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Correlation Between Reid–Eustachian Tube Angle, Length, and Diameter Based on Temporal Bone CT Scan with Severity Level In Chronic Suppurative Otitis Media

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ABSTRACT
Chronic suppurative otitis media (CSOM) is an inflammatory condition of the middle ear characterized by perforation of the tympanic membrane and persistent otorrhea. Globally, it affects an estimated 65–330 million individuals with disproportionately higher rates reported in developing nations, including Indonesia, where the prevalence is approximately 2.7% in rural populations and 0.7% in urban settings. The Reid–Eustachian tube angle, as well as the tube's length and diameter, are considered as key anatomical factors contributing to the pathogenesis of CSOM as it affects ventilation and drainage of the middle ear. This study investigated the relationship between anatomical parameters of the Eustachian tube with the severity of CSOM based on the Middle Ear Risk Index (MERI) Score using temporal bone CT scan. It also aimed to establish optimal cut-off values capable of predicting moderate to severe CSOM. A cross-sectional analytical observational study was conducted on 60 patients diagnosed with CSOM at Prof. Dr. I.G.N.G. Ngoerah Hospital, Denpasar, between January 2019 and December 2024. The Reid–Eustachian tube angle, length, and diameter were quantified via 128/256-slice CT scans with multiplanar reconstruction. The severity of CSOM was assessed using the MERI Score. Spearman correlation, ordinal logistic regression, and ROC curve analysis were implemented to evaluate associations and establish predictive cut-off values. The Reid–Tube angle demonstrated a significant negative correlation with MERI scores ($r = –0.342$; $p = 0.007$). A narrower angle (5–13°) increased the risk of more severe CSOM by 7.823 fold compared to wider angles ($p = 0.011$; 95% CI: 1.587–38.542). The ROC curve analysis identified a cut-off point of 17.8° to distinguish mild from moderate-severe CSOM, and 15.2° for differentiating moderate disease (15.2°–<17.8°) from severe disease (<15.2°). In contrast, Eustachian tube length ($r = –0.040$; $p = 0.763$) and diameter ($r = –0.001$; $p = 0.994$) were not significantly associated with CSOM severity. A 17.8° cut-off yielded 100% sensitivity, 96.2% specificity, and a Youden Index of 0.962, with an AUC of 0.991 confirming excellent diagnostic performance. Overall, the Reid plane-ET angle was negatively correlated with MERI scores, where narrower angle corresponded to greater disease severity. These results highlight the Reid–Tube angle as a reliable anatomical marker for early detection and stratification of CSOM severity, while tube length and diameter had no significant impact.

Keywords: *Chronic suppurative otitis media, Reid–Eustachian tube angle, Reid-Tube angle, Reid plane-ET angle, MERI Score, temporal bone CT scan, optimal cut-off values.*

INTRODUCTION

Chronic suppurative otitis media is a chronic form of middle ear infection characterized by perforated tympanic membrane and persistent otorrhea. Treatment includes antibiotics, pain management, and the installation of ventilation tubes, while prevention can be executed through vaccination and avoidance of risk factors such as cigarette smoking (Schilder et al., 2016).

CSOM affects an estimated 65–330 million people worldwide, with about 60% experiencing clinically significant hearing impairment. Its prevalence varies substantially

across global regions according to the World Health Organization (WHO): Western Pacific (2.5–43%), Southeast Asia (0.9–7.8%), Africa (0.4–4.2%), South and Central America (approximately 3%), the Eastern Mediterranean (1.4%), and Europe (around 0.4%). The prevalence is notably higher in developing countries, where the incidence is approximately 11%, compared with ~2% in more developed regions. In Indonesia, CSOM remains a major public health concern. A 2014 study across six major cities (Bandung, Semarang, Balikpapan, Makassar, Palembang, and Denpasar) reported a substantial prevalence among school-age children. Additional data show that CSOM affects 27 per 1,000 children (2.7%) in rural areas and 7 per 1,000 children (0.7%) in urban settings (Anggraeni et al., 2014). Earlier, a 1996 survey conducted in seven Indonesian provinces estimated a national incidence of 3%, translating to approximately 6.6 million affected individuals out of a population of 220 million at that time (Triola et al., 2023). These figures underscore CSOM as a significant chronic ENT condition requiring appropriate and objective management.

The Reid-Tube angle plays an important role in the pathogenesis of otitis media in children and adults. Given its primary function as middle ear ventilation, secretory drainage, and protection from nasopharyngeal infections, a more horizontal angle in children is considered a major factor in increased susceptibility to otitis media. This condition facilitates the migration of fluids and microorganisms from the nasopharynx to the middle ear in children, causing the risk of developing more severe otitis media (CD. Bluestone, 2005; Sudo & Sando, 1996). In adults, Eustachian tube dysfunction can persist in cases such as allergies, laryngopharyngeal reflux, and chronic exposure to environmental pollutants (Ikeda et al., 2024; Nemade et al., 2018).

