


An Overview of Endoscopic Ear Surgery in 2018

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Objective: To provide an overview of Endoscopic Ear Surgery, its development, principles, and penetration in otology practice in 2018.

Data Source: PubMed review of literature and cross-sectional email survey of otologists.

Methods: We reviewed all PubMed published articles on use of endoscopy in practice of otology over the last 50 years. Articles were categorized based on date of publication and pattern of utilizing the endoscope. We also conducted two identical email surveys in 2010 and 2018 of otologists on the use of endoscope and tabulated and compared results.

Results: The number of publications on use of endoscope has increased from 6 in 1990 to an accumulated total of 451 in 2018. There has been a clear shift in the area of interest away from diagnostic endoscopy, to endoscope-assisted surgery, and lately, to transcanal endoscopic ear surgery (TEES). Survey results further documented the increased awareness of the value of the endoscope and its increased use in clinical practice.

Conclusion: TEES has gained traction as a subject of research interest and in clinical practice and has lately dominated the discussion on the use of endoscope in otology.

Key Words: Endoscopic ear surgery, otoendoscopy, tympanoplasty, myringoplasty, cholesteatoma.

Level of Evidence: NA

INTRODUCTION

The introduction of the operating microscope to ear surgery by Wullstein was a transformative event in the development of ear surgery. Increased ability to visualize disease processes and associated anatomy has resulted in more effective surgery with reduced complications and increased ability to perform reconstructive procedures. In the last three decades, many surgical disciplines have adapted the endoscope as the instrument of choice to access and correct pathology without undue disruption of overlying tissue. Multiple discussions and attempts at using the endoscope in ear surgery over the years have culminated in the development of transcanal endoscopic ear surgery (TEES). We attempt in this report to provide an overview of the development and integration of the endoscope into the practice of otologic surgery.

METHODS

A comprehensive literature search was performed using PubMed to identify studies that reported the use of the endoscope in otologic surgery published as recently as July 2018. The following key terms were used in

combination with Boolean operators (AND, OR): “endoscope,” “otology,” “cholesteatoma,” “tympanoplasty,” “ear surgery,” “otoendoscopy,” “endoscopic ear surgery (EES),” “transcanal ear surgery,” “endoscopic tympanoplasty,” and “endoscopic cholesteatoma surgery.” We examined the abstracts of the records returned by our search for relevance to our subject matter. Articles determined to be relevant to our subject matter were grouped across three time periods: 1967–2000, 2000–2010, and 2010–2018. We then further categorized according to the topics they addressed: endoscope used for visualization and documentation, endoscope used as an ancillary to the microscope in ear surgery, and endoscope used for TEES.

We also designed a survey (see Fig. 1) in an email format using Google surveys as a platform. The survey was sent out in 2010 to all 385 members of the American Academy of Otolaryngology-Head and Neck Surgery who had self-identified themselves as subspecialists in otology or neurotology in their online American Academy of Otolaryngology profile. The same questionnaire was mailed again in 2018 to the same subjects on the original mailing list. The Google survey platform was used to plot and compare results of the two surveys.

RESULTS

A total of 2,944 studies were identified in the PubMed search from 1967 to July 2018. Two thousand four hundred ninety-three studies were excluded due to duplicates and irrelevance. Four hundred fifty-one studies were included in the review.

Figure 2 details the number of publications in each calendar time category and pattern of reported use of the endoscope. From 1967 to 1990, there were no reports on TEES in the literature. This compares with

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Survey of Endoscopic Skills in Otolaryngology

Dear Colleagues,

In 2010, we surveyed the status of endoscopic skills within the otology community through this questionnaire. 8 years later, we are asking you again to respond to the below questions. Data will be used for an original manuscript and possibly submitted to a peer reviewed publication in our field on behalf of the otology international meeting group on endoscopic ear surgery.

What is the percentage of your otology surgical to your overall surgical practice?

- No ear surgery other than ear tubes
- Less than 25%
- About 50%
- 75% to 100%

How often are you doing middle ear surgery?

- once a week or more
- once a month
- very infrequently

How many years have you been practicing?

- 10 years or less
- 10 to 20 years
- 20 years or more

How many years have you been practicing?

- 10 years or less
- 10 to 20 years
- 20 years or more

How old are you?

- Less than 40
- 40 to 50
- Older than 50

Have you received endoscopic nasal surgery training during residency?

- Yes
- No

Do you perform endoscopic sinus surgery?

- Yes
- No

Do you use rigid endoscopes in the clinic to examine the ear?

- Yes
- No

Do you believe that there is a role for the endoscope in Cholesteatoma surgery?

- Yes
- No

Are there other area where you think the endoscope is useful?

- For inspection of the ear
- Removal of Cerumen
- Insertion of ear tubes
- Tympanoplasty
- CP angle surgery

How often do you use the endoscope in cholesteatoma surgery?

- one case per 10 cases
- one case per 5 cases
- Always
- Never

When using the endoscope, which technique do you apply?

