KBB Uygulamaları 2024;12(2):47-55

Original Article / *Özgün Makale*

OPEN ACCESS

Evaluation of eustachian tube and mastoid parameters in chronic otitis media: A computed tomography-based study

Kronik otitis mediada östaki tüpü ve mastoid parametrelerinin değerlendirilmesi: Bilgisayarlı tomografi tabanlı çalışma

Hanife Gülden Düzkalır[1], Melis Demirağ Evman[2]

[1]*Department of Radiology, Kartal Dr. Lütfi Kırdar City Hospital, İstanbul, Türkiye*
[2]*Department of Otolaryngology, Kartal Dr. Lütfi Kırdar City Hospital, İstanbul, Türkiye*

ABSTRACT

Objectives: The study aimed to understand the causes of chronic otitis media (COM) with unilateral or bilateral cholesteatoma by examining the eustachian tube (ET) and mastoid ventilation from preoperative high-resolution temporal computed tomography (HRTCT) scans.

Patients and Methods: In this retrospective case-control study, COM patients with cholesteatoma who underwent preoperative HRTCT scanning between January 2021 and December 2023 were analyzed. The study included 102 ears of 51 participants (31 males, 20 females; mean age: 35.7±14.0 years; range, 18 to 65 years). The participants were divided into three groups, each with 17 individuals: unilateral COM with cholesteatoma, bilateral COM with cholesteatoma, and a healthy control group. Variables, including Reid plane-ET angle, tubotympanic angle (TTA), ET length, ET tympanic orifice and isthmus widths, and mastoid ventilation type and volume, were examined in CT images.

Results: The mean left TTA (p=0.045) was higher in the unilateral cholesteatoma group compared to the control group (148.88±5.30 and 144.24±6.51, respectively; p=0.045). The bilateral cholesteatoma group exhibited higher values for right and left ET isthmus widths (p=0.015 and p=0.014, respectively). The control group had significantly higher mastoid volumes compared to groups with cholesteatoma (p<0.001). Type 3 mastoid distribution was notably higher in groups with cholesteatoma (p<0.001). In the control group, the mean right and left ET angles were 25.13±3.35° and 24.67±3.38°, respectively.

Conclusion: Tubotympanic angle and ET isthmus width may be a potential marker for cholesteatoma. Large-scale studies targeting the anatomy and function of the isthmus in combination with mastoid and ET radiomorphological data and clinical scores using standardized protocols may improve treatment strategies.

Keywords: Chronic otitis media, cholesteatoma, computed tomography, eustachian tube, mastoid.

ÖZ

Amaç: Bu çalışmanın amacı, ameliyat öncesi yüksek çözünürlüklü temporal bilgisayarlı tomografi (BT) taramalarından östaki tüpü (ÖT) ve mastoid ventilasyonunu inceleyerek tek taraflı veya iki taraflı kolesteatomlu kronik otitis media (KOM)'nın nedenlerini anlamaktı.

Hastalar ve Yöntemler: Bu retrospektif vaka kontrol çalışmasında, Ocak 2021 - Aralık 2023 tarihleri arasında ameliyat öncesi yüksek çözünürlüklü temporal BT taraması yapılan kolesteatomlu KOM hastaları analiz edildi. Çalışmaya 51 katılımcının (31 erkek, 20 kadın; ort. yaş: 35.7±14.0 yıl; dağılım, 18-65 yıl) 102 kulağı dahil edildi. Katılımcılar, her biri 17 kişiden oluşan üç gruba ayrıldı: tek taraflı kolesteatomlu KOM, iki taraflı kolesteatomlu KOM ve sağlıklı kontrol grubu. Bilgisayarlı tomografi görüntülerinde Reid düzlem-ÖT açısı, tubotimpanik açı (TTA), ÖT uzunluğu, ÖT timpanik orifis ve isthmus genişlikleri, mastoid ventilasyon tipi ve hacmi gibi değişkenler incelendi.

Bulgular: Sol ortalama TTA tek taraflı kolesteatom grubunda kontrol grubuna kıyasla daha yüksekti (sırasıyla, 148.88±5.30 ve 144.24±6.51; p=0.045). İki taraflı kolesteatom grubunda sağ ve sol ET istmus genişlikleri daha yüksekti (sırasıyla, p=0.015 ve p=0.014). Kontrol grubunun mastoid hacim değerleri kolesteatom gruplarından anlamlı derecede yüksekti (p<0.001). Tip-3 mastoid dağılımı kolesteatom gruplarında belirgin olarak daha yüksekti (p<0.001). Kontrol grubunda sağ ve sol ÖT açıları sırasıyla ortalama 25.13±3.35° ve 24.67±3.38° idi.

Sonuç: Tubotimpanik açı ve ÖT istmus genişliği kolesteatom için potansiyel bir belirteç olabilir. Mastoid ve ÖT radyomorfolojik verileri ve standardize protokoller kullanılarak klinik skorlarla birlikte istmusun anatomisini ve işlevini hedefleyen geniş ölçekli çalışmalar tedavi stratejilerini geliştirebilir.

Anahtar sözcükler: Kronik otitis media, kolestatom, bilgisayarlı tomografi, östaki tüpü, mastoid.

