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Eustachian Tube Anatomical Variations and Their Contribution to Chronic Suppurative Otitis Media Without Cholesteatoma

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ABSTRACT

Introduction: Anatomical variations in the Eustachian tube (ET) contribute to ET dysfunction, which plays a significant role in the development and persistence of chronic suppurative otitis media (CSOM). Evaluating the ET remains challenging due to its complex anatomy and location. Our study aims to investigate the relationship between ET anatomical variations and the risk of developing CSOM without cholesteatoma.
Methods: A retrospective, cross-sectional study was conducted using data from the ORL-HNS Department of Dr. Moewardi Hospital. HRCT scans were performed in the Department of Radiology at the same institution between January 2024 and March 2025. The measurements of the Tubotympanic Angle (TTA), Pretympanic Diameter (PTD), Eustachian Tube Angle (ETA), and Eustachian Tube Length (ETL) were performed by an experienced radiologist familiar with temporal bone imaging. Paired and independent t-tests were used to analyze relationships between variables, and significance was set at $p < 0.05$.
Results: 30 patients were included in this study, aged 18 to 70 years. Statistically significant differences were observed between the affected and unaffected ears in TTA, PTD, and ETA. The affected ear had a higher TTA, a shorter PTD, and a smaller ETA than the unaffected ear ($p < 0.001$).
Conclusion: Anatomical variations of the ET, particularly TTA, PTD, and ETA, increase the risk of CSOM and suggest that measuring ET anatomy may be beneficial for managing CSOM.

Keywords: chronic suppurative otitis media without cholesteatoma; eustachian tube; tubotympanic angle; pretympanic diameter; eustachian tube angle

INTRODUCTION

Chronic Suppurative Otitis Media (CSOM) is a major public health concern due to its long-term impact on hearing and quality of life. The global prevalence of CSOM is estimated at 3.8% of the global population, or about 297 million people. A significant proportion of these cases (85%) occur in low- and middle-income countries, where factors such as inadequate healthcare, poor living conditions, and untreated recurrent ear infections contribute to the high incidence of this condition[1].

The Eustachian tube (ET) is a narrow passage connecting the middle ear to the nasopharynx. It plays a vital role in regulating air pressure, protecting the middle ear from infection, and clearing secretions. ET dysfunction can lead to fluid buildup, negative pressure, and impaired ventilation of the middle ear, creating an environment that fosters bacterial growth and chronic inflammation[2,3].

Anatomical variations in the ET have also been linked to an increased risk of CSOM[4]. However, direct evaluation of ET anatomy remains challenging. Its deep location, complex structure, and dynamic function make it difficult to examine directly. Therefore, our understanding of its structure and function should be improved. However, studies on ET anatomical variations and their relationship to CSOM remain limited[3].

High-Resolution Computed Tomography (HRCT) with multiplanar reconstruction has proven to be an effective tool for evaluating ET. HRCT, particularly for the temporal bone, provides detailed, three-dimensional images of the middle ear and its surrounding structures[5,6]. This advanced imaging technique allows for precise measurement of the ET anatomy, which describes the dysfunction[7].

We investigated the anatomical variations of ET in relation to the risk of developing CSOM without cholesteatoma. By identifying anatomical factors that may influence the risk and severity of CSOM, as well as treatment success, we can predict susceptibility to CSOM[2].

METHOD

A retrospective, cross-sectional study was conducted using the medical records of patients visiting the ORL-HNS outpatient clinic at Dr. Moewardi Hospital, Surakarta, Indonesia. The study was approved by *Komisi Etik Penelitian Kesehatan* (KEPK) at Dr. Moewardi Hospital. HRCT scans of the temporal bone were performed in the Radiology Department at Dr. Moewardi Hospital between January 2024 and March 2025.

We included patients diagnosed with unilateral CSOM without cholesteatoma, aged 18 to 70 years, who underwent HRCT of the temporal bone. Patients with bilateral CSOM, a history of allergy, adenoid hypertrophy, or congenital anomalies affecting any of the external, middle, or inner ear were excluded from the study.

