmen erosion evaluation showed almost perfect agreement ( $\kappa = 0.86$ ), with HRCT correctly identifying no erosion in 33 cases (97.0% specificity) and detecting erosion in 8 out of 9 cases intraoperatively, yielding a false-negative rate of 3.0% and a false-positive rate of 11.8%.

Sigmoid sinus plate erosion evaluation with HRCT showed moderate agreement ( $\kappa = 0.52$ ), correctly identifying no erosion in 29 cases (85.3% specificity) but missing erosion in 2 cases and detecting erosion in 6 out of 8 cases intraoperatively, resulting in false positives in 26.2% of cases (Table 4&5).

**Table 4. Correlation of HRCT and Intraoperative findings**

| Pathological features               | T Findings | Intraoperative findings | False negative | False positive | Accuracy | Sensitivity | Specificity | Kappa |
|-------------------------------------|------------|-------------------------|----------------|----------------|----------|-------------|-------------|-------|
| <b>Tissue mass</b>                  | 42         | 42                      | 0              | 0              | 100      | 100         | -           | 1     |
| <b>Mastoid opacification</b>        | 42         | 42                      | 0              | 0              | 100      | 100         | -           | 1     |
| <b>Ossicular chain erosion</b>      | 35         | 38                      | 0              | 7.9            | 83       | 92.1        | 100         | 0.7   |
| <b>LSSC erosion</b>                 | 13         | 18                      | 0              | 27.8           | 31       | 72.2        | 100         | 0.75  |
| <b>FNC erosion</b>                  | 10         | 19                      | 8.7            | 57.9           | 23.8     | 42.1        | 91.3        | 0.35  |
| <b>Tegmen erosion</b>               | 9          | 9                       | 3              | 11.8           | 21.4     | 88.9        | 97          | 0.86  |
| <b>Sigmoid sinus plate erosion</b>  | 11         | 8                       | 14.7           | 25             | 26.2     | 75          | 85.3        | 0.52  |
| <b>Lateral mastoid wall erosion</b> | 9          | 8                       | 2.9            | 0              | 21.4     | 100         | 97.1        | 0.93  |
| <b>Epidural abscess</b>             | 4          |                         |                |                |          |             |             |       |

N.B LSSC = Lateral Semicircular Canal; FNC = Facial Nerve Canal

**Table 5. Operative findings and radiological features of HRCT in detecting various pathologies in patients with cholesteatoma (N=42)**

|                                     | Operative findings | Radiologic Features |           |             |
|-------------------------------------|--------------------|---------------------|-----------|-------------|
|                                     |                    | Intact              | Abnormal  | Kappa       |
| <b>Soft tissue mass</b>             | <b>Present</b>     | <b>0</b>            | <b>42</b> | <b>1</b>    |
|                                     | <b>Absent</b>      | <b>0</b>            | <b>0</b>  |             |
| <b>Mastoid opacification</b>        | <b>Present</b>     | <b>0</b>            | <b>42</b> | <b>1</b>    |
|                                     | <b>Absent</b>      | <b>0</b>            | <b>0</b>  |             |
| <b>Scutum erosion</b>               | <b>-</b>           | <b>4</b>            | <b>38</b> | <b>-</b>    |
|                                     | <b>-</b>           | <b>0</b>            | <b>35</b> |             |
| <b>Ossicular chain erosion</b>      | <b>Preserved</b>   | <b>4</b>            | <b>3</b>  | <b>0.7</b>  |
|                                     | <b>Eroded</b>      | <b>0</b>            | <b>35</b> |             |
| <b>LSSC erosion</b>                 | <b>Preserved</b>   | <b>24</b>           | <b>0</b>  | <b>0.75</b> |
|                                     | <b>Fistula</b>     | <b>5</b>            | <b>13</b> |             |
| <b>FNC erosion</b>                  | <b>Preserved</b>   | <b>21</b>           | <b>2</b>  | <b>0.35</b> |
|                                     | <b>Dehiscent</b>   | <b>11</b>           | <b>8</b>  |             |
| <b>Tegmen erosion</b>               | <b>Preserved</b>   | <b>32</b>           | <b>1</b>  | <b>0.86</b> |
|                                     | <b>Present</b>     | <b>1</b>            | <b>8</b>  |             |
| <b>Sigmoid sinus plate erosion</b>  | <b>Preserved</b>   | <b>29</b>           | <b>2</b>  | <b>0.52</b> |
|                                     | <b>Present</b>     | <b>5</b>            | <b>6</b>  |             |
| <b>Lateral mastoid wall erosion</b> | <b>Preserved</b>   | <b>33</b>           | <b>0</b>  | <b>0.93</b> |
|                                     | <b>Present</b>     | <b>1</b>            | <b>8</b>  |             |

N.B LSSC = Lateral Semicircular Canal; FNC = Facial Nerve Canal

## 5. Discussion

In this study, preoperative HRCT findings and data obtained during surgery were assessed and compared in patients operated with cholesteatoma.

