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Use of Endoscopic Ear Surgery as Adjunct to Microscopic Surgery in Cholesteatoma Surgery

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ABSTRACT

This study was conducted to review the value of endoscopic ear surgery as adjunct to microscopic surgery in management of cholesteatoma. It aimed to determine the accessibility of hidden sites and to assess surgical outcomes in cholesteatoma surgery with the adjunct use of an endoscope. An extensive review of literature on PubMed was performed to select studies about the use of an endoscope either as an adjunct to or as a replacement for a microscope in cholesteatoma surgery and studies with comparative surgical outcomes of endoscopic ear surgery and microscopic ear surgery in cholesteatoma surgery. The majority of the studies use endoscopic ear surgery as an adjunct or combined with traditional microscopic ear surgery (observational or operative) while a minority use exclusive transcanal endoscopic cholesteatoma surgery. Endoscopic ear surgery in cholesteatoma provides superior visualization of hidden areas with highest risk for residual cholesteatoma, like the sinus tympani. The use of an endoscope showed reducing residual and recurrence cholesteatoma, especially in canal wall up procedure. Transcanal endoscopic cholesteatoma surgery is minimally invasive and uses a natural access and a step-by-step pursuit of cholesteatoma through the middle ear. This review acknowledges the value of microscopic ear surgery but highlights the benefit of endoscopic ear surgery in cholesteatoma surgery, whether used combined or exclusively, by enhanced visualization and ability to visualize hidden areas for identification and removal of cholesteatoma residues and by so reducing recurrence. Endoscopic ear surgery helps in decision making intraoperatively and in preventing unnecessary tissue removal. However, the microscope affords greater comfort in mastoid drilling and cannot be replaced by the endoscope in all cases.

Keywords: Cholesteatoma, cholesteatoma recurrence, endoscopic ear surgery, transcanal endoscopic ear surgery

Introduction

Cholesteatoma is an abnormal accumulation of keratinizing stratified squamous epithelium in the middle ear and/or mastoid process causing local inflammation and destruction.[1] The estimated annual incidence of cholesteatoma is between 9 and 12.6 cases per 100 000 adults and 3 cases per 100 000 children.[2,3] Cholesteatoma is divided into 2 categories: congenital and acquired cholesteatoma. Congenital cholesteatoma is rarer and is specific to children. It is caused by an ectopic deposit of squamous epithelium in the middle ear, growing within an intact tympanic membrane in a patient with no history of chronic middle ear disease or no history of ear surgery. Acquired cholesteatoma is more common; it develops after birth and affects children as well as adults. It is divided into primary and secondary acquired cholesteatoma. Primary acquired cholesteatoma is caused by a tympanic retraction, which is a result of chronic middle ear infection. It can occur at any age, but pediatric primary acquired cholesteatoma typically has a more aggressive growth pattern. Secondary acquired cholesteatoma is caused by direct injury or perforation of the tympanic membrane, due to infection or iatrogenic causes.[1] The growth pattern of a cholesteatoma depends on the site of origin. The most frequent locations of primary acquired cholesteatoma formation are the pars flaccida growing into the epitympanum (or attic) and the postero-superior quadrant of the pars tensa.[4]

Principle of Microscopic and Endoscopic Ear Surgery of Cholesteatoma

Surgical treatment is required for most cholesteatomas. The primary goal of cholesteatoma surgery is the complete eradication of the disease from the middle ear and mastoid in order to create a "dry safe ear" defined as one in which recurrent disease is unlikely to recur.[5] The most significant source of failure

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in cholesteatoma surgery is residual or recurrent disease. After surgical treatment, a cholesteatoma can regrow from incomplete removal at primary surgery. This is often due to incomplete clearance of inaccessible areas which can recur or de novo caused by persistent ventilation dysfunction (eustachian tube or tympanic isthmus). Various surgical techniques have been described according to the cholesteatoma location, spread of the pathology, and preoperative hearing status.

