The Journal of International Advanced Otology

J Int Adv Otol 2024; 20(3): 225–230 • DOI: 10.5152/iao.2024.231122

Original Article

Efficacy of Otoendoscopy for Residual Cholesteatoma Detection During Microscopic Chronic Ear Surgery

Floor Couvreur[1], Elke Loos[1,2], Christian Desloovere[1,2], Nicolas Verhaert[1,2]

[1]Department of Otorhinolaryngology, Head and Neck Surgery, University Hospitals of Leuven, Leuven, Belgium
[2]Department of Neurosciences, Research Group Experimental Oto-Rhino-Laryngology, Leuven, Belgium

ORCID iDs of the authors: F.C. 0000-0002-5463-1049, E.L. 0000-0002-5479-0461, C.D. 0000-0001-9766-8610, N.V. 0000-0002-3512-1334.

Cite this article as: Couvreur F, Loos E, Desloovere C, Verhaert N. Efficacy of otoendoscopy for residual cholesteatoma detection during microscopic chronic ear surgery. *J Int Adv Otol.* 2024;20(3):225-230.

BACKGROUND: The aim of this article is to determine the efficacy of otoendoscopy during microscopic cholesteatoma surgery on residual cholesteatoma rates postoperatively.

METHODS: The medical records of patients (aged 4-90) with primary acquired cholesteatoma who underwent microscopic cholesteatoma surgery (exclusively transcanal approach or canal wall-up tympano-mastoidectomy) with subsequent otoendoscopic examination (80 ears) for intraoperative cholesteatoma residues were retrospectively reviewed. All cases with mixed microscopic/endoscopic, fully endoscopic, or fully microscopic dissection were excluded, as well as cases where a canal wall-down technique was used. After microscopic cholesteatoma removal, the otoendoscope was used to inspect the middle ear recesses for intraoperative cholesteatoma residues. The intra- and postoperative cholesteatoma residue rate were evaluated.

RESULTS: On endoscopic examination, intraoperative cholesteatoma residues were encountered in 24 patients (30%). A total of 30 foci were detected. Most of them were found in the superior retrotympanum (15 foci). In 9 cases an antral remnant guided the surgeon to convert to a canal wall up tympanomastoidectomy. During the postoperative follow-up period, residual cholesteatoma was detected on postoperative magnetic resonance imaging in 6 patients (7.5%). Adding an otoendoscopic examination to microscopic cholesteatoma surgery reduced the postoperative cholesteatoma residues rate (odds ratio = 0.16). A negative otoendoscopic examination led to a cholesteatoma residue-free follow-up period in 95% of cases (NPV = 0.95).

CONCLUSION: Otoendoscopy is effective in identifying intraoperative cholesteatoma residues after microscopic cholesteatoma surgery. It reduces the postoperative cholesteatoma residue rate, and a negative otoendoscopic examination increases the likelihood of a cholesteatoma residue-free follow-up.

KEYWORDS: Cholesteatoma, endoscopy, microscopy, middle ear, mastoidectomy

INTRODUCTION

Primary acquired cholesteatomas are collections of keratinizing squamous epithelium trapped within the middle ear and/or mastoid.[1,2,3] Surgical treatment is the treatment of choice and aims for complete removal of the cholesteatoma and prevention of residual and recurrent cholesteatoma.[4,5] In the early years, the microscope provided magnification and illumination of the mastoid and middle ear spaces. However, poor access to certain areas of the middle ear, such as the tympanic sinus, the epitympanic recess, and the eustachian tube orifice, contributed to residual cholesteatoma rates ranging between 5% and 12% in the canal wall down (CWD) tympanomastoidectomy and up to 47.7% in the canal wall up (CWU) tympanomastoidectomy.[4-11]

To reveal these hidden areas, various adjuncts to microscopy have been suggested, such as the Buckingham mirror or the temporary removal of the posterior canal wall.[11-13] First reports of the rigid endoscope in cholesteatoma surgery to visualize and assist in the removal of residual disease from the difficult-to-reach middle ear areas were already published by Thomassin et al in 1993.[4] Thomassin et al noted a drop in residual cholesteatoma from 47% to 6% by just adding the endoscope.[4] This ratio was further proven in the cohorts of Yung, Badr-El dine, and Benett, who had respectively a postoperative cholesteatoma residue rate of 9.4%, 8.6%, and 2.7%.[5,10,14] By offering the advantage of higher magnification, wider views, the ability to look around the corners, minimal

