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Radiologic CT Scan Assessment of Eustachian Tube Dimensions in a Sample of Filipino Adults with Chronic Otitis Media at the Rizal Medical Center: A Retrospective Study

ABSTRACT

Objective: To describe the radiologic dimensions of the Eustachian tube (pre-tympanic diameter, tubo-tympanic angle, and Eustachian tube angle) among normal ears, ears with chronic otitis media (COM) with and without cholesteatoma, in a sample of Filipino adults with COM; and to compare the dimensions of the three variables.

Methods:

Design: Retrospective Review of Records

Setting: Tertiary Government Training Hospital

Participants: The study included 69 CT scans of adults with COM, with images of 23 ears for each variable (normal ears, COM with and without cholesteatoma formation).

Results: In normal ears, the average pre-tympanic diameter was 3.976 ± 0.78 mm, the average tubo-tympanic angle was 41.529 ± 5.85 degrees, and the average Eustachian tube Angle (Reid Plane) was 27.077 ± 4.62 degrees. In patients with COM without cholesteatoma, the mean pre-tympanic diameter was 4.002 ± 1.13 mm, the mean tubo-tympanic angle was 141.994 ± 6.30 degrees, and the mean measurement of the Reid plane was 24.649 ± 3.10 degrees. In ears with COM with cholesteatoma, the mean pre-tympanic diameter was 4.1993 ± 0.50mm, the mean tubo-tympanic angle was 138.789 ± 7.13 degrees, and the mean Reid plane was 26.483 ± 3.86 degrees. P-values for the pre-tympanic diameter, tubo-tympanic angle, and ET angle were .617, .198, and .098 respectively, indicating that there were no statistically significant differences in the ET dimensions of the ears with COM with cholesteatoma, without cholesteatoma and normal ears.

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Conclusion: In our investigation, we found no statistically significant differences in Eustachian tube dimensions among individuals with normal ears and COM with or without cholesteatoma. This suggests that the Eustachian tube dimensions may not serve as a primary etiological factor for COM among our patients.

Keywords: *chronic otitis media; cholesteatoma; temporal bone CT; eustachian tube dimensions*

Chronic otitis media is defined as chronic inflammation of the middle ear and mastoid cavity accompanied by recurrent ear discharge through a perforated tympanic membrane that persists longer than 3 weeks.[1] COM can occur with or without cholesteatoma. Cholesteatoma formation usually arises as a sequela of chronic suppurative otitis media (CSOM), and contains desquamated debris, principally keratin from the keratinizing squamous epithelial lining.[2] According to data from the World Health Organization (WHO), the prevalence of CSOM in Asian countries is approximately 4%, with similar or varying rates reported in developed countries, where no gender predilection has been observed.[3] In the Philippines, the WHO has classified the country as part of the high-prevalence group, with a CSOM incidence rate ranging from 2% to 4%.[3]

Evaluation of the diameter and assessment of the length of the Eustachian tube may be useful in monitoring the progress of CSOM and investigating its possible role in cholesteatoma formation. There are three measurements used in determining the Eustachian tube dimensions, namely the pretympanic diameter, tubotympanic angle and Eustachian tube angle in Reid plane. A literature search of HERDIN Plus, the Western Pacific Region Index Medicus (WPRIM), the Directory of Open Access Journals (DOAJ), MEDLINE (PubMed and PubMed Central), and Google Scholar using the keywords: "Eustachian tube dimensions," "pretympanic diameter," "tubotympanic angle," and "Eustachian tube angle" revealed a lack of material investigating the Eustachian tube dimensions of adult Filipinos and its relation to COM with and without cholesteatoma formation.

This study aimed to describe the Eustachian tube dimensions in normal ears, and those with COM with or without cholesteatoma in a sample of Filipino adults with COM, and determine if there is a significant difference between each variable which may lead us to consider these dimensions as contributing factors in the incidence of middle ear disease (COM with or without cholesteatoma formation).

METHODS

With Rizal Medical Center Institutional Review Board approval (2023-ORL-#045-RP-1.V), this retrospective review of records considered for inclusion all temporal bone Computed Tomography (CT) scans of adult Filipinos by citizenship aged 19 to 90 years old diagnosed with COM with and without cholesteatoma at the Rizal Medical Center from January 2020 - January 2023. Only temporal bone CT scans obtained from the institution's Department of Radiology and stored in DICOM files were included in this study. Excluded were CT scans of patients with previous ear surgery, or anatomical abnormalities (such as craniofacial defects, nasopharyngeal masses and velopharyngeal insufficiency).