The length of the Eustachian tube is also one of the anatomical factors that affect the drainage, ventilation, and protection function of the middle ear. The shorter tube in children creates an easier pathway for microorganisms from the nasopharynx to enter the middle ear, thus increasing the risk of otitis media (CD. Bluestone, 2005; Cunsolo et al., 2010). Meanwhile, in adults the longer larger Eustachian tube helps prevent middle ear infections by increasing the efficiency of protection against nasopharyngeal reflux. However, cases of CSOM in adults can still occur where the efficiency of Eustachian tube function is highly dependent on interactions with other factors such as tube angle, tissue elasticity, and atmospheric pressure (C. D. Bluestone, 1996; Ikeda et al., 2020).

In children, the Eustachian tube has a smaller diameter compared to adults, predisposing them to impaired drainage, fluid stasis, and subsequent infection. When this anatomical limitation is combined with immature tube musculature, ventilation of the middle ear becomes suboptimal, leading to a higher incidence of otitis media with effusion, as described by Paltura et al. (2017). In adults, CSOM may develop due to localized narrowing of the Eustachian canal caused by fibrosis, mucosal swelling, or chronic inflammatory changes that disrupt normal tube physiology, ultimately contributing to persistent inflammatory fluid accumulation (Varghese et al., 2022).

This research provides a refined perspective on the relationship between Eustachian tube anatomy and the clinical severity of chronic suppurative otitis media (CSOM). By evaluating the Reid plane-ET angle, altogether with the tube's length and diameter as measured on temporal bone CT imaging, the study investigates how these morphometric parameters correlate with the Middle Ear Risk Index (MERI) Score, a prognostic tool widely used to assess disease severity.

This methodology differs from the previous study by Nugraha (2023), which concentrated on the association between selected Eustachian tube anatomical variables, namely the tubotympanic angle and pretympanic diameter, and the occurrence of CSOM accompanied by complications such as cholesteatoma and acute mastoiditis. Using a temporal bone CT cross-sectional approach, Nugraha found that the pretympanic diameter served as a protective parameter, where each 1-mm increase was associated with an 83% reduction in cholesteatoma risk and a 66% reduction in the likelihood of acute mastoiditis. However, the study was limited by the narrow scope of anatomical variables evaluated, excluding Eustachian tube length and the Reid–tube l angle, and by the absence of a standardized clinical metric to quantify disease severity (Nugraha, 2023).

Building upon these limitations, the present study incorporates additional anatomical indicators—including the Reid-Tube angle, tube length, and diameter—via high-resolution temporal bone CT, while integrating a structured clinical evaluation using the Middle Ear Risk Index (MERI) Score. Comprising seven prognostic components (tympanic membrane perforation, ossicular status, middle ear mucosa, cholesteatoma, otorrhea, previous surgery, and complications), the MERI score provides a comprehensive assessment of CSOM severity and plays a key role in predicting outcomes and guiding treatment strategies. By expanding anatomical variables and aligning radiological findings with clinical severity, this study offers a more robust and clinically relevant determination of Eustachian tube anatomical cut-off values for predicting CSOM severity.

From a scientific standpoint, this study addresses an important gap by evaluating how anatomical parameters of the Eustachian tube relate to CSOM severity, rather than merely focusing on the anatomical contributors to disease complications. By integrating high-resolution temporal bone CT imaging with a validated clinical scoring system, this study provides a more holistic evaluation of disease severity.

The objective of this study is to evaluate the association between the Reid–Eustachian tube angle, length, and diameter of the Eustachian tube measured through temporal bone CT, and the severity of CSOM as quantified by the MERI score. In addition, the study aims to establish optimal cutoff values for these anatomical parameters in distinguishing moderate and severe disease. The expected contributions extend to both clinically and academically. Clinically, the findings may introduce supplementary anatomical indicators that improve the precision and objectivity of temporal bone CT interpretations, thereby assisting clinicians in assessing CSOM severity and Eustachian tube function more accurately. Academically, the study enhances current knowledge by elucidating how variations in Eustachian tube morphology relate to disease severity, creating a foundation for subsequent investigations and supporting future decisions regarding treatment strategies, complication prevention, and patient education on disease prognosis and management options.

RESEARCH METHOD

This research employed an analytical observational approach using a cross-sectional design. All variables, both dependent and independent, were assessed simultaneously at a single point in time through non-contrast temporal bone CT scan examinations conducted at Prof. Dr. I.G.N.G. Ngoerah Hospital, Denpasar.