Corresponding author: Floor Couvreur, e-mail: floorcouvreur@gmail.com
Received: March 3, 2023 • **Revision requested:** May 14, 2023 • **Last revision received:** August 20, 2023 • **Accepted:** January 19, 2024 • **Publication Date:** May 23, 2024
Available online at www.advancedotology.org

bone removal, and ameliorated surgical ergonomics, the endoscope seemed to be very promising in reducing the rate of residual disease by detecting intraoperative cholesteatoma residues.[12,15,16]

A decade ago, we implemented the endoscope in our practice. Initially, they were only used to gain access to sites hard to visualize directly with the microscope in cholesteatoma surgery and gradually we evolved to fully endoscopic cases as we became more skilled in using the endoscope. The aim of this study is to evaluate the use of the otoendoscope in our first explorative cohort. We investigated the efficacy of the otoendoscope in detecting intraoperative cholesteatoma residues in the middle ear recesses during microscopic chronic middle ear surgery, and its impact on the incidence of residual cholesteatoma during follow-up. Therefore, we compared our first results to the current available literature.

MATERIAL AND METHODS

This is a retrospective analysis based on data from operative reports and office notes of all otological surgeries between January 2012 and December 2020. A search was performed for all patients who underwent surgery for primary cholesteatoma, either using an exclusively transcanal approach or a CWU tympanomastoidectomy, followed by a subsequent otoendoscopic examination for intraoperative cholesteatoma residues after apparent total removal of cholesteatoma with the microscope (Grade 1 use of operative endoscopic ear surgery according to the Massachusetts Eye and Ear Infirmary[17]). All mixed microscopic/endoscopic (Grade 2a and 2b[17]), fully endoscopic (Grade 3[17]). and fully microscopic (Grade 0[17]) dissection cases were excluded, along with the cases where a CWD tympanomastoidectomy technique was used. In total 80 primary cholesteatoma cases were included. All were operated on by the senior author, a right-handed surgeon. The pre- and postoperative office reports, the pre- and postoperative radiographic images, and the operating report were analyzed.

The Supervisory Committee on Medical Ethics of the University Hospitals Leuven has acknowledged this retrospective study as scientifically relevant and in line with prevailing ethical standards, as confined in the declaration of Helsinki (Approval No: MP017279, Date: January 25, 2021). All patients gave their written informed consent.

Surgical Technique

The surgical procedure consisted of an initial part where the cholesteatoma was removed under the microscope using an exclusively transcanal approach or a CWU tympanomastoidectomy technique. The extent of the opacification and bony erosions, as well as the degree of pneumatization, were evaluated on the preoperative computed tomography (CT). Opacification extending beyond the level of the lateral semicircular canal and diminished pneumatization were factors directing the surgeon toward an upfront CWU tympanomastoidectomy. If available, preoperative MRI was considered during the decision-making process. To increase access to the attic, an atticotomy was used if needed during a transcanal approach.

After apparent total removal of the cholesteatoma with the microscope, in a second phase, the otoendoscope was used to inspect those middle ear and mastoid sites which were difficult to visualize with the microscope for intraoperative cholesteatoma residues. Transcanally, the endoscope was first used to inspect the following areas: inferior retrotympanum, superior retrotympanum, posterior epitympanic space, anterior epitympanic space, protympanum, and hypotympanum. In the cases where a CWU tympanomastoidectomy was performed, we subsequently inspected the epitympanum from a posterior perspective introducing the endoscope through the mastoid. Depending on the case, an otoendoscope of 3 mm diameter and 14 cm length (KARL STORZ SE & Co. KG, Tuttlingen, Germany) was used with an angle of 0, 30, or 45°. If an intraoperative cholesteatoma residue was noted, it was subsequently removed. Our surgical findings were noted on a standard template. We recorded the approach (transcanal (TC) or CWU), the use of the endoscope, and the site of the intraoperative cholesteatoma residues (tympanic sinus, facial recess, eustachian tube orifice, others). In the cases started with an exclusively transcanal approach, special attention was paid to the antrum. A negative otoendoscopic examination in these cases implied that a mastoidectomy could be avoided. If there was an intraoperative cholesteatoma residue in the antrum, unreachable with the microscope by the transcanal route, we converted into a CWU tympanomastoidectomy. At the end of the surgery, the scutum was reconstructed using autologous conchal cartilage.

