

Original Article

# Magnetic Resonance Imaging of the Eustachian Tube and the Paratubal Structures in Patients with Unilateral Acquired Cholesteatoma

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Cite this article as: Şahin MM, Sözmen Cılız D, Çayönü M, Kayalı Dinç S, Akbal Ş, Boynueğri S, et al. Magnetic Resonance Imaging of the Eustachian Tube and the Paratubal Structures in Patients with Unilateral Acquired Cholesteatoma. J Int Adv Otol 2020; 16(3): 373-7.

**OBJECTIVES:** This study aimed to compare the Eustachian tube (ET) and the paratubal structures between the two sides in subjects with unilateral acquired cholesteatoma and a healthy contralateral ear to determine if there are anatomical differences.

**MATERIALS and METHODS:** Of the 217 patients with cholesteatoma evaluated, 36 patients with unilateral cholesteatoma were included in the study. All of the patients had a healthy contralateral ear with no history of surgery. Nine different paratubal parameters were measured through contrast-enhanced magnetic resonance imaging (MRI). The measurements of the ear with cholesteatoma were compared with those of the healthy ear.

**RESULTS:** The bimuscular thickness of the ET lumen, the mucosal thickness of the pharyngeal orifice, the lengths and diameters of the tensor veli palatini muscle and the levator veli palatini muscle, the diameter of the pharyngeal orifice of the ET, the diameter of the lateral pharyngeal recess mucosal thickness, and the diameter between the posterior border of the inferior nasal concha and the pharyngeal orifice of the ET were measured in MRI scans. No statistically significant difference was observed between the healthy ear and the ear with cholesteatoma for any of the parameters measured ( $p > 0.05$ ).

**CONCLUSION:** We did not observe any anatomical differences in the measurements of the ET and the paratubal structures on MRI scans. Although ET dysfunction is considered to be the leading etiologic factor in acquired cholesteatoma, the ET and the paratubal structures may not exhibit an anatomic difference between the ear with cholesteatoma and the healthy contralateral ear.

**KEYWORDS:** Cholesteatoma, chronic otitis media, Eustachian tube, magnetic resonance imaging

## INTRODUCTION

Chronic otitis media (COM) with cholesteatoma is a major health problem; COM is defined as the persistent inflammation of the middle ear. Cholesteatoma is characterized by an intrusion of the keratinizing stratified squamous epithelium into the middle ear and its adjacent structures. It may cause several complications because of its erosive nature. In a large series reported by Osma and colleagues, 78% of subjects who had complications secondary to COM were found to have cholesteatoma<sup>[1]</sup>. The relation between Eustachian tube (ET) dysfunction and cholesteatoma has been clearly stated throughout the historical development of the otologic era. Cholesteatoma usually stems from retraction pockets and invaginations of the tympanic membrane because of ET dysfunction<sup>[2-5]</sup>. The ET is a dynamic structure that connects the nasopharynx with the middle ear and has a complex form with specialized mucosa and paratubal supporting structures, such as soft tissue and muscles.<sup>[6]</sup> Although many factors such as infection, allergy, and anatomic obstruction have been cited as causes of ET dysfunction, a definitive etiologic factor is yet to be determined<sup>[7-11]</sup>. A recent magnetic resonance imaging (MRI) study in patients with COM did not find a significant difference between ears with COM and healthy ears in terms of the anatomy of the paratubal structures<sup>[12]</sup>. In addition, temporal bone computed tomography was performed in patients with unilateral cholesteatoma in two other studies. One of these studies showed that there was no signif-

icant difference between the contralateral healthy ear and the ear with cholesteatoma in terms of the bony structure of the ET, whereas the other study showed that the affected ears of the cholesteatoma patients had a decreased anterior epitympanic space and ET when compared with the healthy control ears<sup>(13,14)</sup>. However, whether there is an anatomical difference between the ET and paratubal soft tissue structures of the affected ear and the healthy contralateral ear in cholesteatoma patients has not been reported in the literature.

This study aimed to investigate the ET and the paratubal structures with contrast-enhanced MRI in a unique patient group with unilateral acquired cholesteatoma, which is the most advanced disease considered to be closely associated with ET dysfunction.

### MATERIALS AND METHODS

Between July 2012 and February 2019, 217 cholesteatoma patients were evaluated for this study. All of the patients had a preoperative MRI and only the patients with unilateral cholesteatoma and a healthy contralateral ear were included in this study. Patients with bilateral COM were excluded from the study. Patients with any history of surgery, including ventilation tubes or paracentesis, were also excluded from the study. According to these criteria, 36 patients were included in the study. The ear with cholesteatoma was assessed as the study group, whereas the healthy ear was assessed as the control group. The MRI findings for the ET and the paratubal anatomical structures were compared between the diseased and the healthy ears.

