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Research Paper

Evaluation and significance of Eustachian tube angles and pretympanic diameter in HRCT temporal bone of patients with chronic otitis media

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ET angles;
Pretympanic diameter

Abstract *Objective:* To evaluate the significance of Eustachian tube (ET) angles and ET pretympanic diameter on high resolution computed tomography (HRCT) Temporal bone in patients with chronic otitis media (COM).
Methods: A retrospective study was carried out at Tertiary care centre. Group A included 92 ears with COM (38 patients with bilateral COM and 16 with unilateral COM); and Group B included 108 normal ears (54 patients with bilateral normal ears). Reid plane-ET angle, Tubotympanic angle and the ET pretympanic diameter was evaluated by HRCT temporal bone, and compared in the two groups. Patients with chronic otitis media (Group A) were subdivided into Group A1 (Blocked ET) and Group A2 (Patent ET). The parameters were evaluated and compared in the subgroups too.
Results: The mean Reid plane-ET angle and Tubotympanic angle in Group A was 25.41 ± 2.57 and 148.12 ± 3.43 respectively; whereas in Group B it was 27.56 ± 3.62 and 145.14 ± 4.34 respectively. Reid plane-ET angle was significantly less in patients with COM and Tubotympanic

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angle was significantly more obtuse in COM patients. ET pretympanic diameter was (5.37 ± 2.10) mm in Group A and (6.47 ± 2.40) mm in Group B. It was significantly less in patients with COM. A significant correlation was found between the ET patency and the two ET parameters (Reid plane-ET angle and pretympanic diameter).

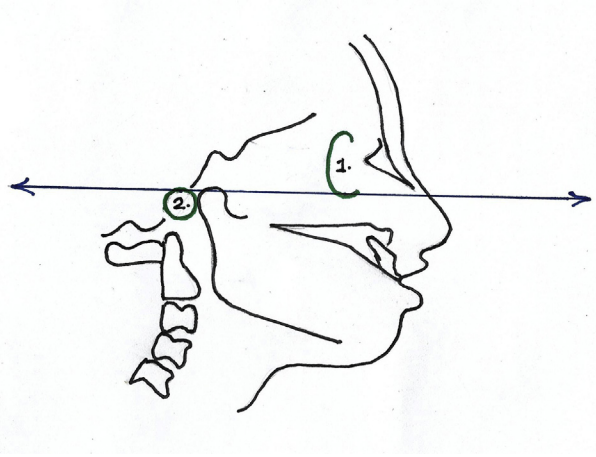
Conclusions: Eustachian tube angles in adults may play a significant role in the etiology of chronic otitis media. Decrease in Reid plane-ET angle and pretympanic diameter on HRCT temporal bone can be used to predict ET dysfunction and to plan the surgical management of chronic otitis media.

Introduction

The Eustachian tube (ET) is of great importance in chronic otitis media (COM), both pathogenetically and surgically, in that ET dysfunction is an important cause of middle ear disease. Radiologic evaluation, and especially computed tomography (CT), is essential when preoperatively evaluating the middle ear and mastoid. The recently developed multiplanar reconstruction technique has made it possible to obtain images parallel or perpendicular to the long axis of the ET. This technique is useful for better understanding the ET and ET-related diseases.[1,2] The angles relative to the plane of ET have previously been measured in a lot of work. These measurements were obtained in mostly cadaver studies. In various studies with the temporal bone CT, the Eustachian tube placement was assessed according to the relationship with other structures.[2] Middle ear ventilation and the drainage of secretions are the basic functions of Eustachian tube. These functions can be achieved optimally with correct placement of Eustachian tube. ET angles give the idea about the direction and placement of the tube. This study aims to summarize the use of imaging in the anatomical assessment of ET angles and to explore how radiological techniques can be used to assess tube function. The objectives of our study are to evaluate the Reid plane-ET angle, Tubotympanic angle and ET pretympanic diameter by high resolution CT (HRCT) Temporal bone, in patients with chronic otitis media and its comparison in normal ears. Correlation between the ET anatomy and ET function was aimed in patients with chronic otitis media. Variation in these angles and pretympanic diameter may be the predisposing factor for ET dysfunction, thus leading to chronic otitis media. In otitis media with perforation of tympanic membrane, transtympanic endoscopy can be used to evaluate the ET tympanic orifice and pretympanic segment. These methods require trained and skilled technicians, as well as special equipment. Moreover, endoscopy has been found unsuitable for assessments around the isthmus owing to its poor resolution and the relatively large diameter of the endoscope.[3] In this study, we assessed ET parameters non invasively by HRCT temporal bone.

