



Review Article

# Current trends and applications in endoscopy for otology and neurotology

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**Abstract** There has been a rapid increase in endoscopic ear surgery for the management of middle ear and lateral skull base disease in children and adults over the last decade. In this review paper, we discuss the current trends and applications of the endoscope in the field of otology and neurotology. Advantages of the endoscope include excellent ergonomics, compatibility with pediatric anatomy, and improved access to the middle ear through the external auditory canal. Transcanal endoscopic ear surgery has demonstrated comparable outcomes in the management of cholesteatoma, tympanic membrane perforations, and otosclerosis as compared to microscopic approaches, while utilizing less invasive surgical corridors and reducing the need for postauricular incisions. When a postauricular approach is required, the endoscopic-assisted transmastoid approach can avoid a canal wall down mastoidectomy in cases of cholesteatoma. The endoscope also has utility in treatment of superior canal dehiscence and various skull base lesions including glomus tumors, meningiomas, and vestibular schwannomas. Outside of the operating room, the endoscope can be used during examination of the outer and middle ear and for debridement of complex mastoid cavities. For these reasons, the endoscope is currently poised to transform the field of otology and neurotology.

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**Abbreviations:** EES, Endoscopic ear surgery; TEES, Transcanal endoscopic ear surgery; TMEES, Transmastoid endoscopic ear surgery; MES, Microscopic ear surgery.

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## Introduction

Over the last four decades, the endoscope has emerged as a powerful surgical tool for minimally invasive surgery, allowing access to hidden recesses for visualization, excision, or correction of pathologies without unnecessary disruption of overlying soft tissue or bone.<sup>1</sup> While it was often met with skepticism, many surgical fields have since adopted the endoscope as an essential tool in their armamentarium, including the fields of rhinology and laryngology. The field of otology and neurotology is currently undergoing a similar evolution, advancing the endoscope's utility from observational to operative. In the last decade, there has been a rapid increase in endoscopic ear surgery (EES) for the management of middle ear and lateral skull base disease in children and adults. As such, the objective of this article is to discuss the current trends and applications in EES by (1) discussing the advantages and disadvantages of EES compared with traditional microscopic approaches, clarifying indications for EES in (2) otology and (3) neurotology, and (4) describing the utility of the endoscope in an office setting.

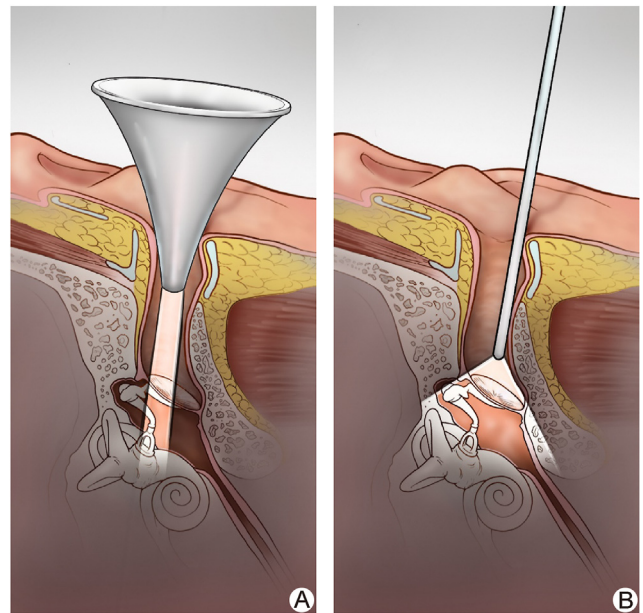
## Discussion

### Advantages and disadvantages of endoscopic ear surgery

The binocular microscope revolutionized otology because of its ability to illuminate and magnify the surgical field, while freeing up a surgeon's hands to allow for two-handed dissection. However, the microscope provides a line-of-sight image with a narrow field of view that is limited by the size and shape of the external auditory canal (EAC) and the speculum (Fig. 1A). It is therefore often necessary for a parallel port to be created through the mastoid to gain access to middle ear spaces that are poorly visualized by the microscope, such as the attic, facial recess, and the hypotympanum.<sup>1</sup> Postauricular approaches require added soft tissue retraction and bony drilling which can lead to dysesthesia or anesthesia of the auricle, hypertrophic scars, keloids, or wound infection.<sup>2</sup>