Received: April 30, 2024
Accepted: May 29, 2024
Published online: June 11, 2024

Correspondence: Hanife Gülden Düzkalır, MD.
E-mail: hanifeduzkalir@gmail.com

Doi: 10.5606/kbbu.2024.83007

Citation:
Düzkalır HG, Demirağ Evman M. Evaluation of eustachian tube and mastoid parameters in chronic otitis media: A computed tomography-based study. KBB Uygulamaları 2024;12(2):47-55. doi: 10.5606/kbbu.2024.83007.

Chronic otitis media (COM) is a persistent middle ear and mastoid cavity inflammation and infection, often due to repeated acute otitis media or eustachian tube (ET) dysfunction. It is common worldwide, particularly in developing countries, and affects all ages.[1] Symptoms typically include hearing loss, tympanic membrane perforation, and damage to middle ear structures. Complications can be severe, including mastoiditis, intracranial spread, and, occasionally, cholesteatoma.

Cholesteatoma is an abnormal epithelial growth in the middle ear, where normal skin cells accumulate and cause damage. It forms due to genetic factors, chronic infections, and ET dysfunction, although the exact mechanisms are unclear. Early diagnosis and treatment are crucial to preventing serious complications.

The ET connects the middle ear to the nasopharynx, balancing ear pressure and draining fluids.[2] Eustachian tube dysfunction, which is embryologically linked to the mastoid, can cause pressure imbalances, fluid buildup, and an increased infection risk. In COM with cholesteatoma, ET dysfunction is common. High-resolution temporal bone computed tomography (HRTCT) and multiplanar reconstruction (MPR) techniques provide detailed evaluations of ET.[2,3]

This study aimed to understand the dynamics of the disease, as well as find new strategies of treatment in unilateral and bilateral cholesteatoma patients by evaluating the ET characteristics, the mastoid ventilation pattern, and the relationship between them in preoperative HRTCT images.

PATIENTS AND METHODS

This single-center, retrospective, case-control study included patients with unilateral or bilateral COM with cholesteatoma who underwent surgery at the Kartal Dr. Lütfi Kırdar City Hospital, Department of Otolaryngology between January 2021 and December 2023. All patients had a preoperative HRTCT. Exclusion criteria were age under 18 or over 65, congenital deformities, previous otolaryngologic surgery, diagnoses of otitis media, paranasal sinus mass, sinonasal polyps, concha bullosa, nasopharyngeal pathology, or history of temporal region trauma. The sample size calculation was based on measurements by Takasaki et al.[4] The minimum required number of ears was 24 (12 patients). The study included 102 ears of 51 participants (31 males, 20 females; mean age: 35.7±14.0 years; range, 18 to 65 years). The participants were divided into three groups, each with 17 individuals: unilateral COM with cholesteatoma, bilateral COM with cholesteatoma, and a control group. The healthy control group included 34 ears with no fluid or mass in the mastoid or tympanic cavity, no loss of ventilation, and no sclerosis or destruction in the temporal bone. A single radiologist with over five years of experience in head and neck imaging evaluated and measured all temporal computed tomography (CT) images, blinded to clinical outcomes. The patients with and without cholesteatoma were compared, as well as affected and unaffected ears in unilateral cases.

A Philips Ingenuity model 128-slice, 64-detector CT scanner (Philips Medical Systems Inc., New York, USA) was used in all HRTCT images. Temporal bone images were acquired in the supine position using soft tissue and bone algorithms with a 0.67-mm section thickness aligned axially to the orbital-meatal line. Coronal and sagittal reconstructions were derived from raw data. The Reid plane-ET angle (ETA), the tubotympanic angle (TTA), the eustachian length, the tympanic orifice width, the tympanic isthmus width, the type of ventilation in the mastoid, and the volume of the mastoid were all measured.

The ETA relative to the Reid plane was evaluated using HRTCT axial sections in our methodology. The inferior orbital walls and superior external ear canal walls were utilized to define the Reid horizontal plane as a reference.[5,6] The ET line was established by aligning the pharyngeal and tympanic orifices of the ET on the same plane using MPR and coronal imaging. Afterward, the ETA between this line and the horizontal plane was measured (Figure 1).[1]

The TTA is defined as the angle between the line through the ET's tympanic orifice and the line through the external ear canal's center (Figure 2). The ET, connecting the tympanic cavity to the nasopharynx, comprises several anatomical regions: *(i)* pharyngeal orifice (semicircular in shape, near the nasopharynx);

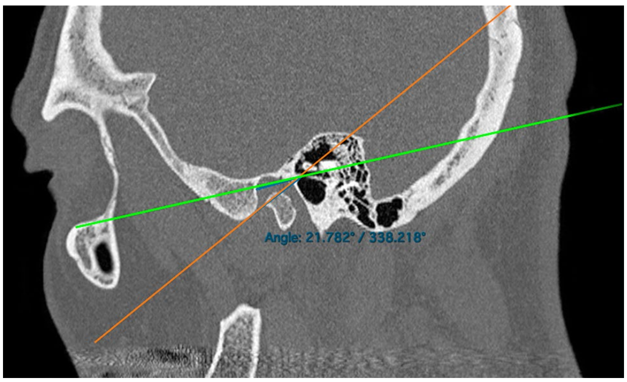

Figure 1. Measurement technique of the eustachian tube angle in Reid's horizontal plane.