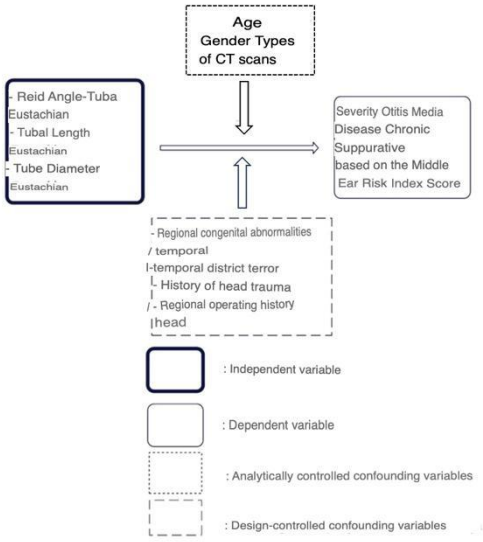


Figure 1. Research Design

Research Location and Time

The study was conducted within the Medical Records Department and Radiology Department of Prof. Dr. I.G.N.G. Ngoerah Hospital, Denpasar–Bali, over a six-month period spanning from January to June 2025.

Population and Sample

The study population encompassed all patients diagnosed with CSOM who had undergone temporal bone CT. The target population consisted of individuals experiencing chronic middle ear infections, defined by tympanic membrane perforation accompanied by persistent or recurrent otorrhea lasting more than 6 to 12 weeks. The accessible population included CSOM patients who received temporal bone CT examinations at Prof. Dr. I.G.N.G. Ngoerah Hospital between January 2019 and December 2024. The research sample comprised all eligible CSOM cases from this period that fulfilled the predefined inclusion and exclusion criteria. Inclusion criteria were patients aged 0–60 years, verified through medical records, with a confirmed clinical diagnosis of CSOM documented in the Hospital Information and Management System (SIMARS) and the INFINITT PACS. Exclusion criteria included incomplete medical documentation, congenital temporal bone anomalies, neoplastic lesions of the temporal region, prior head trauma, or previous cranial surgery. The minimum required sample size for correlation analysis was calculated using the single-sample correlation formula, applying $\alpha = 0.05$ ($Z\alpha = 1.96$), $\beta = 0.1$ ($Z\beta = 1.28$), and an expected correlation coefficient (r) of 0.4, yielding a minimum estimated sample of 51 subjects for adequate statistical power.

Sampling Techniques

The sampling technique used in this study was total sampling, involving all clinical CSOM cases recorded between January 2019 and December 2024. According to data retrieved from SIMARS and the INFINITT PACS system, a total of 60 patients met the initial criteria

within this five-year period. To minimize data loss due to incomplete records or other exclusion criteria, all 60 available CSOM cases were included as the final study sample.

RESULTS AND DISCUSSION

Characteristic of Respondents

This section outlines the demographic and clinical profiles of the study participants, including age, sex, and the morphometric measurements of the Eustachian tube (Reid–Tube angle, tube length, and diameter), as well as the severity of chronic suppurative otitis media (CSOM) determined by the MERI score. The information is summarized using descriptive statistics and frequency tables to provide a clear and comprehensive depiction of the characteristics of the study population.

Table 1. Descriptive Statistics of Research Parameters (n = 60)

Parameter	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	60	4	68	28.6	16.8
Reid–Eustachian Tube Angle (degrees)	60	5.7	25.3	13.4	4.4
Eustachian Tube Length (mm)	60	21.5	35.9	28.8	3.1
Eustachian Tube Diameter (mm)	60	0.3	2.2	1.2	0.5
MERI Score	60	3	9	4.9	1.6

Among the 60 patients included in this study, the average age was 28.6 years (SD = 16.8), with ages ranging from 4 to 68 years, demonstrating that CSOM affects a wide spectrum across childhood to late adulthood. The mean Reid–Tube angle measured 13.4° (SD = 4.4), with values spanning from 5.7° to 25.3°. The Eustachian tube length varied between 21.5 mm and 35.9 mm, yielding an average of 28.8 mm (SD = 3.1). The diameter ranged from 0.3 mm to 2.2 mm, with a mean value of 1.2 mm (SD = 0.5). Sample measurements were visualized and assessed on the axial plane of the CT images (Figure 2). Based on MERI Score, the severity of CSOM presented an average of 4.9 (SD = 1.6), with scores ranging from 3 to 9, indicating that most cases fell within the mild-to-moderate category.

Table 2. Frequency Distribution of Research Subject Characteristics (n = 60)

Variable	Frequency	Percentage (%)
Age		
4–22 years	30	50.0
23–68 years	30	50.0
Gender		
Male	30	50.0
Female	30	50.0
Reid–Eustachian Tube Angle		
5–13 degrees	35	58.3
14–26 degrees	25	41.7
Eustachian Tube Length		
21–28 mm	32	53.3
29–36 mm	28	46.7
Eustachian Tube Diameter		
0.2–1.3 mm	37	61.7
1.4–2.3 mm	23	38.3
Severity Category (MERI Score)		

Variable	Frequency	Percentage (%)
Mild	7	11.7
Moderate	39	65.0
Severe	14	23.3
Type of CT Scan		
Siemens SOMATOM go.Top 128 slice	31	51.7
Siemens Definition DS 256 slice	29	48.3

Most subjects had a Reid–Tube angle between 5° and 13° (58.3%), tube lengths of 21–28 mm (53.3%), and diameters of 0.2–1.3 mm (61.7%). MERI scoring categorized the majority (65.0%) as moderate severity (Figure 3). Age and sex distribution were balanced, with equal proportions (50%) across younger (4–22 years) and older (23–68 years) groups, as well as between males and females. The type of CT scanner used was also nearly even, with 51.7% scanned using the Siemens SOMATOM go.Top 128-slice system and 48.3% using the Siemens Definition DS 256-slice unit.