Endoscopes overcome many of the limitations of the binocular microscope (Table 1) by providing a non-line-of-sight view that is less limited by port size and shape, with both illumination and image capture taking place at the distal tip of the scope in close proximity to the surgical field (Fig. 1B). This is of particular advantage in patients with tortuous or small EACs. The endoscopic image also has an enhanced depth of field with a wide angle view that allows surgeons to "look around corners" into hidden recesses inaccessible by microscope.<sup>3</sup> EES has the ability to revolutionize the field of otology and neurotology by using the EAC as a minimal-access surgical corridor, decreasing the need for added soft tissue retraction or bony drilling.<sup>4</sup>

Advantages of the endoscope extend beyond improved access and visualization. EES also has a lower equipment cost and superior ergonomics as compared to microscopic ear surgery (MES),<sup>5</sup> and is an excellent teaching tool because all users and observers share the same surgical



**Figure 1** Anatomy illuminated by microscope versus endoscope. A: The size and shape of the external auditory canal and speculum limit the microscopic view. B: The endoscopic image is captured in close proximity to the surgical field with a wide angle lens, overcoming many of the anatomic limitations of the microscope. Illustration courtesy of Brian Dunham and Eo Trueblood.

view. Endoscopes, however, are not without their own set of limitations. Downsides of EES include the need to perform all dissection one-handed without suction available in the other hand, and reliance on motion parallax to assess depth perception. There is also a steep learning-curve for non-endoscopic trained surgeons and a lack of exposure during training at most sites. Fortunately, the number of training opportunities has increased as EES has become more popular.

### Ergonomics

Ergonomics is the study of procedures and products that maximize efficiency and safety in the workplace. Prolonged periods of poor posture and poorly designed operating room setups can cause musculoskeletal pain and disability for surgeons. Prolonged microscopic work in particular has been linked to increased risk of neck and back strain,<sup>6</sup> even in the outpatient setting.<sup>7</sup> Most otolaryngologists report low rates of ergonomic training and demonstrate medium to high ergonomic severity risk and high levels of musculoskeletal strain when observed in the operating room.<sup>8</sup> In a UK survey of 325 ENTs, 72% reported back or neck pain and otologists were found to have the highest reported pain of ENT subspecialties, likely related to microscope work that can require hours of static neck, back, and hand positions.<sup>9</sup> Studies have demonstrated that optimal monitor positioning and surgical setting improve performance and efficiency, which can positively impact both cost and patient safety.<sup>10</sup> For this reason, procedures and products that allow for neutral neck, back, or hand positions should be considered.

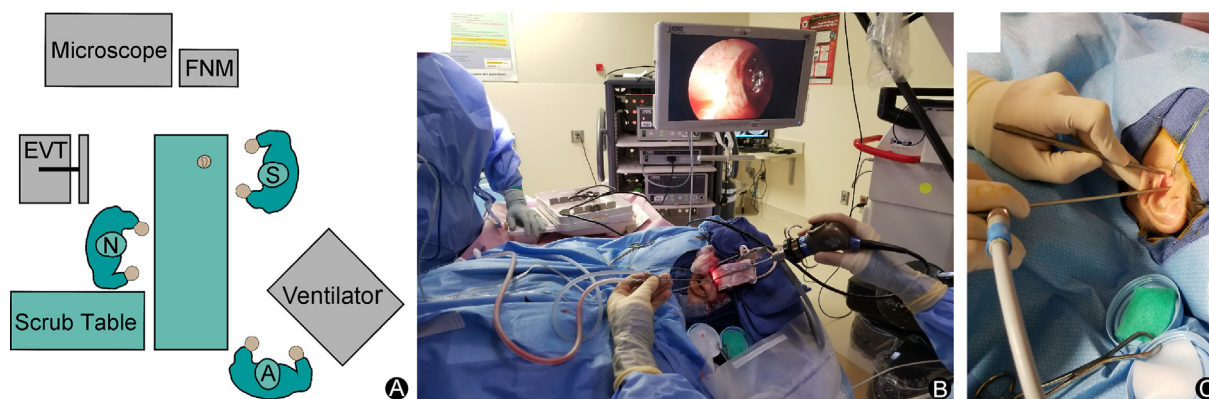
**Table 1** Advantages and disadvantages of endoscopic and microscopic ear surgery.