Postoperative Follow-up

Routine postoperative follow-up consisted of a clinical follow-up (microscopy and audiometry) annually and MRI imaging, using the non-EP DWI technique, 1, 3, and 5 years postoperatively.

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPPS) version 27.0 (IBM SPSS Corp.; Armonk, NY, USA). Patient demographics, as well as intra- and postoperative cholesteatoma residue rates, were described using descriptive statistics. Factors influencing intraoperative cholesteatoma residue rates were described using cross tabs and compared using Pearson's chi-square test or Fisher's exact test. The time to the formation of cholesteatoma residue rates was calculated using Kaplan–Meier curves. Finally, the value of the otoendoscope in microscopic cholesteatoma surgery to reduce cholesteatoma residue rates was evaluated using odds ratio, as well as the negative predictive value.

MAIN POINTS

- Otoendoscopy can be used to detect intra-operative cholesteatoma residues after microscopic cholesteatoma surgery.
- Otoendoscopy reduces the cholesteatoma residue rate in CWU tympanomastoidectomy to the cholesteatoma residue rates seen in CWD tympanomastoidectomies.
- A negative otoendoscopic examination in cholesteatoma surgery results in an uneventful follow-up period in 95% of cases.

RESULTS

Patients' Characteristics

A total of 80 cases were included in this retrospective case series, 48 were male and 32 female. Patients' age ranged from 4 to 90 years old, with a mean age of 30 years (SD = 21.89). In 45 cases (56%), the right ear was operated on, and in 35 cases (44%) the left ear. The indication for the operation and localization of the lesion is summarized

Table 1. Localization and ChOLE Stage of the Lesion according to the Surgical Approach

	Transcanal	CWU	Total
Localization/origin			
Pars flaccida	10	17+4*	31
Pars tensa	13	21+3*	37
Combination	4	6+2*	12
ChOLE grade			
Stage I	15	16+9*	25
Stage II	12	26	38
Stage III	0	2	2

CWU, canal wall up.
*Cases whereby we switched from a transcanal to a canal wall up approach due to antral remnant.
Ch, Cholesteatoma extension; O, Ossicular chain status (at the end of surgery); L, Life threatening complications; E, Eustachian tube ventilation and mastoid pneumatisation.

in Table 1. In 27 cases, the cholesteatoma was removed by an exclusively transcanal approach; in 44 cases, a CWU tympanomastoidectomy was needed; and in 9 cases, we started with a transcanal approach but converted into a CWU tympanomastoidectomy due to an antral remnant extending into the mastoid air cells.

Intraoperative Cholesteatoma Residue Rates

After microscopic resection of cholesteatoma, a Hopkins rod telescope was used to examine the middle ear and mastoid sites which were difficult to visualize with the microscope for intraoperative cholesteatoma residues (Grade I use of operative endoscopic ear surgery according to the Massachusetts Eye and Ear Infirmary[19]). Intraoperative cholesteatoma residues were defined as disease that was not detected during primary microscopic dissection but identified during otoendoscopic examination.

We mapped the hidden middle ear areas intraoperatively. In 24 (30%) cases, an intraoperative cholesteatoma residue was found and removed. We identified a total of 30 foci. The superior retrotympanum was the most common location for intraoperative cholesteatoma residues. Details are shown in Table 2. The 11 cases where an intraoperative cholesteatoma residue was found in the aditus ad antrum were exclusively transcanal approaches. The presence of an attic cholesteatoma residue led to an intraoperative decision to convert into a CWU tympanomastoidectomy in 9 of these cases. Except one, all of these cases had a cholesteatoma extension stage II according to the ChOLE grade (as described by Linder et al[18]). This means that the cholesteatoma involved the middle ear, with further extensions into the attic and antrum up to the level of the lateral semicircular canal within the mastoid, with or without extension in the tympanic sinus. The one exception was classified as a cholesteatoma stage III according to the ChOLE grade.[18] In between surgical planning and surgical procedure, the cholesteatoma had progressed beyond the level of the lateral semicircular canal into the mastoid cavity.