Currently, binocular microscopic surgery remains the gold standard of cholesteatoma surgery, but the endoscope is an emerging surgical approach that has increasingly been used in cholesteatoma surgery either as an adjunct to microscope or even exclusively as an alternative to the microscope.

Cholesteatoma Microscopic Ear Surgery

The introduction of standard microscopic ear surgery was a milestone in the development of modern otology that allowed surgeries of the microscopic middle ear structures. Traditional binocular microscopic surgery has the benefit of allowing a 2-handed dissection as well as a binocular vision with better depth perception compared to the endoscope. Most otologists consider the microscope essential for otologic surgery. Another advantage is better exposure during training leading to greater proficiency or expertise by most surgeons. The microscope provides good visualization of most parts of the middle ear which is sufficient for the majority of dissections but some "hidden areas" (retrotympanum, epitympanum, supratubal recess, protympanum, and hypotympanum) are difficult to visualize and access because of the forced straight view through the auditory canal.[6] This limitation often means that surgeons must make a choice between excessive drilling of bone and removing soft tissues or blind, blunt dissection to remove cholesteatoma in those hidden recesses.[7] Hidden areas, such as the facial recess and sinus tympani, require a posterior tympanotomy to be exposed, and even with extensive mastoidectomy, some areas such as the sinus tympani remain limited in access. Those hidden areas present a risk of residual disease during cholesteatoma surgery. The 2 main approaches in microscopic surgery of cholesteatoma are intact or canal-wall up (CWU) mastoidectomy and canal-wall down (CWD) mastoidectomy.

The CWU approach includes the removal of all mastoid air cells while maintaining the posterior and superior canal walls intact. In contrast, during a CWD approach, the posterior and superior canal wall are removed to create a common cavity which combines the ear canal and mastoid. In more advanced cases of frequently recurring cholesteatoma, a radical mastoidectomy can be indicated with removal of posterior and superior canal wall with meatoplasty and exteriorization of the middle ear. Both microscopic techniques offer a limited view of hidden areas. The current microscopic tympanomastoidectomy techniques have a cholesteatoma recurrence rate of 20% to 50% mostly in the sinus tympani, anterior epitympanum, or facial recess, all with poor access.[8]

Cholesteatoma Endoscopic Ear Surgery

To visualize the "hidden areas" of microscopic ear surgery, the endoscope was developed as a novel way to explore the middle ear cavity. The most widely studied application of endoscopic ear surgery is for management of cholesteatoma. In the 1990s as an extension of many anatomical studies, the endoscope was used as an aid in cholesteatoma surgery for the detection of residual or recurrent disease. Since then, the endoscope has increasingly been used in cholesteatoma surgery mostly as an adjunct to microscope and more recently exclusively as an alternative to the microscope. The constant refining of the endoscope and endoscopic instruments causes rapid growth of the role of endoscopic ear surgery.

The main advantage of endoscopic ear surgery in cholesteatoma is an improved visualization of the middle ear and the ability to look "around the corners" and access the hidden areas including the retrotympanum, epitympanum, supratubal recess, protympanum, and hypotympanum.[6] It offers a wider and more magnified view of the middle ear, coupled with a high-resolution camera system.[9] The endoscope has been shown to increase visualization of all middle ear compartments compared to the microscope, except the antrum.[5] The antrum is inadequately visualized by the microscope as well as the endoscope, and a mastoidectomy should always be considered for optimal visualization.