	Advantages	Disadvantages
Endoscopic ear surgery	<ul style="list-style-type: none"> <li>• Lens is closer to surgical field</li> <li>• Enhanced depth of field</li> <li>• Wide angle view</li> <li>• Superior surgical field illumination, light source at distal tip of endoscope</li> <li>• Ability to look around corners, superior view of hidden recesses, not limited to line-of-sight</li> <li>• Superior ergonomics, heads up surgery</li> <li>• Avoid use of speculum, transcanal view is not limited by size and shape of speculum</li> <li>• Transcanal view is not limited by size and shape of ear canal, optimal for pediatric cases or in those with small or tortuous EAS</li> <li>• Improved visualization of middle ear without extensive bony or soft tissue dissection, reduced need for mastoidectomy/postauricular incision</li> <li>• Teaching tool, all participants share the same view</li> <li>• Lower equipment cost</li> </ul>	<ul style="list-style-type: none"> <li>• No true depth perception with 2D scopes, reliance on motion parallax to assess depth perception</li> <li>• Limited to one hand dissection</li> <li>• No hand available for simultaneous suction</li> <li>• Limited instrumentation</li> <li>• Lack of exposure during training, steep learning-curve</li> <li>• Difficult to fit scope and tools in smallest pediatric canals</li> </ul>
Microscopic ear surgery	<ul style="list-style-type: none"> <li>• Provides true depth perception</li> <li>• Two handed dissection possible</li> <li>• Suction available in one hand</li> <li>• Good for open procedures</li> <li>• More training available using microscope</li> </ul>	<ul style="list-style-type: none"> <li>• Lens is farther from surgical field</li> <li>• Shallower depth of field</li> <li>• Narrower field of view</li> <li>• Inferior surgical field illumination, light source located outside of surgical corridor</li> <li>• No ability to look around corners, inferior view of hidden recesses, limited to line-of-sight</li> <li>• Inferior ergonomics, heads down surgery</li> <li>• Speculum used, transcanal view limited by size and shape of speculum</li> <li>• Transcanal view is limited by size and shape of ear canal, challenging in pediatric cases or in those with small or tortuous EAS</li> <li>• Limited view of middle ear, more likely to require mastoidectomy/postauricular incision</li> <li>• Challenging to use for teaching purposes, surgeon and trainees have different views</li> <li>• Higher equipment cost</li> </ul>

The operating room setup for EES, while similar to that of traditional MES, requires additional considerations to optimize body mechanics and allow for “heads up” ear surgery. *The endoscopic video tower or mounted video screen should be placed directly across from the surgeon, as close to eye level as possible to keep the neck in a comfortable neutral position.* The scrub nurse and scrub table should be next to the video monitor, with instruments being passed over the patient’s torso (Fig. 2B). The anesthesiologist should be facing the surgeon for ease of conversation during the case. The microscope should remain available at all times in case of the need for conversion to the microscope. Keep in mind that the operating room layout is dependent upon the sidedness of the case (Fig. 2A).

Positioning of the body in a comfortable and safe position is critical to prevent muscle fatigue and camera shake. The surgeon should sit in a standard otologic chair with armrests. Forearms and elbows should be stabilized by resting them on the armrests, table, or gently on the patient’s shoulder. The endoscope itself should be stabilized by resting it gently on the cartilaginous meatus (Fig. 2C).<sup>4</sup> Endoscope holders are available and can be safe if used with frequent aspiration and irrigation,<sup>11</sup> but are not recommended due to risk of injury if the patient moves unexpectedly and the potential for dangerous levels of thermal radiation.<sup>5,12</sup>

It is also critical to note that a *right-handed surgeon* will likely find a *left-sided case* to be easier and should therefore start with left-sided cases. In this situation, the dominant



**Figure 2** Operating room setup. A: Operating room layout for maximum ergonomic benefit in a left-sided endoscopic ear surgery case. A right-sided case uses an inverted layout. EVT: Endoscopic video tower, FNM: facial nerve monitoring, S: surgeon, N: scrub nurse, A: anesthesiologist. B: Left-sided middle fossa craniotomy. The endoscopic video monitor should be placed at eye level, directly across from the surgeon. The scrub nurse is positioned next to the monitor. C: Hand placement during left-sided transcanal EES for a left-handed surgeon or an advanced right-handed surgeon. The endoscope is gently resting on the cartilaginous meatus to provide stability.

