DOI: 10.7860/JCDR/2025/78823.21597

Original Article

Radiology Section

# Quantitative Assessment of Cholesteatoma using CT Hounsfield Units: A Retrospective Observational Study

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## ABSTRACT

**Introduction:** Cholesteatoma is a degenerative middle ear pathology that, unless treated, can cause bone erosion and serious complications. High-Resolution Computed Tomography (HRCT) aids in the diagnosis by evaluating structural integrity and bone alterations. Hounsfield Unit (HU) measurements can be used to enhance diagnostic accuracy in cholesteatoma evaluation.

**Aim:** To compare the HRCT-derived HU indexes in cholesteatoma-affected middle ear structures from healthy controls.

**Materials and Methods:** The present retrospective observational study was conducted from May 2023 to April 2024 in the Department of Radiodiagnosis and Imaging of Justice KS Hegde Hospital, Mangalore, Karnataka, India. The study included 150 participants spanning a range of ages from 18 to 70 years. The study participants were divided into 75 healthy controls and 75 patients with surgically proven right unilateral cholesteatoma. HRCT images were used to determine HU values at five anatomical sites: the scutum, malleus, incus, fallopian canal, and lateral semicircular canal. The data were analysed using an unpaired t-test, with p-values <0.05 considered significant.

**Results:** The mean age of the cholesteatoma group was 42.6±12.4 years, while the healthy group had a mean age of 45.3±11.8 years. There were 47 (62.7%) male patients and 28 (37.3%) female patients in the cholesteatoma group, 44 (58.7%) male patients, and 31 (41.3%) female patients in the non cholesteatoma group. Cholesteatoma-affected ears had considerably lower HU values than healthy controls in all examined areas (p<0.001). The malleus and lateral semicircular canal showed the most affecting changes.

**Conclusion:** HRCT-based HU values demonstrate a promising aid for detecting cholesteatoma-related bone alterations. The constant and considerable reduction in HU values across distinct middle ear structures demonstrates its potential to improve diagnostic confidence and clinical decision-making.

**Keywords:** Cholesteatoma, Computed tomography, Hounsfield Units, Temporal bone

## INTRODUCTION

Cholesteatoma is a benign but potentially destructive infection in the middle ear or mastoid cavity, commonly resulting from chronic ear infections or eustachian tube malfunction. It forms a cyst-like structure from skin cells and other debris, which can grow and injure the ossicles and ear bone walls [1,2]. Cholesteatoma can have a significant effect on the middle ear ossicles. As the cholesteatoma develops, it might erode the ossicles, primarily the malleus and incus. The cyst's enzymatic activity promotes the deterioration of these delicate bones [3]. During the past few years, there has been a rapid development in the imaging of cholesteatoma, which has resulted in a wide variety of possibilities for identifying and evaluating the prevalence and localisation of cholesteatomas [4,5]. Magnetic Resonance Imaging (MRI) has shown its ability to distinguish cholesteatoma from surrounding structures and other soft-tissue lesions within the middle ear [6]. With the help of these exquisitely precise soft-tissue images, cholesteatoma can be distinguished from other ear diseases [7].

High-resolution Computed Tomography (HRCT) is the most common approach for detecting and assessing cholesteatomas because of its spatial resolution [8]. Computed Tomography (CT) scans provide a comprehensive view of the temporal bone, allowing for information on the location, extent, and underlying cholesteatoma-related problems [9]. It also demonstrated its advantage in accurately localising and assessing cholesteatoma with its surrounding anatomical components [10]. The relative radiodensity of the tissues in a CT scan is measured using HU. The scale was created to provide a numerical value that represents the amount of X-ray attenuation that happens depending on the attenuation of X-rays as they pass through various materials [11]. HU is utilised in CT imaging to represent the density of tissues. According to this scale, water is assigned a value of zero HU, air is assigned a negative value, and dense things such as bone are allocated a positive value. The linear attenuation coefficient, which measures the degree to which a material suppresses the intensity of X-ray rays, is the origin point from which the HU scale emerged [12]. Only a few studies use HU measurements to differentiate cholesteatoma in otology [13,14]. We anticipate that the bony HU density index can be utilised as a practical and easy-to-use technique for evaluating the bony variations and changes brought on by cholesteatoma. This can significantly aid in ascertaining the disease's stage and extent of involvement and impact the surgical decision. The aim of the present study was to compare the HRCT-derived HU indexes in distinguishing cholesteatoma-affected middle ear structures from healthy controls.

## MATERIALS AND METHODS

The present retrospective observational study was conducted from May 2023 to April 2024 in the Department of Radiodiagnosis and Imaging of Justice KS Hegde Hospital, Mangalore, Karnataka, India. The Institutional Ethics Committee (IEC) approval was obtained. (EC/NEW/INST/2022/KA/0174). The Ethical Committee waived the informed consent requirement due to the retrospective study design. The study included 150 participants spanning a range of ages from 18 to 70 years. The study participants were divided into 75 healthy controls and 75 cholesteatoma participants.