A list of all patients initially diagnosed with CSOM, along with their temporal bone CT scans obtained in our institution and stored in DICOM files, was compiled. Patients were seen at the outpatient department (OPD), emergency room (ER), or in-patient services. Each ear (right or left) was considered as one sample. The samples were then classified as normal, COM with or without choleastatoma. The radiologic diagnosis of the said patients and review of their clinical history were documented and confirmed by the primary investigator (GJVR) and an otology consultant (AMVA).

The radiologic assessment of Eustachian tube dimensions was conducted using data from high-resolution temporal bone CT scans, obtained from a 16-slice GE Revolution ACT (GE HealthCare, USA) with axial thickness of 1.25mm and reconstruction of 0.625mm. The imaging utilized a 1024 x 1024 image matrix and was viewed using bone windows, with window width at 4000 HU and window level at 700 HU. Each ear from the CT scans was assigned a serial code. For ears with COM with cholesteatoma, serial codes were assigned starting from P0001, while for ears with COM without cholesteatoma assigned codes started with S0001. A radiologically normal or non-pathologic ear on the contralateral side was classified as a normal ear, with codes starting from N0001.

Given a hypothesized difference[1] of 3 degrees and population variant of 17.64 degrees, 80% power at 99% confidence interval, the minimum computed sample size was 69. Stratified random sampling was conducted using an electronic GIGAcalculator list randomizer, available from *https://www.gigacalculator.com/randomizers/randomizer.php* (GIGAcalculator.com 2017-2025, Web Focus LLC, Sofia, Bulgaria). All of the codes were stratified by the year the patient was diagnosed. For each year from 2020-2022, seven codes for each variable were selected using the randomizer (total of 21) and for January 2023,

two codes for each variable were selected to complete the 23 sample size per variable.

Following data collection, two raters—the primary investigator (GJVR) and a senior otologist (AMVA) —performed synchronous measurements using the same free and open-source medical image viewer, Horos™ version 3.0 for Mac OS X (Horosproject.org and Nimble Co. LLC d/b/a Purview, Annapolis, MD USA) in order to obtain three measurements: the pre-tympanic diameter, the tubo-tympanic angle, and the Eustachian tube (ET) angle in the Reid plane.

The pre-tympanic diameter was recorded in millimeters. This measurement was taken using the axial view in the bone window, specifically focusing on the antero-posterior dimension of the Eustachian tube's most lateral segment as seen in *Figure 1*.

The tubo-tympanic angle was expressed in degrees. This measurement was obtained from the axial view of the bone window, representing the angle formed by the long axis of the external auditory canal and the long axis of the Eustachian tube as seen in *Figure 2*.

The Eustachian tube (ET) angle in the Reid Plane was also expressed in degrees. Using the bone window in the sagittal view, this measurement was determined by the plane (horizontal line) from the inferior border of the orbit to the superior border of the external auditory meatus, intersecting the line between the pharyngeal and tympanic orifices as seen in *Figure 3*.

Data Analysis

Data was collated using Microsoft® Excel for Mac version 16.95.4 (Microsoft Corp., Redmond WA, USA) and statistical software using IBM® SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). Pre-tympanic diameter, tubo-tympanic angle, and ET angle measurements were recorded as means and standard deviations. Statistical comparison of Eustachian tube dimensions among the three variables (pre-tympanic diameter, tubo-tympanic angle and ET angle/ Reid plane), was conducted using ANOVA, with a significance level set at 0.05.

RESULTS

Out of 130 temporal bone CT scans initially considered for inclusion, a total of 69 CT scans from adult patients (aged 19 to 90 years) seen at the outpatient department (OPD), emergency room (ER), and in-patient services were finally included, all diagnosed with COM with or without cholesteatoma.