The temporal bone scans were performed on GE Revolution Evo 128-slice and Siemens Somatom Force 576 with 0.67 mm and 0.37 mm slice gaps, respectively, and were then reconstructed. The reconstruction was performed in Radiant DICOM viewer at 200% magnification to provide optimal visualization.

The pharyngeal orifice of the Eustachian tube (ET) is the point nearest the pharynx where the tube's loop-shaped lumen becomes visible. The tympanic orifice is the point where the Eustachian tube is closest to the external auditory canal, as observed on cross-sectional imaging. The length of the Eustachian tube (ETL) is the distance between the pharyngeal and tympanic orifices. The Eustachian tube angle (ETA) is the angle between a straight line representing the tube's length and Reid's standard plane, which connects the infraorbital margins and the upper margins of both external auditory meatuses[8].

The Tubotympanic Angle (TTA) is the angle between the line extending along the Eustachian tube's (ET) tympanic orifice and the longitudinal axis drawn from the center of the bony external ear canal. Measurements were obtained in the axial plane, where the Eustachian tube is most clearly visible. The segment of the Eustachian tube near the tympanic orifice, known as the pretympanic segment, has the largest diameter of any part of the tube. The maximum cross-sectional diameter of this segment is defined as the Pretympanic Diameter (PTD)[7].

All these measurements were performed by a radiologist experienced in temporal bone scanning who has been working and lecturing for more than ten years.

We compared these parameters in both the affected and unaffected ears. Subsequently, the affected ETs were compared with the ET function, measured with ETF. The results of the ETF test were categorized as patent, while obstructed and partially obstructed results were collectively classified as obstructed. We also observed the characteristics of CSOM. SPSS version 25 was used for statistical analysis. A paired-samples t-test was used to assess the statistical significance of differences between affected and unaffected ears in TTA, PTD, ETA, and ETL. We then analyzed differences between the affected ET ear and CSOM characteristics, as well as ET function, using an independent t-test. A *p*-value of less than 0.05 was considered statistically significant.

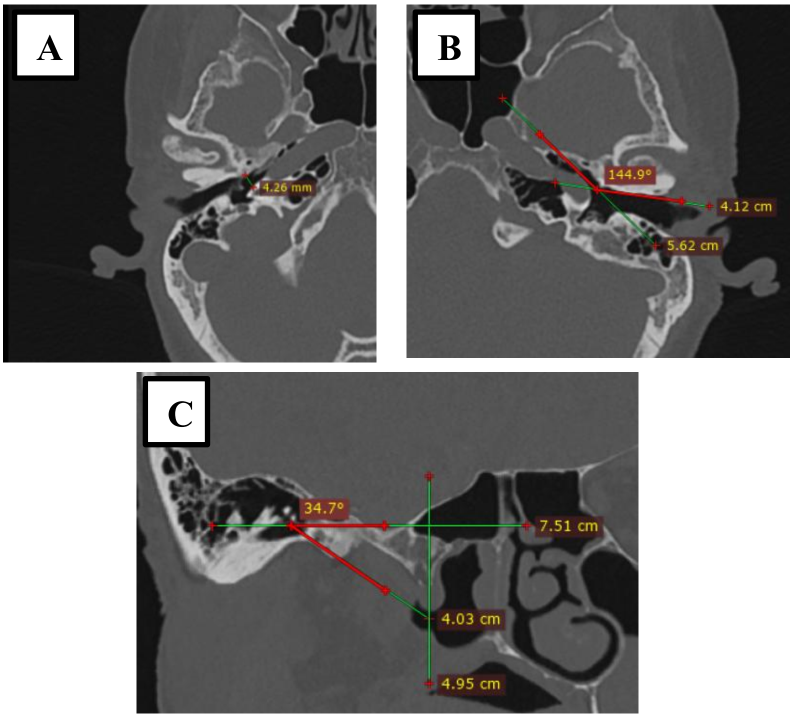

Figure 1. Multiplanar reconstruction of ET Anatomy measurements. A. Pretympanic Diameter (PTD); B. Tubotympanic Angle (TTA); C. ET Length (ETL) and ET Angle (ETA).