Materials and methods

We retrospectively studied 108 patients who underwent HRCT Temporal bone in our Institute between January 2013 and January 2017. Institutional Review Board approval was taken. The study was performed according to the guidelines and ethical standards of the Helsinki Declaration. We evaluated the Reid plane-ET angle, Tubotympanic angle and ET pretympanic diameter by HRCT Temporal bone in these patients. Out of the total 108 patients, 54 patients had COM without cholesteatoma (38 patients had bilateral disease and 16 patients had unilateral disease). 54 patients had normal ears and had CT examination of temporal bone done for another reason. Thus the diseased ears were 92 (Group A) and healthy ears were 108 (Group B). Patients with age group 15—65 years were included. We excluded patients with any congenital deformity of ear and patients with previous ear surgery. HRCT Temporal bone with Eustachian tube multiplanar reconstruction (GE Revolution ACTS EX 16 slice CT machine -USA) was done in all patients. The slice thickness was 1 mm. The horizontal plane, crossing bilateral inferior orbital wall and the bilateral upper wall of the external ear canal known as "Reid plane," was selected (Schema 1, Fig. 1). The orifices of Eustachian tubes could be seen in the same section by using multiplanar reconstruction technique in the coronal images. Pharyngeal and tympanic orifices of the Eustachian tubes were demonstrated exactly at the same section. This direction was determined as the line of the Eustachian tube. The angle was measured between the horizontal plane



Schema 1 Reid plane passing through inferior wall of orbit and superior wall of external auditory canal (EAC). Labels: 1- Orbit, 2- External auditory canal.

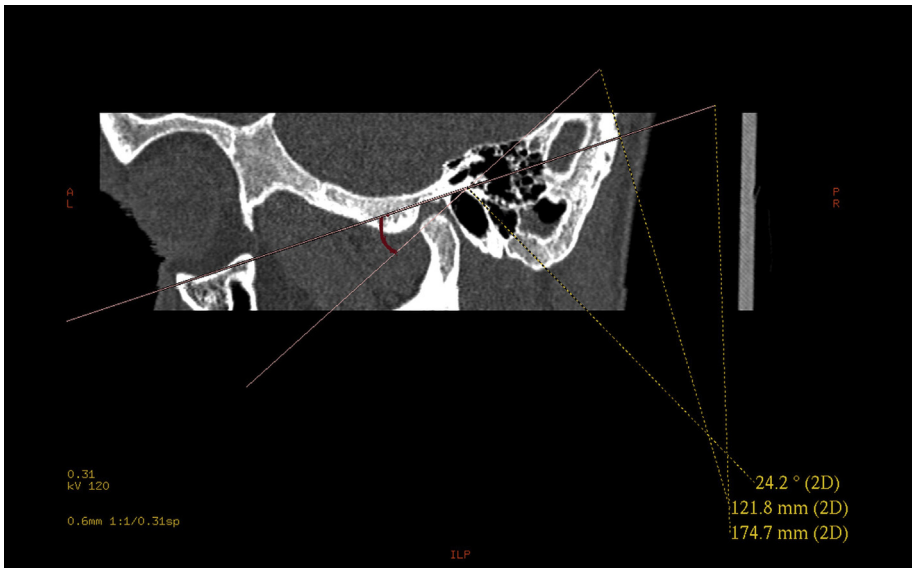
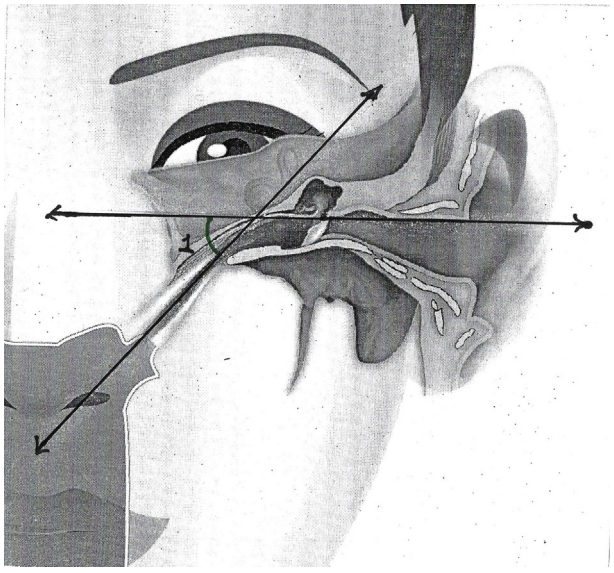