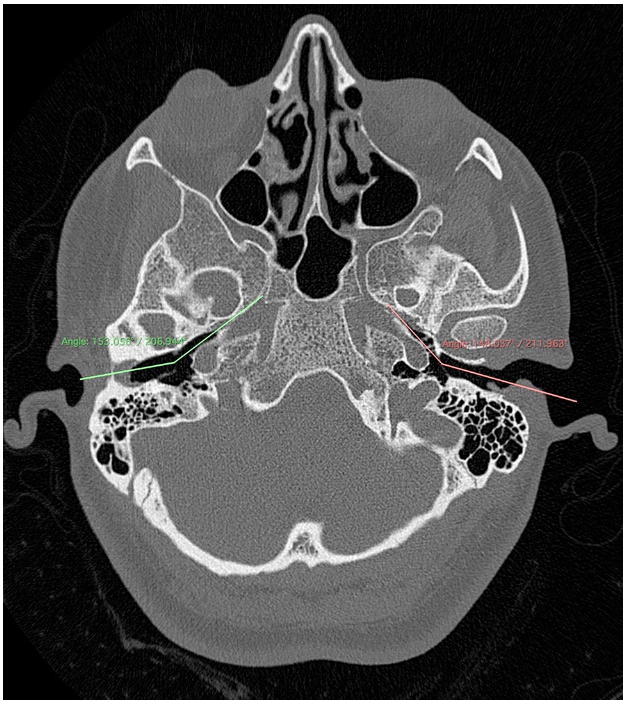

Figure 2. Tubotympanic angle: Measurement between the center of the line passing through the tympanic hole of the eustachian tube and the center of the line passing through the middle of the external ear canal.

Figure 3. Measurement of the total length of ET: In reformatted images, the sum of the cartilage ET length from the isthmus to the pharyngeal orifice on the left and the bone ET length measurement from the isthmus to the tympanic hole.
ET: Eustachian tube.

(ii) tympanic orifice (located at the ET's junction between the posterior edge of the carotid canal and the basal turn of the cochlea); *(iii)* isthmus (the location where bone and soft tissue segments of the ET merge); *(iv)* cartilaginous ET (extends from the isthmus to the pharyngeal orifice); *(v)* bony ET (extends from the isthmus to the tympanic orifice).[7-9] In this study, the total length of the ET was determined by measuring its cartilaginous and bony portions. The cartilaginous length from the isthmus to the pharyngeal orifice was measured. The ET's cranial boundary was defined by a bony eminence near the carotid canal, while the caudal boundary was defined by the soft tissue tip of the torus tubarius (Figure 3). Each patient's left and right cartilaginous ET length was measured in millimeters. For the bony portion, we measured from the isthmus to the tympanic orifice using coronal reformatted HRTCT

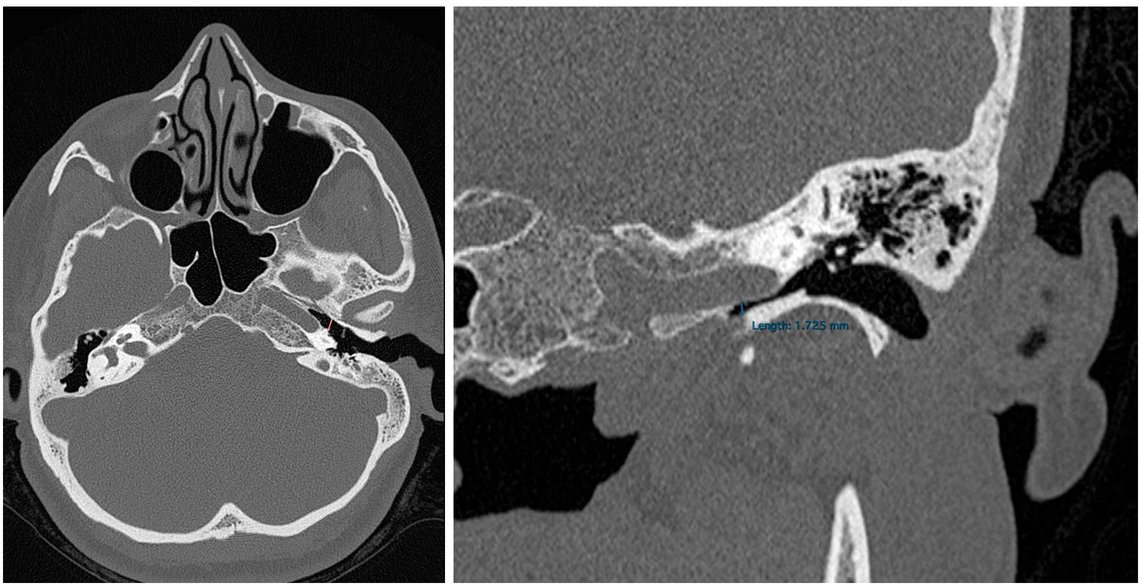

Figure 4. Measurement technique of the eustachian tympanic orifice in axial plane high-resolution CT images (right image) and eustachian isthmus width in coronal plane high-resolution CT images (left image).
CT: Computed tomography.

images. These measurements were summed to calculate the total ET length. The widths of the tympanic orifice and isthmus were also measured in millimeters (Figure 4).[10,11]

The mastoid air cells were classified based on pneumatization: *(i)* cellular mastoids (complete), *(ii)* diploic mastoids (partial), and *(iii)* sclerotic mastoids (none).[12]

The OsiriX MD software (Pixmeo SARL; Bernex, Switzerland) was used to measure the mastoid volume in temporal bones from HRTCT DICOM (Digital Imaging and Communications in Medicine) images.[13] The mastoid region was identified on axial plane images, and the sequential cutting method was used to measure the volume to enhance accuracy. The region of interest in each mastoid section was semiautomatically marked, and the axial plane regions of interest were verified and manually corrected in the sagittal and coronal planes. We calculated the total volume by summing the product of the area of each section and the intercut distance (Figure 5).