- Through post auricular stab incision for inspection of mastoid
- For inspection after completion of tympanomastoidectomy to examine for residual disease
- To pursue and remove disease under endoscopic control
- Through transcanal approach for removal of cholesteatoma

Have you attended any educational program on endoscopic ear surgery?

- I attended AAO HNS instructional course
- I attended a session at a major otolaryngology conference
- I attended a dedicated conference on endoscopic ear surgery
- I attended a hands on dissection course on endoscopic ear surgery

SUBMIT

Fig. 1. "Survey of endoscopic skills in otology" questionnaire.

283 publications on TEES from 2010 to 2018. Over the last 50 years period, the total number of articles published on visualization and diagnostic use were 86, endoscope as an ancillary to the microscope: 46, and TEES: 319.

The number of otologists who participated in our survey was 47 in 2010 and 28 in 2018. In the 2010 survey,

40% of participating otologists were 10 years or less in practice and in 2018 survey, 55% of otologists were 20 years or more in practice. The survey indicated that 35 (74%) otologists in 2010 and 23 (82%) in 2018 performed one or more middle ear procedure per week.

There was wide variation in the technique of using the endoscope during middle ear surgery in both surveys (Fig. 3). Exclusive EES for cholesteatoma removal has increased from 14% in 2010 to 53% in 2018 survey. Forty-six percent of respondents in the 2010 survey never used an endoscope during middle ear surgery as compared to 17% in the 2018 survey.

The survey also enquired about different types of educational events attended on EES. Around 81% of participating otologists did not attend any educational event on EES in 2010. In contrast, in 2018, 86% of participating otologists attended a conference/session on EES, an endoscopic ear cadaveric dissection course, or both (Fig. 4).

Participants were also asked about the role of the endoscope in cholesteatoma surgery. Eighty-three percent of respondents in 2010 and 96.4% in 2018 felt that the endoscope had a clear role in cholesteatoma surgery (Fig. 5).

DISCUSSION

What constitutes EES is difficult to define in clinical practice. Cohen et al¹ attempted to introduce a classification system using the following categories: class 0 is defined by using the microscope only; class 1 describes the use of endoscopy for inspection without dissection; and class 2 describes mixed use of the endoscope and the microscope. It is further subdivided into 2a and 2b, where the endoscope is used for less than 50% of dissection and more than 50% of dissection, respectively. Class 3 describes the use of the endoscope for the entire surgery. We believe that the patterns of use of the endoscope described by this classification system represent the timeline of the process of integration of the endoscope into ear surgery rather than representing distinct approaches to EES.

1. The Diagnostic and documentation aspect of the endoscope (Cohen's class 1) initially had the most widely recognized role. Transtympanic middle ear endoscopy was initially reported by Nomura² and Takahashi et al.³ Poe and Bottrill used transtympanic endoscopy for the confirmation of perilymphatic fistula and the identification of other middle ear pathologic conditions.⁴ Kakehata et al used microendoscopy and transtympanic endoscopy for evaluation of conductive hearing loss and inspection of retraction pockets.⁵⁻⁷
2. The second classification category (Cohen class 2a) involves the use of the endoscope to assist in removal of disease, as an adjunct to the main workhorse, the microscope. Thomassin et al reported on operative ear endoscopy for mastoid cavities and designed an instrument set to be used for that purpose.⁸ Badr-el-Dine and El-Meslaty et al reported on the value of endoscopy as an adjunct in cholesteatoma surgery and documented a reduced risk of recurrence when the endoscope was used.^{9,10} The reduction in residual disease was further

ARTICLES ON USE OF ENDOSCOPE IN EAR SUREGRY

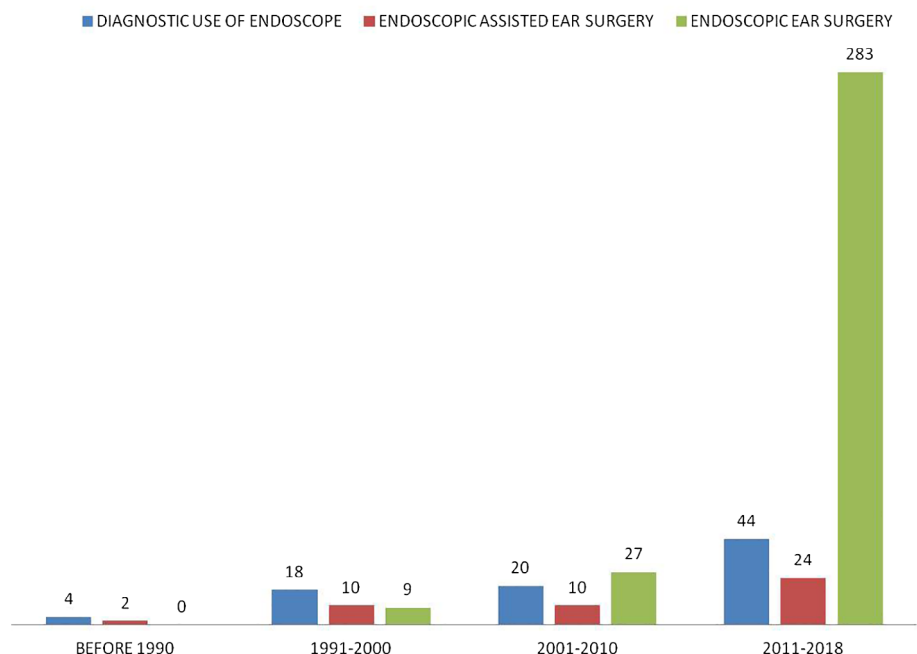


Fig. 2. Number of publications categorized by the pattern of utilization of the endoscope in ear surgery per the last four decades.