RESULT

This study included 30 subjects, comprising 16 females and 14 males, aged 18 to 70 years, with a mean age of 42.43 years. CSOM was observed in both the right ($n = 15$) and left ($n = 15$) ears. Most subjects had mild-to-moderate hearing loss ($n = 25$) (Table 1).

HRCT measurements showed significant differences in TTA, PTD, and ETA. The affected ear had a greater TTA than the unaffected ear ($146.59^0 \pm 5.81$ vs $140.03^0 \pm 5.22$; $p < 0.001$). The PTD of the affected ear was shorter than that of the unaffected ear (3.55 ± 0.87 mm vs 4.36 ± 0.66 mm; $p < 0.001$). The ETA of the affected ear was smaller than that of the unaffected ear (25.59 ± 4.60^0 vs 29.86 ± 3.99^0; $p < 0.001$). The ETL was shorter in the affected ear than in the unaffected ear, but the difference was not statistically significant (table 2).

The comparison of ET anatomical variations in patent ET with those in obstructed ET revealed significant differences (TTA: 143.80^0 vs 151.42^0; $p < 0.001$; PTD: 3.89 mm vs 3.21 mm; $P = 0.004$; and ETA: 27.41^0 vs 22.45^0; $p = 0.002$) (Table 3).

Table 1. Characteristics of the research subjects

Variable	n	(%)
Age (18-70 y. o.)	30	100
Sex		
Male	14	46.67
Female	16	53.33
Affected Ear		
Right	15	50
Left	15	50
Hearing Loss		
Mild ~ Moderate	25	83.33
Moderate-Severe	5	16.77
Discharge Frequency (month)		
≤ 6 times	18	60
> 6 times	12	40
Length of Illness		
≤ 10 years	18	60
> 10 years	12	40
Perforation		
Central	22	73.33
> Subtotal	8	26.67
Granulation		
Yes	9	30
No	21	70

Table 2. Comparison of ET anatomy within the affected and unaffected ear

Variable	Mean ± SD	*p Value*	CI
TTA (^{0})			
Affected ear	146.59 ± 5.81	< 0.001*	3.92 – 9.20
Unaffected ear	140.03 ± 5.22		
PTD (mm)			
Affected ear	3.55 ± 0.87	< 0.001*	-0.11 – -0.56
Unaffected ear	4.36 ± 0.66		
ETA (^{0})			
Affected ear	25.59 ± 4.60	< 0.001*	-5.91 – -2.61
Unaffected ear	29.86 ± 3.99		
ETL (cm)			
Affected ear	4.29 ± 0.47	0.493	-0.21 – 0.10
Unaffected ear	4.33 ± 0.26		

*Statistically significant

Table 3. Association of ET anatomy and ET function

Variable	n (%)	TTA (^{0})	*p*	PTD (mm)	*p*	ETA (^{0})	*p*	ETL (cm)	*p*
ET Function									
Patent	19	143.80	0.001*	3.89	0.004*	27.41	0.002*	4.24	0.382
Obstructed	11	151.42		3.20		22.45		4.37	

*Statistically significant

DISCUSSION

Assessing the function and anatomical variations of the ET remains a longstanding challenge due to the limitations of traditional clinical methods[9]. The anatomical complexity and dynamic nature of the ET further complicate assessment, as it is located deep within the skull base and requires HRCT imaging for accurate evaluation[10]. In this context, HRCT with multiplanar reconstruction has emerged as a useful, noninvasive tool that enables detailed visualization of the ET and its anatomical structures[7,11].