Cholesteatoma proliferation was assessed in cases using surgical reports, preoperative HRTCT, and presurgical examination notes, classifying it based on the condition of the attic, antrum, mesotympanum, hypotympanum, and all pneumatized parts of the mastoid bone.

Statistical analysis

The data was analyzed using IBM SPSS version 29.0 software (IBM Corp., Armonk, NY, USA). Descriptive statistics were expressed as frequency (n), percentage (%), mean±standard deviation (SD), median, and range. The Shapiro-Wilk test was used for the normality evaluation, while the Levene test assessed variance homogeneity. Cross-group numerical comparisons were conducted using analysis of variance (ANOVA) for normally distributed data and Kruskal-Wallis for nonnormally distributed data. Post hoc tests included Duncan for ANOVA and Dunn-Bonferroni for Kruskal-Wallis. In unilateral cases, a paired t-test or Wilcoxon test compared numerical variables between the affected and unaffected sides. Categorical variables were analyzed using Pearson's chi-square and the Fisher-Freeman-Halton exact tests. In unilateral cases, the McNemar-Bowker test was used to compare mastoid types. Subgroup analyses used the Bonferroni-corrected two-percentage z test. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1 presents a comparison of variables by groups. Sex and age distributions were similar across groups (p=0.720 and p=0.187, respectively). The left TTA was significantly higher in the unilateral group than in the control group (p=0.045).

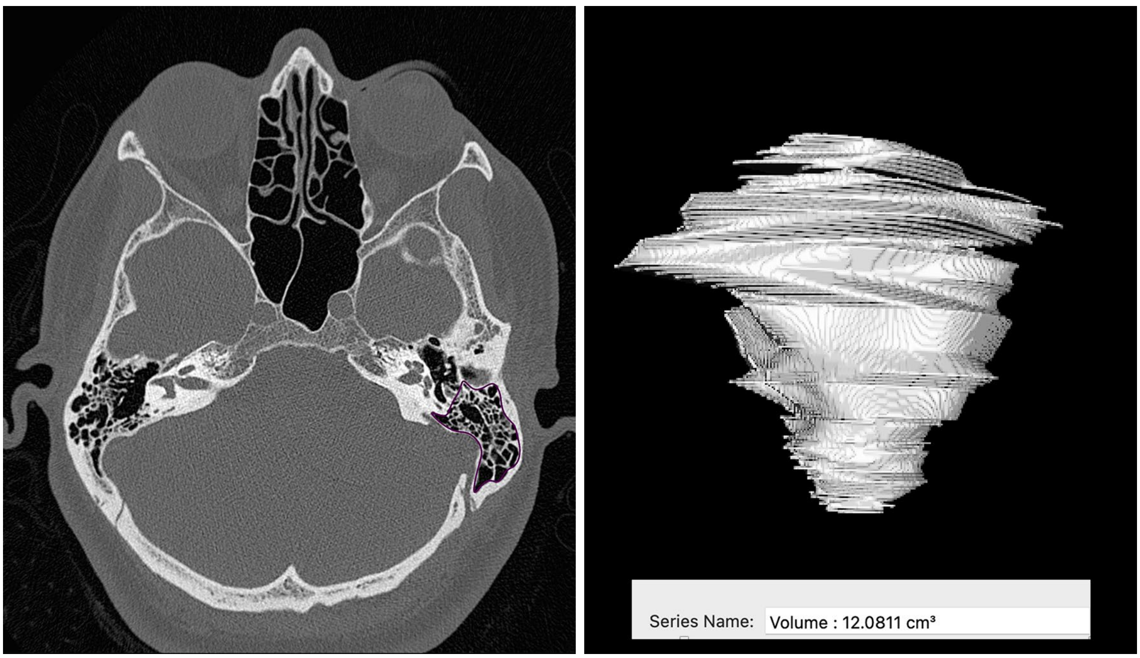

Figure 5. The mastoid volume measurement technique: Mastoid area measurement in each section in the axial plane (right picture) and the calculation method of total mastoid volume.