hand is used for dissection and the non-dominant hand can rest on the patient's shoulder to stabilize the endoscope. A left-sided case will feel different than a right-sided case because the vectors of the endoscope and dissection instruments are influenced by anterior canal wall overhang. In left-sided cases, this overhang biases the endoscope toward the mesotympanum and epitympanum for excellent visualization of the facial nerve and the ossicles.<sup>13</sup>

#### Endoscopic ear surgery is compatible with pediatric anatomy

As mentioned previously, EES is of particular advantage over line-of-sight MES when the patient has a small ear canal. EES is therefore ideally suited for the pediatric population. However, the relative ratio of the endoscope diameter to that of the ear canal presents an additional anatomic challenge.<sup>2</sup> A 2017 study of CT scans from 40 pediatric subjects with a median age of 8.5 years found that the average pediatric EAC isthmus is 5.4 mm in diameter, as compared to 6.9 mm in adults, and that 84% of pediatric patients were able to undergo transcanal EES with a 3 mm endoscope.<sup>14</sup> For smaller ear canals, 2.7 mm and 1.9 mm scopes are available. Additionally, the more acute angle of the EAC relative to the tympanic membrane in children presents another anatomic challenge, as this can interfere with visualization of the epitympanum and the retrotymppanum for both microscopes and 0° endoscopes. Angled endoscopes paired with angled instruments are useful in this situation but should be reserved for surgeons with ample EES experience.<sup>2</sup> These anatomical differences make microscopy especially challenging in a pediatric population, often necessitating a postauricular approach. In such cases, transcanal endoscopic ear surgery can reduce the need for a postauricular incision and avoid the associated postoperative challenges.

#### Applications of endoscopic ear surgery for otology

In otology, the endoscope's utility has advanced from observational to operative. Endoscopes were first used in

otology solely to describe ear anatomy,<sup>15,16</sup> and then as adjuncts in MES to search for residual disease following cholesteatoma resection.<sup>17</sup> The late 1990s brought the advent of EES, and the endoscope graduated from an adjunct observational tool (otoendoscopy) to a principal operative tool.<sup>18</sup> In the last decade, there has been a rapid increase in EES for the management of middle ear disease in children and adults.<sup>19</sup> Cholesteatoma management is the most widely studied EES application, but there has been a recent surge of studies on non-cholesteatoma otologic endoscopic procedures as well.<sup>19</sup> Thanks to these studies, applications of EES have grown rapidly (Box 1). Notable otologic indications include tympanic membrane perforations and chronic ear diseases such as cholesteatomas and otosclerosis. For both routine and complex middle ear diseases, EES has allowed surgeons to perform a greater number of transcanal dissections. When a postauricular approach is necessary, endoscopic-assisted transmastoid removal of chronic ear disease can help to avoid a canal wall down approach.<sup>2</sup>

#### Transcanal endoscopic ear surgery (TEES)

The advantages and disadvantage of EES and MES were discussed in detail in the first section of this article and are presented in Table 1. In short, the image provided by a microscope is limited by the size and shape of the EAC and speculum. A parallel port created through the mastoid is sometimes required to gain access to middle ear spaces that are poorly visualized by the microscope.<sup>1</sup> The endoscopic view is less limited by EAC size and shape because illumination and image capture take place at the distal tip of the scope in close proximity to the surgical field.<sup>3</sup> Establishing the EAC as a feasible access port to the middle ear is the main benefit of EES, as this reduces the need for postauricular approaches that can cause dysesthesia or anesthesia of the auricle, hypertrophic scars, keloids, or wound infection. Mastoid care can be especially challenging for children, and a transcanal approach can help avoid mastoid dressing changes, suture removal, water precautions, and the need for frequent postoperative



**Box 1. Indications for endoscopic ear surgery**

## External ear

- Cerumen debridement
- External canal cholesteatoma
- Resection of exostoses
- Canalplasty
- Documentation of exam

## Middle ear

- Tympanostomy tube placement
- Myringoplasty
- Tympanoplasty
- Tympanic membrane retraction
- Cholesteatoma
- Ossicular chain reconstruction
- Middle ear neoplasm (e.g., glomus tumor, adenoma, cholesterol cyst)

## Inner ear/skull base

- Perilymph fistula repair
- Petrous apex cyst
- Intracochlear or intralabyrinthine schwannoma
- Vestibular schwannoma

## Middle cranial fossa

- Super canal dehiscence repair Posterior fossa/cerebellopontine angle
- Detection and removal of residual tumor in internal auditory canal (IAC) fundus
- Identification and plugging of exposed air cells following IAC decompression

debridement.<sup>2</sup> For these reasons, transcanal endoscopic ear surgery (TEES) has become a topic of great interest to otologists in the last decade, with the number of TEES publications increasing from 36 before 2010 to 283 between 2011 and 2018.<sup>1</sup> These studies have illuminated the many possible applications for TEES, including cholesteatomas of the middle ear, tympanoplasty, and stapes surgery.