In this study, we compared variations in ET structure among subjects with unilateral CSOM. The ET of the right and left ears can exhibit subtle anatomical differences in length, angle, and diameter, influenced by genetic, developmental, and environmental factors[12]. Recurrent inflammation can cause structural changes, including edema, fibrosis, and scarring, leading to narrowing or distortion of the ET[13]. Chronic inflammation can alter ET anatomy, increasing the risk of middle ear infections and dysfunction[14,15].

Our study revealed significant differences in the ET anatomy of subjects with unilateral CSOM, with the affected ears showing a greater TTA, a shorter PTD, and a smaller ETA than the unaffected ears. These findings align with previous studies highlighting the role of these anatomical variations in ET dysfunction and the development of CSOM[7]. They reported that greater TTA and a shorter PTD impair the ET's ability to equalize middle ear pressure and clear secretions, thereby increasing the risk of CSOM[4,16,17].

A greater TTA creates a less efficient drainage pathway, leading to fluid stagnation and an increased risk of infection, such as CSOM. A shorter PTD reduces the lumen size, impairing ventilation of the middle ear and effective drainage of fluid. It also limits the mechanical efficiency of the ET's opening and closing mechanisms[7]. Additionally, when the ET angle is small, the tube may not open properly, making it more difficult for air to enter the middle ear and for fluid to drain out. This inefficiency causes fluid accumulation and a negative-pressure environment, both of which favor bacterial growth and infection[8,18].

Moreover, the findings suggest that these anatomical variations of the ET may predispose individuals to chronic or recurrent otitis media, reinforcing the significance of ET structure in determining the risk and severity of CSOM[7,19,20]. Moreover, we found that these anatomical features were closely linked to ET function, as assessed by tubal function tests (ETF). Subjects with a patent ET showed significant differences in ET anatomy, including a smaller TTA, a longer PTD, and a more blunted ETA, compared with those with an obstructed ET. This aligns with studies by Vivek et al. and Ridwan et al., which reveal that anatomical measurements such as TTA and PTD are key indicators of ET dysfunction and contributors to CSOM[7,17]. This relationship highlights the benefit of HRCT as a diagnostic tool for assessing ET function[21,22].

This study provides a detailed assessment of Eustachian tube (ET) anatomy using parameters such as TTA, PTD, ETA, and ETL, evaluated by a consultant radiologist specializing in head and neck imaging. To our knowledge, this topic has not been extensively investigated in relation to CSOM susceptibility in the Indonesian population. However, our study has several limitations. The relatively small sample size of 30 subjects may limit the generalizability of the findings. Additionally, as a single-center study, the results may be subject to location-specific biases. Furthermore, reliance on a single radiologist to evaluate the HRCT scans introduces the possibility of reader bias, given the lack of an assessment of inter-observer variability. Therefore, future multicenter studies involving larger and more diverse populations are needed to validate these findings and improve their generalizability. In addition, including multiple radiologists with formal assessment of inter-observer variability would strengthen the reliability and reproducibility of HRCT-based measurements of Eustachian tube anatomy.

Understanding anatomical ET variations through HRCT is beneficial for CSOM. HRCT multiplanar reconstructions provide an efficient, user-friendly approach to assessing the ET and offer clinicians more effective methods for predicting not only the likelihood of developing CSOM but also its potential severity. By recognizing these anatomical variations early, ENT specialists can devise more tailored and effective treatment plans, including surgical options such as tympanoplasty or Eustachian tube balloon dilation, and also predict the outcome of those interventions[3,21,22].

CONCLUSION

In conclusion, our study highlights the significant role of ET anatomical variations, particularly TTA, PTD, and ETA, in the development of CSOM. Our findings suggest that measuring TTA, PTD, and ETA is useful for determining the management of CSOM without cholesteatoma. However, further study is required to explore the long-term impact of these anatomical variations on the success of CSOM intervention and on ET function restoration.

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CONFLICT OF INTEREST

There is no conflict of interest in this study.

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