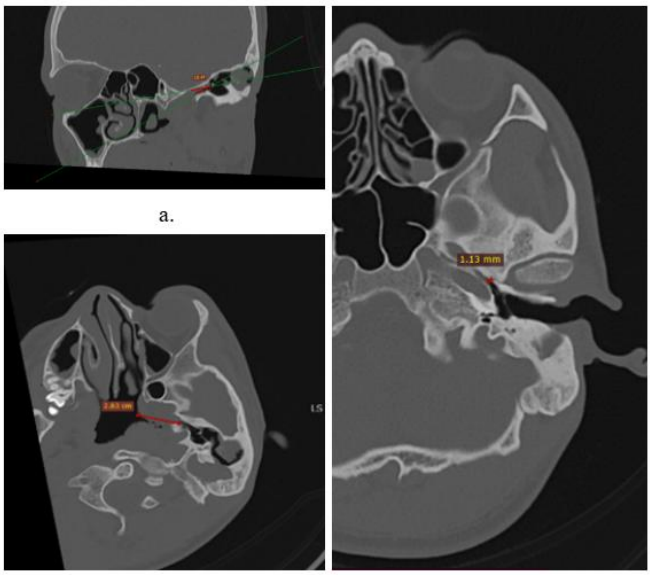
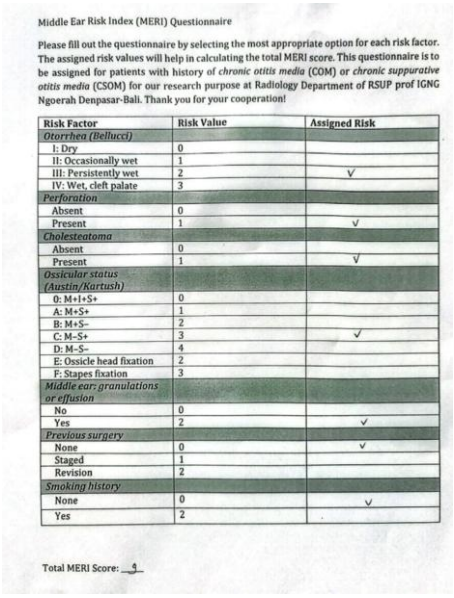


Figure 2. Representative morphometric assessment in a 21-year-old male patient with unsafe-type left-ear CSOM complicated by a mastoid fistula, demonstrating: (a) Reid–Eustachian tube angle, (b) Eustachian tube length, and (c) Eustachian tube diameter.



Middle Ear Risk Index (MERI) Questionnaire

Please fill out the questionnaire by selecting the most appropriate option for each risk factor. The assigned risk values will help in calculating the total MERI score. This questionnaire is to be assigned for patients with history of *chronic otitis media* (COM) or *chronic suppurative otitis media* (CSOM) for our research purpose at Radiology Department of RSUP prof IGNG Ngoerah Denpasar-Bali. Thank you for your cooperation!

Risk Factor	Risk Value	Assigned Risk
Otorrhea (Bellucci)		
I: Dry	0	
II: Occasionally wet	1	
III: Persistently wet	2	√
IV: Wet, cleft palate	3	
Perforation		
Absent	0	
Present	1	√
Cholesteatoma		
Absent	0	
Present	1	√
Ossicular status (Austin/Kartush)		
0: M+I+S+	0	
A: M+S+	1	
B: M+S–	2	
C: M–S+	3	√
D: M–S–	4	
E: Ossicle head fixation	2	
F: Stapes fixation	3	
Middle ear: granulations or effusion		
No	0	
Yes	2	√
Previous surgery		
None	0	√
Staged	1	
Revision	2	
Smoking history		
None	0	√
Yes	2	

Total MERI Score: 4

Figure 3. MERI scoring sheet documenting disease severity in the same patient.

Correlation of Reid-Tube Angle, Eustachian Tube Length and Diameter (CT Scan) with CSOM Severity (MERI Score)

To determine the relationship between the anatomical parameters of the Eustachian tube and the severity of CSOM, a Spearman correlation analysis of the Reid–Tube angle, length of the tube, and diameter of the tube was performed based on temporal bone CT scan with a severity score based on the MERI Score. The results of the analysis are presented in the following table.