confirmed by Yung¹¹ and Ayache et al.¹² Abdel Baki et al¹³ reported on using endoscopic technique to evaluate disease within the sinus tympani. Mattox reported on endoscopy-assisted surgery of the petrous apex.¹⁴ Magnan and Sanna,¹⁵ Bader-el-Dine and El-Garem,¹⁶⁻¹⁸ and Rosenberg et al¹⁹ reviewed the role of the endoscope in neurotologic procedures. McKennan described an approach to second-look endoscopic inspection of the mastoid cavity that was achieved through a small postauricular incision.²⁰

3. The third wave involved the advent of TEES, utilizing the endoscope as the main workhorse in ear surgery

and the ear canal as the main access point (Cohen class 2B and 3). This is the topic of this review. The senior author adopted this approach in his clinical practice in 1992 and published an initial report in 1997 on his experience with endoscopic cholesteatoma surgery,²¹ tympanoplasty, and Stapes surgery.²² Prior to that, there was one earlier report in 1992 of endoscopic myringoplasty from El-Guindy.²³ In 2007, Stephane Ayache (France) proposed “the creation of an international Society of otoendoscopy” (later to be renamed the International Working Group on Endoscopic Ear Surgery [IWGEES]) to advocate and

USE OF ENDOSCOPE IN EAR SURGERY

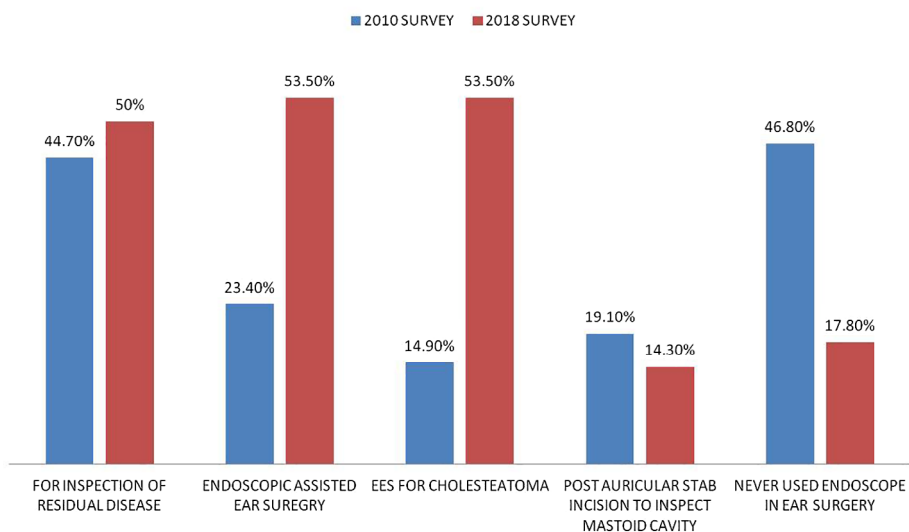


Fig. 3. Survey results in 2010 and 2018 of answers to the question “When using the endoscope, which technique do you apply?”

EDUCATIONAL ACTIVITIES ATTENDED

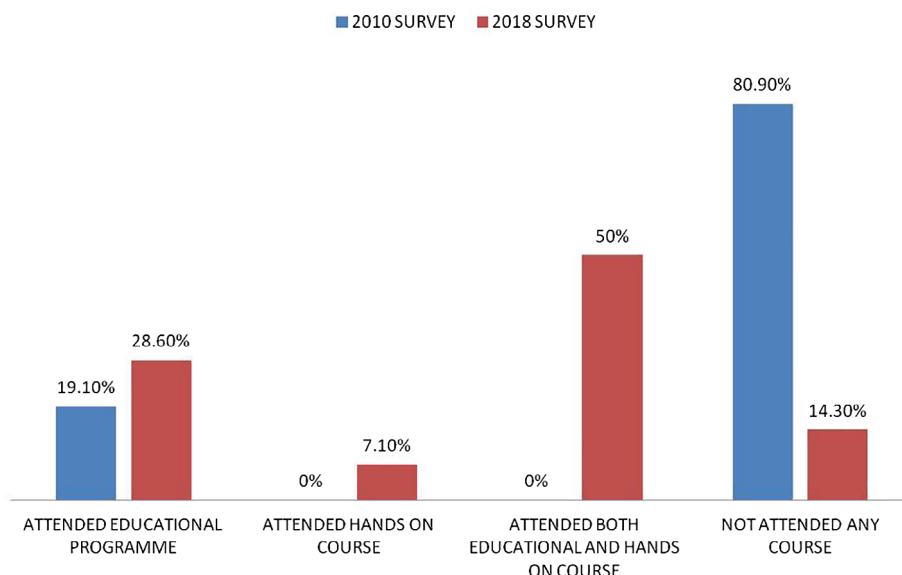


Fig. 4. Survey results in 2010 and 2018 of answers to the question “Have you attended any educational program on endoscopic ear surgery?”

collaborate for further development of this approach to ear surgery. The founding members included Muaaz Tarabichi (UAE), Daniele Marchioni (Italy), Livio Pre-sutti (Italy), Dave Pothier (Canada), Mohamed Badrel-dine (Egypt), and Seiji Kakehata (Japan). The IWGEES has grown to a membership of 125 members from 35 countries and has been instrumental in standardizing, teaching, and spreading of the technique.

