Endoscopic Anatomy of the Tensor Fold and Anterior Attic

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Abstract

Objectives. The objectives of the study were to (1) study the anatomical variations of the tensor fold and its anatomic relation with transverse crest, supratubal recess, and anterior epitympanic space and (2) explore the most appropriate endoscopic surgical approach to each type of the tensor fold variants.

Study Design. Cadaver dissection study.

Setting. Temporal bone dissection laboratory.

Subjects and Methods. Twenty-eight human temporal bones (26 preserved and 2 fresh) were dissected through an endoscopic transcanal approach between September 2016 and June 2017. The anatomical variations of the tensor fold, transverse crest, supratubal recess, and anterior epitympanic space were studied before and after removing ossicles.

Results. Three different tensor fold orientations were observed: vertical (type A, 11/28, 39.3%) with attachment to the transverse crest, oblique (type B, 13/28, 46.4%) with attachment to the anterior tegmen tympani, and horizontal (type C, 4/28, 14.3%) with attachment to the tensor tympani canal. The tensor fold was a complete membrane in 20 of 28 (71.4%) specimens, preventing direct ventilation between the supratubal recess and anterior epitympanic space. We identified 3 surgical endoscopic approaches, which allowed visualization of the tensor fold without removing the ossicles.

Conclusions. The orientation of the tensor fold is the determining structure that dictates the conformation and limits of the epitympanic space. We propose a classification of the tensor fold based on 3 anatomical variants. We also describe 3 different minimally invasive endoscopic approaches to identify the orientation of the tensor fold while maintaining ossicular chain continuity.

Keywords

endoscopic surgery, middle ear ventilation, cholesteatoma, middle ear anatomy, tensor fold, cog, transverse crest

The surgical anatomy of the epitympanic space has been challenging to study because of its complex mucosal folds, pouches, and ligaments. In the past decades, the anatomical studies describing the anatomy of the epitympanic space were conducted through microscopic anatomical dissections and histological slides of sectioned specimens.¹⁻⁴ Although these important studies were essential to better understand the anatomy of this complex space, many of the illustrations were difficult to comprehend because they were obtained through vertically sectioned specimens that poorly correlated to the surgical anatomy. In addition, for the surgeons operating in the middle ear under the microscopic view, the epitympanic space is difficult to access since this area is hidden by the lateral wall of the tympanic portion of the temporal bone. Traditionally, a mastoidectomy with malleus head and incus removal is required to visualize the anterior limit of the epitympanic space. The tensor fold, being a mucosal structure, is not always easy to identify under inflammatory conditions. On the other hand, the transverse crest, also known as the cog, has been considered an easier bony landmark to identify after mastoidectomy and removal of the ossicles. Conventionally, the cog is considered the dividing landmark between the anterior and the posterior epitympanic compartments. The main objective of this study is to take advantage of the wide-field magnification and angled views provided by endoscopy to study the anatomy of the tensor fold and its relations with the surrounding structures in a surgeon’s perspective. A secondary
objective is to describe the most appropriate transcanal endoscopic approach to identify the tensor fold while maintaining preservation of the ossicular chain. In addition, we aim to gain insight on whether the variations in the tensor fold anatomy may have an impact on attic and mastoid ventilation.

Materials and Methods

Twenty-six preserved and 2 fresh cadaveric temporal bones were provided by the Anatomy Bequest Program from the University of Minnesota Medical School. All dissections were performed from September 2016 to June 2017 at the Temporal Bone Dissection Laboratory at the University of Minnesota, Department of Otolaryngology. Institutional review was exempted by the University of Minnesota Institutional Review Board since the study subjects were deidentified specimens.

Surgical Technique

All dissections were performed with 0-degree and 30-degree 3-mm rigid endoscopes (Karl Storz Endoscopy-America, El Segundo, California). Through the ear canal, a posteriorly based tympanomeatal flap was elevated to gain access to the middle ear. The tympanic membrane was then carefully dissected off the malleus lateral process and handle in a superior to inferior fashion, without disruption of the ligaments, folds, and chorda tympani nerve. The 0-degree and 30-degree endoscopes were placed at the protympanum (anterior approach) and the anterior tympanic isthmus (posterior approach) to visualize the tensor tympani tendon and the tensor fold. An atticotomy was then performed by curetting the scutum to expose the epitympanum. The epitympanic space was inspected with the 30-degree endoscope. The incus and the malleus head were subsequently removed to fully expose the tensor fold, epitympanic space, and supratubal recess region. Still images and videos were taken for review and documentation. The variations of tensor fold, transverse crest (cog), anterior epitympanic space, and supratubal recess were observed and documented by 2 independent observers (B.L. and M.F.).