Factors Influencing Intraoperative Cholesteatoma Residue Rate

Using crosstabs, the Pearson's chi-square test and the Fisher's exact test, we evaluated if any factors were influencing the intraoperative cholesteatoma residue rates found on otoendoscopic examination of the middle ear and mastoid sites. Factors evaluated were age, gender, operation side, microscopic location of the lesion (pars flaccida vs pars tensa), ChOLE grade (as described by Linder et al[18]) and sinus tympani depth (defined according to the radiologic sinus tympani classification of Marchioni et al[19]). None of them had a significant impact on the intraoperative cholesteatoma residue rate found on otoendoscopic examination. An overview of these data is given in Table 3.

Table 2. Localization of the Intraoperative Cholesteatoma Residues Found Upon Otoendoscopic Examination

	No of Cholesteatoma Remnants
Total	30
Superior Retrotympanum	
Tympanic sinus	7
Posterior stapedial crus	1
Pyramidal eminence	2
Facial recess	5
Inferior Retrotympanum	
Subtympanic sinus	1
Protympanum	
Eustachian tube orifice	1
Supratubal recess	1
EPITYMPANUM	
Epitympanum	1
Antrum	11

Cholesteatoma Residue Rates

Mean follow-up time was 29.5 months. During the postoperative follow-up period, cholesteatoma recidivism was encountered in 9 cases (11.25%). In 6 cases (7.5%), there was one foci of residual cholesteatoma, located in the sinus tympani (n=2), the oval window niche (n=1), around the incudomalleolar joint (n=1), inferior to a dehiscent tympanic segment of the facial nerve (n=1), or the epitympanic recess (n=1). In 3 cases (3.75%), there was a recurrent cholesteatoma arising from a new epitympanic retraction.

The cumulative cholesteatoma residue rate was calculated using Kaplan–Meier survival analysis, taking the patients lost to follow-up into account. At 1 year postoperatively, 97.2% of patients did not show residual cholesteatoma. This percentage decreased to 90.7% at 3 years postoperatively and 75.6% at 5 years postoperatively. Details are shown in Figure 1. Unfortunately, a portion of our patients were lost to follow-up or were postoperatively followed by the center who initially referred them.

Value of the Otoendoscope in Microscopic Cholesteatoma Surgery

If the otoendoscopic examination did not show any intraoperative cholesteatoma residue, 3 patients from a total of 56 still developed a cholesteatoma residue in the postoperative follow-up period (Table 4). This leads to a negative predictive value of 0.95. Meaning that a negative otoendoscopic examination in cholesteatoma surgery results in an uneventful follow-up period in 95% of cases.

$$NPV = \frac{TN}{TN + FN} = \frac{53}{53 + 3} = 0.95$$

Table 3. Factors Influencing Intraoperative Cholesteatoma Residue Rate

	No of Intraoperative Cholesteatoma Residue	Intraoperative Cholesteatoma Residue	
Total	56 (70%)	24 (30%)	
Age			
≤12 years	18 (69%)	8 (31%)	
>12 years	38 (70%)	16 (30%)	*P* = .9203
Gender			
Male	34 (71%)	14 (29%)	
Female	22 (69%)	10 (31%)	*P* = .8415
Operation side			
Right ear	31 (69%)	14 (31%)	
Left ear	25 (71%)	10 (29%)	*P* = .8065
Location on otomicroscopy			
Pars flaccida	24 (77%)	7 (23%)	
Pars tensa	23 (62%)	14 (38%)	
Pars tensa and flaccida	9 (75%)	3 (25%)	*P* = .3605
ChOLE grades			
Stage 1	27 (75%)	9 (25%)	
Stage 2	28 (67%)	14 (33%)	
Stage 3	1 (50%)	1 (50%)	*P* = .509 (Fisher)
Sinus tympani depth			
Type I	15 (75%)	5 (25%)	
Type II	38 (69%)	17 (31%)	
Type III	2 (50%)	2 (50%)	*P* = .686 (Fisher)