Table 1
Comparison of variables by groups

	Unilateral cholesteatoma					Bilateral cholesteatoma					Control					Test value	p value
	n	%	MeanSD	Median	IQR	n	%	MeanSD	Median	IQR	n	%	MeanSD	Median	IQR	*p*	*p*
Age (year)			31.5±13.4					35.2±12.8					40.2±15.1			1.735	0.187†
Sex																0.658	0.720¥
Male	11	64.7				9	52.9				11	64.7					
Female	6	35.3				8	47.1				6	35.3					
Right eustachian angle			25.94±5.19					22.61±4.04					25.13±3.35			2.815	0.070†
Left eustachian angle			25.32±4.45					23.16±3.80					24.67±3.38			1.371	0.264†
Right tubotympanic angle			148.52±5.58					146.28±4.36					144.75±5.91			2.157	0.127†
Left tubotympanic angle			148.88±5.30^{a}					147.29±3.92^{ab}					144.24±6.51^{b}			**3.310**	**0.045†**
Right eustachian bone length (mm)			11.97±1.23					11.82±1.49					12.02±1.80			0.074	0.928†
Left eustachian bone length (mm)			11.94±1.26					11.21±1.39					11.14±1.49			1.766	0.182†
Right eustachian cartilage length (mm)			25.93±1.97					26.69±2.76					26.00±2.84			0.452	0.639†
Left eustachian cartilage length (mm)			25.74±1.48					26.08±2.50					26.10±2.06			0.164	0.849†
Total length of the right eustachian (mm)			37.90±1.56					38.51±2.29					38.02±2.50			0.381	0.685†
Total length of the left eustachian (mm)			37.69±1.86					37.29±2.07					37.24±2.54			0.214	0.808†
Right eustachian tympanic orifice width (mm)			4.63±0.60					4.36±0.50					4.56±0.70			0.930	0.402†
Left eustachian tympanic orifice width (mm)			4.75±0.60					4.36±0.35					4.57±0.70			1.981	0.149†
Right eustachian isthmus width (mm)			1.62±0.24^{a}					1.89±0.27^{b}					1.73±0.27^{a}			**4.552**	**0.015†**
Left eustachian isthmus width (mm)			1.67±0.21^{a}					1.91±0.25^{b}					1.76±0.25^{ab}			**4.672**	**0.014†**
Right mastoid volume (cm^3)				1.67^{a}	3.24				2.42a	2.50				8.87^{b}	7.64	**18.743**	**<0.001&**
Left mastoid volume (cm^3)				1.68^{a}	5.60				1.91a	1.49				10.45^{b}	6.25	**18.983**	**<0.001&**
Right mastoid type																23.788	<0.001‡
1	3^{a}	17.6				0^{a}	0.0				12^{b}	70.6					
2	3^{a}	17.6				2^{a}	11.8				2^{a}	11.8					
3	11^{a}	64.7				15^{a}	88.2				3^{b}	17.6					
Left mastoid type																24.072	<0.001‡
1	4^{a}	23.5				1^{a}	0.0				11^{b}	64.7					
2	4^{a}	23.5				2^{a}	11.8				4^{a}	23.5					
3	9^{a}	52.9				15^{a}	88.2				2^{b}	11.8					

SD: Standard deviation; IQR: Interquartile range; † One-way analysis of variance; ¥ Pearson chi-square test; & Kruskal-Wallis H test; ‡ Fisher-Freeman-Halton exact test. Superscripts a and b indicate differences between groups in each row. There is no statistical difference between groups with the same superscript.