All investigations were performed in accordance with the Declaration of Helsinki on biomedical studies involving human subjects, and informed consent was obtained from all of the study subjects. The study was approved by the local Institutional Review Board (17.03.2019/E-19-2499).

### Radiological examination

All of the MRI examinations were obtained with an Excite 1.5 T MR unit (GE Medical Systems, Milwaukee, WI, USA). The gradient power was 33 mT/s. Axial T1-weighted, T2-weighted, 3D-FIESTA, contrast-enhanced axial, and coronal T1-weighted sequences were used for routine temporal MRI and gadolinium chelate at a dose of 0.1 mL/kg was used as the contrast agent. The parameters for imaging employed in the study were as follows: T1-weighted (TR, 500 ms; TE, 15.7 ms; slice thickness, 3 mm; interslice gap, 0.5 mm; field of view, 20 × 20 cm; matrix, 320 × 224; excitations, 3); T2-weighted (TR, 3000 ms; TE, 104.8 ms; slice thickness, 3 mm; interslice gap, 0.5 mm; field of view, 20 × 20 cm; matrix, 320 × 224; excitations, 3); 3D-FIESTA (TR, 4.8 ms; TE, 1.4 ms; slice thickness, 0.5 mm; field of view, 18 × 18 cm; matrix, 352 × 192; excitations, 4). T2-weighted images were obtained with fast spin echo sequences. Fluid-attenuated inversion recovery (repetition time, 8.402 ms; echo time, 95.5 ms; slice thickness: 5 mm; interslice gap: 1.5 mm, matrix: 288 × 192; excitations, 1) images and diffusion-weighted sequence images (repetition time, 10,000 ms; echo time, 85.8 ms; slice thickness: 4 mm; interslice gap: 1 mm; matrix: 128 × 128) were obtained from the patients to enable differential diagnosis of cholesteatoma. The measurements were made on post-contrast axial T1 images.

The diameter of the pharyngeal orifice of the ET, the bimuscosal thickness of the lumen of the ET, and the mucosal thickness at the level of

the pharyngeal orifice were measured (Figures 1 and 2). In addition, the diameter of the lateral pharyngeal recess mucosal thickness and the diameter from the pharyngeal orifice of the ET to the posterior border of the inferior nasal concha were measured (Figure 3). Also, the lengths and diameters of the tensor veli palatini muscle (TVPM) and the levator veli palatini muscle (LVPM) were measured at the longest axis that could be obtained (Figures 4 and 5).

### Statistical Analysis

The data were analyzed using the Statistical Packages for the Social Sciences (SPSS) 16.0 (SPSS Inc., Chicago, IL, USA). A paired sample t-test was used to compare the parameters investigated between the groups. The level of significance was set at 0.05.

### RESULTS

In total, 36 patients (18 females and 18 males) aged from 16 to 64 years with a mean age of 36.3 years were included in the study. The

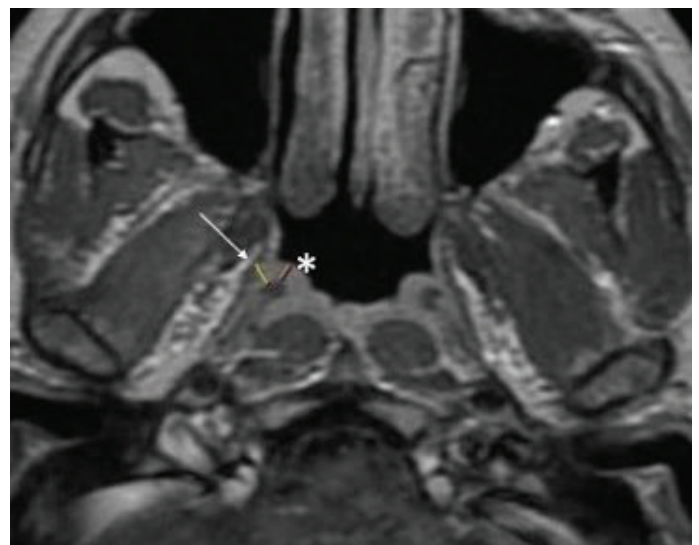


Figure 1. Measurements of bimucosal thickness of the lumen of ET ( ) and mucosal thickness at the level of pharyngeal orifice (\*) on MRI scan.

