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Training and Education in Endoscopic Ear Surgery

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Abstract With rising global interest in minimally invasive surgical approaches and the cumulative advances in technology, there is a growing population of otolaryngologists incorporating endoscopic ear surgery into clinical practice and residency training. To date, limited data are available on the learning curve and training process involved in this technique. While the endoscopic approach to the ear has several advantages, it carries also unique challenges and risks that one should be aware of as they impact endoscopic skill acquisition. The current practices in endoscopic ear surgery training involve sharing of technical pearls and a graded step-by-step approach to endoscopic skill development through clinical practice and hands-on courses. In the academic environment, the endoscopic approach carries several advantages for the trainees—through improvement in teaching and the relative ease of the technique as compared to the traditional microscopic approach.

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Introduction

Since the introduction of endoscopy for examination of the middle ear by Mer et al. [1], endoscopic ear surgery has developed slowly through cumulative advances in technique, quality of equipment and the continued efforts and enthusiasm of leading endoscopic ear surgeons. Compared to the traditional microscopic approach, endoscopy is currently less frequently used in the day-to-day surgical management of ear diseases around the world. However, in parallel with the improvement in optical technologies, the last decade has seen an exponential rise in the overall interest in endoscopic ear surgery within the otology community, as reflected by the significant increase in publications, presentations and training courses offered in this field.

The currently published literature compares endoscopic ear surgery techniques and outcomes to traditional microscopic surgery for a wide variety of otologic procedures including ventilation tube placement [2], tympanoplasty [3•, 4•], stapedotomy [5–7], cholesteatoma [8••, 9], and skull base surgeries [10]. As the efficacy of the technique and good patient outcomes are documented, some authors share technical pearls to help those interested in introducing this technique into their practice [11••]. While some authors mention that the learning curve for endoscopic middle ear surgery is long, even for surgeons experienced in microscopic middle ear surgery [12], others argue that those experienced with endoscopy will find the technique easy to master [11••]. The current literature is, however,

lacking data on the learning curves of endoscopic ear surgeries, the case load needed to achieve proficiency and the overall volume of experience of endoscopic ear surgery training of residents and fellows.

In this context, this chapter proposes a discussion of the educational aspects of endoscopic ear surgery through a review of the advantages of the endoscopic view, the challenges of endoscopic training and the risks of the endoscopic approach. Current practices in endoscopic training are summarized and experiences with the introduction of endoscopic ear surgery to clinical practice and residency training are discussed.

General Principles of Endoscopic Ear Surgery

Advantages of the Endoscopic Field of View

When compared to the microscopic approach to the ear, endoscopic ear surgery is essentially a different method of viewing the surgical site. The basic surgical principles and instruments are fundamentally similar between endoscopic and microscopic approaches to the ear, but the method and extent of visualization are different [13]. The view from the microscope during transcanal surgery is limited by the narrowest segment of the ear canal [14••]. In contrast, the endoscope bypasses this narrow segment and provides a very wide view that allows the surgeon to "look around corners." Consequently, narrow external auditory canals and anterior canal bony prominences are not nearly as much of an impediment to endoscopic ear surgery as they are to microscopic surgery. An anterior tympanic membrane perforation can, therefore, be repaired without a postauricular incision [13].

As the surgeon moves toward the middle ear, the endoscope allows a clear view of hidden recesses within the hypotympanum, retrotympanum, and epitympanum while decreasing the required extent of scutal curetting. It avoids a postauricular incision and mastoidectomy that are traditionally part of the microscopic access to these spaces [14••]. As the entrance to the ear canal is not constrained by a speculum, instruments can also be manipulated through a wider angle, allowing access to these hidden recesses [11••]. In cholesteatoma surgery, the complementary value of endoscopes to the traditional microscopic eradication of disease has been well established since the ability to view blind spots decreases residual disease and recurrence rates when compared to surgeries that used microscopy alone [9, 15]. In stapes surgery, the use of the endoscope decreases the need for scutal curetting and is associated with less injury to the chorda tympani nerve [5–7].

Overall, endoscopy allows the surgeon to view hidden structures thus facilitating a minimally invasive operation with greater healthy tissue preservation.