Figure 1 Reid- ET angle on HRCT temporal bone.

passing through inferior orbital wall and this line (Fig. 1, Schema 2). In addition, Tubotympanic angle was measured in all patients. Tubotympanic angle was considered as the angle between the line extending through the tympanic orifice of the Eustachian tube and the center of the longitudinal axis drawn from the bony external ear canal center (Fig. 2, Schema 3). Pretympanic segment is the funnel shaped portion of Eustachian tube adjacent to the tympanic orifice. On the axial view, it was easy to find the lumen of the pretympanic segment (Fig. 3).

In the preoperative evaluation of patients with chronic otitis media, we evaluated the ET function by the perception of ear drops reaching throat in dry ear. We classified the patients of chronic otitis media (Group A) in two subgroups. Group A1 ($n = 42$) included patients with blocked ET and Group A2 ($n = 50$) included patients with patent ET. With the purpose of correlating ET anatomy and ET function, we compared the parameters in the subgroups too.

Statistical significance between the two groups was calculated by paired *t*-test (SPSS software). *P* value < 0.05 was considered to be statistically significant. The odds ratios (*OR*) and 95% confidence intervals (*CI*) were added, if *P* value was less than 0.05.



Schema 2 Reid plane-ET angle.

Results

The mean age was (38.4 ± 7.9) years with a range of 15—65 years. The male to female ratio was 1:0.76.

Discussion

The Eustachian tube is a complex and inaccessible structure, which maintains middle ear ventilation to facilitate transmission of sound from the tympanic membrane to the cochlea. A renewed interest in treatments for Eustachian tube dysfunction has led to a demand for methods of imaging the Eustachian tube, and assessing tube opening noninvasively.[4] There are two clinical requirements for radiological assessment of the ET: a reliable test of ET function and detailed anatomical imaging of the ET and its surrounding structures for surgical planning.[5] Reid horizontal plane was found in 1962 by the world federation of radiology. It is the plane at bilateral inferior orbital walls and superior walls of the bilateral external ear canal. This plane is considered to be the position at which the head in a neutral anatomical position. Reid plane-Eustachian tube angle is defined as the angle between tympanic pharyngeal orifice and Reid plane.[6] (Schema 2; Fig. 1) Tubotympanic angle is an angle more recently associated with chronic