Furthermore, assuming that all intraoperative cholesteatoma residues become cholesteatoma residues during postoperative follow-up (if the otoendoscopic examination and further dissection were not performed), we can evaluate the assumed benefit of the endoscope in microscopic cholesteatoma surgery. Table 5 shows the number of cholesteatoma residues encountered during the postoperative follow-up in the "otoendoscopy +" and "otoendoscopy –" group. The "otoendoscopy +" group is our study cohort, whereas the "otoendoscopy –" group is a fictitious group. The latter consists of the same patient cohort, but we assume the endoscope was not used for detection of intraoperative cholesteatoma residues. In the "otoendoscopy +" group a cholesteatoma residue was detected in 6 cases from a total of 80 during the postoperative follow-up period. The "otoendoscopy –" group includes the 24 cases with an intraoperative cholesteatoma residue, of which we assume would become a cholesteatoma residue and 3 patients with a negative otoendoscopic examination who nevertheless developed a cholesteatoma residue, making a total of 27 patients. Out of this we can calculate the odds ratio as follows:

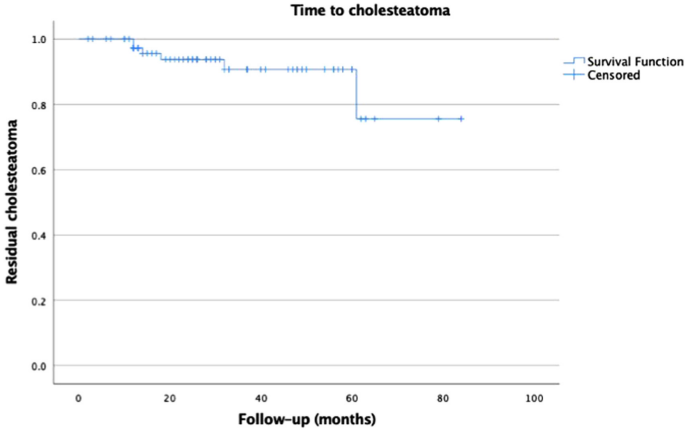

Figure 1. Time to residual cholesteatoma (m = months).

Table 4. Value of a Negative Otoendoscopic Examination

		Postoperative Cholesteatoma Residue?		Total
		Cholesteatoma +	Cholesteatoma –	
Otoendoscopic control	Negative	3	53	56
	Remnant present	3	21	24
	TOTAL	6	74	80

$$OR = \frac{ad}{bc} = \frac{6 \times 53}{74 \times 27} = 0.16$$

Since the odds ratio is below 1, we can state that the otoendoscope has a significant (*P* = .001) positive impact on the postoperative cholesteatoma residue rate according to the Pearson chi-square test.

DISCUSSION

In this study, we used the otoendoscope at the end of the microscopic cholesteatoma surgery to verify the completeness of its removal (Grade I use of operative endoscopic ear surgery according to the Massachusetts Eye and Ear Infirmary[17]). In spite of conscientious dissection of cholesteatoma under the microscope, we found intraoperative cholesteatoma residues in 30% of operated ears. This rate was not influenced by any of the following factors: age, gender, operation side, microscopic location of the lesion (pars flaccida vs pars tensa), CHOLE grade (as described by Linder et al[18]) nor sinus tympani depth (defined according to the radiologic sinus tympani classification of Marchioni et al[19]). Our intraoperative cholesteatoma residue rate is comparable with rates already reported in literature ranging from 17.18% reported by Bennett et al in their CWU subpopulation[5] to 77.38% noted by Ayache et al in their CWU and transcanal subgroup.[7] Furthermore, Good et al reported an intraoperative cholesteatoma residue rate of 24.11% in their CWU tympanomastoide ctomies,[9] Badr-El-Dine et al had a comparable rate of 25.61%[14] and El-Meselaty et al a higher percentage of 50%.[20] These rates support the view that the otoendoscope can be used to detect intraoperative cholesteatoma residues. Secondly, in cases when a purely transcanal approach is chosen, the endoscope could help to guide the surgeon intraoperatively to decide if a mastoidectomy is necessary or not. Disease limited to the tympanic space with limited extension toward the attic can be eradicated by an exclusively transcanal approach and the lateral semicircular canal is postulated as the distal limit.[21] Aggressive cholesteatomas may grow in between surgical planning and surgical procedure, making it uncertain if the cholesteatoma can

Table 5. Benefit of the Otoendoscope on Postoperative Cholesteatoma Residue Rate

		Postoperative Cholesteatoma Residue?		Total
		Cholesteatoma +	Cholesteatoma –	
Use of otoendoscope	Otoendoscope +	6	74	80
	Otoendoscope –	27 (24 +3*)	53	80

*3 of the 6 patients with a residue in the postoperative setting had a negative otoendoscopic control but developed nevertheless a cholesteatoma residue.

be taking out completely by a transcanal approach. In these cases, the endoscope can help the surgeon decide if a mastoidectomy is needed to complete cholesteatoma removal.