The surgical principles of microscopic and endoscopic ear surgery remain the same; cholesteatoma is traced from its origin and followed up to the fundus for complete removal. The complementary use of an endoscope in microscopic ear surgery improves the visualization of the hidden areas and helps in the decision making of the surgical plan permitting complete cholesteatoma removal with better preservation of normal mastoid bone and/or mucosa.[10]

The endoscope has an important role in cholesteatoma surgery by offering a new way of looking at the anatomy and allowing a better understanding of the middle ear physiology and in particular to the ventilation pathways and middle ear folds that might cause pathology if impaired.[11,12] It improves the insight of cholesteatoma pathophysiology and its progression through the temporal bone and allows to perform a more "physiological" surgery. The selective epitympanic dysventilation syndrome, described by Marchioni et al implies that an attic retraction pocket and/or cholesteatoma are caused by blockage of the ventilation pathway of the epitympanum (isthmus), combined with a complete epitympanic diaphragm. This blockage completely excluded the epitympanum and mastoid while the remaining mesotympanic space is ventilated by the eustachian tube.[11]

The transcanal approach of endoscopic ear surgery also offers the advantage of rediscovering the ear canal as an access port. In most cases, acquired cholesteatoma is the result of advanced retraction of the tympanic membrane with the sac advancing into the middle ear cavity and then into its extensions such as the sinus tympani, the facial recess, the hypotympanum and the epitympanum, and finally in advanced cases further into the mastoid cavity. Transcanal approach is minimally invasive and allows a more natural and direct access to the middle ear and a step-by-step pursuit of the cholesteatoma sac as it passes through the middle ear, as shown in Figure 1.[13] Figure 2 shows progressive visualization and transcanal removal of cholesteatoma using the endoscope and a curved suction dissector.

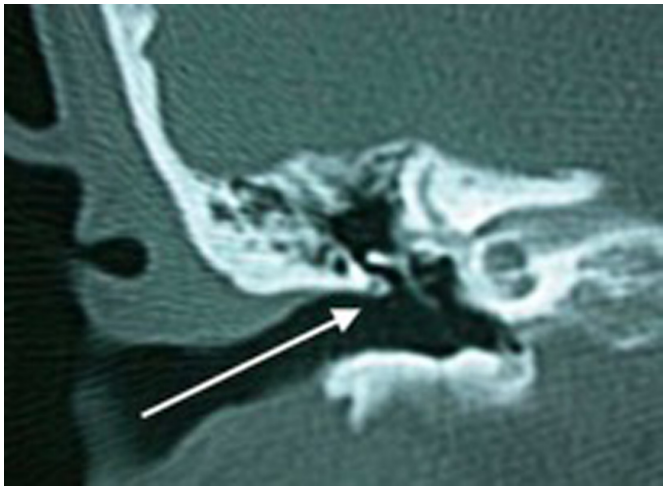

Figure 1. Temporal bone coronal computed tomographic section. Note that an axis line drawn through the ear canal ends in the attic rather than the mesotympanum.[13]

Outcomes of Microscopic and Endoscopic Ear Surgery of Cholesteatomas

Residual and Recurring Cholesteatoma

Complete removal of cholesteatoma is dependent on optimal visualization of the middle ear. The most common locations of primary acquired cholesteatoma are the epitympanum (or attic) and the retrotympanum.[4]

Cholesteatoma Microscopic Ear Surgery

The overall rates of residual and recurrent cholesteatoma following traditional microscopic surgery are well known. As explained earlier, the recurring cholesteatoma rates with the current microscopic tympanomastoidectomy techniques range from 20% to 50% and are almost exclusively found in the middle ear space rather than in the mastoid.[14,15] The most frequent sites of cholesteatoma recurrences are the sinus tympani, anterior epitympanum (both ≥20%), and facial recess, which are all locations with poor visualization.[8]

The CWU approach or closed technique is designed for better preservation of the middle ear anatomy. It offers a better healing process with simpler post-operative care and simpler follow-up maintenance compared to the CWD approach.[16] However, the residual and recurrence rate of cholesteatoma in CWU are often higher in comparison to CWD, thus requiring closer follow-up for signs of recurrence or even second-look surgery. One meta-analysis revealed that a CWU approach is 2.87 times more likely to develop a recurrence compared to the CWD approach.[17]

The CWD approach or open technique offers improved visualization of cholesteatoma by lowering the canal wall. This offers significantly lower recurrence rate but at the cost of a greater morbidity with the lifelong necessity of maintenance of the mastoid cavity, cosmetic alterations of the meatus, and lifelong issues with water precautions. The recurrence rates shown in the literature for CWU approach range from 9% to 70% while in CWD approach vary between only 5% and 17%.[17-20] The recurrence rates are presumably due to incomplete access to hidden areas such as the sinus tympani even after extended mastoidectomy and after lowering the canal wall.