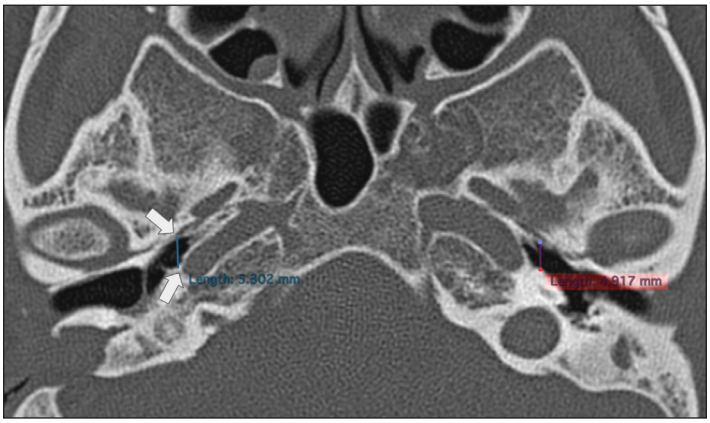

Figure 1. This bone window axial CT scan shows the pre-tympanic diameter of both the right (measuring 5.302mm) and the left ear (measuring 4.917mm). The superior arrow indicates the anterior part of the bony Eustachian tube and the inferior arrow indicates the posterior part of the bony Eustachian tube.

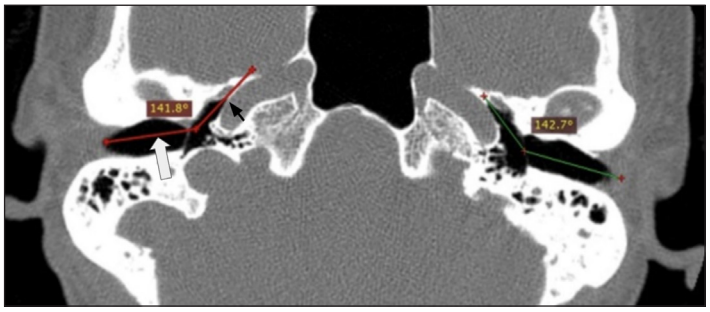

Figure 2. This bone window axial CT scan shows the tubo-tympanic angle on both right (141.8 degrees) and left (142.7 degrees). The white arrow indicates the long axis of the external auditory canal while the black arrow indicates the long axis of the Eustachian tube.

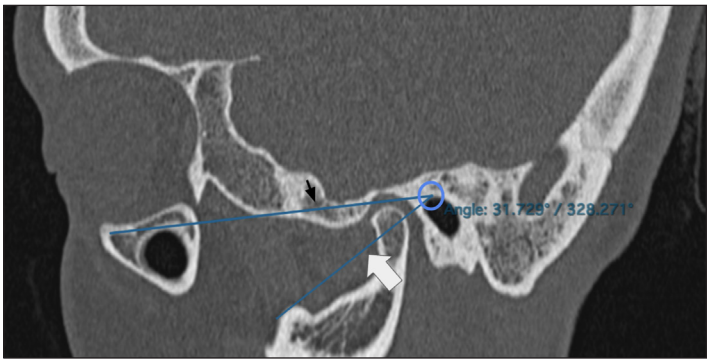

Figure 3. This bone window CT scan in sagittal section shows the Eustachian tube angle in the Reid plane. The black arrow indicates the plane from the inferior border of the orbit to the superior border of the external auditory meatus (encircled area) while the white arrow indicates the intersecting line between the pharyngeal and tympanic orifices.

The average pre-tympanic diameter of normal ears was 3.976 ± 0.78 mm. The average tubo- tympanic angle in normal ears was 41.529 ± 5.85 degrees. The average ET Angle (Reid Plane) in the normal ears was 27.077 ± 4.62 degrees. On the other hand, the mean pre-tympanic

diameter in ears with COM without cholesteatoma was 4.002 ± 1.13 mm, the mean tubo-tympanic angle was 141.994 ± 6.30 degrees, and the mean measurement of the Reid plane was 24.649 ± 3.10 degrees. Lastly, ears with COM with cholesteatoma had the following measurements: mean pre-tympanic diameter was 4.1993 ± 0.50 mm, mean tubo-tympanic angle was 138.789 ± 7.13 degrees, and mean Reid plane mean was 26.483 ± 3.86 degrees. *(Table 1)*

Table 1. Comparison of Eustachian Tube Dimensions (mm)

ET Dimensions	Ears with COM without cholesteatoma	Ears with COM with cholesteatoma	Normal Ears
Pretympanic Diameter	4.002 ± 1.13	4.1993 ± 0.50	3.976 ± 0.78
Tubotympanic Angle	141.994 ± 6.30	138.789 ± 7.13	41.529 ± 5.85
ET Angle (Reid Plane)	24.649 ± 3.10	26.483 ± 3.86	27.077 ± 4.62

Statistical comparison of the Eustachian tube dimensions of the three variables (pre-tympanic diameter, tubo-tympanic angle and ET angle/Reid plane), using ANOVA revealed p-values for the pre-tympanic diameter, tubo-tympanic angle, and ET angle of .617, .198, and .098, respectively, indicating that there were no statistically significant differences in the ET dimensions of the ears with COM with and without cholesteatoma and normal ears.