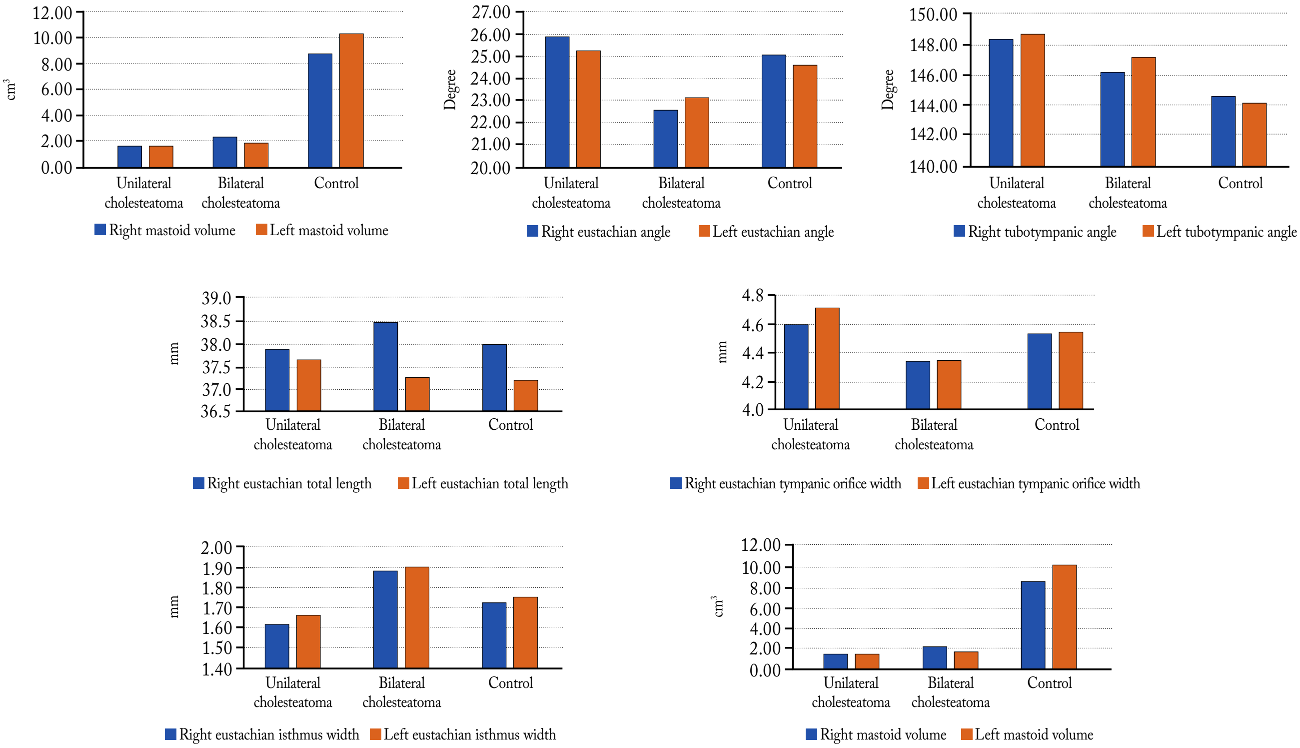

Figure 6. Comparative data of eustachian tube and mastoid ventilation parameters of the groups.

Statistically significant differences were found in the width of the right and left ET isthmus between the groups (p=0.015 and p=0.014, respectively). In the bilateral group, the right ET isthmus width was higher than the others. In the bilateral group, the left ET isthmus width was higher than in the unilateral group.

Right and left mastoid volume values in the control group were statistically significantly higher than both COM groups (p<0.001). The groups' right mastoid type distributions were different (p<0.001). The number of type 3 patients was statistically higher, whereas the number of type 1 patients was lower in the COM groups compared to the control group. Comparative data of ET and mastoid ventilation parameters of the groups are summarized in Figure 6.

Table 2
Sites of involvement in the unilateral group

Sites of involvement	n	%
Attic + mastoid	2	11.8
Attic + tympanic cavity	1	5.9
Attic + tympanic cavity + mastoid + sinus tympani	4	23.5
Attic + tympanic cavity + mastoid + supratubal recess	1	5.9
Attic + tympanic cavity + sinus tympani	1	5.9
Attic + tympanic cavity + sinus tympani + supratubal recess	1	5.9
Sinus tympani	3	17.6
Sinus tympani + tympanic cavity	1	5.9

In the unilateral group, 52.9% (n=9) were affected in the right ear, and 47.1% were affected in the left ear. The areas with the highest rates of cholesteatoma retention were the attic + tympanic cavity + mastoid + sinus tympani (n=4) and sinus tympani (n=3) (Table 2). Table 3 shows a comparison of variables on the sick and healthy sides in unilaterally affected patients. Mastoid volume was significantly lower on the affected side (p=0.001), with differing mastoid type distributions (p=0.049), notably higher type 3 prevalence.

DISCUSSION

All ages, particularly in developing countries, experience COM, which necessitates early diagnosis and treatment due to its severe complications. Existing studies link COM with ET anatomical and physiological abnormalities.[1,2,14] The present study differs from the literature by uniquely evaluating various ET and

Table 3
Comparison of healthy and dysfunctional side ear findings in the unilateral cholesteatoma group

	Healthy side ear (n=17)					Sick side ear (n=17)						
	n	%	MeanSD	Median	IQR	n	%	MeanSD	Median	IQR	Test value	*p*
Eustachian angle			25.33±4.33					25.93±5.28			0.586	0.566†
Tubotympanic angle			148.46±5.46					148.94±5.41			0.412	0.686†
Eustachian bone length (mm)			11.74±1.25					12.17±1.21			0.905	0.379†
Eustachian cartilage length (mm)			26.02±1.18					25.65±2.15			0.721	0.481†
Eustachian total length (mm)			37.76±1.54					37.83±1.88			0.135	0.894†
Eustachian tympanic orifice width (mm)			4.71±0.46					4.67±0.73			0.185	0.855†
Eustachian isthmus width (mm)			1.62±0.23					1.67±0.22			0.743	0.468†
Mastoid volume (cm^3)				2.83	6.31				1.29	0.78	**3.195**	**0.001‡**
Mastoid type											6.000	0.049*
1	5[a]	29.4				3[b]	11.8					
2	5[a]	29.4				2[a]	11.8					
3	7[a]	41.2				13[a]	76.4					

† Paired samples t-test; ‡ Wilcoxon test; * McNemar Bowker, test. Superscripts a and b indicate differences between groups in each row. There is no statistical difference between groups with the same superscript.

mastoid ventilation parameters with preoperative HRCT in COM patients with unilateral and bilateral cholesteatoma.

Kourtidis et al.[11] reported that the healthy side had a higher visualization of the ET bone segment than the pathological side and that the length correlated with the clinical score. In our study, there was no significant difference between the groups in terms of ET length. Takasaki et al.[4] and Dinç et al.[15] calculated ET length as 42.7 (2.9) mm and 39.3 mm (range, 31 to 44), respectively. In our study, the total ET length in the unilateral COM, bilateral COM, and healthy groups on the right side was 37.90±1.56, 38.51±2.29, and 38.02±2.50, and on the left side, it was 37.69±1.86, 37.29±2.07, and 37.24±2.54, respectively. Comprehensive prospective studies using standardized imaging (valve-CT) and measurement parameters correlated with clinical scores are necessary due to differences in the literature.