Cholesteatoma Endoscopic Ear Surgery

The most widely studied application of endoscopic ear surgery is for management of cholesteatoma. Studies can be differentiated between microscopic ear surgery combined with endoscopic ear surgery (observational and operative) or transcanal endoscopic cholesteatoma surgery. The adjunct use of EES in MES has also been described as either only observational or operative. In observational endoscopic surgery, the endoscope is used as an inspection tool to detect possible remaining cholesteatoma in the middle ear which is removed microscopically. In contrast, operative endoscopic surgery also uses the endoscope as a complement to detect possible remaining cholesteatoma but uses mixed microscopic and endoscopic dissection techniques.

A recent systematic review by Verma and Dabholkar[10] included 16 publications about endoscopic ear surgery consisting of 1685 cholesteatoma cases of which in 82.19% (1385 cases) the endoscope was used as a complement to the microscope while 17.92% (302 cases) consisted of exclusively transcanal endoscopic surgery. Intra-operatively residual cholesteatoma was identified by the endoscope after complete removal by microscopic mastoid surgery in 15.82% (267 cases). Residual cholesteatoma was most commonly identified in the sinus

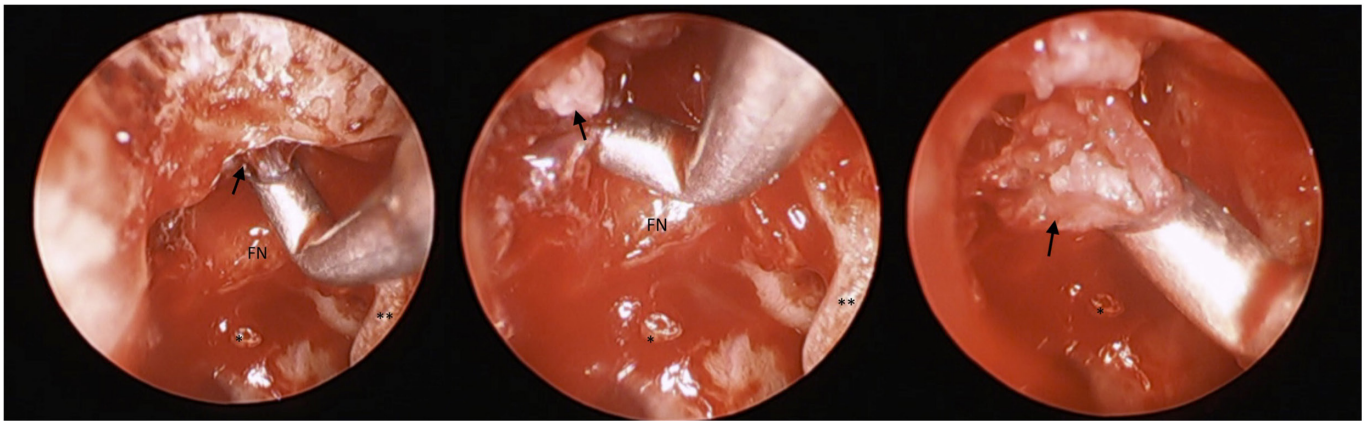

Figure 2. Progressive visualization and transcanal removal of cholesteatoma in a right ear using the endoscope and a curved suction dissector. Arrow, cholesteatoma in the attic; *, head of stapes; **, malleus; FN, facial nerve.

tympani, facial recess, and anterior epitympanic space. During post-operative follow-up, with a mean follow-up ranging from 11 to 28 months, residual or recurrent cholesteatoma was found in 6.4% (108 cases). Sinus tympani was the commonest site of recurrence, even in the second-look procedure.[10] Recurrent cholesteatoma was almost always found in areas of residual disease during primary surgery highlighting that a negative endoscopic evaluation during primary surgery is highly predictive of no recurrence.

