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ORIGINAL ARTICLE

Intricacies of the Epitympanum-Endoscopically Revisited

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Abstract Endoscopic demonstration of the temporal bone and its related structures is a better tool specially for understanding the complex intricacies of the middle ear. In this study we aim to understand the anatomy of the epitympanum/attic with the aid of Otoendoscopy using transmastoid and transattic approaches. Fifty four adult cadaveric temporal bones were dissected at our centre. Transcanal and transmastoid approaches were performed to visualize the middle ear spaces. We could demonstrate Cog, a ridge of bone that extends inferiorly from the tegmen plate just anterior to the head of malleus, epitympanic diaphragm by exploring the three malleal ligamental folds, Prussak's space and its boundaries, pathways of ventilation. Better understanding of the ventilation pathways of the middle ear, restoration of adequate air access in the attic help in better healing and prevent recurrences of diseases. Thus having a three dimentional orientation of the attic and its contents aid the surgeon in performing better surgery and thus provide disease free ear.

Keywords Middle ear spaces · Endoscope · Prussak's space

Introduction

The middle ear cavity is an irregular air-filled space in the center of the temporal bone. It lies at the intersection between two axes: one latero-medial between the external and internal auditory canals, the other antero-posterior between the mastoid antrum and the eustachian tube.

Although performing middle ear dissection microscopically is a tradition, endoscopic demonstration of the temporal bone and its related structures is a better tool specially for understanding the complex intricacies of the middle ear. The first description of middle ear imaging by endoscopes was introduced in 1967. Using endoscopes with varied angulations allows the surgeon to see 'around corners', giving the ability to explore all of the hidden areas that are often not visualized using a microscope [1, 2]. A good understanding of the anatomy of the middle ear mucosal folds and their relationships inside the middle ear cavity is fundamental in the learning process of functional middle ear surgery.

The middle ear is divided into three parts based on its relation with tympanic membrane: Epitympanum (attic), mesotympanum and hypotympanum. Epitympanum is located above the level of anterior and posterior spines (Notch of Rivinus). Mesotympanum lies between the Notch of Rivinus superiorly to inferior tympanic annulus inferiorly. The part of middle ear below the level of inferior tympanic annulus is hypotympanum. The Epitympanum or attic is the space defined superiorly by the tegmen plate, medially by the prominence of horizontal facial canal and ampullary ends of lateral and superior semi-circular canals, laterally by the scutum and posteriorly it communicates with antrum through aditus and antrum.

The mucous membrane is thrown into a series of mucosal folds by the intra tympanic structures. The mucosal folds occur in fairly constant anatomical positions but are often considered as residues of inflammation and as adhesions. These in turn divide the middle ear into definite compartments. In this study we aim to understand the

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anatomy of the epitympanum/attic with the aid of Otoendoscopy using transmastoid and transattic approaches.

Objective

To understand the 3D orientation of Epitympanum with the aid of otoendoscopy.

Materials and Methods

Fifty four adult cadaveric temporal bones were dissected at our centre. In all the temporal bones, dissection was performed using an endoscope with two different angles (0 and 45 degree scope) and a digital video camera. The bones were mounted on a House-Urban temporal bone holder. The equipments used included high-speed (reverse and forward cutting) drill up to 35,000 rpm, cutting burrs of 6, 3 mm, diamond burrs of 2 and 1 mm, curette, micro scissors,drip stand, suction irrigation, operating gown, goggle and apron.

Transcanal and transmastoid approaches were performed to visualize the middle ear spaces. A posterior tympanomeatal flap was created with the 0 degree endoscope using a double ended knife with the superior incision at the 12 o'clock position and the inferior incision at the 6 o'clock position. The tympanomeatal flap was elevated and transposed inferiorly.

We have demonstrated Tympanic diaphragm and its orientation in the middle ear cavity, mucosal folds and the epitympanum. In our study we have demonstrated the attic and its contents by placing the endoscope through the aditus.ie.,we have been demonstrated with intact tympanic membrane using angled endoscopes. Superior view of the epitympanum and its contents have been demonstrated by transmastoid and transattic approaches.