TEES is optimal for cholesteatoma management, as a transcanal approach aligns with the anatomical progression of the cholesteatoma disease process.<sup>1</sup> Primary acquired cholesteatomas result from retraction of the tympanic membrane, which extend first into the tympanic cavity, and then to the sinus tympani, facial recess, hypotympanum, and attic. Only the most advanced cases extend into the mastoid. Using the transcanal approach, the sac can be traced along its anatomical growth pattern and can be detached from ossicles and ligaments, removing the cholesteatoma en bloc from the tympanic cavity, leaving a greater chance of preserving the ossicles.<sup>20</sup> TEES also provides an improved view of typical cholesteatoma sites such as the protympanum, epitympanum, and retrotympanum, which reduces the need for canal wall up mastoidectomies

that are traditionally used to explore these spaces.<sup>2</sup> Most MES failures in the treatment of cholesteatomas occur in the tympanic cavity and its extensions, and the most frequent site of cholesteatoma is the attic. These spaces are easily accessed with TEES through the EAC after removal of the scutum.<sup>1</sup> Importantly, mastoid tissue preservation also maintains normal middle ear gas exchange.<sup>20</sup> Several systematic reviews and meta-analyses between 2016 and 2019 have reported comparable or improved rates of cholesteatoma control and significantly lower recurrence rates in TEES as compared to MES.<sup>19,21</sup> In a 2020 literature review, EES demonstrated improved quality of life and less surgical morbidity, avoided postauricular incisions, had shorter healing time, and caused less post-operative pain as compared to MES.<sup>20</sup> For these reasons, there is a clear indication for EES in cholesteatomas limited to the middle ear and antrum. In the case of complex cholesteatomas extending to the mastoid, the choice between EES and MES is less clear.<sup>2,20</sup>

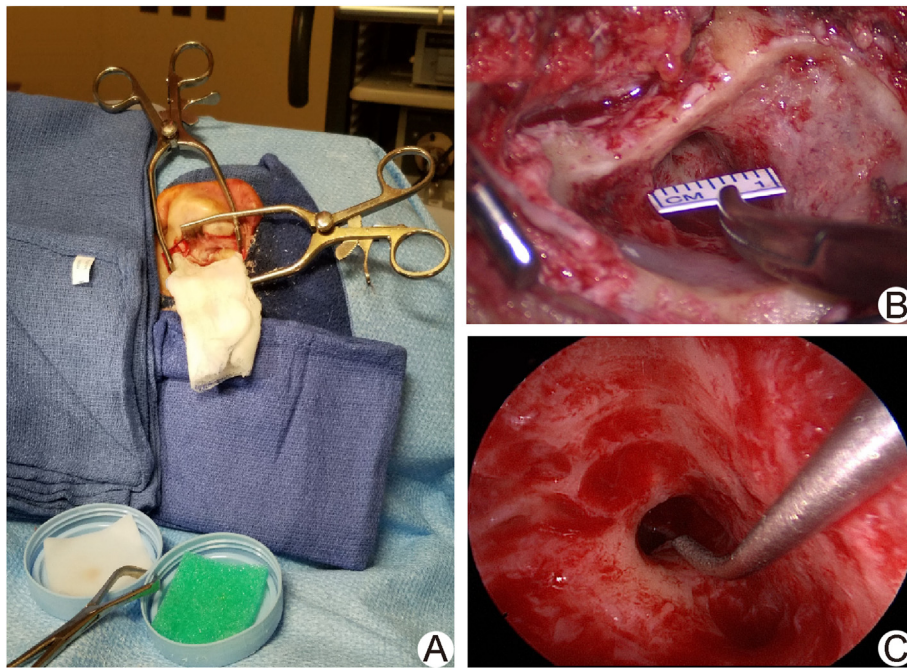
In children and adults, recent meta-analyses have demonstrated that tympanoplasty performed with EES caused lower canalplasty rates, better cosmetic outcomes, shorter operative times, similar audiological outcomes, a similar graft success rate, and a similar complication rate as compared to MES.<sup>22,23</sup> In the pediatric population, the graft success rate of tympanoplasty was not statistically different between EES and MES groups, and audiological outcomes were similar.<sup>21</sup> Among stapes surgeries, the endoscopic approach demonstrated a significantly decreased incidence of postoperative pain and chorda tympani injury, but was similar to the microscopic approach with respect to audiological outcome, postoperative dizziness, and operative time.<sup>22</sup>