It is evident from our review of publications that TEES is an emerging area that is attracting a significant amount of interest. The interest in the ancillary use of the endoscope as adjunct to routinely performed microscopic procedures seems to have waned. We see similar findings in our

questionnaire data with decreased interest in the use of the endoscope as an ancillary instrument to the microscope and increased recognition of TEES as viable option. We have attempted to contact the same group of physicians with our questionnaire to check for a “changed attitude,” but recognize that our reduced response rate on the second questionnaire might reflect that the surgeons who did not participate are growing more dismissive of the value of this technique.

Rationale of TEES

The basic advantages of the endoscope are better alignment of surgical access to the underlying anatomy,

ROLE OF ENDOSCOPE IN CHOLESTEATOMA SURGERY

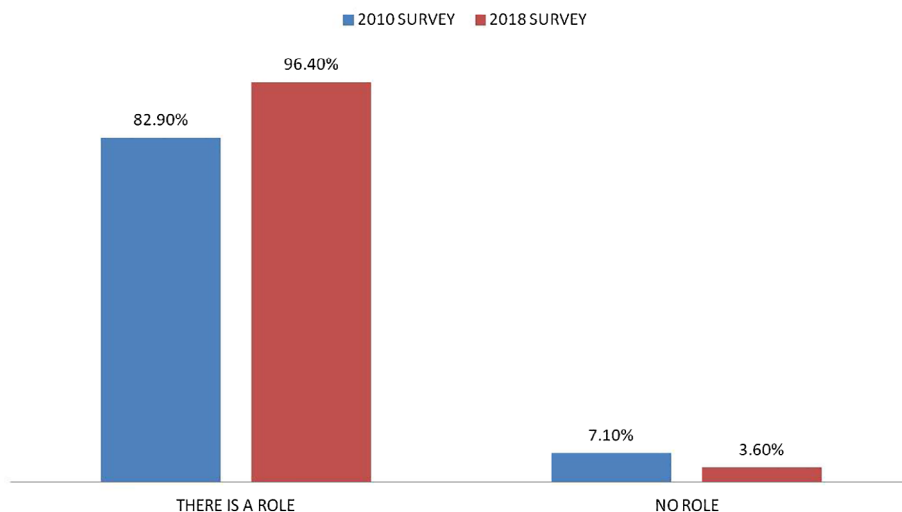


Fig. 5. Survey results in 2010 and 2018 of answers to the question “Do you believe that there is a role for the endoscope in Cholesteatoma surgery?”

disease process, and ventilation. The use of the ear canal, a natural access point, adds a minimally invasive aspect to this technique.

ALIGNING SURGICAL ACCESS WITH UNDERLYING ANATOMY AND DISEASE PROCESS.

Acquired cholesteatoma is usually a manifestation of advanced retraction of the tympanic membrane that occurs when the sac advances into the tympanic cavity proper and then into its extensions such as the sinus tympani, the facial recess, the hypotympanum, and the attic.²⁴ Only in advanced cases does a cholesteatoma progress further to reach the mastoid cavity proper. Most surgical failures associated with a postauricular approach seem to occur within the tympanic cavity and its difficult-to-reach extensions rather than in the mastoid.^{25,26} Therefore, the most logical approach to the excision of a cholesteatoma involves transcanal access to the tympanic membrane and tympanic cavity and the subsequent step-by-step pursuit of the sac as it passes through the middle ear. Mainstream ear surgery has usually involved the mastoid and the postauricular approaches because operating with the microscope through the auditory canal provides a limited surgical field. The view during microscopic surgery is defined and limited by the narrowest segment of the ear canal (Fig. 6). This basic limitation has forced surgeons to create a parallel port through the mastoid to gain access to the attic, the facial recess, and the hypotympanum (Fig. 7). In contrast, transcanal operative endoscopy bypasses the narrow segment of the ear canal and provides a wide view that enables surgeons to look “around the corner.” Even with a zero-degree endoscope, a structure like the facial recess becomes widely accessible for inspection and removal of disease (Fig. 8). Another anatomic observation that supports transcanal access to the attic, which is the most frequent site of cholesteatoma,²⁷ is the orientation of the ear canal in relation to the attic. Figure 9 shows a coronal computed tomographic section through the temporal