In one of the largest studies, Badr-El-Dine used observational endoscopic ear surgery in 294 cases following CWU and CWD procedures and described a residual rate of 16.7% missed by microscope but detected by endoscope.[21] Residual disease was most frequently found in both CWU and CWD groups in the sinus tympani (36.7%), followed by the facial recess (28.6%) and the anterior epitympanic recess (14.3%). Last, residual disease was also frequently found specifically after CWU approach in the undersurface of the scutum (20.4%).

Comparing the adjunct role of endoscope during CWU and CWD cholesteatoma surgery, Yung[22] reported in another large, included study of 231 cases a recurrence rate of 9.4% in CWU (closed cavity) and 8.7% in CWD (open cavity) after use of operative endoscopy. In this study, the use of operative endoscopy has decreased the recurrence rates in closed techniques to almost similar rates as the open technique recurrence rates. This study showed that the use of operative endoscopy has not eradicated residual cholesteatoma but has decreased the recurrence rates in closed techniques to single figures almost similar as the open technique recurrence rates.

Another recent systematic review and meta-analysis by Li et al[23] included 13 studies comparing outcomes between microscopic surgery and the use of endoscope in cholesteatoma surgery in adults and pediatric patients. A microscopic approach was performed in a total of 441 ears, a combined approach in 489 and exclusive transcanal endoscopic ear surgery (TEES) in a few studies. The meta-analysis showed a clear benefit of using endoscopic ear surgery within the EES group with significantly fewer residual cholesteatomas and a significantly lower recurrence rate than in the traditional MES group. Lastly, there were no significant differences between MES and EES in other post-operative outcomes, such as graft intake success rate and auditory performance nor in the operation time duration.

The use of the intra-operative endoscope reduces the recurrence rate and overall costs by reducing the number of second looks and follow-up MRIs.[24]

Graft Intake Success Rate

The meta-analysis of Li et al[23] shows no significant differences in graft intake success between MES and EES groups.

Audiological Outcome

The auditory outcomes between CWU and CWD are closed across the literature. The post-operative hearing outcomes after microscopic and endoscopic surgery are similar and significantly improved with air-bone gap closure by removal of the cholesteatoma and ossiculoplasty if ossicular destruction was present. Studies comparing EES with MES did not show significant difference between endoscopic and microscopic cholesteatoma surgery.[23-27]

Operation Time

The operating time of microscopic and endoscopic cholesteatoma surgery is widely variable. Some studies describe an equivalent operating time, others an increased operating time because of the learning curve of the endoscopic technique.[25,26] Lastly, some studies describe a mean decrease in EES operating time especially in limited attic cholesteatoma.[27] The meta-analysis of Li et al[23] shows no significant differences in operating time between MES and EES groups.

Recovery and Complications

Acute post-operative complications after microscopic, combined, or endoscopic-only cholesteatoma surgery are rare and similar without significant differences, namely facial nerve injury, dizziness, dysgeusia, or decreased hearing.[28] Some studies described less pain and decreased recovery time with endoscopic approach since it is less invasive without the need to perform a mastoidectomy, but the difference was not statistically significant.[25,29]

Limitations of Endoscopic Ear Surgery of Cholesteatoma

Although endoscopic ear surgery offers an improved visualization, there are also obvious limitations during cholesteatoma surgery. These include one-handed surgery, lack of depth perception, which can lead to disorientation and difficulty with hemostasis. Single-handed technique allows free movement with magnified view and precision surgery, but it has also limitations. Especially in cholesteatoma surgery, 2-handed surgery is often necessary in dissection of cholesteatoma from ossicles, stapes footplate, or even a dehiscent facial nerve. Ossicular reconstruction after cholesteatoma removal is also very difficult to complete with only one operating hand. A static endoscope-holding system was introduced to support the two-handed technique, but its stability is not clear, and it has not been widely used.[18]