**Transmastoid endoscopic ear surgery (TMEES)**

The endoscope can also serve an important role in cases where a postauricular approach is required. Transmastoid endoscopic ear surgery (TMEES) uses the mastoid as a corridor to the epitympanum and upper mesotympanum. A smaller mastoidectomy can be used for TMEES (Fig. 3). In our experience, TMEES has been used to remove residual disease from the aditus ad antrum and attic in cases of extensive cholesteatoma, reducing the need for a canal wall down mastoidectomy.<sup>19</sup> *When performing TMEES, the endoscope should rest on a moist gauze sponge placed in the mastoid cavity for image stability (Fig. 3A).*<sup>2</sup> The endoscope should not rest directly on the retractor or the bony mastoid cavity, or the user will have a difficult time stabilizing the image.

**Applications of endoscopic ear surgery in neurotology**

The endoscope has several applications in tumor removal, permitting enhanced tumor visualization and reducing the need for unnecessary dissection. Several studies have demonstrated its utility in the treatment of various skull base lesions including glomus tumors, meningiomas, and vestibular schwannomas, especially improving on the limitations of the retrosigmoid approach when appropriate.<sup>24–26</sup> Endoscopic inspection has also been shown to



**Figure 3** Transmastoid endoscopic ear surgery. A: Left ear following transcanal endoscopic resection of cholesteatoma and canal up mastoidectomy. It is important to place a bumper or moist sponge in the mastoid cavity to stabilize the endoscope. B: A left ear microscopic view following a canal up mastoidectomy. This image demonstrates the approximate space needed to accommodate the endoscope and curved instruments during transmastoid removal of middle ear disease. C: The same left ear under endoscopic visualization, demonstrating use of a 30° endoscope and 3 French curved suction during endoscopic assisted transmastoid dissection.

significantly improve detection of residual tumor overlooked by microscopic visualization and improving prediction of tumor resection.<sup>26</sup> Additionally, endoscopic assistance in microvascular decompression of the cerebellopontine angle can reduce morbidity through enhanced identification and tracking of offending structures while improving the overall efficiency of the procedure.<sup>27</sup>

Endoscopic techniques have also proved to be particularly valuable in reducing the risk of inadequate repair in superior canal dehiscence (SCD), allowing an illuminated, high definition view of the surgical field and better detection of blue-lined SCDs and dehiscent geniculate ganglion that may be missed by a conventional microscopic approach.<sup>28</sup> At Massachusetts Eye and Ear Infirmary, endoscopic-assisted middle fossa craniotomy repair is performed routinely and results in improved identification of arcuate eminence defects and a smaller craniotomy, requiring less dural dissection and brain retraction.<sup>29</sup> In plugging of SCD, underwater EES has been performed through the transmastoid approach and allows superior operative field of view while reducing the likelihood of damage to the inner ear through inadvertent aeration during surgery.<sup>30</sup>

### In-office otology practices and procedures

The advantages of endoscopy translate to applications outside of the operating room and can broaden the scope of office-based otologic procedures. Outer and middle ear inspection and minimally invasive treatments can be

performed using endoscopy in the office setting, eliminating the risks and costs associated with the operating room.<sup>31</sup> The patient should be placed in the supine position



**Figure 4** Left ear endoscopic-assisted debridement of EAC. In-office endoscopic procedures require ergonomic optimization for both the patient and the provider. The patient should be placed in the supine position for maximal head stabilization. Cables can rest on the chair underneath the patient's neck to reduce traction on the provider's camera hand. Finally, the endoscopic video system must be placed at eye level directly opposite the provider to allow for a comfortable neutral neck position.