The ETA changes may affect the middle ear and mastoid pneumatization, but studies report no significant differences between healthy individuals and COM patients.[4,11,14,15-17] However, patients with cholesteatoma have shown a higher ETA on the contralateral side.[18] The present study found no significant ETA differences in the unilateral group, possibly influenced by our adult-only sample. Established healthy adult ETA values include 27.3±2° (right) and 27.3±2.8° (left) by Takasaki et al.,[4] 27.56±3.62 degrees by Nemade et al.,[14] and 23.6±2.4 degrees by Dinç et al.[15] In our study, we found the ETA value to be 25.13±3.35° on the right and 24.67±3.38° on the left.

Recent studies identify the TTA as relevant to COM.[14] Nemade et al.[14] reported a mean TTA of 148.12±3.43° for affected ears and 145.14±4.34° for healthy ones. Aksoy et al.[1] found TTA values of 145.17°±6.36° in COM patients with cholesteatoma, 147.13°±6.38° in the healthy ear of the same patients, and 144.58°±6.72° and 146.29°±5.82° in COM patients without cholesteatoma. They noted no significant TTA difference in bilateral COM cases. The present study shows that the unilateral group had a higher left TTA compared to controls (148.88±5.30 *vs.* 144.24±6.51, p=0.045), suggesting a possible link between increased TTA and susceptibility to otitis media and cholesteatoma, although more data is needed for confirmation.

In addition to tympanoplasty, balloon dilatation is also used for middle ear ventilation.[19,20] This technique involves expanding a balloon catheter within the flexible cartilage segment of the ET.

Preoperatively, HRTCT can measure the lengths of the bone and cartilage sections, as well as the isthmus width, of the ET. Its length varies widely in the literature.[20] In our study, there was no significant difference between the groups in terms of the lengths of these ET segments. Since the goal of the procedure is to place the catheter into the isthmus, changes in isthmus width can lead to placement errors and potential complications.[10] As a result, it is critical to assess both the isthmus and the cartilage ET length. In our study, we detected a difference in isthmus width. The isthmus width in the bilateral group was statistically wider than that in both the right unilateral group and control group, as well as the left unilateral group (p=0.015 and p=0.014, respectively). Measuring cartilage ET helps surgeons select and position the catheter effectively. The differences in isthmus width between our groups suggest that a comprehensive study on the anatomical targeting and functional impact of the isthmus would be informative.

Mastoid size affects middle ear pressure, with studies showing a decrease in mastoid air cell volume correlating with COM duration.[21,22] Koç et al.[23] found a mean mastoid volume of 7.9±2.3 cm^3 in 100 healthy ears, with moderate pneumatization being most common. In our study, he healthy group's median mastoid volumes were 8.87 (IQR: 7.64) on the right and 10.45 (IQR: 6.25) on the left, which is higher than average. Type 3 pneumatization was more frequent and type 1 was less frequent in the unilateral and bilateral cholesteatoma groups compared to controls. In cases of unilateral cholesteatoma, the mastoid volume on the affected side was much lower than on the healthy side (p=0.001), and there was a higher rate of type 3 pneumatization (p=0.049).

This study had limitations, including a small sample size and the exclusion of pediatric patients. It was also constrained by the requirement of preoperative CT images for all participants and the inability to perform age-related subgroup analysis or compare ET morphological parameters with clinical ET scores. The absence of Valsalva-CT, which clarifies ET evaluation during imaging, was another limitation. Future prospective studies incorporating the Valsalva maneuver during imaging could provide deeper insights.

In conclusion, COM and cholesteatoma remain significant causes of hearing loss in developing countries. Understanding their etiology and identifying new treatment targets are crucial for effective and early intervention. Comprehensive studies that integrate radiological morphological parameters of the mastoid region and ET with clinical scores could help develop personalized treatment plans.

Ethics Committee Approval: The study protocol was approved by the Kartal Dr. Lütfi Kırdar City Hospital Ethics Committee (date: 27.09.2023, no: 2023/514/258/27). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Has mainly contributed to the conceptualization, methodology and original drafting of the study, has mainly contributed to the data collection and research of the study, has mainly contributed to the writing-reviewing and editing of the study, has mainly contributed to the data analysis and resources of the study, has mainly contributed to the supervision and writing-review of the study: H.G.D., M.D.E.; Has mainly contributed to the methodology and editing of the study: H.G.D.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Aksoy S, Sayin I, Yazici ZM, Kayhan FT, Karahasanoglu A, Hocaoglu E, et al. The evaluation of the angles of Eustachian tubes in the patients with chronic otitis media on the temporal computerized tomography. Niger J Clin Pract 2016;19:318-22. doi: 10.4103/1119-3077.179274.
2. Ku D, Copson B, Fiorentino M, Gerrard JM, O'Leary S. A new "practical" plane for Eustachian tube measurements and its application in predicting middle ear dysfunction in patient with acquired cholesteatomas. Eur Arch Otorhinolaryngol 2022;279:4917-23. doi: 10.1007/s00405-022-07345-3.
3. Sirikci A, Bayazit YA, Bayram M, Kanlikama M. Significance of the auditory tube angle and mastoid size in chronic ear disease. Surg Radiol Anat 2001;23:91-5. doi: 10.1007/s00276-001-0091-1.
4. Takasaki K, Takahashi H, Miyamoto I, Yoshida H, Yamamoto-Fukuda T, Enatsu K, et al. Measurement of angle and length of the eustachian tube on computed tomography using the multiplanar reconstruction technique. Laryngoscope 2007;117:1251-4. doi: 10.1097/MLG.0b013e318058a09f.
5. Cho ZH. 7.0 Tesla MRI Brain Atlas: In: Vivo Atlas with Cryomacrotome Correlation. Introduction 2; 2010.
6. Kretschmann HJ, Weinrich W. Neuroimaging and clinical neuroanatomy: Magnetic resonance imaging. Vol. 1. Stuttgart: Thieme; 2010.
7. Yoshida H, Kobayashi T, Morikawa M, Hayashi K, Tsujii H, Sasaki Y. CT imaging of the patulous eustachian tube--comparison between sitting and recumbent positions. Auris Nasus Larynx 2003;30:135-40. doi: 10.1016/s0385-8146(03)00006-3.