Table 3. Correlation Between Eustachian Tube Parameters and MERI Score (n = 60)

Parameter	Correlation Coefficient (r)	p-value
Reid–Eustachian Tube Angle (degrees)	-0.342**	0.007
Eustachian Tube Length (mm)	-0.040	0.763
Eustachian Tube Diameter (mm)	-0.001	0.994

Note: ** indicates a statistically significant correlation ($p < 0.01$)

The analysis demonstrated that among all measured anatomical parameters, only the Reid–Eustachian tube angle exhibited a statistically significant association with CSOM severity as assessed by the MERI Score, yielding a correlation coefficient of –0.342 ($p = 0.007$). This inverse relationship indicates that larger Reid-Tube angles are linked to lower degrees of disease severity. Conversely, neither the Eustachian tube length nor its diameter showed a meaningful correlation with MERI scores, as reflected by their respective p-values of 0.763 and 0.994.

Based on the findings from the Spearman correlation test (Table 3), the Reid–Tube angle emerged as the sole anatomical factor significantly correlated with CSOM severity. Consequently, only this parameter was advanced to the ordinal logistic regression analysis to evaluate its influence on disease severity while adjusting for potential confounding factors such as age and sex.

Table 4. Estimated Parameters of Ordinal Regression on the Severity of CSOM Based on MERI Score (n = 60)

Variable	Odds Ratio (OR)	95% CI (OR)	p-value
Gender	1.147	0.383 – 3.431	0.807
Age Category	0.523	0.165 – 1.659	0.271
Type of CT Scan (128 vs 256 slice)	0.894	0.295 – 2.708	0.845
Reid–Eustachian Tube Angle (5–13° vs 14–26°)	7.823	1.587 – 38.542	0.011

Note: Significant at $p < 0.05$

The ordinal regression analysis demonstrated that among all variables tested, only the Reid–Eustachian Tube angle significantly influenced CSOM severity ($p = 0.011$). After adjusting for potential confounders such as age, sex, and CT scan type, individuals with a Reid–Tube angle between 5–13° were found to have a 7.823-fold increased likelihood of presenting with more severe CSOM compared to those with angles ranging from 14–26° (95% CI: 1.587–38.542). In contrast, sex ($p = 0.807$), age group ($p = 0.271$), and CT scan model ($p = 0.845$) showed no meaningful association with disease severity, as reflected by p-values greater than 0.05 and confidence intervals encompassing the null value.

Cut-off Value of Eustachian Tube Angle (CT Scan) to CSOM Severity (MERI Score)

Receiver Operating Characteristic (ROC) analysis was used to determine the optimal threshold (cut-off) of the Reid–Eustachian tube angle in differentiating CSOM severity categories according to the MERI score. The selection of cut-off points is guided based on the sensitivity, specificity, and highest Youden index values, which reflect the best balance between the ability to accurately detect positive and negative cases.

Table 5. Optimal Cut-off Points of Reid–Eustachian Tube Angle Based on ROC Curve Coordinates

Degree of CSOM	Range of Reid–Eustachian Tube Angle (°)	Sensitivity	Specificity	Youden Index
Mild	17.8 – 26	100%	96.2%	0.962
Moderate	15.2 – <17.8	100%	~77–81%	~0.79
Severe	<15.2	100%	~77–81%*	~0.79*

Note: *Approximate values based on ROC curve estimation

Analysis of the ROC curve demonstrated that the Reid–Eustachian Tube angle possesses outstanding discriminative performance for predicting CSOM severity, reflected by an AUC of 0.991. The optimal threshold identified was 17.8°, offering the most favorable sensitivity–specificity balance for distinguishing mild cases from the moderate–severe group. An additional threshold at 15.2° further differentiates moderate from severe CSOM, although this secondary cut-off is associated with a reduction in specificity.

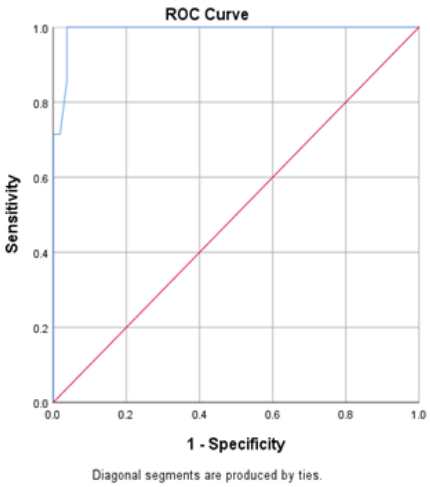


Figure 4. ROC curve for determining the optimal cut-off point of the Reid–Tube angle for CSOM severity based on the MERI score

Discussion

Correlation of Reid-Eustachian Tube Angle, Length and Diameter (CT Scan) with CSOM Severity (MERI Score)

The relationship between the anatomical parameters of the Eustachian tube and the severity of CSOM was the main focus of this study, utilizing respondent characteristic data and statistical analysis. Based on a literature review, the Eustachian tube has an important role in ventilation, drainage, and protection of the middle ear, so its anatomical abnormalities can affect the pathogenesis of CSOM (Soepardi et al., 2012; Bluestone, 2005). This investigation evaluated three anatomical components derived from temporal bone CT imaging, namely the Reid–Tube angle, tube length, and tube diameter, and assessed how these parameters correlate with CSOM severity as determined by the MERI Score.

