The Epitympanum Revisited: Endoscopic Anatomy

Muaaz Tarabichi¹ · Daniele Marchioni² · Mustafa Kapadia¹

Received: 14 April 2016 / Accepted: 3 June 2016 / Published online: 8 June 2016
© Association of Otolaryngologists of India 2016

Abstract In contrast to other means of studying the epitympanum, the endoscope allows unparallel access without disruption of anatomy. The aim of this study is to delineate the anatomy of the epitympanum through transcanal endoscopy. Systematic dissection of anatomic specimens. We performed systematic endoscopic dissection of 20 ears in 10 fresh frozen anatomical specimens. A detailed flow sheet was filled up documenting the status of the lateral attic folds, the tensor fold, the cog and the tensor folds, the supratubal recess, and the patency of the anterior and posterior isthmus. None of the ears showed indication of previous chronic otitis media. The lateral incudomalleal fold was intact in all but one ear. The lateral malleal fold was intact in all specimens. The tensor fold was complete in 16 ears and partial in four. Two of these ears belonged to the same specimen. The epitympanic diaphragm was complete in 15 out of 20 ears in 10 anatomic specimens. The endoscope allows for assessment of the attic anatomy and integrity of the diaphragm without undue disruption of anatomy. The epitympanic diaphragm is present in the majority of healthy ears and can in theory serve as the anatomic basis for the isolated attic retraction.

Keywords Epitympanum 1 · Endoscopic ear surgery 2 · Lateral incudomalleal fold 3 · Lateral malleal fold 4 · Tensor fold 5 · Epitympanic diaphragm 6

Introduction

The anatomy of the temporal bone has been the subject of study for countless investigators and reports. This has mainly been done through study of histological sections by a very dedicated and inspiring group of researchers. The epitympanum has been intensely scrutinized as the most common site of Cholesteatoma [1]. There were also a lot of work done on the surgical anatomy of the attic and tympanic cavity. This was done by clinicians studying both diseased ears and anatomic specimens through standard trans mastoid surgical approaches to the various areas within the middle ear [2]. Transcanal endoscopic assessment of the epitympanum provides unique way of evaluating anatomy and disease of the epitympanum without undue disruption of underlying anatomy [3–6]. This distinct advantage of transcanal endoscopy bridges the gap between what has long been described by histological sectioning on one side and the domain of clinicians on the other [7]. It will also provide for fresh and rich source of clinical observations that might help in the understanding of disease within this important anatomic area of the ear.

Methods

Based on previous experience with endoscopic hands on dissection courses that were organized by the authors, we designed a systematic dissection worksheet that starts

✉ Mustafa Kapadia
mustafakapadia089@gmail.com

Muaaz Tarabichi
mtarabichi@ahdubai.com

Daniele Marchioni
marchionidaniele@yahoo.it

¹ Section of Otolaryngology, American Hospital Dubai, Dubai, United Arab Emirates

² Department of Otolaryngology, University Hospital of Modena, Modena, Italy

Fig. 1 Right ear: fibrous layer of the TM is pulled down off the handle of Malleus revealing the Posterior Malleolar Ligament (PML) and the Chorda Tympani (CT)

with the removal of skin and epithelial layer of the tympanic membrane, then the upper mesotympanum is explored through by taking down the fibrous layer of the tympanic membrane (Fig. 1), then anterior isthmus is inspected and an attempt is made to visualize the tensor fold and the COG (Fig. 2). Then, a careful atticotomy is performed and evaluation of the integrity of the lateral incudomalleolar and lateral malleolar folds are observed (Fig. 3). Then, enough bone is removed from the bony annulus anteriorly to introduce the scope anterior to the handle of malleus and inspection of the supratubal recess and the anterior aspect of the tensor fold is performed using angled 30° endoscope in a superior and then in a posterior direction (Fig. 4). Then the atticotomy is widened and any superior ligaments and folds are observed (Fig. 5). Then the incus is removed and the status of the tensor folds were observed from the posterior aspect through a 30° endoscope oriented anteriorly. Then, the head of the malleus is transected and removed and the anterior attic is observed along with the tensor fold and the relationship to the COG (Figs. 6, 7). This systematic dissection was performed in 20 ears in 10 fresh frozen anatomic specimens (transected full cadaver heads). The specimens were left to thaw for 5 h prior to the dissection. These anatomic specimens were obviously adults and no attempt was made to determine the gender of the specimen. No medical history was available except for negative serological testing for infectious diseases. The dissection was performed by the first two authors over a 2 day period of time. Some minimal dissection tasks that involved the removal of skin and tympanic membrane were performed by senior otolaryngology residents in their fourth and fifth year of training under the supervision by one the first two authors. A flow sheet was filled up for every ear and multiple photographic documentation of findings was performed.