Challenges of Endoscopic Ear Surgery

Although the principles and steps of ear surgery are similar in the endoscopic and microscopic approach, the skills required for hand-eye coordination are different given that the visualization methods differ. First and foremost, the endoscopic approach requires proper use of the endoscope, thus explaining why those comfortable with endoscopic sinus surgery often find the transition to endoscopic ear surgery considerably easier. Overcoming the challenges outlined below are definite steps in the learning curve of endoscopic ear surgery that requires training and practice; however, the slope of the learning curve will vary and will likely be commensurate with one's prior experience and comfort with using an endoscope.

Distortions and Wide Angle

While endoscopes provide the surgeon with a way to effectively look around corners without additional tissue removal, retraction or further drilling, getting used to the orientation and the anatomy as they appear through endoscopes, especially angled endoscopes, requires practice. A significant learning curve exists for these angled endoscopes, and the greater the angle the greater chance for disorientation [10]. One feature that is typical to all endoscopic views is the "fish-eye" nature of the image where the peripheral surgical field of view is more magnified than the center. This is important to keep in mind when outlining the cuts of the tympanomeatal flap whose length can be misjudged due to this optical effect leading to a flap that is too short and difficult to replace along the bony ear canal [11••].

One-Handed Surgery

One of the biggest challenges of transcanal endoscopic ear surgery is the one-handed nature of the technique. Typically the non-dominant hand holds the endoscope, and the surgery is performed one-handed with the surgeon's dominant hand. Although the inability to operate bimanually is a clear disadvantage, the actual functional limitations are not as significant as they might initially appear. On analysis, the function of the non-dominant hand during traditional surgery is usually to maintain suction and remove blood from the operative field while the dominant hand still performs the majority of the delicate surgery [11••]. For optimal performance as a one-

handed surgeon, proper hemostasis is therefore critical. From the outset, with the reduced trauma to normal tissues, the endoscopic approach fosters less bleeding. In addition, several technical pearls, which are discussed in a later section of this review, are acquired through experience and help optimize one's performance in the one-handed approach.

Lack of Depth Perception

Another perceived challenge of the endoscopic view when compared to the microscopic one is the two-dimensional nature of the image that hinders stereotactic vision and depth perception. Therefore, the endoscopic surgeon must learn to accommodate the loss of depth perception. Most authors agree that this is easily overcome with practice [9, 11••]. This is even reported to be the case for stapes surgery where stereoscopic vision has traditionally been considered as necessary for perceiving subtle differences of depth when cutting the stapedial tendon or affixing the prosthesis to the incus [5]. Some have hypothesized that the compensation for depth perception is accounted by our ability to associate small movements of the scope with corresponding changes in the field of view to obtain a three-dimensional appreciation of the anatomy [12]. Therefore, with practice, the brain is able to appreciate the three-dimensional nature of the surgical field through a two-dimensional picture.

Risks of Endoscopic Ear Surgery

Awareness of the risks inherent to the endoscopic approach is essential when learning this technique to minimize adverse events.

Thermal Injury

Since the light source at the tip of the endoscope is in close proximity to the operating field, there is a concern for potential thermal injury to the middle ear structures and the inner ear through the round window. We know that the temperature can be as high as 104 °C at the tip of a 4 mm, 0 degree endoscope [16]. Cooling however occurs rapidly after the light source is switched off. A recent study has found that in a tight place like the middle ear, there is rapid temperature elevation up to 8 mm from the tip that can reach up 46 degrees C in less than 2 min [17]. This means that working in a specific area without moving for a long time carries the risk of thermal injury. It is therefore recommended to use submaximal light intensity, suction, irrigation, and frequent repositioning or removal of the endoscope to allow tissue cooling [17].

Mechanical Injury

Mechanical injury due to endoscopes is another potential risk, particularly in beginners, as the scope has a chance to come very close to delicate middle ear structures, potentially dislocating the ossicles, injuring the facial nerve or a low-lying tegmen [9]. Therefore, the endoscope should be manipulated with great care if it is introduced beyond the tympanic annulus. Some authors recommend the use of a larger 4-mm endoscope initially as an extra safety margin as it has been argued that it is almost impossible to advance it far enough into the tympanic cavity to cause injury [14••].

Introducing Endoscopic Ear Surgery to Clinical Practice

For a surgeon aware of the advantages, challenges and risks of the endoscopic approach, who wishes to introduce endoscopic ear surgery to practice, the following sections summarize some technical 'pearls' proper to this approach, outline a graded approach to skill development, and detail the expected benefits of formal training through hands-on courses.