Results

Tensor Fold Anatomic Variations

The tensor fold was complete with an intact membrane in 20 of 28 (71.4%) specimens and incomplete with a membranous defect in 8 of 28 (28.6%) specimens. Three different orientations of the tensor fold were observed similarly to previous studies. We divided these conformations into 3 different types: vertical (type A), oblique (type B), and horizontal (type C) (Table 1 and Figure 1).

Table 1. Tensor Fold Anatomic Variations.

<table>
<thead>
<tr>
<th></th>
<th>Type A (Vertical), No.</th>
<th>Type B (Oblique), No.</th>
<th>Type C (Horizontal), No.</th>
<th>Total, No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
<td>7</td>
<td>10</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>Incomplete</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>13</td>
<td>4</td>
<td>28</td>
</tr>
</tbody>
</table>

Type A. In 11 of 28 (39.3%) of the specimens, the tensor fold had a vertical orientation and inserted to the transverse crest (cog). In this group of specimens, the supratubal recess was large and characterized by a smooth concave shape. The epitympanic space was composed of 1 single confluent space without an obvious division plane. The transverse crest did not separate the anterior from the posterior epitympanic space; rather, the transverse crest represented the bony boundary between the supratubal recess and the confluent epitympanic space.

Type B. In the majority of the specimens, 13 of 28 (46.4%), the tensor fold had an oblique orientation and attached to the anterior tegmen tympani. In this group of specimens, the supratubal recess and anterior epitympanic space were both well defined and separated by the tensor fold. The transverse crest served as the division plane between the anterior and the posterior epitympanic space.

Type C. In 4 of 28 (14.3%) of the specimens, the tensor fold had a horizontal orientation, attaching to the tensor tympani canal. In this group of specimens, the supratubal recess was small or nonexistent. The anterior epitympanic space was large and was divided from the posterior epitympanic space by the transverse crest.

There was no statistical difference of tensor fold orientation between specimens with complete vs incomplete tensor fold ($P = .76$, $\chi^2$ test).

Transverse Crest Anatomic Variations

The transverse crest was identified in all 28 specimens. Two variations were observed: complete and rudimentary. In 25 of 28 (89.3%) specimens, the transverse crests were complete. Within this group, the transverse crest attached to the cochleariform process in 16 of 25 (64%) and extended in proximity of the geniculate ganglion region in 9 of 25 (36%) specimens. In 3 of 28 (10.7%) specimens, the transverse crest was a small rudimentary bony ridge pointing toward the cochleariform process.

Surgical Approach to the Tensor Fold

Visualization of all 3 tensor fold orientations without disrupting the ossicular chain was achievable with 2 different surgical approaches.

Anterior approach to the tensor fold. For the horizontal and oblique variants of the tensor fold, optimal visualization was provided by advancing a 30-degree endoscope immediately anterior to the manubrium of the malleus and adjusting the viewing angle aiming superiorly (Video 1, available in the online version of the article). The oblique tensor fold was the most challenging to visualize because its location was anterior and medial to the head of the malleus. Visualization was possible in majority of the cases (10/13) with the anterior approach. In a minority of cases (3/13), the
oblique conformation was partially visualized with the ante-
rior approach. For research purposes, in the case of partially
visualized oblique tensor fold, the orientation was further
confirmed after curetting the scutum, removing the incus,
and transecting the head of the malleus.

Posterior approach to the tensor fold. For the vertical tensor
fold, visualization was possible by placing a 0-degree or 30-
degree endoscope at the tympanic isthmus between the
incus and the manubrium of the malleus (Video 1, available
in the online version of the article).

Figure 1. (A) Type A vertical tensor fold. (B) Type B oblique tensor fold. (C) Type C horizontal tensor fold. Blue arrows: ventilation path-
ways. AES, anterior epitympanic space; COG, transverse crest; CT, chorda tympani; ES, epitympanic space; ET, eustachian tube; M, malleus;
PES, posterior epitympanic space; SR, supratubal recess; TC, transverse crest; TF, tensor fold; TT, tensor tendon; TTC, tensor tympani
canal.
Table 2. Comparison of Tensor Fold Anatomic Variations in Cadaveric Dissection.