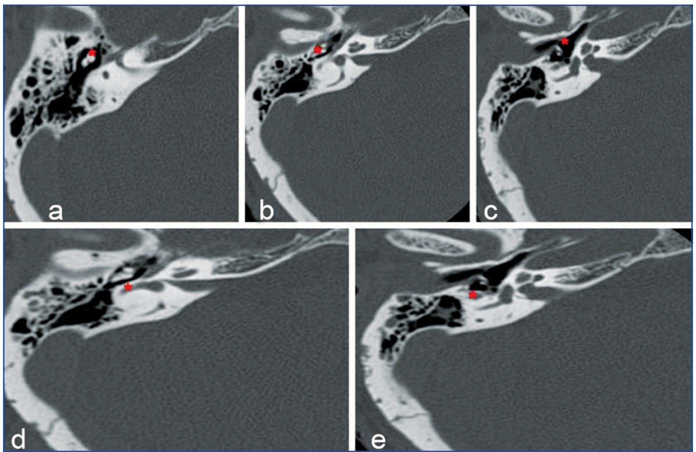
**Inclusion criteria:** Individuals with anatomically healthy ears and accessible preoperative HRCT scans available in the imaging database were included as controls. Additionally, the ones diagnosed with cholesteatoma were included in the case group.

**Exclusion criteria:** Patients with congenital inner-ear abnormalities, bilateral cholesteatoma, history of prior otological surgery, ear infections unrelated to cholesteatoma, which include otitis media and uncooperativeness during evaluation.

### Study Procedure

The HU index in cholesteatoma-affected ears was repeatedly measured and contrasted the results with healthy non cholesteatoma ears. Using the GE Revolution EVO 128 slice system (slice thickness 0.625mm, pitch 0.531.1 & matrix 768 x 768), all measurements were carried out on a coronal HRCT scan of the temporal bone. The coronal plane was utilised to measure the HU index. Five distinct measurements for each ear at the following levels were taken: 1) the scutum; 2) the malleolus; 3) the incus; 4) the fallopian tube; and 5) the lateral semicircular canal. All measurements were conducted using a defined ROI of 0.3 $mm^2$ to maintain uniformity. ROIs were carefully placed in anatomically acceptable areas, avoiding nearby air cells and bone borders, to prevent partial volume effects. Anatomical landmarks were used to guide placement, which was then validated using multiplanar reconstruction.

To reduce intraobserver and interobserver variability, all measures were carried out jointly by authors and an experienced radiologist. Each parameter was measured six times, with the average value being recorded. Measurements were performed on a dedicated Picture Archiving and Communication System (PACS) workstation equipped with calibrated HU settings and precision tools consisting of a zoom and cross-reference [Table/Fig-1].




**[Table/Fig-1]:** Coronal HRCT scans of the temporal bone, demonstrating areas of measurements: a) Malleus; b) Incus; c) Stapes; d) Lateral semicircular canal; e) Fallopian canal.

## STATISTICAL ANALYSIS

The data were entered and coded in MS Excel, and analysis was done using Statistical Package for Social Sciences (SPSS) (V29.0). The quantitative data was expressed as Mean±SD and qualitative data as frequency (percentage). An unpaired t-test was used to compare HU measurements among the healthy and cholesteatoma groups. The p-value<0.05 was considered statistically significant.

## RESULTS

In total, 150 patients were enrolled in the study. There were 47 (62.7%) male patients and 28 (37.3%) female patients in the cholesteatoma group, 44 (58.7%) male patients, and 31 (41.3%) female patients in the non cholesteatoma group. The mean age of the cholesteatoma group was 42.6±12.4 years, while the healthy group had a mean age of 45.3±11.8 years. Cholesteatoma-affected ears had considerably lower HU values than healthy controls in all examined areas (p<0.001) [Table/Fig-2].

| Group | | Mean | Std. Deviation | t value | p-value |
|---|---|---|---|---|---|
| Scutum | Cholesteatoma | 512.324 | 7.163 | 290.851 | <0.001 |
| | Non cholesteatoma | 856.128 | 7.313 | | |
| Incus | Cholesteatoma | 498.856 | 8.861 | 167.894 | <0.001 |
| | Non cholesteatoma | 715.106 | 6.775 | | |
| Lateral semicircular canal | Cholesteatoma | 1044.954 | 7.260 | 84.539 | <0.001 |
| | Non cholesteatoma | 1133.303 | 8.588 | | |
| Malleus | Cholesteatoma | 1047.182 | 5.892 | 333.947 | <0.001 |
| | Non cholesteatoma | 1413.280 | 7.445 | | |
| Fallopian canal | Cholesteatoma | 467.550 | 8.647 | 60.490 | <0.001 |
| | Non cholesteatoma | 544.085 | 6.730 | | |