Technical pearls for endoscopic ear surgery beginners

1. The endoscope is held in the non-dominant hand with two-point stabilization to help provide a stable visual field [12]. The shaft of the scope rests firmly on the side of the opening of the external auditory canal while the surgeon's elbow or forearm is supported by an operating chair armrest or adjustable Mayo stand to avoid fatigue and allow for a more comfortable operating posture [13] (Fig. 1).
2. To avoid smearing the endoscope each time it is introduced into the ear, the external auditory canal hairs are trimmed using small curved scissors. Operating instruments held in the dominant hand are used to gently retract the tragus anteriorly and increase space to pass the endoscope into the external auditory canal.
3. A zero degree endoscope is often favored in the early stages of training due to it is ease of use; however, in our experience as comfort increases with the technique many transition toward a 30 degree endoscope given the benefits of angulation, and the reduced need to change scopes throughout a procedure.
4. As previously mentioned, proper hemostasis is essential to optimize performance in this one-handed technique which can be ensured by the following steps:

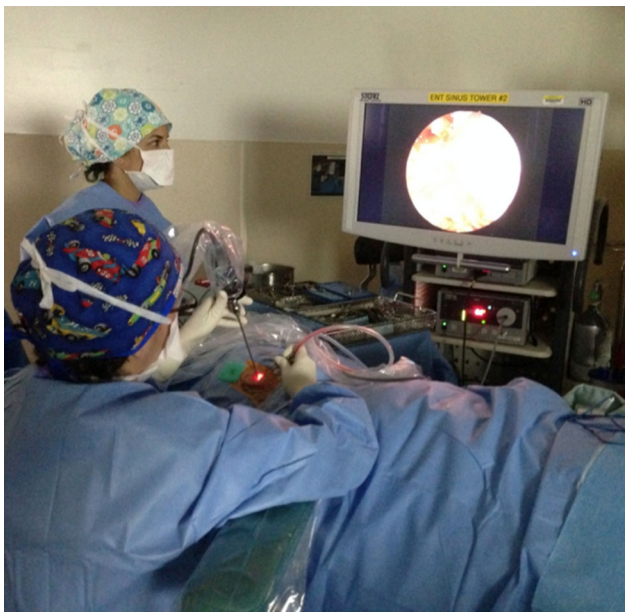

Fig. 1 Positioning for surgery: the endoscope is held in the non-dominant hand

- The external auditory canal is infiltrated with a mixture of local anesthetic and epinephrine. Xylocaine 1–2 % with epinephrine 1:100,000 is commonly used. The external auditory canal is then packed with neuro-patties soaked in topical epinephrine 1:10,000. This is performed before the patient is 'prepped and draped' to allow time for the vasoconstrictive effect to take place.
- Hypotensive anesthesia and gentle head elevation can also help minimize bleeding [13].
- Instrument manipulation in the external canal is done carefully to avoid injuring the canal wall, which generates swelling and bleeding that can compromise the visibility within the operative field.
- Outlining and elevating the tympanomeatal flap is often the most challenging and the bloodiest step of the surgery; however the bleeding often subsides once the flap is elevated and tucked in the anterior tympanic crease. Applying an epinephrine soaked patty to the bleeding edge while avoiding direct suctioning on the edges of the incision is often sufficient to minimize the bleeding and complete the elevation. Alternately, a suction round knife can be used for flap elevation (Videos 1, 2) or an assistant can suction gently behind the round knife using a "three-handed technique." The "three-handed technique" can be performed by the supervising surgeon who stands beside the primary surgeon and uses an extra instrument in the field to help guide the trainee through the steps of the surgery, either by pointing at relevant structures or assisting where necessary with suctioning or gentle retraction (Video 3).

5. If bleeding is encountered at any other moment during the surgery, application of an adrenaline soaked patty or Gelfoam® over the area for a few minutes is sufficient. Alternatively, applying a piece of Gelfoam® and irrigating the area gently with saline can also assist with hemostasis. Most importantly, one must be patient and give hemostasis time to take place.
6. When outlining the tympanomeatal flap incision one should remember the "fish-eye" optical distortion of the endoscope and use the round knife to gauge the actual distances to avoid having a flap that is too short. In our experience, the width of two to three large round knives yields an adequate flap length for most cases (Video 4), but keep in mind that the flap length needed will vary according to the nature of the procedure.
7. If the view is limited around the scutum, only a small amount of bone needs to be removed to increase exposure considerably. A few millimeters of additional curetting results in significantly increased visualization with the endoscopic approach.