Uncovering intraoperative cholesteatoma residues allowed us to subsequently remove them and to prevent further development into clinical cholesteatoma residues. Although we could not diminish the cholesteatoma residue ratio to zero, we were able to reduce it in a significant way. Only 6 patients (7.5%) were diagnosed with residual cholesteatoma during the postoperative follow-up period. Assuming all intraoperative cholesteatoma residues develop into postoperative cholesteatoma residues, a reduction in cholesteatoma residue rate from 30% to 7.5% was obtained when using the endoscope (Grade 1). This reduction in residual cholesteatoma was already mentioned by Thomassin et al, who noted a drop in residual cholesteatoma from 47% to 6% by just adding the endoscope.[4] Similar results were found by Benett et al, who were able to reduce their 20% residue rate down to only 2.7%.[5] The research group of Yung and Badr-El-Dine reported respectively a residual cholesteatoma rate of 9.4% and 8.6% if an endoscopic examination took place at the end of the microscopic cholesteatoma removal.[10,14] In other words, using the otoendoscope reduced the cholesteatoma residue rate in CWU tympanomastoidectomy to the cholesteatoma residue rate of CWD tympanomastoidectomies and could therefore overcome the major drawback of the CWU technique, by revealing the hidden middle ear areas. Poor access to the sinus tympani, anterior epitympanic recess, and eustachian tube has always been considered the major reason for residual disease in CWU tympanomastoidectomies.[14] During the last decade, the otoendoscope has therefore become established in our practice as a complement to the microscope consequently a CWD tympanomastoidectomy has become obsolete. It is important to stress that the indication to obliterate or not the mastoid and paratympaic spaces and its effect on recurrence rate is outside the scope of this research.

Already in 1995 Bowdler et al demonstrated that residual disease is most common in the hidden areas of the middle ear (oval window niche, sinus tympani, eustachian tube orifice, and aditus ad antrum) and that these areas are difficult to visualize with the microscope and difficult to reach with conventional instruments.[22] Bennett et al, on the other hand, showed that the endoscope provided better visualization of all middle ear areas.[23] In our case series intraoperative cholesteatoma residues were most often detected in the superior retrotympanum (50%), more specifically in the tympanic sinus (23%) and the facial recess (16%). A comparable result was reported by Bennet et al. In their case series, 50% of the intraoperative cholesteatoma residues were found in the superior retrotympanum, mainly in the tympanic sinus.[5] In literature, even higher percentages are reported. Studies by several authors reported that approximately 80% of the intraoperative cholesteatoma residues are located in the superior retrotympanum and in the case series of Good et al all intraoperative cholesteatoma residues were identified in this hidden area.[7,9,14,20] The sinus tympani is the most common middle ear area, where intraoperative cholesteatoma residues hide. It is therefore especially important to check this area with the otoendoscope.

A limitation of the current study is the lack of an appropriate control group of patients operated purely under the otomicroscope, with no subsequent otoendoscopic examination. Furthermore, it is unclear if all intraoperative cholesteatoma residues encountered during otoendoscopic examination would have developed into symptomatic cholesteatoma residues during follow-up. We assumed that cholesteatoma growth between surgical planning and surgery led to the need to convert to a CWU tympanomastoidectomy when an antral cholesteatoma residue could not be removed via a transcanal approach. Alternatively, it could also be that these cases had a longer time interval between imaging and surgery, a factor we did not investigate. Also, pediatric and adult cases were observed together. Additionally, we would like to mention that repetitive postoperative MRI (non-EPI DWI) remains a cornerstone in the postoperative follow-up in cholesteatoma surgery,[24,25,26] since the additional use of an otoendoscope could only reduce the risk of cholesteatoma residues but not eliminate it.