<table>
<thead>
<tr>
<th>Study</th>
<th>Orientation, No./Total No. (%)</th>
<th>Configuration, No./Total No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Horizontal</td>
<td>Oblique</td>
</tr>
<tr>
<td>Hoshino(^3)</td>
<td>11/16 (69)</td>
<td>5/16 (31)</td>
</tr>
<tr>
<td>Yamasoba et al(^2)</td>
<td>19/50 (38)</td>
<td>20/50 (40)</td>
</tr>
<tr>
<td>Onal et al(^4)</td>
<td>25/30 (83)</td>
<td>5/30 (17)</td>
</tr>
<tr>
<td>Palva et al(^1)</td>
<td>11/51 (22)</td>
<td>40/51 (78)</td>
</tr>
<tr>
<td>Marchioni et al(^11)</td>
<td>7/12 (58)</td>
<td>5/12 (42)</td>
</tr>
<tr>
<td>Tarabichi et al(^12)</td>
<td>4/20 (20)</td>
<td>16/20 (80)</td>
</tr>
<tr>
<td>Our study</td>
<td>4/28 (14.3)</td>
<td>13/28 (46.4)</td>
</tr>
</tbody>
</table>

Discussion

In 1946, Chatellier and Lemoine\(^5\) introduced the concept of the “epitympanic diaphragm,” composed of various membranous ligaments (tensor fold being one of these ligaments), which, together with the malleus and the incus, form the floor of the epitympanic compartment.

Aeration pathways from the eustachian tube to the mastoid have been studied by earlier authors\(^1,6,7\) and more recently revisited.\(^8\)

The major aeration route between the eustachian tube and the epitympanic and mastoid space passes through the tympanic isthmus, located between the incus and the malleus.

The presence of mucosal webs or granulation tissue at the tympanic isthmus impedes the main pathway of ventilation, excluding the epitympanic space from the mesotympanum. In the case of blockage of the tympanic isthmus associated with a complete tensor fold membrane, the epitympanic and mastoid space receive no ventilation. This condition may lead to selective attic retraction with subsequent development of attic cholesteatoma. This process would explain the presence of normal-appearing pars tensa and a normal functioning eustachian tube along with selective attic retraction.\(^8,9\) On this basis, the orientation and completeness of the tensor fold may have a determinant role in the pathophysiology of attic disease.

Several authors reported on the anatomical variations of the tensor fold and proposed several classification systems based on its orientations.\(^1,4\) The earlier anatomical studies of the anterior epitympanum were mainly based on histological sections. More recent studies provided important insights on the anatomy as seen by endoscopy.\(^10,12\) With the advancement of the angled endoscope and high-resolution camera, it has been possible to look around the corner and magnify small details of this complex anatomy. To summarize the results of these previous anatomical studies, we illustrate a table with the reported findings (Table 2).

One of the challenges in understanding the anatomy of this region was due to the fact that previous publications illustrated temporal bone specimens cut through a vertical axis with ossicles in situ. In addition, black and white photography and lower definition optics posed additional difficulties for the surgeon trying to compare the anatomopathological studies to surgical anatomy. These prior illustrations have lacked surgical relevance because they have not been from the surgeon’s point of view. Moreover, the multitude of different descriptions by several independent authors created overlapping nomenclature of the same anatomical structure: for example, the supratubal recess was described also as the “anterior malleolar space,”\(^7\) the “supratubal space,”\(^7\) the “sinus epitympani,”\(^1,13\) and the “anterior epitympanic space.”\(^1,3\)