Results

With the endoscopic approach, we could appreciate the epitympanum/attic which is lying above the level of anterior and posterior tympanic spines. We could demonstrate Cog, a ridge of bone that extends inferiorly from the tegmen plate just anterior to the head of malleus (Fig. 1). It lies immediately superior to and just posterior to cochleariform process. It divides the epitympanum into posterior and anterior epitympanic space. The body of the incus articulates with the head of the malleus to form an ossicular mass that occupies most of the epitympanum.

It was possible to document the characteristics of the epitympanic diaphragm by exploring the three malleal

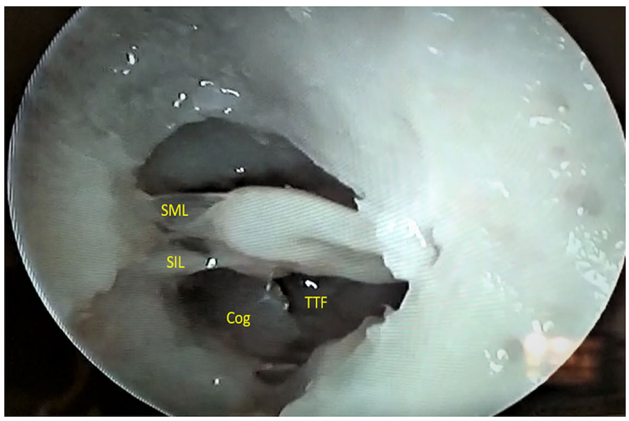

Fig. 1 Endoscopic demonstration of the Superior malleal ligament(SML), Superior incudal ligament(SIL), Cog dividing the medial epitympanic space into anterior and posterior attic spaces, Tensor tympani fold (TTF) in the attic

ligamental folds (the anterior, lateral and posterior), and the two purely membranous folds (the tensor tympani fold and the lateral incudomalleal fold) forming the Tympanic diaphragm (Fig. 3). The diaphragm dividing the attic into upper and lower units (Prussak's space) was noted. The ventilation pathways namely anterior and posterior tympanic isthmus were noted.The anterior tympanic isthmus lies between the tensor tympani fold and the stapes. Posterior tympanic isthmus lies posterior to the stapes. (Fig. 5)

Middle ear space namely Prussak's space in the epitympanum could be demonstrated endoscopically in all the cadavers we dissected. The superior limit of Prussak's space was the lateral malleal ligament inserting laterally onto the medial wall of the scutum. The medial and inferior aspects of Prussak's space were formed by the neck and the lateral process of the malleus respectively. Laterally bounded by the pars flaccida. No anatomical variations of the neck and the lateral process of the malleus were observed during the dissections. (Fig. 6)

It was noted that the anterior attic is divided by the cog into anterior epitympanic space (supratubal recess) and anterior malleal space. Superior incudal fold divides the posterior attic into medial and lateral posterior attic (Figs. 1, 2, 3, 4, 5, 6, 7, 8).

The air pathways of ventilation are: anterior most air pathway lying between the tensor tympani canal medially, tensor tympani tendon posteriorly and anterior malleal ligament laterally. Middle air pathway lies between the tensor tympani anteriorly, facial canal medially and incudomalleolar joint laterally. Posterior air pathway lies between the long process of incus and posterior incudal ligament laterally,facial canal medially and posterior tympanic wall posteriorly (Fig. 7).

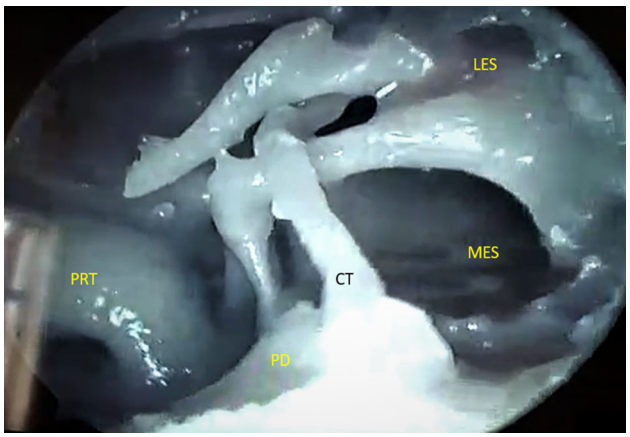

Fig. 2 Demonstration of the ossicles along with chorda tympani nerve (CT), Lateral epitympanic space (LES), Medial epitympanic space (MES), Pyramid(PD), Promontory(PRT)