Finally, we believe that both the microscope and the endoscope are of value in cholesteatoma surgery. It is not a matter of choosing one over the other, but rather we use the most appropriate combination to remove the cholesteatoma and reconstruct the middle ear. However, starting with an angled endoscope in the retrotympanic space may deter a microscopic trained surgeon, since endoscopic surgery has a steep learning curve. We agree with Pothier who suggested it is better to start out with surgeries that are likely to go well, such as an underlay tympanoplasty with a 0° endoscope, and once you have built up your skills to dive into the retrotympanic space with an angled endoscope of 30° or 45°.[21]

Otoendoscopy can be seen as a means to identify intraoperative cholesteatoma residues after microscopic cholesteatoma surgery. By looking "around the corners," the otoendoscope can reduce greatly the cholesteatoma residue rate in CWU tympanomastoidectomy or an exclusively transcanal approach. Furthermore, it can help guide the surgeon in the intraoperative decision to proceed with a purely transcanal surgery or to include a mastoidectomy.

Ethics Committee Approval: This study was approved by the Supervisory Committee on Medical Ethics of the University Hospitals Leuven (Approval No: MP017279; Date: January 25,2021).

Informed Consent: Informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – F.C., N.V.; Design – F.C., N.V.; Supervision – N.V., E.L., C.D.; Resources – N/A; Materials – N/A; Data Collection and/or Processing – F.C.; Analysis and/or Interpretation – F.C., N.V.; Literature Search – F.C., N.V.; Writing – F.C., N.V.; Critical Review – N.V., E.L., C.D.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: Nicolas Verhaert has received a grant (FWO 1804821N) from Research Foundation—Flanders (FWO) as a senior clinical investigator, and Elke loos from the UZ Leuven KOOR Research Fund of the University Hospitals of Leuven.