Fig. 2 Left ear: peaking through the isthmus with a 30° endoscope. *HM* handle of malleus, *IS* incudostapedial joint, *CO* the COG, *TT* tendon of the tensor tympani, *TF* tensor fold, *RE* the recess formed through the insertion of the fold anterior to the COG

Fig. 3 Left ear: the relatively straight insertion line of the Lateral incudo-malleolar ligament (IML) and the downward sloping insertion line of the lateral malleolar ligament (LML)

Results

All anatomic specimens were well preserved through freezing with a near normal quality of the soft tissue. Endoscopic inspection of the tympanic membrane showed no indication of chronic ear disease in all specimens except for one ear which were identified by one of the authors with mild retraction but the collective judgment of the authors was that this is within normal limit. The area in between the tensor tympani tendon and the incudostapedial joint was patent in all specimens and did not contain any mucosal folds. The lateral incudomalleolar folds were intact in all but one ear and in these 19 ears. The lateral malleolar folds were intact in all specimens. These lateral folds prevented any ventilation through the lateral compartment. Superiorly, the suspensory ligaments and folds were variable but incomplete in all of our specimens and allowed for

Fig. 4 Left ear: *HM* handle of malleus, *STS* supratubal recess, *TF* the tensor fold which when *TTM* tensor tympani muscle's bony encasement, *BA* bony annulus, *CA* carotid artery

Fig. 5 Left ear: the lateral attic wall is removed and the ossicles exposed. *TE* tegmen, *IN* Incus, *CT* chorda tympani, *SL* superior incudal ligament

ventilation from the medial to the lateral compartments. The assessment of the integrity of the tensor folds did not change throughout the dissection. The status as determined by inspection through the isthmus, when possible, matched the assessment of the folds obtained from anteriorly, and ultimately matched the most direct inspection after removal of the head of malleus which would indicate that process of dissection did not alter the integrity of the tensor folds. The tensor folds were intact in 16 ears and partial in 4 with two of the ears belonging to the same anatomic specimen and the other two belonging to two other anatomic specimens that had intact folds on the contralateral side. All the incomplete tensor folds were vertically oriented. The tensor folds were almost vertical in orientation in the clear

Fig. 6 Left ear with the tensor fold inserting anterior to the COG with clear recess in between: the incus and the head of malleus have been removed. *HM* handle of malleus, *TT* tensor tympani tendon, *TF* tensor fold, *CO* COG. *RE* the recess formed by the insertion of the tensor fold anterior to the COG

Fig. 7 Left ear with the tensor fold inserting on the COG with no recess: the incus and the head of malleus have been removed. *HM* handle of malleus, *TT* tensor tympani tendon, *TF* tensor fold, *COG* COG

majority of ears and there were only four ears belonging to two anatomic specimens that had an almost horizontal tensor folds. The tensor fold inserted on the COG in four ears belonging to two anatomic specimens and inserted anterior to the COG with clear recess that extended medial to the COG in 16 ears.

Discussion

The attic is the most common site of involvement with cholesteatoma and therefore was intensively studied and scrutinized by clinicians and basic scientists over the last century [8]. The temporal bone histopathologists had long described with great deal of accuracy and over an extended

period of time the anatomy of this area and how it interfaces with development of cholesteatoma. In 1946 Chatellier and Lemoine studied frontal histological sections of newborns temporal bone and described an “attico tympanic diaphragm” that results in a clear separation of the attic from the mesotympanum [9]. Palva through meticulous observations of healthy and diseased specimens defined this further anatomically and used the term “epi-tympanic diaphragm” and emphasized the role of the “tympanic Isthmus” in the ventilation of the attic [10, 11]. He also described several diseased specimens in children and demonstrated pathology involving the isthmus [12].

Classical surgical approaches to the attic with microscopic trans mastoid technique results in poor access to the anterior attic and extensive removal of much of the associated anatomy in order to access these areas. In contrast, the endoscope offers clear glimpses of the anatomy and pathology without undue disruption of the anatomy, making it easier to understand both the underlying anatomy and any disease process within this area [3–6]. This is particularly true when considering the tensor fold. Because of the location and orientation of this fold, it is a structure that can not be seen through traditional microscopic transcanal and transmastoid approaches to the anterior attic [13]. The only exception is a determined look for this structure through a widely opened facial recess, and only after removal of incus. It is often helpful to push the handle of malleus laterally for a more open view. This observation is usually made more difficult while operating on diseased ears because of the existing medialization of the handle of malleus and the fact that blood tends to pool in this area because of the position of the head in traditional mastoid surgery. The endoscope allows for inspection of this fold in healthy ears by using a 30° endoscope and looking through the isthmus (Fig. 2). In diseased ears, the isthmus is obstructed and narrow because of medialization of the handle of malleus and tensor fold can be visualized endoscopically either by looking superiorly and posteriorly with and an angled scope that is positioned anterior to the handle of malleus (Fig. 8) or by looking forward with an angled scope after removal of the incus and head of malleus (Fig. 9).