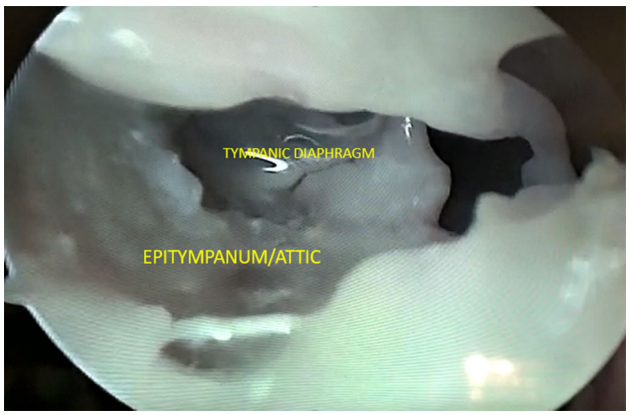

Fig. 3 Demonstration of the Epitympanum/attic, Tympanic diaphragm. (Superior view)

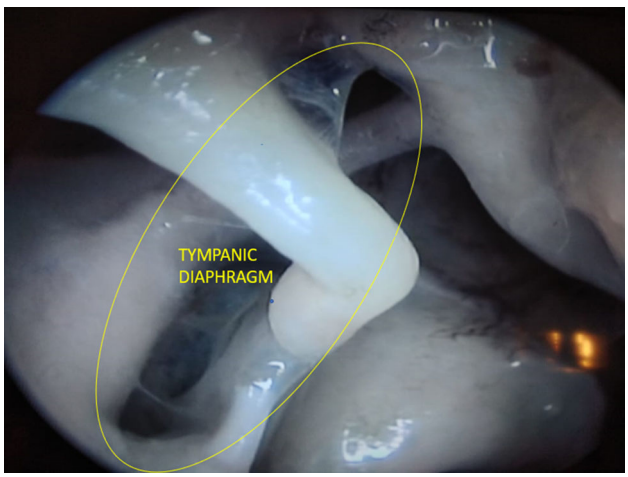

Fig. 4 Demonstration of tympanic diaphragm and tympanic isthmus. (Inferior view)

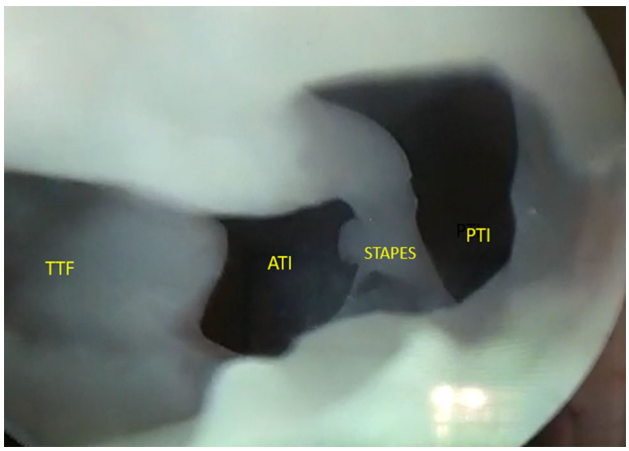

Fig. 5 Demonstrating the ventilation pathways: Anterior tympanic isthmus(ATI) and Posterior tympanic isthmus(PTI), stapes and the tensor tympani fold(TTF).(Superior view)

Fig. 6 Demonstration of superior view of Prussak's space(encircled) with intact tympanic membrane. It is bounded by Lateral Malleal Fold (LMF) superiorly, lateral process of malleus inferiorly, medially by the neck of malleus and laterally by the pars flaccida