Based on Table 1, the average age of respondents was 28.6 years (SD = 16.8), ranging from 4 to 68 years, confirming that CSOM affects a wide span of age groups, consistent with prior evidence showing that both pediatric and adult populations are vulnerable (Schilder et al., 2016). The balanced distribution across age groups (50% in the 4–22 years group and 50% in the 23–68 years group) and equal gender representation (50% male and female) indicate a heterogeneous sample that strengthens the generalizability of the findings. The average Reid–Tube angle measured 13.4° (SD = 4.4), with an average tube length of 28.8 mm (SD = 3.1) and tube diameter of 1.2 mm (SD = 0.5). Although these values fall within the typical adult range, the angles tended to be more horizontal and shorter than those reported in healthy adults (35–45 mm and a 45° angle) (Bluestone, 2005; Nemade et al., 2018).

The results of Spearman's correlation analysis in Table 3 demonstrated a statistically significant negative correlation between the Reid–Tube angle and MERI Score ($r = –0.342$; $p = 0.007$). This indicates that a larger (steeper) Reid–Tube angle is associated with lower CSOM severity. This finding aligns with established literature suggesting that a more vertical Eustachian tube angle in adults facilitates superior drainage and reduces the likelihood of retained secretions that sustain chronic infection (Bluestone, 2005; Swarts & Bluestone, 2003). Conversely, children typically exhibit a more horizontal configuration (around 10°), which

predisposes them to ascending nasopharyngeal infection, consistent with higher CSOM incidence among younger populations (Sudo & Sando, 1996).

In contrast, neither tube length ($r = –0.040$; $p = 0.763$) nor tube diameter ($r = –0.001$; $p = 0.994$) displayed meaningful associations with MERI Score. Although adult Eustachian tubes are generally longer (31–38 mm) than those in children (18–22 mm), the variability in tube length within this study (21.5–35.9 mm) was insufficient to demonstrate a significant impact on disease severity (Cunsolo et al., 2010). Similarly, although narrow tube diameters (0.3–2.2 mm) may contribute to obstruction from chronic inflammation, no direct correlation with CSOM severity was identified—likely because other pathological factors such as fibrosis and mucosal edema exert a greater influence on functional obstruction (Varghese et al., 2022).

The ordinal regression analysis in Table 4 confirmed that the Reid–Tube angle was the sole anatomical parameter exerting a significant effect on CSOM severity ($p = 0.011$), generating an odds ratio of 7.823 (95% CI: 1.587–38.542). After adjusting for age and sex, individuals with a narrower angle (5–13°) had a 7.8-fold greater likelihood of presenting with more severe CSOM compared to those with wider angles (14–26°). This supports the hypothesis that a narrow angle compromises middle-ear ventilation and drainage, generating negative pressure and exacerbating chronic disease progression (Nemade et al., 2018). Meanwhile, age ($p = 0.271$) and sex ($p = 0.807$) did not significantly influence CSOM severity, consistent with research highlighting that anatomical variations of the Eustachian tube contribute more strongly to disease pathophysiology than demographic factors (Alshehri et al., 2020). Measurement variability or other contributing factors, such as chronic mucosal inflammation or fibrosis, may also contribute, although not explicitly assessed in this study. Moreover, the sample size ($n = 60$) may have limited the statistical power to detect more subtle relationships involving these anatomical features.

The Eustachian tube functions for ventilation, drainage, and protection of the middle ear from nasopharyngeal infections (Soepardi et al., 2012). Dysfunction in this structure—whether due to an excessively horizontal orientation or a reduced luminal diameter—can promote secretion stasis and negative middle ear pressure, thereby facilitating bacterial colonization by organisms such as Pseudomonas aeruginosa and Staphylococcus aureus (Mittal et al., 2015). In the present study, a smaller Reid–Tube angle appeared to confer a protective effect, which may be attributed to reduced retrograde flow of nasopharyngeal secretions, in line with the mechanism described by Bluestone (2005).

Table 2 shows that most individuals exhibited a Reid–Tube angle between 5–13° (58.3%) and were predominantly categorized as having moderate disease severity according to the MERI Score (65%). This pattern is characteristic of the tubotympanic (safe) variant of CSOM, which typically presents with central perforation of the pars tensa and lacks cholesteatoma (Soepardi et al., 2012). Meanwhile, only 23.3% of subjects represented the atticoantral (unsafe) type with cholesteatoma, consistent with its known lower prevalence and higher complication risk (Verhoeff et al., 2006).