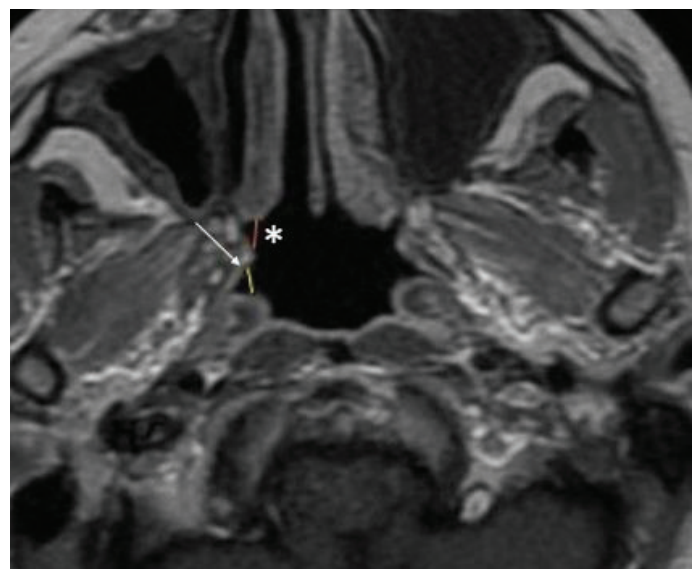


Figure 2. Measurement of diameter from the pharyngeal orifice of the ET to posterior border of inferior nasal concha (\*). Measurement of the pharyngeal orifice of the ET ( ).

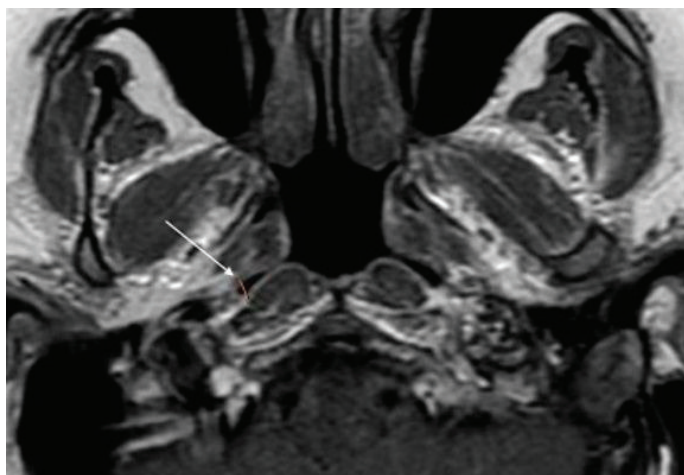


Figure 3. Measurement of lateral pharyngeal recess mucosal thickness ( ).

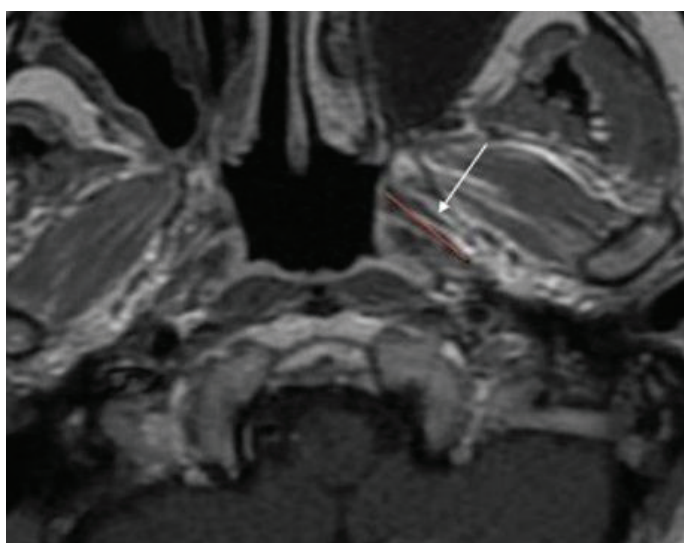


Figure 4. Measurement of length and diameter of the TVPM ( ).

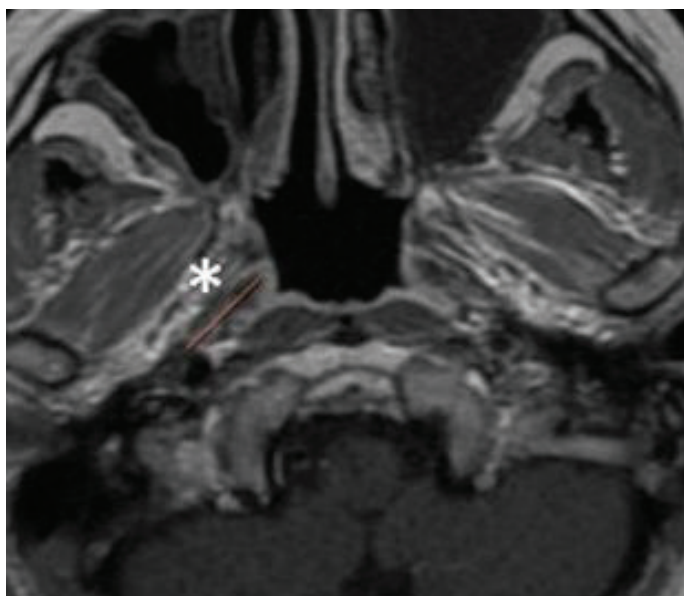


Figure 5. Measurement of length and diameter of the LVPM (\*).