8. Yoshida H, Kobayashi T, Takasaki K, Takahashi H, Ishimaru H, Morikawa M, et al. Imaging of the patulous Eustachian tube: High-resolution CT evaluation with multiplanar reconstruction technique. Acta Otolaryngol 2004;124:918-23. doi: 10.1080/00016480410017422.
9. Kikuchi T, Oshima T, Hori Y, Kawase T, Kobayashi T. Three-dimensional computed tomography imaging of the eustachian tube lumen in patients with patulous eustachian tube. ORL J Otorhinolaryngol Relat Spec 2009;71:312-6. doi: 10.1159/000265939.
10. Falkenberg-Jensen B, Hopp E, Jablonski GE, Pripp AH, Silvola JT. The cartilaginous Eustachian tube: Reliable CT measurement and impact of the length. Am J Otolaryngol 2018;39:436-40. doi: 10.1016/j.amjoto.2018.04.010.
11. Kourtidis S, Bier G, Preyer S, Hempel JM. Morphologic measurements of 3D Eustachian tube model and their diagnostic value regarding Eustachian tube dysfunction - A cross-sectional observational study. Eur J Radiol 2021;136:109563. doi: 10.1016/j.ejrad.2021.109563.
12. Sethi A, Singh I, Agarwal AK, Sareen D. Pneumatization of mastoid air cells: Role of acquired factors. Int J Morphol 2006;24:35-8. doi: 10.4067/S0717-95022006000100007.
13. Rosset A, Spadola L, Ratib O. OsiriX: An open-source software for navigating in multidimensional DICOM images. J Digit Imaging 2004;17:205-16. doi: 10.1007/s10278-004-1014-6.
14. Nemade SV, Shinde KJ, Rangankar VP, Bhole P. Evaluation and significance of Eustachian tube angles and pretympanic diameter in HRCT temporal bone of patients with chronic otitis media. World J Otorhinolaryngol Head Neck Surg 2018;4:240-5. doi: 10.1016/j.wjorl.2017.12.012.
15. Dinç AE, Damar M, Uğur MB, Öz II, Eliçora SŞ, Bişkin S, et al. Do the angle and length of the eustachian tube influence the development of chronic otitis media? Laryngoscope 2015;125:2187-92. doi: 10.1002/lary.25231.
16. Yegin Y, Çelik M, Şimşek BM, Olgun B, Karahasanoğlu A, Çolak C, et al. Correlation between the degree of the mastoid pneumatization and the angle and the length of the Eustachian tube. J Craniofac Surg 2016;27:2088-91. doi: 10.1097/SCS.0000000000003071.
17. Yegin Y, Çelik M, Altintaş A, Çolak C, Kayhan FT. Do the angle and length of the Eustachian tube affect the success rate of pediatric cartilage type 1 tympanoplasty? J Craniofac Surg 2017;28:e227-31. doi: 10.1097/SCS.0000000000003434.
18. Tsai LT, Wang CY, Lo YC, Lin CD, Tsai MH. Three-dimensional image analysis of the temporal bone in patients with unilateral attic cholesteatoma. Neuroradiol J 2010;23:307-12. doi: 10.1177/197140091002300308.
19. Schröder S, Lehmann M, Ebmeyer J, Upile T, Sudhoff H. Balloon Eustachian tuboplasty: A retrospective cohort study. Clin Otolaryngol 2015;40:629-38. doi: 10.1111/coa.12429.
20. Silvola J, Kivekäs I, Poe DS. Balloon dilation of the cartilaginous portion of the Eustachian tube. Otolaryngol Head Neck Surg 2014;151:125-30. doi: 10.1177/0194599814529538.
21. Sadé J, Fuchs C. Secretory otitis media in adults: II. The role of mastoid pneumatization as a prognostic factor. Ann Otol Rhinol Laryngol 1997;106:37-40. doi: 10.1177/000348949710600107.
22. Kaya K, Türk B, Akova Soytaş P, Vanli E, Turgut S. Tek taraflı kronik otitis media ile nazal septum ve östaki tüpü açılarının ilişkisi. KBB Uygulamaları 2019;7:38-42. doi: 10.5606/kbbu.2019.24008.
23. Koç A, Ekinci G, Bilgili AM, Akpinar IN, Yakut H, Han T. Evaluation of the mastoid air cell system by high resolution computed tomography: Three-dimensional multiplanar volume rendering technique. J Laryngol Otol 2003;117:595-8. doi: 10.1258/002221503768199906.