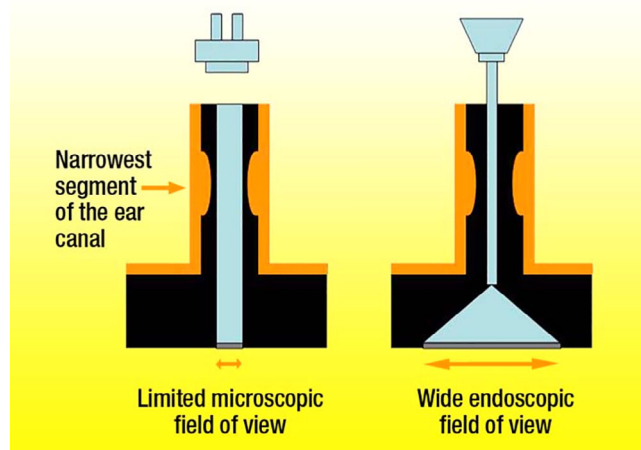


Fig. 6. The view from the microscope during transcanal surgery is defined and limited by the narrowest segment of the ear canal. In contrast, the endoscope bypasses this narrow segment and provides a very wide view that allows the surgeon to “look around corners,” even when the zero-degree scope is used.

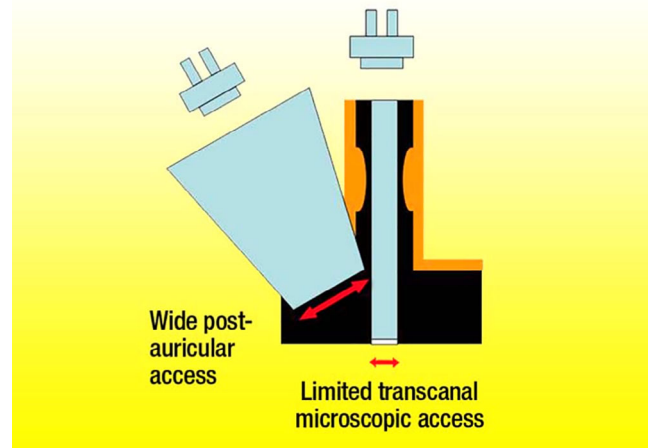


Fig. 7. The limited view provided by the microscope during transcanal procedures has forced surgeons to perform postauricular mastoidectomy, in which a port parallel to the attic is created after a considerable amount of healthy bone has been removed to enable anterior keyhole access to the attic and access to facial recess and posterior mesotympanum.

bone, which reveals that an axis line drawn through the ear canal ends in the attic rather than the mesotympanum. The only structure that is in the way is the scutum, and its removal allows wide and open access to the attic, which is the natural cul de sac of the external auditory canal. Rediscovering the ear canal as the access port to the tympanic cavity is the main story and the main advantage of EES. Figure 10 shows transcanal endoscopic view of the tympanic cavity with the center of endoscopic field aligning with the cochleariform process, a structure that usually marks the most anterior limit of the field during microscopic transcanal surgery. Figure 11 shows multiplanar images of a normal middle ear cleft with the cochleariform process being the anatomic center of the tympanic cavity. Therefore, transcanal endoscopic access

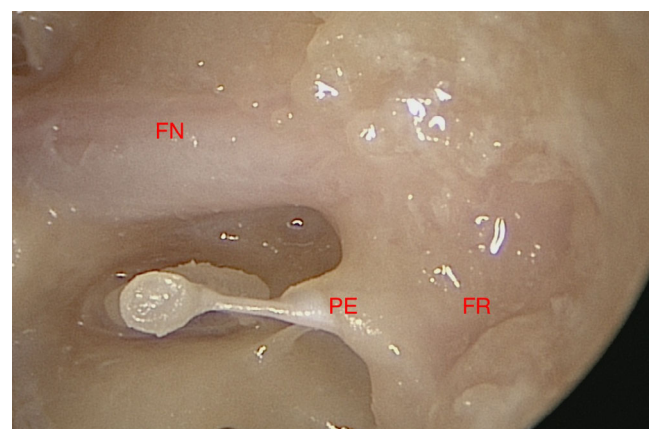


Fig. 8. Left ear. Endoscopic view through a transcanal endoscopic access after minor removal of bone; the FR is very shallow and more of a flat depression, more or less at the same level as the PE and the vertical segment of FN. FN = facial nerve; FR = facial recess; PE = pyramidal eminence.

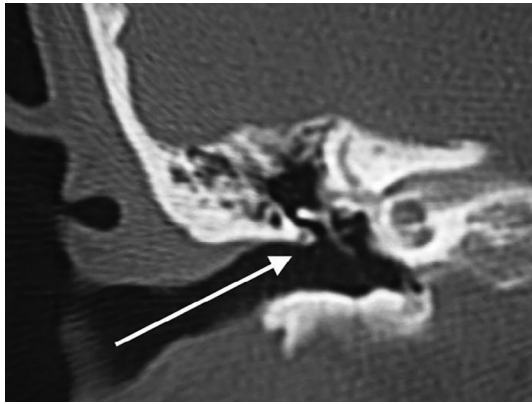


Fig. 9. A coronal computed tomographic section of the temporal bone, which shows that an axis line drawn through the ear canal ends in the attic rather than the mesotympanum. This almost universal anatomic orientation enables a natural transcanal access to the attic.

aligns surgical access with anatomic reality and allows wide access to the tympanic cavity, the birthplace of chronic ear disease.