The MERI Score, which encompasses otorrhea status, tympanic membrane integrity, ossicular chain conditions, presence of cholesteatoma, and prior surgical history, serves as a validated predictor of CSOM severity and postoperative outcomes (Becvarovski & Kartush, 2001). In this study, the mean MERI Score of 4.9 (moderate category) indicated that most patients were suitable for conservative management or tympanoplasty with relatively low complication risk (Sharma et al., 2017).

The significant association between the Reid–Tube angle and CSOM severity suggests its potential value as a prognostic indicator. Individuals with a larger angle may require less aggressive intervention, whereas smaller angles may warrant closer monitoring to mitigate risks such as mastoiditis or cholesteatoma formation (Nursiah, 2003; Soepardi et al., 2012).

CSOM pathogenesis is closely tied to Eustachian tube dysfunction leading to inadequate aeration, secretion retention, and persistent inflammation (Alshehri et al., 2020). In this study, a larger Reid–Tube angle appeared protective by diminishing nasopharyngeal reflux. Conversely, the non-significant findings for tube length and diameter likely reflect interindividual anatomical variability or unmeasured factors such as chronic mucosal fibrosis (Varghese et al., 2022).

High-resolution temporal bone CT imaging, using systems such as the Siemens SOMATOM go.Top (128-slice) and Siemens Definition DS (256-slice), enabled precise assessment of Reid–Tube angle, Eustachian tube length, and luminal diameter via multiplanar reconstruction techniques (Siemens Healthineers, 2024). Additionally, the increased acquisition speed of 256-slice CT can further reduce radiation exposure, which is particularly advantageous in children and patients requiring multiple scans (Oncology Systems, 2023). The greater spatial resolution and reduced slice thickness (0.4–0.5 mm) of 256-slice scanners enhance visualization accuracy, reinforcing the reliability of measuring these anatomical parameters (Nemade et al., 2018). With regard to the scanner type used in this study, namely the comparison between 128-slice and 256-slice devices, the ordinal regression analysis demonstrated no significant influence on the severity of CSOM ($p = 0.845$). This suggests that both scanners deliver comparable accuracy in evaluating Eustachian tube anatomy for CSOM assessment.

The results of this study reinforce the role of the Reid–Tube angle as a clinically relevant predictor of CSOM severity and support its integration into CT-based diagnostic algorithms for stratifying risk and informing management strategies. Future investigations should include additional anatomical and physiological parameters, such as tubal tissue elasticity or biofilm formation, and larger study populations, coupled with advanced imaging modalities, to further validate and expand upon these results (Alanazy et al., 2023; Varghese et al., 2022).

Cut-off Value of Eustachian Tube Angle (CT Scan) to CSOM Severity (MERI Score)

Receiver Operating Characteristic (ROC) curve analysis was utilized to establish the most appropriate threshold (cut-off) for the Reid–Eustachian angle in differentiating the severity levels of CSOM as determined by the MERI Score. It serves as a diagnostic evaluation method that compares sensitivity (the ability to identify true-positive cases) and specificity (the ability to identify true-negative cases) across various potential cut-off points (Hanley & McNeil, 1982).

Measurement of the Reid plane-ET angle in this study was conducted via multiplanar reconstruction (MPR) of temporal bone CT, enabling precise visualization in axial, coronal, and sagittal planes (Nemade et al., 2018). The utilization of 128-slice and 256-slice CT systems (e.g., Siemens SOMATOM go.Top and Definition DS) provides high spatial resolution (0.4–0.5 mm), supporting strong accuracy in obtaining anatomical measurements (Siemens Healthineers, 2024). This ensures that the identified cut-off value can be applied reliably in clinical practice.

The primary aim of determining this threshold is to identify Reid–Tube angle values that can reliably predict disease severity with high diagnostic accuracy. The ROC analysis revealed that the Reid–Tube angle demonstrates exceptional discriminative power, reflected by an Area Under the Curve (AUC) of 0.991. According to Swets (1988), AUC values greater than 0.9 indicate outstanding diagnostic performance. The optimal cut-off was found to be 17.8°, yielding 100% sensitivity and 96.2% specificity, with a Youden Index of 0.962. A high Youden Index indicates superior overall diagnostic performance (Youden, 1950; Fluss et al., 2005). This threshold effectively separates mild CSOM cases from those in the moderate-to-severe group.

An additional threshold of 15.2° was identified to further distinguish moderate from severe CSOM, although its lower specificity (approximately 77–81%) suggests it is more appropriate as a secondary stratification tool. Consequently, angles below 17.8° indicate a heightened likelihood of moderate-to-severe CSOM, while angles under 15.2° signify a higher risk of severe disease. These findings reinforce the value of the Reid–Tube angle as a key anatomical parameter for assessing CSOM severity through temporal bone CT imaging.