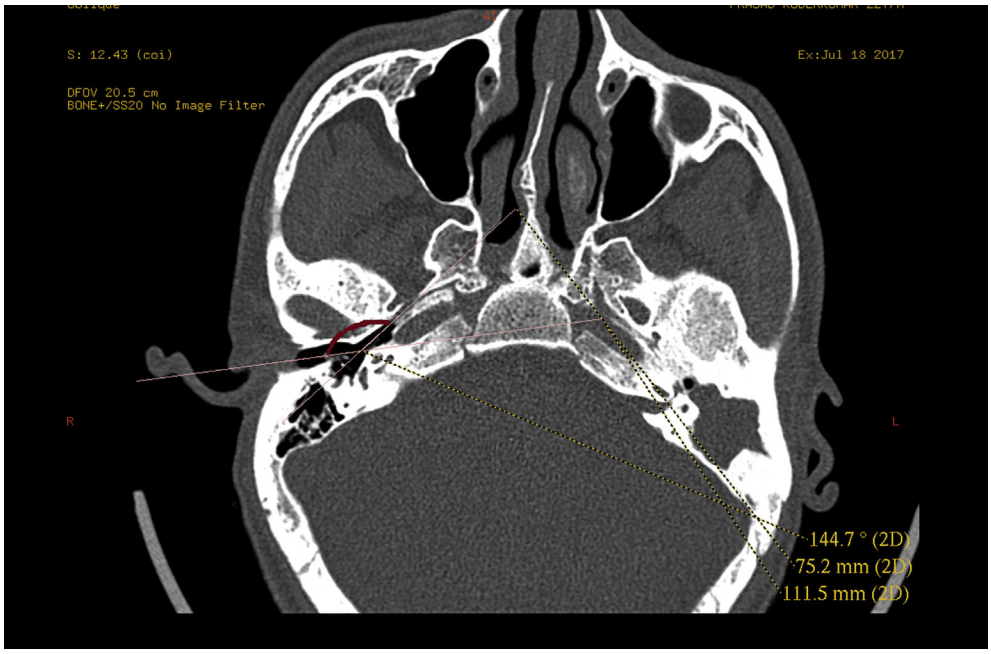
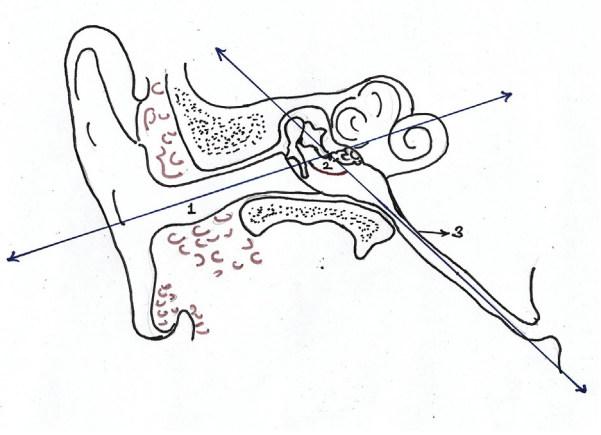


Figure 2 Tubotympanic angle on HRCT temporal bone.



Schema 3 Tubotympanic angle between the lines passing through long axis of EAC and long axis of ET. Labels: 1- External auditory canal, 2- Tubotympanic angle, 3- Eustachian tube.

otitis media (COM). This angle is defined as the angle of the longitudinal axis of the ET along the tympanic orifice and the longitudinal axis of the center the bony external ear canal in the axial plane.[6] (Schema 3; Fig. 2) According to the genetic theory of the temporal bone pneumatization, the pneumatization is genetically determined and bad pneumatized ears are candidates for COM. The environmental theory supporters claim that environmental factors such as frequent upper respiratory tract infections, poor living conditions and smoking that causes chronic otitis media make reduced temporal bone pneumatization.[7] The variation in the ET angles can affect the middle ear and mastoid pneumatization secondary to poor ventilation through ET.

Takasaki et al[7] detected the ET angles in Reid plane $27.3^{\circ} \pm 2.0^{\circ}$ for the right ear, $27.3^{\circ} \pm 2.8^{\circ}$ for the left ear in the normal adult population. In our study, the mean Reid plane-ET angle was 27.56 ± 3.62 in healthy ears and 25.41 ± 2.57 in diseased ears (Table 1). Here, the angle in normal individuals was seen to be close to the angle measured by Takasaki et al.[7] We found this angle significantly less in the patients with COM. This may affect the pneumatisation of mastoid due to inadequate ventilation of middle ear and mastoid through the ET, thus contributing to the factors developing chronic otitis media. We found the average value of Tubotympanic angle 148.12 ± 3.43 in the diseased ears and $145.14^{\circ} \pm 4.34^{\circ}$ for the healthy ears (Table 1). These values suggest that the Tubotympanic angle is more obtuse in patients with COM. This might increase the chances of upper respiratory infections spreading to the middle ear and contributing to the factors causing otitis media. As we found, the decrease in Reid plane-ET angle and increase in Tubotympanic angle increases the susceptibility to otitis media.