Our study has the intent of clarifying both the surgical anatomy as well as the nomenclature of the tympanic cavity. The transverse crest, also frequently known as “cog,” has been conventionally considered the “bony divider” between the anterior and the posterior epitympanum. Our endoscopic study demonstrates that the tensor fold, which is a soft tissue landmark, is the real defining structure dividing the compartments of the epitympanic space. Such defining role is likely derived by its embryological origin. The tensor fold derives from the fusion of the 2 embryonal sacs that developed during the primitive formation of the tympanic cavity: the saccus anticus and the saccus medius. The saccus anticus extends upward anterior to the tensor tendon to form the anterior pouch of von Troltsch. The saccus medius forms the attic.\(^7\) This embryological origin leads us to consider the tensor fold as an anatomical boundary between the protympanum and epitympanum. In our study, the tensor fold is always present, but in approximately one-third of the cases, it is an incomplete membrane. In this situation, the tensor fold remains the anatomical boundary between the protympanum and epitympanum, but due to direct communication through the membranous defect, it does not functionally separate the 2 compartments. Our anatomical classification and the preponderance of the tensor fold orientation are in agreement with prior studies. Each anatomical variant of the tensor fold, vertical, oblique, and horizontal, can theoretically have an impact on the pathophysiology of chronic ear disease (Figure 1).

In type A and type B, the epitympanic space is ventilated through the anterior and posterior isthmus, while the supratubal recess is ventilated directly by the eustachian tube (Figure
In type C, the epitympanum is characterized by a wide space with a large anterior portion ventilated by the anterior isthmus, and it is excluded from direct ventilation from the eustachian tube when the tensor fold is complete. When the tensor fold is an incomplete membrane, the anterior epitympanic space receives additional ventilation through the eustachian tube. In case of complete tensor fold membrane and inflammatory tissue blocking the tympanic isthmus, type C could be predisposed to more likely anterior epitympanic dysventilation with a subsequent development of anterior attic retraction (anterior epitympanic cholesteatoma) (Figure 1C). A preliminary study of the tensor fold in patients with attic cholesteatoma described a large prevalence of a horizontally oriented complete membranous tensor fold.10

We propose 2 endoscopic transcanal surgical approaches to the tensor fold without disruption of the ossicular chain. The anterior approach gives the best view of the horizontal and oblique tensor folds. The posterior approach gives the best view of the vertical tensor fold. Identification of the tensor fold and understanding of its complex anatomy are of paramount importance to restore an anterior epitympanic ventilation. Therefore, we strongly recommend integration of endoscopic dissection into educational training to understand this complex anatomy.

In our opinion, there are multiple clinical indications to remove the complete membrane of the tensor fold. In patients with attic cholesteatoma, inspection of the anterior epitympanic space can be assessed after removal of the tensor fold. In patients with attic block, opening of the tensor fold can establish an additional ventilation to the anterior attic in addition to removal of adhesions and inflammatory tissue in the region of the anterior tympanic isthmus. In patients with chronic ear disease with tympanic membrane perforation, tympanosclerotic blocks are frequently found in the region of the tensor fold, and the removal of these obstructions is recommended to optimize tympanic membrane reconstruction and middle ear ventilation. Opening of the horizontal and oblique tensor folds can be easily performed endoscopically with a curved Rosen pick using the anterior approach. In vertically oriented tensor folds, opening of the membrane is performed with a curved Rosen pick using the posterior approach, with care taken to avoid injury to the incudostapedial joint and the stapes.

There are several limitations in our study. The anatomical dissections were performed on healthy temporal bones. The prevalence of each tensor fold anatomical variation in diseased ears may be different. Additional clinical studies are necessary to understand the real impact of these anatomical variants on clinical cases. Future larger scale studies observing the tensor fold variations in diseased ears may further prove this connection.

Conclusions

According to our study, the tensor fold has 3 orientations: horizontal, oblique, and vertical. The oblique orientation is the most common of the 3 orientations. The tensor fold is a complete membrane in most cases and prevents direct ventilation between the supratubal recess and the anterior epitympanic space. The utilization of 0-degree and 30-degree endoscopes in the tympanic cavity provides visualization of the horizontal, oblique, and vertical tensor fold, maintaining ossicular preservation. The endoscopic study of the anatomy of the middle ear provides better understanding of this complex anatomy and should become an integrative part in educational training.

Author Contributions

Bin Li, study design, data collection, data analysis, manuscript preparation; Phi Doan, data collection, data analysis, manuscript preparation; Robert R. Gruhl, data analysis, manuscript preparation; Alessia Rubini, data analysis, manuscript preparation; Daniele Marchioni, study design, interpretation of data, manuscript preparation, editing of illustrations; Manuela Fina, study design, data collection, data analysis, manuscript preparation, video editing.

Disclosures

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Supplemental Material

Additional supporting information is available in the online version of the article.

References