ALIGNING SURGICAL ACCESS WITH VENTILATION. Microscopic access through the mastoid is focused on the most posterior part of the air cell system, and therefore, the most downstream in terms of ventilation. The upstream parts of the ventilation system, the Eustachian tube isthmus, protympanum, anterior mesotympanum, and the tympanic isthmus are barely visualized with the posterior, mastoid-based, microscopic approach. The endoscope allows our access to be oriented toward the anterior upstream areas of the ventilation system, therefore aligning ventilation with surgical access as demonstrated in Figure 12.

Chronic ear surgery has always revolved around removing disease and regaining function without much attention to the pathophysiologic process underlying the disease. Since much of the obstruction sites lie anteriorly, out of reach of our traditional instruments, it is always assumed that time and age have resolved any obstruction.²⁸

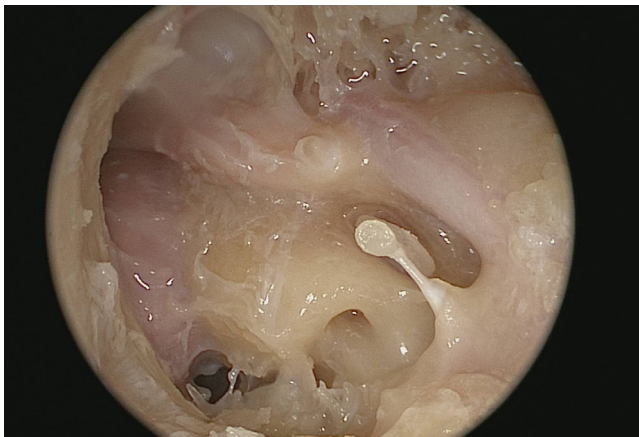


Fig. 10. Transcanal wide view of the tympanic cavity with the cochleariform process at the center of the visual field.

Failures in chronic ear surgery have been shown to correlate to persistent ventilation failure and Eustachian tube dysfunction.²⁹ The more anterior approach of EES has provided us access to the “Twin Isthmus” of the temporal bone air cell system: the tympanic Isthmus and the Eustachian tube isthmus as a possible source of ventilation failure.

Tympanic Isthmus

The use of transmastoid approach to cholesteatoma also blurs our understanding of the clear anatomical, morphological, and functional partitioning of the middle ear cleft between two distinct compartments: The first compartment, a superior posterior one, formed by the mastoid and attic. The second compartment is an antero-inferior one that is formed by much of the tympanic cavity proper. These two compartments are separated anatomically by the epitympanic diaphragm.³⁰ The diaphragm is composed laterally by the lateral incudomalleolar and lateral malleolar folds which separate the lateral attic from the mesotympanum. Anteriorly, the tensor fold separates the attic from the anterior mesotympanum and the Eustachian tube and forms the anterior part of this diaphragm (Fig. 13). In the majority of ears, there are only two points of communication, the main one is the tympanic isthmus (Fig. 14), the space defined by the incudostapedial joint and the tensor tympani tendon, and a very variable posterior isthmus just posterior to the incudostapedial joint. This anatomic separation is poorly visualized with the microscope and these two structures, the tensor fold and the lateral attic folds, are rarely identified and visualized in day-to-day surgery. In contrast, the endoscope allows for routine inspection of these structures through the transcanal access. Additionally, during transmastoid microscopic surgery, the surgeon peaks through into the tympanic cavity after creating a large working space in the mastoid and connecting it to the tympanic cavity to gain access. So by the time the tympanic cavity is reached, these two cavities have already been joined. The previously described anatomic separation mirrors a functional separation with a primarily a mucociliary clearance function anteroinferiorly provided through a ciliated pseudostratified epithelium that is populated by numerous mucous secreting cells and covered with cilia. The posterior-superior compartment has a gas exchange function through a thin layer of simple cuboidal cells, thin stroma, and blood vessels that lay much in closer proximity to the surface and therefore to the interface with the air filled mastoid cavity. The distinction carries through also morphologically with a very different look in these two compartments with the antero-inferior compartment being smooth walled and the posterior compartment that is filled with excrescences. This separation and the narrow isthmus serve as the most probable cause of isolated attic cholesteatoma in the presence of a normal mesotympanum.