to stabilize the head (Fig. 4). Angled endoscopes should not be used in the clinic, as this increases the risk of pain and bleeding due to contact with the EAC.<sup>2</sup> The following is a list of practices and procedures that can be performed using endoscopy in an office setting.<sup>31</sup>

- Narrow or stenotic ear canals, bulges in the ear canal, or a prominent tragus can obscure the anterior tympanic annulus or full margins of a tympanic membrane perforation when using a microscope. An endoscope can bypass these features, exposing the anterior rim of the tympanic membrane and allowing for in-office myringoplasty for anterior perforations.
- The decision to surgically explore a cholesteatoma requires its distinction from a retraction pocket, which can be followed clinically. This distinction is made through radiologic findings and visual examination. As endoscopy provides an improved view of the depth of retraction pockets, the decision to perform surgery for a cholesteatoma may change with the use of endoscopes in the office.
- Transtympanic middle ear endoscopy for the inspection of the ossicular chain or other middle ear pathologies is also possible in the office setting but requires a smaller diameter endoscope for middle ear access through a small myringotomy (less than 2 mm).
- Intratympanic injections for the treatment of sudden sensorineural hearing loss and intractable Meniere's Disease can be performed using endoscopy in the office setting.
- Debridement of complex mastoid cavities.
- Projecting the endoscopic image on a monitor in the office setting is helpful for patient counseling and teaching purposes.

## Conclusion

Three decades after the Hopkins-rod telescope revolutionized rhinology and laryngology, the endoscope is poised to transform the field of otology and neurotology. The recent surge of clinical studies on endoscopic middle ear surgery has confirmed comparable outcomes as compared to microscopic approaches, while utilizing less invasive surgical corridors such as the EAC. The endoscopic view provides improved depth of field and a wide angle view for superior visualization of hidden recesses and is less constrained by the size and shape of the ear canal compared to the microscopic view, which is especially advantageous in pediatric cases. These advantages have helped to reestablish the EAC as a minimally invasive surgical corridor, thereby reducing the need for postauricular incisions and extensive bony dissection (e.g. mastoidectomy). When a postauricular approach is required, the endoscopic-assisted transmastoid approach can avoid a canal wall down mastoidectomy in cases of cholesteatoma. The endoscope has also demonstrated utility in the management of superior canal dehiscence and various skull base lesions. In the office setting, the endoscope can be used for documentation of the outer and middle ear exam and for debridement of complex mastoid cavities. Finally, the endoscope optimizes

ergonomics by allowing the surgeon to keep the neck, back, and arms in a comfortable and neutral position.

## Declaration of competing interest

The senior author has financial relationships with 3NT Medical, Akouos, Frequency Therapeutics, Boston Pharmaceuticals, and Agilis.