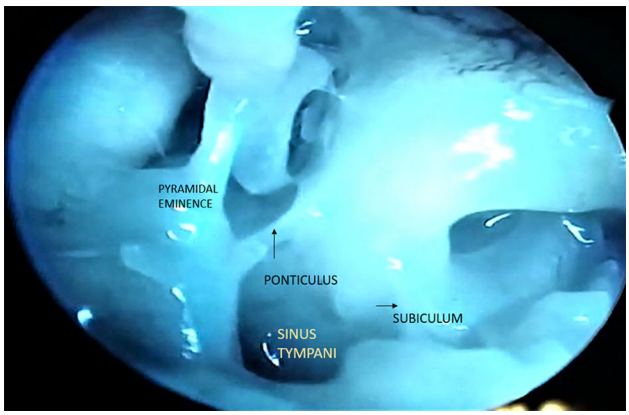

Fig. 7 Demonstration of sinus tympani between ponticulus and subiculum

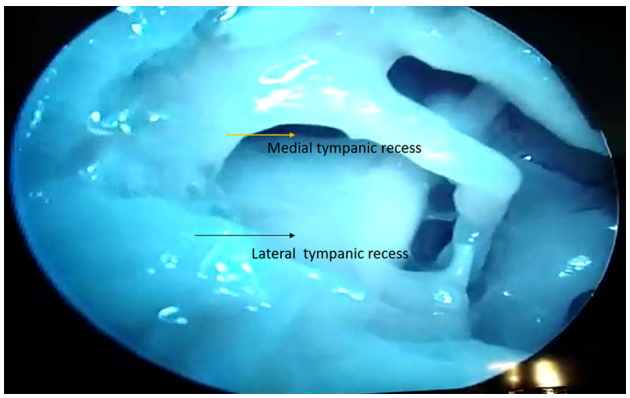

Fig. 8 Demonstartion of medial and lateral tympanic recesses

Discussion

The middle ear is an air filled space formed by extension of the foregut into the anlage of the temporal bone. It is a complex region comprising of the osscicles, mucosal folds, tendons, muscles, spaces, recesses and the vascular and neuronal supply. Also these structures are in close proximity to vital structures like facial nerve, carotid artery, middle cranial fossa. Understanding the intricacies of middle ear and its contents is quite challenging and on performing multiple temporal bone dissections, one can excel in knowing the anatomy perfectly. (Fig. 9)

Endoscopes offer wide fields of view with minimal exposure, looking behind the obstructions or overhangs, and peering into recesses with much less requirement for surgical exposure than demanded by conventional techniques. The endoscopic approach guaranteed a good exposure of the middle ear ligamental folds, mucosal folds and middle ear spaces. (Fig. 10)

Chatellier and Lemoine [3] introduced the concept of the 'epitympanic diaphragm' in 1946, upon which the

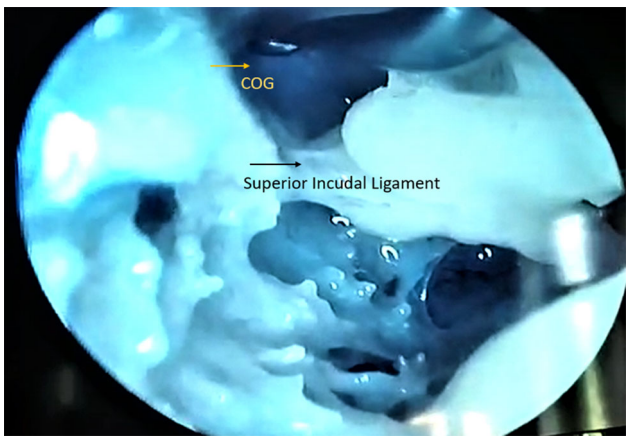

Fig. 9 Demonstration of Cog

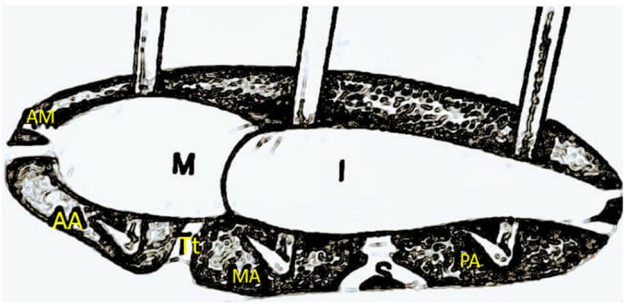

Fig. 10 Demonstration of ventilation pathways. *AA* Anterior air pathway, *Tt* Tensor tympani tendon, *Am* Anterior malleal ligament, *MA* Middle air pathway, *PA* Posterior air pathway