High-resolution computed tomography (HRCT) is critical in assessing cholesteatoma, particularly in detecting soft tissue masses and delineating their location and extent, as demonstrated by Plikkal et al., Abdulmonaem et al., and Khavasi et al (6, 8, 10, 11). These studies highlighted that soft tissue density lesions frequently occur in non-dependent regions such as the epitympanum, aditus ad antrum, mesotympanum, and mastoid antrum. HRCT has been shown to possess a 100% sensitivity for identifying soft tissue in the epitympanum, with frequent extension into the mastoid.

Our findings corroborate these results, showing 100% sensitivity in detecting soft tissue masses. All cases in our study involved extensive lesions affecting the mesotympanum and mastoid antrum, likely due to delayed presentation of patients in our local clinical setting.

Cholesteatoma frequently leads to erosion of the ossicular chain, predominantly affecting the incus and stapes. The long process of the incus is most commonly damaged due to weak ligamentous support and inadequate blood supply. The stapes is the second most commonly affected ossicle, primarily involving its superstructures. These erosions, particularly in advanced cases, significantly contribute to hearing impairment, as highlighted by studies from Bernadette et al., Abdulmonaem et al., and Khavasi et al (6, 8, 10).

These studies indicated high sensitivity and specificity (85-95%) of high-resolution computed tomography (HRCT) in identifying the status of the ossicles. In our study, overall ossicular erosion was observed in 83.3% of patients, with HRCT demonstrating 100% specificity and 92.1% sensitivity compared to intraoperative findings. However, false positives were noted in 7.9% of cases. There were also limitations in clearly reporting the condition of each ossicle. Although the preoperative status of the ossicles does not significantly impact surgical risk, it is crucial for anticipating post-surgical hearing outcomes. For example, patients with an intact stapes generally experience better hearing outcomes compared to those with an absent stapes superstructure (8).

Erosion of the lateral semicircular canal (LSCC) commonly occurs due to its proximity to the attic's medial wall. Studies by Pilakkal et al., Abdulmonaem et al., and Khavasi et al. have demonstrated a strong correlation between LSCC fistula detected on high-resolution computed tomography (HRCT) and intraoperative findings, highlighting high sensitivity and specificity. They underscored the pivotal role of axial scans, Axial scans proved superior for detecting LSCC fistulas due to their ability to present the entire canal with minimal artifact, although complementary information from coronal views was also valuable. The optimal assessment of LSCC fistula necessitates both axial and coronal imaging.

Our study also showed substantial agreement ( $\kappa = 0.75$ ), with HRCT accurately identifying intact canals in 24 cases (100% specificity). However, it missed erosions in 5 cases, resulting in a 27.8% false-negative rate.

Erosion of the LSSC by cholesteatoma in the absence of vertigo is presumably due to the cholesteatoma sealing the defect. If removed at mastoidectomy, such a patient may well become vertiginous. So Preoperative HRCT may have a medico-legal role before mastoid surgery (8).

Pilakkal et al (6) also stated close contact with cholesteatoma should be reported as the labyrinth may get damaged during surgery.

Tegmen erosion evaluation showed almost perfect agreement ( $\kappa = 0.86$ ), with HRCT correctly identifying no erosion in 33 cases (97.0% specificity) and detecting erosion in 8 out of 9 cases intraoperatively, yielding a false-negative rate of 3.0% and a false-positive rate of 11.8%.

In one of the case the scan suggested the tegmen to be breached but surgically proven to be intact and also another one case showed vice versa. A study by Abdulmonaem (8) also shared similar misinterpretation w/c may arise due to volume averaging effect but emphasized the coronal plane in aiding better tegmen visualization.

Many authors showed poor radio surgical correlation for facial canal dehiscence, which is a fairly common finding in suppurative ear diseases, usually occurring in the tympanic portion of the facial canal. Partial volume averaging played the main reason here also where even a non-pathologic ear can appear dehiscent as the facial canal can be so thin (6, 8). Our study similarly demonstrated fair agreement ( $\kappa = 0.35$ ), with HRCT detecting 10 cases out of 19 confirmed intraoperatively, resulting in false negatives in 57.9% of cases.

We found HRCT to be most accurate in identifying the destruction of lateral cortical wall of mastoid with 100% sensitive and 97.1 % specific, similar to study by khavasi et al (10) and almost perfect agreement with intraoperative finding (Kappa-0.93)

## **6. Conclusion:**

This study underscores the pivotal role of high-resolution computed tomography (HRCT) in the comprehensive evaluation of cholesteatoma. With 42 patients aged 14 to 60, our findings highlight HRCT's excellent sensitivity and specificity in identifying key pathological features.