DISCUSSION

Our study revealed that the Eustachian tube dimensions were nearly identical across all variables, whether in ears with COM with or without cholesteatoma or in normal ears.

In comparison to the study conducted by Babu *et al.*,[1] our findings showed no significant differences in any of the measured Eustachian tube dimensions. In contrast, their study identified a reduced ET angle, reduced pre-tympanic diameter, and increased tubo-tympanic angle as predisposing factors for cholesteatoma and COM among their study population. Our study observed a reduced pre-tympanic diameter in normal ears, rather than in those with pathology, although this reduction was not statistically significant.

The reduction in pre-tympanic diameter, as described by Nemade *et al.*,[4] has been observed in patients with mucosal swelling, such as those with allergic rhinitis and chronic rhinosinusitis. This suggests that factors other than COM may affect the pre-tympanic diameter. In our study, patients with underlying allergic rhinitis or chronic rhinosinusitis were excluded, further limiting us from exploring paranasal conditions as possible contributing factors in the development of COM with or without cholesteatoma formation. This is one limitation of our study.

In the study by Ratag *et al.*,[5] which examined Eustachian tube dimensions in an Indonesian population, the pre-tympanic diameter and tubo-tympanic angle were also measured. However, their study focused on the length of the cartilaginous portion of the Eustachian tube, rather than using the Reid Plane dimensions. They explored gender and laterality differences in Eustachian tube dimensions but found no significant differences. Although our dimensions were consistent with those of Ratag *et al*., we did not explore gender and laterality differences.

Our study assigned normal ears of patients with unilateral COM as the control. In contrast, studies such as that of Aksoy *et al.*,[6] used data from individuals with no history of COM who underwent temporal bone CT scans for unrelated conditions. This difference in the selection of control groups is another limitation that may also have influenced the outcomes of our study. In future studies, assigning a control group with radiologically normal temporal bone CT scans is recommended for achieving a homogenous control group for comparative analysis.

The study of Aksoy *et al.*[6] also suggested that genetic and environmental factors can influence the progression of chronic conditions leading to cholesteatoma. Environmental factors such as frequent upper respiratory tract infections, poor living conditions, and smoking can reduce temporal air pneumatization, contributing to COM. Our study did not consider such environmental factors, and such risk factors may be included as variables in future studies.

A study conducted by Islam *et al.*[7] compared tubo-tympanic and attico-antral types of COM. They described tubo-tympanic disease as being associated with intermittent, primarily mucoid or mucopurulent discharge, often triggered by upper respiratory tract infections or water entering through a tympanic membrane perforation. In contrast, the attico-antral type typically involves the epitympanum and is characterized by the presence of cholesteatoma, with underlying mechanisms such as retraction pockets or squamous metaplasia.[7] Tubo-tympanic disease generally corresponds to COM without cholesteatoma, while attico-antral disease aligns with COM involving cholesteatoma. Their study is of interest as it considered socio-economic status, characteristics of the ear discharge, otoscopic findings, and hearing status, in the incidence of the two aforementioned types of

chronic otitis media.

Our study did not classify COM into tubo-tympanic or attico-antral types. The focus of our study was on radiologic diagnosis and measurements in the temporal bone CT scans, which described measurements among the three variables. With this, we recommend that future studies consider including otoscopic evaluations and additional factors, such as socio-economic background and demographic factors for a more comprehensive classification and understanding of the incidence of COM.

In conclusion, while variations in the mean values of pre-tympanic diameter, tubo-tympanic angle, and Eustachian tube angle (as measured in the Reid plane) were noted across each variable, statistical analysis showed that these differences were not significant. This suggests that Eustachian tube anatomy alone may not be a primary contributing factor in the development of COM with or without cholesteatoma and highlights the need to explore other possible etiological factors and comorbid conditions when evaluating patients with chronic otitis media.

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