In 16 out of 20 ears dissected, the anterior attic was completely separated from the anterior mesotympanum and the Eustachian tube. There are two main variations of the tensor fold: The first is an almost horizontal orientation where the fold attaches to the tensor tendon posteriorly and to the tympanic wall anteriorly very close the anterior tympanic spine (Fig. 8). This orientation occurred in 4 out of 20 ears and was bilateral (present in both ears in two anatomic specimens). The tensor fold of this variety was always complete in these four ears. The second is when the

Fig. 8 Right ear intra-operative view of the tensor fold that has an almost horizontal orientation without any formation of supratubal recess. **a** A general view; **b** close up view; ABA anterior bony annulus, TTM tensor tympani muscle canal, TF horizontal tensor fold, HM handle of malleus; arrow Eustachian tube

Fig. 9 Left ear intra-operative view. The incus and the head of malleus is removed and looking forward with a 30° scope toward the anterior attic at a tensor fold with almost vertical orientation. CT transected chorda tympani, HM handle of malleus, COG the COG, TT tensor tympani tendon, TF tensor fold, FN horizontal segment of the facial nerve

supratubal recess is well developed and when it pushes the folds almost to a vertical position (Fig. 9).

The attic and the supratubal recess are two distinct areas anatomically and developmentally and they are separated by the tensor fold. Anatomically, the supratubal recess is often a smooth walled cavity; in contrast, the attic wall has numerous tags and excrescences. The transverse crest is a

Fig. 10 Left ear: the tensor tendon is transected and the handle of the malleus is removed, so was the anterior spine, anterior malleal ligament and the chorda tympani. *CO* COG, *TF* remnant tensor fold. *STR* supratubal recess, *CG* cochleariform process, *IG* first genu of the facial nerve and neighboring geniculate ganglion, *LC* lateral semicircular canal

semicircular bony ridge that starts at the medial wall of the attic, runs across the roof, and then the lateral wall of the attic and marks the border between the tags and excrescences filled anterior attic and the smooth walled supratubal recess (Fig. 10). Its medial limb starts from the area of the cochleariform process and forms the COG, a commonly recognized surgical term and a bony protrusion on the medial anterior attic wall [3, 4]. The tensor fold inserted on the COG in four ears belonging to two anatomic specimens and inserted anterior to the COG with clear recess that extended medial and anterior to the COG in 16 ears.

Developmentally, the middle ear spaces are formed from four pouches or sacs (the saccus anticus, saccus medius, saccus superior, and saccus posticus) that bud out from the Eustachian tube [14]. The attic is formed from the saccus medius, which divides into three saccules, anterior, medial, and posterior. The supratubal recess may be formed by either the saccus anticus. The anterior saccule of the saccus medius meets the slower growing saccus anticus at the level of the semicanal of the tensor tympani, thus forming a horizontally positioned tensor tympani fold (Fig. 11a) [15]. Alternatively; the saccus anticus may occasionally extend upward to the tegmen, pushing the tensor fold into an almost vertical position (Fig. 11b) and in the process, forming a well developed supratubal space [15]. The expansion from the bony Eustachian tube to form the supratubal recess begins at a late fetal stage and continues throughout childhood [16], by contrast, growth of the tympanic cavity, the attic, and the mastoid antrum is virtually complete by birth [17].

Fig. 11 The tensor fold position is related to the balance between the embryological development of the saccus anticus and the saccus medius. **a** A horizontally position of the tensor fold because of the saccus anticus overtaking the medius. **b** A vertical position of a tensor fold because of saccus anticus overtaking the saccus medius

In the presence of an intact tensor fold, there is a fully formed diaphragm that separates the attic from the mesotympanum. This diaphragm is formed by the lateral incudomalleal and malleal folds laterally and the tensor folds anteriorly. The only ventilation port is through the anterior and posterior isthmus. The anterior isthmus is the area in between the incudo stapedial joint and the tensor tympani tendon [18]. The posterior isthmus is the area posterior to the incudostapedial joint and is often extremely narrow and has many other structures such as the chorda and the pyramidal eminence; as well as variable mucosal folds. So the anterior isthmus or the “tympanic isthmus” is the main point of attic ventilation with a very long channel that extends medial to the ossicles and then superior to the ossicles to ventilate the lateral and anterior attic. This long channel is also populated by other partial folds and suspensory ligaments which provide other opportunities for impaired ventilation.