The high AUC value (0.991) underscores the robustness of the Reid–Eustachian tube angle as a classifier of disease severity. This aligns with previous evidence indicating that Eustachian tube morphology strongly influences middle-ear ventilation and drainage, key elements in the pathogenesis of CSOM (Nemade et al., 2018). The angle, measured between the petrotympanic line and the Reid plane, reflects functional Eustachian tube efficiency. More vertical angles (approaching 45° in adults) enhance drainage, whereas more horizontal angles (approximately 10° in children) predispose to reflux and infection (Bluestone, 2005). The <17.8° threshold identified in this study suggests that angles smaller than the population mean (13.4°) correlate significantly with more severe CSOM.

Clinically, the 17.8° cut-off point can be used as a screening tool to identify patients at moderate to severe risk of CSOM. In clinical practice, patients with Reid-Tube angle below this value may require more intensive evaluations, such as otoscopic examinations to detect tympanic membrane perforations or cholesteatomas, as well as CT scans to assess temporal bone structure damage (Benson & Lane, 2022). This is in line with the recommendation to use high-resolution CT scans in CSOM evaluation (Aksoy et al., 2016).

Pathophysiologically, the association between smaller Reid–Tube angles and increased CSOM severity can be attributed to compromised Eustachian tube ventilation, chronic mucosal inflammation, or fibrosis, all of which predispose to fluid accumulation and infection (Varghese et al., 2022). These mechanisms facilitate bacterial colonization—particularly by organisms like Pseudomonas aeruginosa—which exacerbates disease severity (Mittal et al., 2015).

The MERI Score, on the other hand, incorporating parameters such as otorrhea, tympanic membrane perforation, ossicular integrity, and cholesteatoma, is well validated for evaluating CSOM severity (Becvarovski & Kartush, 2001). With an average MERI value of 4.9 in this study, most subjects presented with moderate disease severity—a finding consistent with the predominance of Reid–Tube angles in the 5–13° range (58.3%). The association between sub-17.8° angles and elevated MERI Scores further emphasizes the relevance of this anatomical parameter in identifying patients at risk for complications such as ossicular erosion and cholesteatoma (Sharma et al., 2017). Adopting the 17.8° threshold may facilitate earlier and more targeted interventions. Patients with more horizontal angles may warrant aggressive

therapeutic approaches, including tympanoplasty or mastoidectomy when cholesteatoma is present (Soepardi et al., 2012). Conversely, those with more vertical angles may benefit from conservative management strategies (Nursiah, 2003).

Although the ROC analysis demonstrated excellent diagnostic performance (AUC = 0.991), the relatively small sample size (n = 60) restricts the broader applicability of these findings. Moreover, individual anatomical variations of the Eustachian tube—such as differences in tissue elasticity or the extent of fibrosis—were not assessed, and these factors may influence the association between Reid–Tube angle and CSOM severity (Takasaki et al., 2007b). Larger-scale studies are therefore required to validate the proposed cut-off values. These results also highlight the need for further investigations into the prognostic value of the Reid–Tube angle in CSOM. Future prospective studies could examine whether the 17.8° threshold is consistent across diverse populations and whether additional factors such as adenoid hypertrophy or nasopharyngeal infections modify this association (Qureishi et al., 2014). Integrating CT-based anatomical evaluation with functional assessments, such as tympanometry, may enhance prediction accuracy for CSOM severity.

Overall, a Reid–Tube angular threshold of <17.8° emerges as a strong predictive marker for identifying moderate to severe CSOM, demonstrating high sensitivity and specificity. These findings reinforce the role of temporal bone CT scans as a key modality for assessing Eustachian tube anatomy and guiding CSOM management. This parameter can help clinicians recognize high-risk patients earlier, although additional research is needed to strengthen these conclusions and explore other anatomical or pathological contributors to CSOM progression (Alanazy et al., 2023; Varghese et al., 2022).

CONCLUSION

Based on the findings and subsequent analysis, several key conclusions can be formulated. (1) The Reid–Tuba angle demonstrated a significant inverse association with MERI scores ($r = –0.342$; $p = 0.007$), indicating that a narrower angle (5–13°) markedly elevates the likelihood of more advanced CSOM, with an adjusted risk increase of approximately 7.8-fold ($p = 0.011$; 95% CI: 1.587–38.542). ROC curve evaluation identified 17.8° as the optimal threshold for differentiating mild from moderate–severe CSOM, while a secondary threshold of 15.2° effectively separated moderate (15.2°–<17.8°) from severe disease (<15.2°). (2) No meaningful correlation was observed between Eustachian tube length and CSOM severity ($r = –0.040$; $p = 0.763$). (3) Likewise, Eustachian tube diameter showed no significant relationship with disease severity ($r = –0.001$; $p = 0.994$). (4) The most robust diagnostic parameter identified was the Reid–Tuba angle, with an optimal cut-off of 17.8°, achieving a sensitivity of 100%, a specificity of 96.2%, and a Youden Index of 0.962 (AUC = 0.991). Tube length and diameter were not subjected to further modeling given their lack of statistical significance.

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