A general limitation of endoscopic ear surgery is the frequent fogging or smearing of the endoscope lens, which requires cleaning and application of defogging solutions and can increase operative time. If there is bleeding, the view is impaired and it is necessary to take the time to control the bleeding. When a mastoidectomy is performed in cholesteatoma surgery, there is often blood, bone dust, and irrigating solutions obscuring the operating field, causing difficulties for the surgeon. To overcome this problem, Nishiike et al[30] described endoscopic hydro-mastoidectomy where drilling and endoscopic visualization is done under water, with continuous irrigation washing out bone dust and blood. Another limitation is that the endoscope occupies itself a certain amount of space in the narrow surgical field, which affects the use of other bigger instruments, especially drills. This is the reason why mastoid surgery still remains the main case for combined microscope and endoscope surgery. Another debated limitation is the risk of thermal injuries in the event of prolonged motionless surgery with an endoscope.[31] Lastly, endoscopic ear surgery has a steeper learning curve and is limited by lack of exposure during residency and fellowship training.

These limitations as well as the good outcome already acquired with traditional techniques explain why exclusive endoscopic ear surgery of cholesteatoma has not gained widespread acceptance yet. Unfortunately, this is unlike sinus surgery where nasal endoscopic surgery has gained wide acceptance. The endoscope is an effective alternative to the microscope, but it cannot replace the microscope in all cases.

Pre-Operative Planning

Adequate pre-operative assessment of the extent of the cholesteatoma is necessary in deciding if cholesteatoma surgery can be performed by using an endoscopic approach. Computed tomography scan of the temporal bone is used to assess the size of the cholesteatoma and its involvement with the middle ear anatomy: with the ossicles, sinus tympani, mastoid, etc. The microscopic and endoscopic view of the middle ear presented by Benett et al helps determine when and where to use an endoscope for combined microscopic–endoscopic ear surgery in places where it adds value by reducing recurrence, as shown in Figures 3 and 4.[5]

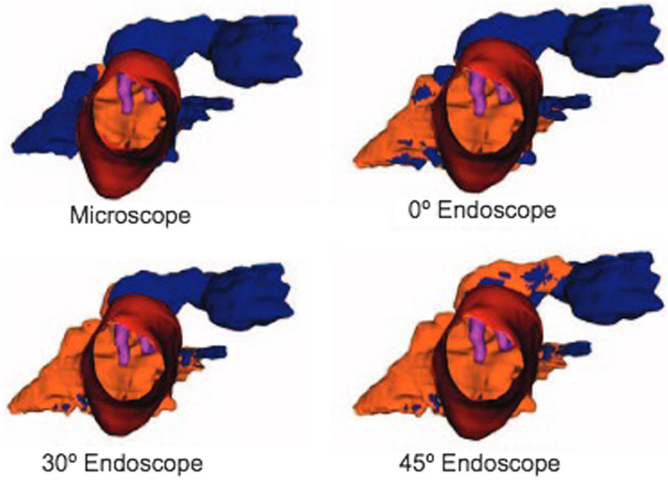

Figure 3. Visualization middle ear with ossicles present. Red, external auditory canal; magenta, ossicles; orange, regions of the middle ear that are viewable; blue, regions of the middle ear that are hidden.[5]