The Eustachian Tube Isthmus

Linstrom et al described their experience in using fiber-optic flexible mini scopes introduced through the ear during chronic ear surgery to evaluate the patency of the Eustachian tube. Their results indicated that much of the obstruction existed in the protympanic segment of the

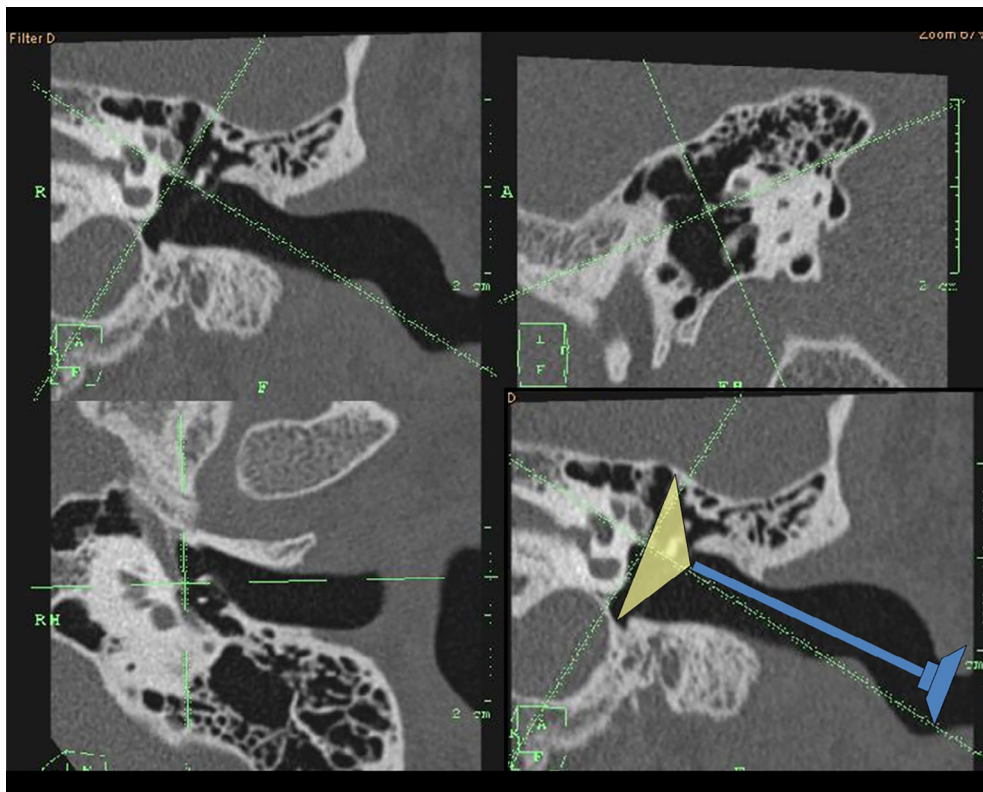


Fig. 11. Multiplanar computerized tomography of a normal tympanic cavity with axial, sagittal, and coronal views demonstrates that the cochleariform process is the anatomic center of the cavity which is aligned with what we see endoscopically in Figure 10.

Eustachian tube. He also found that in cases where the obstruction can be bypassed, the obstructed segment did not extend much beyond that point.²⁸ However, it should be indicated that the quality of the images obtained with the fiber optic device he used is very limited which can lead to misleading assessment of these images. EES with rigid scopes

allows the high-resolution evaluation and instrumentation of the protympanic segment of the tube.³¹ We have reproduced Linstrom study using high-resolution rigid scopes and valsalva computerized tomography and confirmed his findings in our patient population: namely that the distal tube is patent and the proximal part is the site of the obstruction in chronic ear disease.³² This area contains the isthmus, the

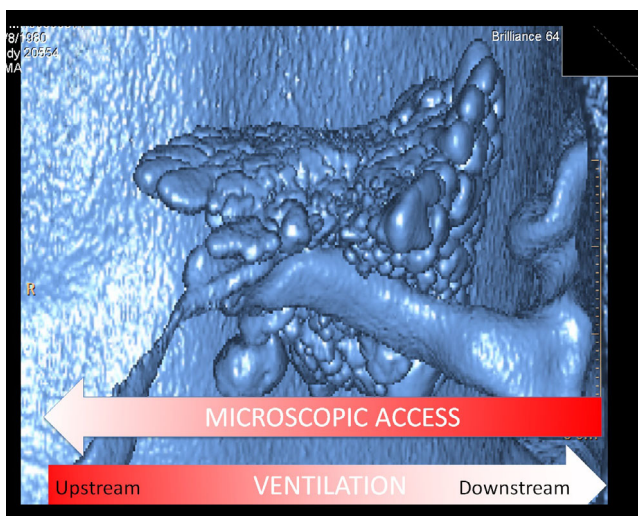


Fig. 12. Three-dimensional reconstruction of the air spaces within temporal bone, which was derived from a valsalva computerized tomography of a normal temporal bone. Note that microscopic access is misaligned with the most important areas of ventilation, the upstream part of the air cell system.