**[Table/Fig-2]:** Comparison of cholesteatoma and non cholesteatoma (HU values) in different regions.

## DISCUSSION

The CT is extremely useful in detecting and analysing cholesteatoma because it offers high-resolution imaging of the middle and inner ear structures [15,16]. CT scans provide comprehensive visualisation of bone erosion, allowing assessment of the extent of damage to the structures [17]. Imaging with CT for cholesteatoma involves precise and thorough scans that assess the intricate structures of the ear. It assists in detecting soft-tissue masses, evaluating their extent, and planning effective surgical approaches for treatment [18,19]. HU is the linear variation of the linear attenuation coefficient measurements, and every biological tissue has its own distinct HU values [12,20]. CT HU values offer crucial insights that are necessary for the accurate measurement of bone density and the detection of abnormalities that are brought about by abnormal conditions or structural alterations [21]. In a retrospective study conducted in South Korea 2012, Ahn SH et al., investigated the reliability and accuracy of HU measurements in diagnosing and assessing congenital cholesteatoma [13]. HU measurements were done on the soft-tissue masses in the middle ear cavity between cholesteatoma and Chronic Otitis Media (COM) group. The congenital cholesteatoma group had a mean HU of (37.36±6.11) while the COM group had a mean HU of (76.09±8.74) (p<0.001). The authors demonstrated that HU index values <55.5 indicated congenital cholesteatoma, whereas higher values were compatible with COM. This was due to 55.5 being the cut-off number between the two groups. The authors concluded that congenital cholesteatoma diagnosis may benefit from using HU measurement if used as an extra parameter.

Lee DH et al., evaluated the variations in the HU index of 91 patients between patients with cholesteatoma and COM through preoperative HRCT images [22]. According to the findings, the non cholesteatomatous lesions had mean HU values between 32.9 and 51.3 HU, while the cholesteatomatous lesions had mean HU values between 35.7 and 66.6 HU. There was no significant statistical difference between two distinct types of lesions. Based on evaluating these results, the authors deemed the HU index unsuitable for clinical use. Another retrospective study by Salepci E et al., investigated the potential utility of HU density in distinguishing cholesteatoma from other sources of opacification in ears that have undergone prior surgery [23]. The HU density was measured by placing ROI at aditus ad antrum. There was no significant difference in HU densities between the groups with and without cholesteatoma.

A study illustrated by Park MH et al., examined the variations in HU index values at the mastoid antrum between COM and cholesteatoma [14]. Eighty-two patients made up their study; the initial group had a clinically proven cholesteatoma, and the second group had middle ear granulation tissues. At the lateral semicircular canal level, the axial plane's antrum was used to calculate the HU index. In the cholesteatoma group, the HU measured as (42.68±24.42), whereas in the non cholesteatoma group, it was (86.07±26.50). The group variations were all statistically significant. They concluded that cholesteatoma diagnosis sensitivity and specificity might be increased by assessing the HU index.

The present study demonstrated how variations in the HU index can be utilised to detect and diagnose cholesteatoma. There might be an association between the destructive character of cholesteatoma and the significant drop in radiodensity, which is revealed by the significant decline in HU values. While the GE Revolution EVO scanner offers high-quality images for temporal bone evaluation, limitations include motion artifacts and scanner-specific reconstruction algorithms that may affect reproducibility across different settings. While age was not analysed, its potential influence is acknowledged, and future research will explore age-related variations in HU values to enhance clinical and diagnostic understanding.

## Limitation(s)

As the study design was retrospective, inherent risk of selection bias exist. Small sample size and limited generalisability as the study was carried out in a single centre. HU values can vary with scanner type, slice thickness, and reconstruction algorithms. Cholesteatoma may have overlapping HU values with other middle ear pathologies (e.g., granulation tissue, fluid, or fibrosis), which was not analysed in the present study. The lack of age and gender matching among participants may introduce confounding variable that could impact the results. The study solely examines right unilateral cholesteatoma, which may not account for variances in patients with the left ear or bilateral disorders. Gender wise and age wise comparison of HU values in unilateral cholesteatoma was not performed.

# CONCLUSION(S)

According to the findings of the current study, the HU index is an effective method for the early diagnosis of right unilateral cholesteatoma, particularly in cases when erosion of the middle ear cleft is indicated. The HU index has the potential to enhance diagnostic accuracy and contribute to the early detection of alterations that are associated with cholesteatoma.

## Declaration

**Data Availability:** The datasets used and/or analysed during the current study are accessible from the corresponding author upon reasonable request.

**Authors' contributions:** All authors read and approved the final manuscript.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Feb 28, 2025
- Manual Googling: Jun 12, 2025
- iThenticate Software: Jun 14, 2025 (3%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: Feb 21, 2025
Date of Peer Review: May 16, 2025
Date of Acceptance: Jun 17, 2025
Date of Publishing: Oct 01, 2025