## References

1. Kapadiya M, Tarabichi M. An overview of endoscopic ear surgery in 2018. *Laryngoscope Invest Otolaryngol.* 2019;4:365–373.
2. Miller KA, Fina M, Lee DJ. Principles of pediatric endoscopic ear surgery. *Otolaryngol Clin North Am.* 2019;52:825–845.
3. Kozin ED, Gulati S, Kaplan AB, et al. Systematic review of outcomes following observational and operative endoscopic middle ear surgery. *Laryngoscope.* 2015;125:1205–1214.
4. Kozin ED, Lee DJ. Basic principles of endoscopic ear surgery. *Oper Tech Otolaryngol - Head Neck Surg.* 2017;28:2–10.
5. Ryan P, Wuesthoff C, Patel N. Getting started in endoscopic ear surgery. *J Otol.* 2020;15:6–16.
6. Vijendren A, Devereux G, Kenway B, Duffield K, Yung M. Effects of intensive microscopic work on neck and back strain and the benefits of a prototype ergonomic chair. *J Laryngol Otol.* 2016;130:S53–S54.
7. Govil N, DeMayo WM, Hirsch BE, McCall AA. Optimizing positioning for in-office otology procedures. *Otolaryngol Head Neck Surg.* 2017;156:156–160.
8. Vaisbuch Y, Aaron KA, Moore JM, et al. Ergonomic hazards in otolaryngology. *Laryngoscope.* 2019;129:370–376.
9. Babar-Craig H, Banfield G, Knight J. Prevalence of back and neck pain amongst ENT consultants: national survey. *J Laryngol Otol.* 2003;117:979–982.
10. Ramakrishnan VR, Montero PN. Ergonomic considerations in endoscopic sinus surgery: lessons learned from laparoscopic surgeons. *Am J Rhinol Allergy.* 2013;27:245–250.
11. Ozturan O, Dogan R, Eren SB, Aksoy F. Intraoperative thermal safety of endoscopic ear surgery utilizing a holder. *Am J Otolaryngol.* 2018;39:585–591.
12. Kozin ED, Lee DJ. Staying safe during endoscopic ear surgery. *ENT Audiol News.* 2016;25:3–6.
13. Kozin ED, Kiringoda R, Lee DJ. Incorporating endoscopic ear surgery into your clinical practice. *Otolaryngol Clin North Am.* 2016;49:1237–1251.
14. Sun WH, Kuo CL, Huang TC. The anatomic applicability of transcanal endoscopic ear surgery in children. *Int J Pediatr Otorhinolaryngol.* 2018;105:118–122.
15. Mer SB, Derbyshire AJ, Brushenko A, Pontarelli DA. Fiberoptic endoscopes for examining the middle ear. *Arch Otolaryngol.* 1967;85:387–393.
16. Nomura Y. Effective photography in otolaryngology-head and neck surgery: endoscopic photography of the middle ear. *Otolaryngol Head Neck Surg.* 1982;90:395–398.
17. Thomassin JM, Inedjian JM, Rud C, Conciatori J, Vilcoq P. Otoendoscopy: application in the middle ear surgery. *Rev Laryngol Otol Rhinol (Bord).* 1990;111:475–477.
18. Tarabichi M. Endoscopic management of acquired cholesteatoma. *Am J Otol.* 1997;18:544–549.
19. Kiringoda R, Kozin ED, Lee DJ. Outcomes in endoscopic ear surgery. *Otolaryngol Clin North Am.* 2016;49:1271–1290.
20. Hu Y, Teh BM, Hurtado G, Yao X, Huang J, Shen Y. Can endoscopic ear surgery replace microscopic surgery in the treatment of acquired cholesteatoma? A contemporary review. *Int J Pediatr Otorhinolaryngol.* 2020;131:109872.



21. Han SY, Lee DY, Chung J, Kim YH. Comparison of endoscopic and microscopic ear surgery in pediatric patients: a meta-analysis. *Laryngoscope*. 2019;129:1444–1452.
22. Manna S, Kaul VF, Gray ML, Wanna GB. Endoscopic versus microscopic middle ear surgery: a meta-analysis of outcomes following tympanoplasty and stapes surgery. *Otol Neurotol*. 2019;40:983–993.
23. Tseng CC, Lai MT, Wu CC, Yuan SP, Ding YF. Comparison of the efficacy of endoscopic tympanoplasty and microscopic tympanoplasty: a systematic review and meta-analysis. *Laryngoscope*. 2017;127:1890–1896.
24. Pollak N, Soni RS. Endoscopic excision of a tympanic paraganglioma: training the next generation of ear surgeons. *World J Otorhinolaryngol Head Neck Surg*. 2017;3:160–162.
25. Samii M, Alimohamadi M, Gerganov V. Endoscope-assisted retrosigmoid infralabyrinthine approach to jugular foramen tumors. *J Neurosurg*. 2016;124:1061–1067.
26. Corrivetti F, Cacciotti G, Scavo CG, et al. Flexible endoscopic assistance in the surgical management of vestibular schwannomas. *Neurosurg Rev*. 2021;44:363–371. <https://doi.org/10.1007/s10143-019-01195-0>.
27. Zanoletti E, Mazzoni A, Martini A, et al. Surgery of the lateral skull base: a 50-year endeavour. *Acta Otorhinolaryngol Ital*. 2019;39:S1–S146.
28. Cheng YS, Kozin ED, Lee DJ. Endoscopic-assisted repair of superior canal dehiscence. *Otolaryngol Clin North Am*. 2016;49:1189–1204.
29. Carter MS, Lookabaugh S, Lee DJ. Endoscopic-assisted repair of superior canal dehiscence syndrome. *Laryngoscope*. 2014;124:1464–1468.
30. Yamauchi D, Hara Y, Hidaka H, Kawase T, Katori Y. How I do it: underwater endoscopic ear surgery for plugging in superior canal dehiscence syndrome. *J Laryngol Otol*. 2017;131:745–748.
31. Fina M, Chieffe D. Office-based otology procedures. *Otolaryngol Clin North Am*. 2019;52:497–507.

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