modern theories of tympanic ventilation have been developed. Currently it is understood that the ossicular chain, associated ligaments and mucosal folds almost completely partition the epitympanic space from the mesotympanum except a few small but constant openings. These are called "air pathways" between the mesotympanum and epitympanum. The tensor tympani fold and (mucosal fold between anterior mallear ligament and tensor tympani tendon) of anterior malleolar space is perforated and forms an air pathway called anterior air pathway. In the medial part of attic, two openings called anterior and posterior isthmus are located anterior and posterior to the long process of incus respectively. The anterior isthmus (middle air pathway) lies between tensor tympani tendon and stapes posteriorly. Posterior isthmus (posterior air pathway) lies posterior to the stapes and medial incudal fold. (Fig. 11)

The tympanic diaphragm separates the upper unit of the attic superiorly from the mesotympanum and the lower unit, Prussak's space inferiorly. The lateral malleal fold separates Prussak's space from the upper unit of the epitympanum, hence its called the lower unit of the attic. The attic and the mastoid are isolated from the mesotympanum by the tympanic diaphragm. Aeration to the attic occurs through a 2.5 mm opening in the diaphragm called the tympanic isthmus. The entire attic is ventilated through tympanic isthmus. However the prussak's space is ventilated through the posterior pouch of Von Troltsch. The isthmus is divided into two portions by the medial incudal fold.

There is a discrepancy in understanding the exact anatomy of middle ear spaces inspite of performing dissections. Few authors state that the attic is divided into medial and lateral attic space. The medial attic space is further divided into medial and lateral attic spaces by the cog.

Literatures have reported that an endoscopic approach to attic cholesteatoma [4] allows clear observation of the tensor fold area and further excision of the tensor fold modifies the epitympanic diaphragm. This permits the