This clinical significance of the “epitympanic diaphragm” remains to be elucidated. It remains to be seen if this diaphragm is the anatomic basis for the retraction and cholesteatoma in the attic in ears with no disease within the mesotympanum. Marchioni and colleagues have recently described a “selective dysventilation syndrome” by using transcanal endoscopy to document the obstructive changes affecting the isthmus [13]. It remains to be seen if this anatomic orientation and the obstruction of the isthmus is the main reason for development of attic cholesteatoma. This hypothesis will be further tested in the future with the wider utilization of the endoscope which allows the evaluation of the isthmus and the epitympanic diaphragm during routine surgical management of patients with attic cholesteatoma.

Conclusion

The endoscope allows for assessment of the attic anatomy and integrity of the epitympanic diaphragm without undue disruption of anatomy. The tensor fold is complete in the majority of anatomic specimens and has a variable position and relationship to the COG. The lateral malleal folds and incudomalleal folds are intact in the wide majority of specimens and would prevent the direct ventilation of the attic through the lateral compartment. The epitympanic diaphragm is present in the majority of healthy ears and can in theory serve as the anatomic basis for the isolated attic retraction and Cholesteatoma.

Compliance with Ethical Standards

Conflict of interest All of the authors have read and approved the manuscript. The authors have no funding, financial relationships, or conflicts of interest to disclose.

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. Kinney SE (1982) Five years experience using the intact canal wall tympanoplasty with mastoidectomy for cholesteatoma: preliminary report. *Laryngoscope* 92(12):1395–1400
2. Sheehy JL (1976) Surgery of chronic otitis media. In: *Otolaryngology: a textbook*, 1st edn. Harper & Row, Hagerstown
3. Tarabichi M (1997) Endoscopic management of acquired cholesteatoma. *Am J Otol* 18:544–549
4. Tarabichi M (1999) Endoscopic middle ear surgery. *Ann Otol Rhinol Laryngol* 108:39–46
5. Tarabichi M (2000) Endoscopic management of cholesteatoma: long-term results. *Otolaryngol Head Neck Surg* 122:874–881
6. Tarabichi M (2004) Endoscopic management of limited attic cholesteatoma. *Laryngoscope* 114:1157–1162
7. Tarabichi M (2010) Transcanal endoscopic management of cholesteatoma. *Otol Neurotol* 31:580–588
8. Prussak A (1867) Zur Anatomie des menschlichen Trommelfells. *Arch Ohrenheilkd* 3:255–278
9. Chatellier HP, Lemoine J (1946) Le diaphragme interatticotympanique du nouveau-ne. *Ann Otolaryngol Chir Cervicofac* 13:534–566
10. Palva T, Johnsson L (1995) Epitympanic compartment surgical considerations: reevaluation. *Am J Otol* 16:505–513
11. Palva T, Ramsay H, Böhling T (1997) Tensor fold and anterior epitympanum. *Am J Otol* 18:307–316
12. Palva T, Böhling T, Ramsay H (2000) Attic aeration in temporal bones from children with recurring otitis media: tympanostomy tubes did not cure disease in Prussak's space. *Am J Otol* 21:485–493
13. Marchioni D, Alicandri-Ciufelli M, Molteni M (2010) Selective Dysventilation Syndrome. *Laryngoscope* 120:1028–1033
14. Hammar JA (1902) Studien Uper Die Entwicklung Des Vorderdarms und Einiger Angrenzenden Organe. *Arch Mikroskop Anat* 59:471–628
15. Proctor B (1964) The development of the middle ear spaces and their surgical significance. *J Laryngol Otol* 78:631–648
16. Tono T, Schachern PA, Morizono T, Paparella MM, Morimitsu T (1996) Developmental anatomy of the supratubal recess in temporal bones from fetuses and children. *Am J Otol* 17:99–107
17. Schuknecht HF, Gulya AJ (1986) Anatomy of the temporal bone with surgical implications. Lea & Febiger, Philadelphia, pp 89–90
18. Aimi K (1978) The tympanic isthmus: its anatomy and clinical significance. *Laryngoscope* 88(7 Pt 1):1067–1081