In the present study, we chose the pretympanic portion as the measured target among the 6 segments of the ET: the pharyngeal portion, the mid portion, the pre-isthmus portion, the isthmus portion, the post-isthmus portion and the pretympanic portion (Schema 4). Pretympanic portion is not only the largest one in the entire ET, but it is also the area most affected by middle ear pathology. A histopathology study reported that the percentage of the luminal circumference occupied by inflammatory reaction in each ET segment is increased from the pharyngeal portion (42%) to the pretympanic portion (62%).[7] Mucosal swelling of the pretympanic portion is a major factor for differentiating patients with COM from normal subjects. On the axial view, it is easy to find the lumen of the pretympanic segment (Fig. 3), where it connects with the bulging of the tensor tympani muscle on its roof and it is located in the lateral side of the internal carotid artery and cochlea. The average anteroposterior (AP) distance of the pretympanic bony ET

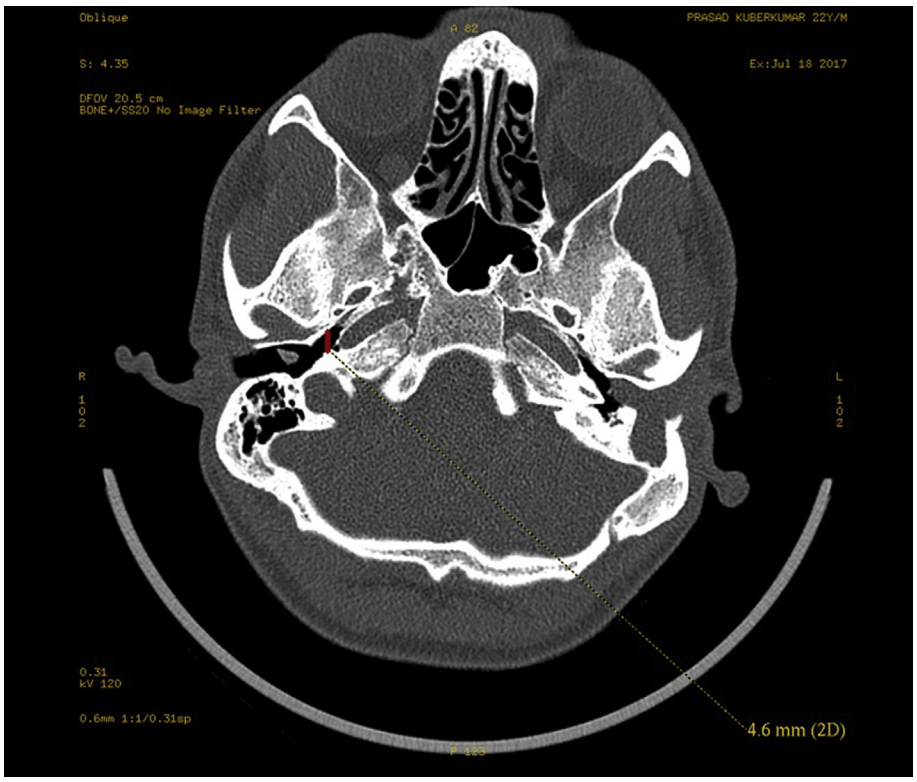
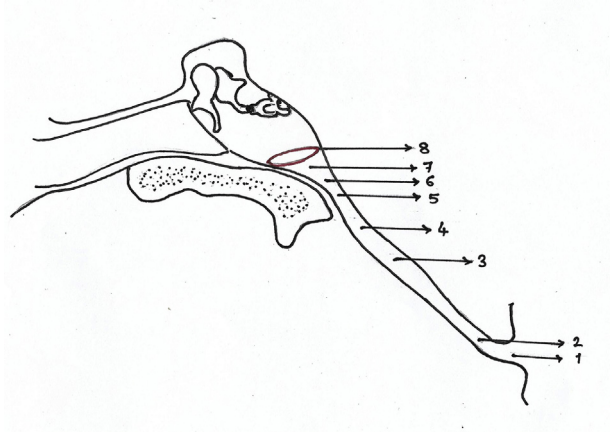


Figure 3 Pretympanic diameter of Eustachian tube on HRCT temporal bone.