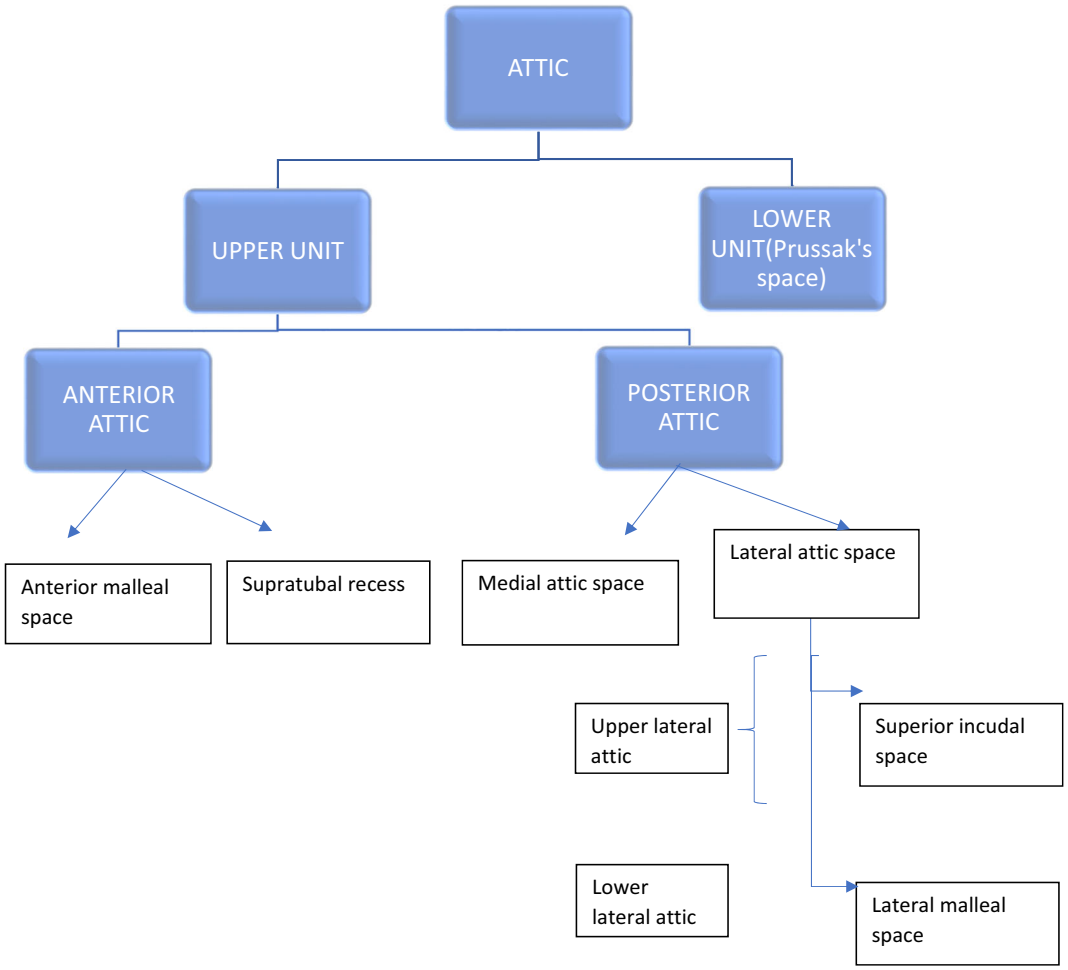

Fig. 11 Attic and its compartments

removal of cholesteatoma and direct ventilation of the epitympanum, preventing the development of a retraction pocket or attic cholesteatoma recurrence, with good functional results.

Morimitsu et al. [5] stated that with 'anterior tympanostomy' i.e., removal of the bone from the lateral attic to the zygoma drilling in front of the head of the malleus, it was possible to expose the tensor fold area and excise it.

Unroofing of the attic spaces by removing the outer attic wall,with or without intact ossicular chain is called atticotomy. Palva et al. [6] suggested an 'Endaural Atticotomy' which extends to the supratubal recess. Exposure of the tensor fold area was possible cutting the neck of the malleus to allow a lateral lifting of the manubrium.

In the current study, we found that the success in understanding the epitympanum, its associated spaces, ligaments and mucosal folds could be well understood and offering a 3D orientation was attributed to the use of the endoscopic approach. Compared to the microscopic technique for middle ear dissection, the endoscope allows better understanding of the delicate middle ear structures. Moreover, the endoscope allows a very close observation of anatomical structure and thus also magnification without losing illumination.

Conclusion

On endoscopic dissection of the epitympanum, the following structures were identified: Malleus (Neck, short process,lateral process, manubrium and umbo), Incus(-Body, long process, lenticular process, incudostapedial joint),

Tympanic diaphragm (anterior,posterior and lateral malleolar ligaments, lateral incudomalleolar ligamental fold,tensor tympani fold),chorda tympani, Tympanic isthmus and ventilation patterns to the antrum,processus

cochleariformis, Tensor tympani muscle, tendon and bony canal.

The Head of malleus and body of incus lodged in the attic was appreciated.

Endoscopic exploration and thorough knowledge of the complex fold anatomy improve more functional attempts to deal with middle ear inflammatory pathology during middle ear surgery. Better understanding of the ventilation pathways of the middle ear, restoration of adequate air access in the attic help in better healing and prevent recurrences of diseases. Thus having a three dimentional orientation of the attic and its contents aid the surgeon in performing better surgery and thus provide disease free ear.

Compliance with Ethical Standards

Conflict of interest The authors declare no conflict of interest, financial or otherwise.

Ethical Approval The study was conducted after obtaining Institutional Ethical Clearance and authors assert that all procedures contributing this work comply with ethical standards.

Human and Animal Participants The authors declare no human or animal participants were involved in the study.

Informed Consent The study was conducted on cadaveric temporal bones after obtaining Institutional Ethical Clearance.

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