MRI measurements of the ET and the paratubal structures are summarized in Table 1. Nine different parameters were evaluated in the

Table 1. Descriptive statistics of the study

Measured parameters	Cholesteatoma group (n=36)	Control group (Contralateral healthy ear) (n=36)	p
Bimucosal thickness of ET lumen (mm)	3.22±0.6	3.18±0.6	0.75
Mucosal thickness of pharyngeal orifice of ET (mm)	2.6±0.8	2.36±0.7	0.26
Length of TVPM (mm)	21.4±0.2	21.1±0.2	0.48
Diameter of TVPM (mm)	2.5±0.7	2.53±0.7	0.86
Length of LVPM (mm)	19±1.5	19.2±1.2	0.72
Diameter of LVPM (mm)	3.9±0.9	3.9±0.8	0.88
Diameter of pharyngeal orifice of ET (mm)	2.5±0.1	2.8±0.1	0.26
Diameter of lateral pharyngeal recess (mm)	3.96±0.7	3.93±0.8	0.87
Gap between posterior border of INC and pharyngeal orifice of ET (mm)	2.5±0.8	2.8±0.6	0.1

ET: Eustachian tube; TVPM: tensor veli palatini muscle; LVPM: levator veli palatini muscle; INC: inferior nasal concha.

MRI scans. These parameters included the bimucosal thickness of the ET lumen, the mucosal thickness of the pharyngeal orifice, the lengths and diameters of the TVPM and the LVPM, the diameter of the pharyngeal orifice of the ET, the diameter of the lateral pharyngeal recess mucosal thickness, and the diameter between the posterior border of the inferior nasal concha and pharyngeal orifice of ET. No statistically significant difference was observed between the study and the control groups for any of the parameters ( $p>0.05$ , Table 1).

## DISCUSSION

The current investigation had one major finding. According to our results, we did not find any significant differences in the MRI results between the ear with cholesteatoma and the contralateral healthy ear in terms of the investigated measurements related to the ET and the paratubal soft tissue structures.

The ET is an anatomic structure located between the nasopharynx and the middle ear. The ET tube is a dynamic organ responsible for ventilation, clearance, and protection of the middle ear. The ET has a complex structure and its functional role should be assessed as a whole considering the adjacent surrounding tissues<sup>[15, 16]</sup>. Although some studies claimed that the LVPM played a major role in opening the lumen of the ET, opening was mainly attributed to the effects of the TVPM<sup>[6]</sup>. Thus, anatomical and functional abnormalities of the ET and the paratubal structures might be the reason for the development of cholesteatoma. As a result, studies were performed on the ET, the mastoid and middle ear aeration, and the paratubal soft tissues. In one study, it was found that short-term ET opening was related to TVPM contraction and that the tube maintained its openness through the LVPM<sup>[17]</sup>. The first EMG studies of the ET were performed in the 1970s and it was claimed that there was no significant relationship between ET dysfunction and muscular dysfunction<sup>[17, 18]</sup>. In a study by

Sapcı et al.<sup>[19]</sup>, the authors did not observe any electrophysiological differences between the paratubal muscles of the healthy group and those of the COM group when compared with a group with palatal pathology. Nevertheless, Chang KH et al.<sup>[16]</sup> observed a decrease in LVPM amplitudes in patients with ET dysfunction, and they indicated that LVPM dysfunction rather than TVPM dysfunction might be an indicator of ET dysfunction. Poe et al.<sup>[20]</sup> applied high-speed video endoscopy, which might be a functional method for evaluating ET dysfunction, in 58 ears with clinical evidence of ET dysfunction and they observed reduced tubal dilatation in all participants. The principal limitation of this method was that it could only evaluate the ET orifice rather than the ET as a whole. Lindstrom et al. passed a 0.5 mm flexible endoscope through the ET from the tympanic orifice into the pharyngeal orifice and they were successful in only 16% of patients with COM. Rates of stenotic blockage were found to be 42% and 37% at the isthmus and the infundibulum, respectively. The ET mucosa was found to be abnormal in 64% of cases. The main limitation of their study was the absence of a control group.<sup>[7]</sup> Karasen et al.<sup>[9]</sup> applied ventilation scintigraphy and they observed decreased uptake in 11 of 16 patients (68.7%) with one-sided ET dysfunction. However, they found abnormal uptake in 23% of the healthy population. The small number of participants was a limitation of that study<sup>[9]</sup>. These limited and conflicting data obtained from functional tests illustrate the challenges of evaluating the ET.