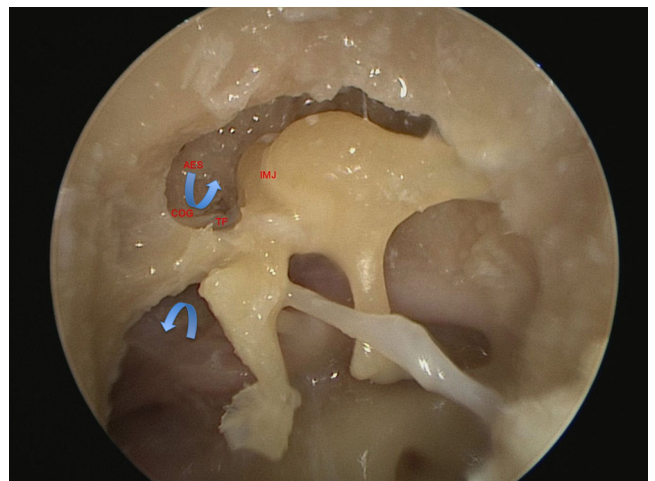


Fig. 13. Left ear: The anterior attic is separated from the supratubal recess and the Eustachian tube by the tensor fold, so there is no direct communication or ventilation anteriorly between the attic and the Eustachian tube.

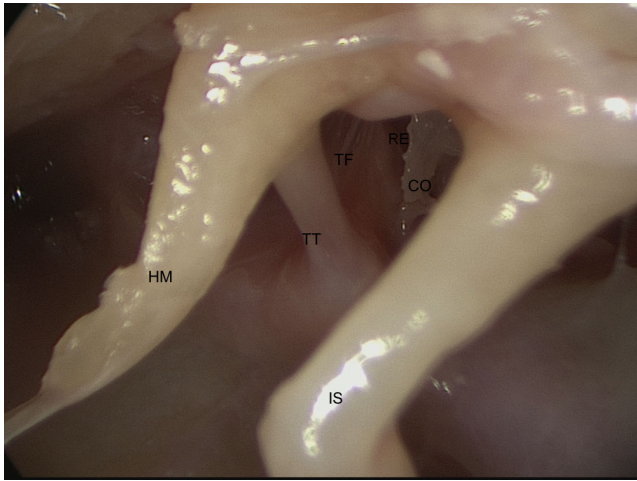


Fig. 14. Left ear: Peeking through the isthmus with a 30° endoscope. CO = the COG; HM = handle of malleus; IS = incudostapedial joint; RE = the recess formed through the insertion of the fold anterior to the COG; TF = tensor fold; TT = tendon of the tensor tympani.

narrowest segment of the cartilaginous tube and is in close proximity to the tympanic cavity and any recurrent inflammatory process within it during childhood years. However, it stands to reason that there is a degree of variability in the site of obstruction and that some of our patients do have obstruction in other more distal locations in the Eustachian tube. In our opinion, the access into the protympanum and the proximal Eustachian tube might add tremendous amount of knowledge on the pathophysiology of chronic ear disease as it gives the clinicians the opportunity to routinely examine and access this important part of the anatomy. It also might change long held nomenclature and understandings of this area's anatomy. Microscopic and gross anatomical observations of the "bony tube" have long made a distinction between the "Protympanum," a tympanic cavity structure, and a more anterior and inaccessible "Bony

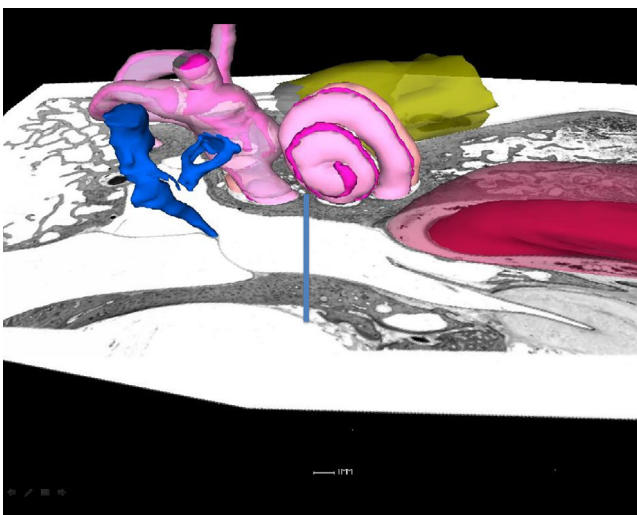


Fig. 15. Axial histological section of the temporal bone with the cochlea and malleus simulated for orientation. The blue line is an arbitrary separation between protympanum and "bony Eustachian tube." ET = Eustachian tube; FP = false passage.

Eustachian tube." Endoscopic observation of that area allows a very different view of anatomy and renders this distinction arbitrary and irrelevant. Indeed, by observing the protympanum from this perspective, it is clear that the bony Eustachian tube and the protympanum are essentially one and the same (Fig. 15). We believe that this calls for a redefinition the Eustachian tube as a fibrous/cartilaginous structure that stretches from the nasopharynx to the most anterior part of the tympanic cavity (the protympanum along with what used to be referred to as bony tube).³³ This clear anatomic redefinition is critical for any further observations and instrumentation in that area. What used to be described as a junctional area of the Eustachian tube is really the most proximal segment of that cartilaginous Eustachian tube surrounded by the bony encasement of the petrous bone or the "Protympanum." In our opinion, it is this proximal end of the tube that is being observed, instrumented, and dilated with transtympanic methods.

CONCLUSION

TEES is developing rapidly and attracting the attention of researchers and clinicians. Much more needs to be done to standardize technique and nomenclature, investigate and compare outcomes, and develop further dedicated instruments.

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