A Graded Approach for Endoscopic Skill Development

For a surgeon starting with the endoscopic approach, it is advisable to have both the endoscope and the microscope available and ready for use in all cases until confidence from experience with endoscopy has been achieved. This allows the advantages of each tool to be used when required and to switch between modalities when needed, thus building endoscopic skills step-by-step. With increased endoscopic skill development, the reliance on the microscope for middle ear surgery steadily decreases.

To get familiar with the endoscopic view of the ear, one can start by performing otoendoscopies for physical examination in the outpatient clinic, graduating to myringotomy and ventilation tube placement or fat graft myringoplasty (Video 5) as comfort increases. As a more complex procedure is tackled, it is important to remember that raising the tympanomeatal flap is one of the more difficult steps of the endoscopic approach primarily because bleeding is more difficult to manage in a one-handed technique. For this reason, some surgeons might start microscopically until the middle ear is reached, at which point the endoscope is introduced [11••].

As discussed, the endoscopic view is particularly advantageous when assessing cholesteatoma extension and residual disease in the retrotympanum and epitympanum (Videos 6, 7, 8, 9). Initially, a beginner endoscopist might use the endoscope to 'look around' the middle ear and familiarize themselves with the 'wide-angle' view of the

anatomy. Rapidly, it will be clear that the endoscopic view is particularly favorable for the dissection of tympanic membrane retraction and cholesteatoma. The reconstructive steps are, however, more challenging with the endoscope since the optimal prosthesis, cartilage or graft placement is easier to achieve with two hands (Video 10).

Overall, the dual approach with both the endoscope and microscope is therefore encouraged at the beginning. Performing ear surgery exclusively with the endoscope is challenging, but regular practice and a step-by-step progression from easy to more challenging cases make the technique attainable for any motivated otologist (Video 11). When starting, it can also be useful to collaborate with surgeons who are more familiar with endoscopic ear surgery to overcome more rapidly some of the challenges of this technique.

The endoscope should be considered the tool of choice in the middle ear, with the microscope reserved for disease extension beyond the reaches of an endoscope into the mastoid cavity. It is not a failure to convert to an open microscopic mastoidectomy approach as this is appropriate for more extensive disease involving the deeper recesses of the mastoid cavity. The authors' opinion is that that the limit of the endoscopic approach is typically disease extension beyond the posterior limb of the lateral semicircular canal. One of the most difficult aspects of endoscopic ear surgery to master is making the decision to convert to an open approach in a timely efficient manner, but this will vary according to clinical factors as well as the skill and confidence levels of the surgeon.

Hands-On Endoscopic Ear Surgery Courses

Although no formal training is strictly necessary when beginning endoscopic ear surgery, attending a course can be valuable even for the most experienced otologist since it allows for more rapid acquisition of skill and an opportunity to overcome the challenges posed by the endoscopic approach in a risk-free environment. It is the authors' recommendation that at least one hands-on endoscopic course be taken before embarking with endoscopic ear surgery; it not only increases confidence but it will also help ensure more consistent progress when getting started.

Most courses span over 2–3 days and involve lectures, live demonstration dissections and hands-on cadaveric dissections of fresh-frozen or partially preserved specimens [11••]. The courses aim to develop the trainee's understanding of the endoscopic anatomy of the middle and inner ear through transcanal access and focus on the unique configuration of the cholesteatoma-bearing areas of the middle ear [18]. In addition, the unrestricted dissection of the cadaveric ear and the practice of surgical steps allow the development of hand-eye coordination and bolster skills that are required for endoscopic ear surgery.

The sustained teaching efforts of the International Working Group on Endoscopic Ear Surgery (www.iwgees.org) have lead to an exponential rise in the number of courses offered around the world. From two annual courses given in 2009, the IWGEES successfully ran thirteen courses in 2014 thus providing surgeons around the world with the skills and techniques necessary to begin endoscopic ear surgery.

Introducing Endoscopic Ear Surgery to Residency Training

Impact of the Endoscopic View on Otology Surgical Skills Acquisition

For surgeons that are proficient in microscopic ear surgery, the advantages of endoscopic visualization are attributed to the wider endoscopic view that allows access to hidden spaces with minimal normal tissue removal. However, for the trainee inexperienced in otologic surgery, several other features of the endoscopic approach can contribute to an easier learning experience when compared to the microscopic approach.