The prevalence of cholesteatoma peaks in the third decade of life, with a mean age of 30.1 years. HRCT demonstrated 100% sensitivity for detecting soft tissue masses and mastoid opacification, crucial for early diagnosis.

Significant involvement of the ossicular chain (83.3%) and common erosions such as scutum (90.5%), LSCC (31%), and tegmen (21.4%) were effectively identified. However, challenges remain in detecting facial nerve canal erosion, with a fair agreement ( $\kappa = 0.35$ ). The excellent correlation between HRCT and intraoperative findings for most parameters, including ossicular chain erosion ( $\kappa = 0.70$ ) and tegmen erosion ( $\kappa = 0.86$ ), underscores its utility in preoperative planning and postoperative follow-up.

Our study agrees with existing literature and emphasizes HRCT's critical role in cholesteatoma management, facilitating accurate diagnosis, effective surgical planning, and improved patient outcomes

## 7. Recommendation:

- HRCT should be employed as the primary diagnostic tool in cases of suspected cholesteatoma due to its high sensitivity for detecting characteristic features such as soft tissue masses and mastoid opacification. It is crucial for early and accurate diagnosis, allowing timely and effective interventions.
- Preoperative HRCT scans should be conducted for all patients to evaluate the extent of the disease and identify complications like ossicular chain and tegmen erosion, aiding in precise surgical planning and better patient outcomes.
- Special attention should be given to assessing ossicular chain erosion, particularly involving the incus and stapes, where HRCT demonstrates high specificity and substantial sensitivity.
- Dual axial and coronal imaging is recommended for comprehensive evaluation of LSCC erosion, enhancing diagnostic accuracy and surgical preparedness.
- Despite the fair agreement in detecting facial nerve canal erosion, consistent documentation and correlation with intraoperative findings are essential for improving diagnostic precision and preventing complications.
- Coronal HRCT should be prioritized for assessing tegmen erosion to mitigate misinterpretation from volume averaging effects, ensuring accurate diagnosis and effective surgical planning.
- Integrating HRCT findings into surgical decision-making is crucial for determining the extent of disease involvement and selecting appropriate surgical approaches. Additionally, specialized training for radiologists and surgeons in HRCT interpretation is recommended to enhance diagnostic accuracy and reduce false positives or negatives.

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## APPENDIX

### ANNEX :

#### Structured Data Collection Template

Name of data collector \_\_\_\_\_

Signature \_\_\_\_\_

Date \_\_\_\_\_

#### Patient demographic data

|            |  |
|------------|--|
| MRN        |  |
| Age (yrs.) |  |
| Gender     |  |

#### Disease characteristics

|                       |  |
|-----------------------|--|
| Clinical presentation |  |
| Duration of illness   |  |

|                           |         |   |                     |   |
|---------------------------|---------|---|---------------------|---|
| Affected bone             | HRCT No | % | No in surgery<br>No | % |
| Non-dependent soft tissue |         |   |                     |   |
| Scutum                    |         |   |                     |   |
| Incus                     |         |   |                     |   |
| Stapes                    |         |   |                     |   |
| Labyrinth                 |         |   |                     |   |
| Tegmen tympani            |         |   |                     |   |
| Fascial canal             |         |   |                     |   |

|                      | Operative finding | Radiologic features |          |       |
|----------------------|-------------------|---------------------|----------|-------|
|                      |                   | Intact              | Abnormal | Kappa |
| <b>Scutum</b>        | <b>Preserved</b>  |                     |          |       |
|                      | <b>Blunted</b>    |                     |          |       |
| <b>Incus</b>         | <b>Preserved</b>  |                     |          |       |
|                      | <b>Eroded</b>     |                     |          |       |
| <b>Stapes</b>        | <b>Preserved</b>  |                     |          |       |
|                      | <b>Absent</b>     |                     |          |       |
| <b>Labyrinth</b>     | <b>Preserved</b>  |                     |          |       |
|                      | <b>Fistula</b>    |                     |          |       |
| <b>Tegmen</b>        | <b>Preserved</b>  |                     |          |       |
|                      | <b>Eroded</b>     |                     |          |       |
| <b>Fascial canal</b> | <b>Preserved</b>  |                     |          |       |
|                      | <b>Dehiscent</b>  |                     |          |       |

## Declaration

I, the principal investigator of this study, agree to accept all responsibilities for the scientific and ethical conduct of this research project. I will provide a timely progress report to my advisors and seek the necessary advice and approval from my primary advisors during the course of this research.

Name of the student: **Dr. Natnael Fikadu**

Signature: \_\_\_\_\_

Date: August 2024

## Approval of the Primary Advisor

Name of the primary advisor: **Dr. Yonas**

Signature: \_\_\_\_\_

Date: \_\_\_\_\_

## Approval of the Co-Advisor

Name of the secondary advisor: **Dr Seman K Ousman (PhD)**

Signature:

Date: August 2024