Table 1 Statistical comparison of ET parameters in the groups A and B.

Group	Case no.	Reid plane-ET angle	Tubotympanic angle	Pretympanic diameter (mm)
Group A (COM)	92	25.41 ± 2.57	148.12 ± 3.43	5.37 ± 2.10
Group B (Healthy ear)	108	27.56 ± 3.62	145.14 ± 4.34	6.47 ± 2.40
Two tailed *P* value		0.0003 (<0.05)	0.0019 (<0.05)	0.0099 (<0.05)
t value with 95° *CI*		6.472	5.2453	2.8852
Degree of freedom/ Standard error of difference		7/0.332	6/0.569	8/0.381



Schema 4 Parts of Eustachian tube. Labels: 1-Pharyngeal orifice, 2-Pharyngeal portion, 3-Mid-portion, 4-Pre-isthmus, 5-Isthmus, 6- Post-isthmus, 7-Pretympanic, 8- Tympanic orifice.

in normal adults was estimated to be 8.4 mm.[7] In our study, the mean AP diameter of the pretympanic segment in normal ears was (6.47 ± 2.40) mm; and in the diseased ears, it was significantly less (5.37 ± 2.10) mm (Table 1). In chronic otitis media patients with ET dysfunction, we found a significant decrease in pretympanic diameter and the Reid plane-ET angle; but the Tubotympanic angle did not show any association with ET dysfunction (Table 2). ET dysfunction affects the middle ear ventilation thus exacerbating middle ear pathology. It is an important prognostic factor for the success in tympanoplasty.[8] ET dysfunction secondary to infection and inflammation can be treated with medications, but the bony narrowing of pretympanic segment demands the surgical modification in middle ear keeping in mind the post operative hypoventilation of middle ear. Surgical modification can be done by using cartilage graft, for better stability and thus preventing

Table 2 Statistical comparison of ET parameters in the groups A1 and A2.

Group		Case No.	Reid plane-ET angle	Tubotympanic angle	Pretympanic diameter (mm)
Group A (COM)	Group A1 (Blocked ET)	42	24.16 ± 1.70	148.17 ± 3.24	4.79 ± 1.88
	Group A2 (Patent ET)	50	26.18 ± 2.46	148.02 ± 3.58	5.99 ± 2.12
Two tailed *P* value			0.0202 (<0.05)	0.4676 (>0.05)	0.0117 (<0.05)
t value with 95° *CI*			3.7356	0.8018	3.8730
Degree of freedom/Standard error of difference			4/0.541	4/0.150	5/0.258

medialisation of the graft. During tympanoplasty, the graft (temporalis fascia/perichondrium) can be supported by single cartilage slice anteriorly. This offers extremely reliable method for reconstruction of tympanic membrane in cases of ET dysfunction.[8] In cases of severe ET dysfunction due to pretympanic segment narrowing, balloon tuboplasty of the pretympanic segment can be combined with tympanoplasty, resulting in significantly high graft take up rate and restoration of middle ear integrity.[9,10] In our study, we found that decrease in pretympanic diameter and Reid plane-ET angle coexist with ET dysfunction, thus demanding intraoperative surgical modifications. This research will be continued further by us; assessing the postoperative ventilation of middle ear and its correlation with the ET angles and ET pretympanic diameter.

Conclusion

Despite an increasing number of technological advances, access to the Eustachian tube remains challenging. High Resolution Computed Tomography of Temporal bone with multiplanar reconstruction is a non invasive, reliable and easy investigation to assess the Eustachian tube parameters. Although chronic otitis media is a multifactorial disorder, the decrease in Reid plane- ET angle, ET pretympanic diameter and increase in Tubotympanic angle in adults may play a significant role in its etiology. Decrease in ET pretympanic diameter and Reid plane-ET angle can be used to predict the ET dysfunction and to plan the surgical treatment accordingly.

Conflicts of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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