A speculum is often used with the microscopic approach, and many trainees initially find it challenging to hold the speculum and suction with their non-dominant hand simultaneously. The use of longer endoscopes than the traditional oto-endoscope places the surgeon's two hands at different distances from the ear canal and they are therefore less likely to interfere with one another during surgery [11••]; this further decreases the clutter around the ear that is challenging for novices. The initial struggles of instruments' shafts and surgeons' hands compromising the microscopic view are avoided as the endoscopic 'bird's-eye' view of the field is beyond the entrance of the external auditory canal [14••]. With practice, the position of the scope can be adjusted to allow safe insertion and removal of instruments from the ear and to allow optimum angulation and movement of instruments within the ear [12].

For optimization of the visual field, endoscopic adjustments are easier than manipulations of the microscope. With the endoscope, slight movements of the wrist or hand alter the surgical exposure and optimize the view for the specific task at hand without putting down any of the instruments [13]. Changing the magnification with the endoscope is simply achieved by moving it closer to the structure in question without the need for refocusing when changing position [14••]. By removing the frequent microscope manipulations that are typical for junior trainees, the endoscopic approach is a simpler first step when being introduced to otologic surgery and the wider field of view helps foster an understanding of anatomy and key anatomic relationships in the middle ear.

Endoscopy as a Teaching Tool

Several authors describe the endoscopic approach to ear surgery as highly suitable for education [3•, 5, 13]. Since the surgeon, all the trainees and operating room staff can view the same high-definition images displayed on the monitor, teaching of the anatomy, surgical steps and the complex three-dimensional relationships of structures of the middle ear is enhanced and simplified, thus facilitating a quality learning process for all those attending the surgery and not only the senior trainee sitting at the 'coveted side viewer' of the microscope.

In addition, trainees are often allowed to progress further as the primary surgeon in endoscopic cases versus microscopic cases. Having an identical surgical view allows the supervising staff to better guide the trainee and feel more confident that the steps of the procedure are being performed adequately.

With the decreasing prevalence of ear pathology and growing number of trainees, the use of the endoscope can optimize the learning potential of every surgical case.

The University of British Columbia Experience with Endoscopic Ear Surgery Training

In 2014 an informal survey of residents and fellows at the University of British Columbia was completed to better understand the learning experiences and trainee attitudes toward endoscopic ear surgery ($n = 13$). All trainees were found to have a positive attitude toward endoscopic ear surgery and felt they would implement endoscopic ear surgery techniques into their future practice.

Fellows had extensive microscopic ear surgery experience with over 200 tympanomeatal flaps raised. Fellows with more than 20 endoscopic tympanomeatal flaps started to prefer the endoscope to the microscope for flap elevation. In contrast, a fellow with similar microscopic experience, but only five flaps raised endoscopically, still reported the microscopic approach to be easier. Junior residents with a similar endoscopic case log (five cases), but with much lower overall otologic experience, preferred the endoscopic approach to the microscopic approach for tympanomeatal flap elevation. This is not surprising given the previously outlined technical simplifications that are facilitated by the endoscopic approach. Among fellows, endoscopic tympanoplasty was preferred over the microscopic approach after 40 endoscopic ear cases.

This is a very small experience of postgraduate training in endoscopic ear surgery at one institution, but the data support the concept that endoscopic ear surgery is likely easier to master than microscopic ear surgery for a novice trainee in otologic surgery. For those who are already comfortable with the microscopic approach, it seems that more cases are needed to prefer the endoscopic technique.

A study comparing endoscopic to microscopic myringoplasty revealed that most residents were willing to become more familiar with endoscopic techniques and invest time to learn this new technique [4•]. It was concluded that endoscopic ear surgery "does seem to have a place in resident training and would be accepted with reasonable enthusiasm" [4•].

Conclusions

The popularity of the minimally invasive endoscopic approach to ear surgery is on the rise. The number of Otolaryngologists around the world seeking advanced training in this technique is increasing exponentially. With its introduction into academic centers and residency training, it is likely that the popularity of this technique will continue to expand and will be supported by technological progress in optical quality and instrumentation. With the growing pool of endoscopy learners, more data should become available on the learning curves and optimal training processes with this technique.

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Compliance with Ethics Guidelines

Conflict of Interest Dr. Mijovic and Dr. Lea declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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