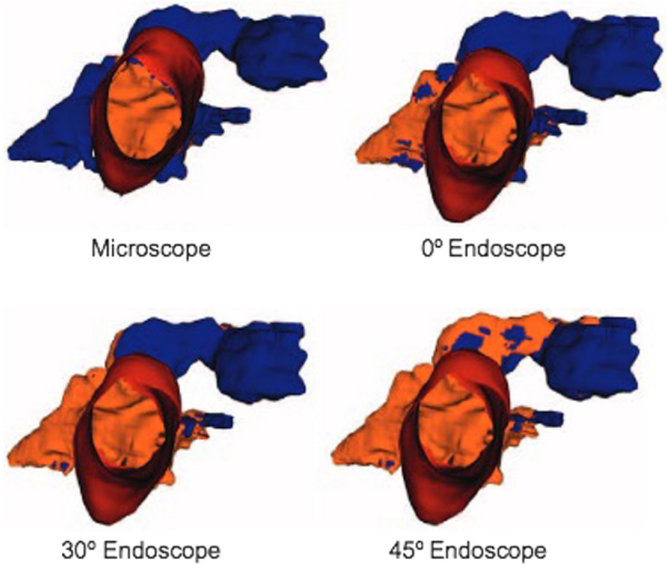

Figure 4. Visualization middle ear with ossicles absent. Red, external auditory canal; orange, regions of the middle ear that are viewable; blue, regions of the middle ear that hidden.[5]

Theoretically, if cholesteatoma is limited to the mesotympanum, the microscope is adequate to determine whether the ossicles are present or absent. This is the only compartment adequately visualized during microscopic ear surgery. If cholesteatoma extends into the eustachian tube, hypotympanum, sinus tympani, or the supratubal recess, a 0°endoscope should be used as adjunct to the microscope and even considered for dissection. If cholesteatoma extends into the epitympanym, the microscope has limited visualization even after removal of the incus and malleus while a 30°-40° endoscope provides superior visualization (or 0°if the ossicles are absent except for the antrum, epitympanum, and facial recess). If cholesteatoma extends into the antrum, it is inadequately visualized by neither the microscope nor endoscope even if the ossicles are absent, therefore a mastoidectomy should be considered for optimal visualization. Finally, if cholesteatoma reaches within the mastoid, the endoscope is of limited use within the mastoid cavity and the disease is best eradicated using traditional microscopic approaches.[5] In practice, potential residual and recurring cholesteatoma are rarely seen in the eustachian tube and mastoid, in which case an endoscope has little additional value and the dissection in these areas can likely be adequately performed by the traditional microscope alone. However, for residual cholesteatoma in the rest of the middle ear, the endoscope provides a clear improved visualization and prevents disease recurrence. The endoscope should especially be considered during second-look procedures considering that most residual cholesteatoma are found in the anterior tympanum and sinus timpani which are hidden areas for the microscope.

Conclusion

The efficiency and success of cholesteatoma surgery depends on complete eradication of the disease from the middle ear and mastoid. Different studies acknowledge the value of microscopic ear surgery but highlight the benefit of the use of an endoscope in cholesteatoma surgery because it improves visualization and the surgeon's ability to see hidden areas of the middle ear and improve outcomes yielded by traditional microscopic techniques. Most studies in the literature use the endoscope as an adjunct or in combination with traditional microscopic surgery while a small but growing group of surgeons describe exclusive transcanal endoscopic surgery (TEES) of cholesteatoma. Whether used combined or exclusively, endoscopic ear surgery showed an indispensable role in identification and removal of cholesteatoma residues in primary and second-look surgery and by so reducing residual and recurrence cholesteatoma, especially in CWU procedure. Endoscopic ear surgery helps in decision making intraoperatively and in preventing unnecessary healthy bone and/or mucosa removal. However, the microscope is needed for mastoid drilling and cannot be replaced by the endoscope in all cholesteatoma cases. Adequate preoperative assessment is necessary to determine the extent of the cholesteatoma and in deciding if endoscopic ear surgery

is recommended. Compared to endoscopic sinus surgery, which has found a rapid wide acceptance, there has been a slower acceptance of endoscopic ear surgery in cholesteatomas. The main limitations are its single-handed technique, lack of depth perception, and lack of exposure during residency. Overall, the use of the endoscope in cholesteatoma surgery can be safely recommended.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

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Author Contributions: Concept and Design - C.L.; Supervision - P.L.; Literature Review - C.L.; Writing - C.L.; Critical Review - P.L.

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