Cholesteatoma might be considered the most advanced form of COM. The presence of cholesteatoma was the most important indicator of an irreversible ongoing dysfunction in the middle ear. Although the pathogenesis of acquired cholesteatoma remains controversial, the most common theory was the formation of a retraction pocket in the tympanic membrane because of the dysfunction of the ET (hydrops ex vacuo theory)<sup>[21, 22]</sup>. Therefore, we thought that the presence of unilateral cholesteatoma, while the contralateral ear was completely healthy, was the best criterion to determine the population in order to evaluate ET dysfunction.

In this study, we used MRI to evaluate the ET and the paratubal structures through high-contrast resolution of the soft tissue. Similarly, several studies in the literature used MRI to assess the ET and the paratubal structures<sup>[10-12]</sup>. In an MRI study of 16 patients with a clinical diagnosis of ET dysfunction, the authors found failure in the opening of the ET and abnormalities of the paranasal sinuses and nasopharynx. They concluded that ET opening failure might be because of the swelling of the mucosa and could be associated with tumors. However, the control group of that study was not the healthy side of the study group<sup>[10]</sup>. In addition, another MRI study that investigated age-related changes in paratubal structures found that the ET cartilage and the TVPM did not exhibit any difference during the period in which age-related reduction was being observed in the Ostmann fat pad<sup>[11]</sup>. Measurements of ET mucosal thickness were carried out for both the lumen mucosa and pharyngeal orifice mucosa. We measured the lengths and the diameters of the TVPM and the LVPM as well as the diameter of the pharyngeal orifice of the ET. We did not observe any differences between the healthy contralateral ears and the ears with cholesteatoma in any of these parameters. Similar to our study, Terzi et al.<sup>[12]</sup> did not observe any difference in these parameters in their study that comprised 40 patients with COM. However, heterogeneous COM groups were included in their study: 15 of

the 40 patients were diagnosed with progressive COM and the cholesteatoma group consisted of only eight patients<sup>[12]</sup>. In our study, we formed a homogeneous group of patients with unilateral cholesteatoma, which is the most advanced disease considered to be closely associated with ET dysfunction.

ET dysfunction was also seen in diseases such as nasopharyngeal tumors and masses, pharyngeal mucosal swelling, and nasal-paranasal diseases that cause mechanical stenosis in the ET orifice.<sup>[10,20]</sup> We measured the diameter of the lateral pharyngeal mucosa, which is the most common site of nasopharyngeal cancer, and the gap between the posterior border of the inferior nasal concha and the pharyngeal orifice of the ET with the aim of not ignoring mechanical obstruction. There were no differences between groups according to these parameters.

## CONCLUSION

This paper reports that MRI scans showed no significant differences in the ET and the paratubal structures between unilateral cholesteatoma ears and contralateral healthy ears. Although ET dysfunction is considered to be the leading etiologic factor in acquired cholesteatoma, the ET and the paratubal structures may not exhibit an anatomic difference between the ear with cholesteatoma and the healthy contralateral ear. This is an important issue in considering the causes of cholesteatoma.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Ethics Committee of Ankara Numune Training and Research Hospital.

**Informed Consent:** Informed consent is not necessary due to the retrospective nature of this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – M.M.Ş., D.S.C., M.Ç., A.E.; Design – MMS, DSC, MC, SKD.; Supervision – M.M.Ş., M.Ç., A.E.; Resource – M.M.Ş., D.S.C., M.Ç., S.A.; Materials – M.M.Ş., D.S.C., S.K.D., S.A., S.B.; Data Collection and/or Processing – M.M.Ş., D.S.C., M.Ç., S.A., S.B.; Analysis and/or Interpretation – M.M.Ş., D.S.C., M.Ç.; Literature Search – M.M.Ş., D.S.C., S.K.D., S.A., S.B., A.E.; Writing – M.M.Ş., M.C., A.E.; Critical Reviews – M.M.Ş., D.S.C., M.Ç., A.E.

**Conflict of Interest:** The authors have no conflict of interest to declare.

**Financial Disclosure:** The authors declared that this study has received no financial support.

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