REFERENCES

1. Jackler RK, Santa Maria PL, Varsak YK, Nguyen A, Blevins NH. A new theory on the pathogenesis of acquired cholesteatoma: mucosal traction. *Laryngoscope*. 2015;125(suppl 4):S1-S14. [CrossRef]
2. Yung M, Tono T, Olszewska E, et al. EAONO/JOS joint consensus statements on the definitions, classification and staging of middle ear cholesteatoma. *J Int Adv Otol*. 2017;13(1):1-8. [CrossRef]
3. Olszewska E, Wagner M, Bernal-Sprekelsen M, et al. Etiopathogenesis of cholesteatoma. *Eur Arch Otorhinolaryngol*. 2004;261(1):6-24. [CrossRef]
4. Thomassin JM, Korchia D, Doris JM. Endoscopic-guided otosurgery in the prevention of residual cholesteatomas. *Laryngoscope*. 1993;103(8):939-943. [CrossRef]
5. Bennett M, Wanna G, Francis D, Murfee J, O'Connell B, Haynes D. Clinical and cost utility of an intraoperative endoscopic second look in cholesteatoma surgery. *Laryngoscope*. 2018;128(12):2867-2871. [CrossRef]
6. Kerckhoffs KGP, Kommer MBJ, Van Strien THL, et al. The disease recurrence rate after the canal wall up or canal wall down technique in adults. *Laryngoscope*. 2016;126(4):980-987. [CrossRef]
7. Ayache S, Tramier B, Strunski V. Otoendoscopy in cholesteatoma surgery of the middle ear: what benefits can be expected? *Otol Neurotol*. 2008;29(8):1085-1090. [CrossRef]
8. Abtahi SH, Abootalebian F, Rogha M, Berjis N. The value of otoendoscopy in the management of middle ear cholesteatoma. *J Res Med Sci*. 2015;20(12):1182-1185. [CrossRef]
9. Good GM, Isaacson G. Otoendoscopy for improved paediatric cholesteatoma removal. *Ann Otol Rhinol Laryngol*. 1999;108(9):893-896. [CrossRef]
10. Yung MW. The use of middle ear endoscopy: has residual cholesteatoma been eliminated? *J Laryngol Otol*. 2001;115(12):958-961. [CrossRef]
11. Tarabichi M. Endoscopic management of limited attic cholesteatoma. *Laryngoscope*. 2004;114(7):1157-1162. [CrossRef]
12. Aoki K. Advantages of endoscopically assisted surgery for attic cholesteatoma. *Diagn Ther Endosc*. 2001;7(3-4):99-107. [CrossRef]
13. McElveen JT, Hulka GF. Reversible canal wall down tympanomastoidectomy. An alternative to intact canal wall and canal wall down mastoidectomy procedures. *Am J Otol*. 1998;19(4):415-419.
14. Badr-El-Dine M. Value of ear endoscopy in cholesteatoma surgery. *Otol Neurotol*. 2002;23(5):631-635. [CrossRef]
15. Kozin ED, Lee DJ. Basic principles of endoscopic ear surgery. *Op Tech Otolaryngol Head Neck Surg*. 2017;28(1):2-10. [CrossRef]
16. Verma B, Dabholkar YG. Role of endoscopy in surgical management of cholesteatoma: a systematic review. *J Otol*. 2020;15(4):166-170. [CrossRef]
17. Cohen MS, Basonbul RA, Barber SR, Kozin ED, Rivas AC, Lee DJ. Development and validation of an endoscopic ear surgery classification system. *Laryngoscope*. 2018;128(4):967-970. [CrossRef]
18. Linder TE, Shah S, Martha AS, Röösli C, Emmett SD. Introducing the "ChOLE" classification and its comparison to the EAONO/JOS consensus classification for cholesteatoma staging. *Otol Neurotol*. 2019;40(1):63-72. [CrossRef]
19. Marchioni D, Valerini S, Mattioli F, Alicandri-Ciufelli M, Presutti L. Radiological assessment of the sinus tympani: temporal bone HRCT analyses and surgically related findings. *Surg Radiol Anat*. 2015;37(4):385-392. [CrossRef]
20. El-Meselaty K, Badr-El-Dine M, Mandour M, Mourad M, Darweesh R. Endoscope affects decision making in cholesteatoma surgery. *Otolaryngol Head Neck Surg*. 2003;129(5):490-496. [CrossRef]
21. Pothier DD. Introducing endoscopic ear surgery into practice. *Otolaryngol Clin N Am*. 2013;46(2):245-255. [CrossRef]
22. Bowdler DA, Walsh RM. Comparison of the otoendoscopic and microscopic anatomy of the middle ear in canal wall-up and canal wall down temporal bone dissections. *Clin Otolaryngol Allied Sci*. 1995;20(5):418-422. [CrossRef]
23. Bennett ML, Zhang D, Labadie RF, Noble JH. Comparison of middle ear visualization with endoscopy and microscopy. *Otol Neurotol*. 2016;37(4):362-366. [CrossRef]
24. Jeunen G, Desloovere C, Hermans R, Vandecaveye V. The value of magnetic resonance imaging in the diagnosis of residual or recurrent acquired cholesteatoma after canal wall-up tympanoplasty. *Otol Neurotol*. 2008;29(1):16-18. [CrossRef]
25. De Foer B, Vercruysse JP, Bernaerts A, et al. Detection of postoperative residual cholesteatoma with non-echo-planar diffusion-weighted magnetic resonance imaging. *Otol Neurotol*. 2008; 29(4): 513-517. [CrossRef]
26. Steens S, Venderink W, Kunst D, Meijer A, Mylanus E. Repeated postoperative follow-up diffusion-weighted magnetic resonance imaging to detect residual or recurrent cholesteatoma. *Otol Neurotol*. 2016;37(4): 356-361. [CrossRef]

Supplementary Table 1. Preoperative and postoperative hearing results (expressed in dB HL) according to the SAMEO-ATO classification for type of ossicular chain reconstruction

	N	CWU tympanomastoidectomy		N	Transcanal approach	
		Pre-operative	Post-operative		Pre-operative	Post-operative
On (intact)	6	27.39 (0-48.33)	22.73 (10-28.33)	11	27.33 (0-45)	21.94 (6.67-25)
On (no data)	6	27.31 (20-55)	22.61 (16.67-63.33)	1	13.33	20
Osi (mimix)	5	22.87 (16.67-33.33)	16.94 (11.66-23.33)	9	27.35 (10-36.67)	22.92 (0-31.67)
Osm (PORP-M)	13	27.04 (16.67-50)	21.92 (11.67-46.67)	9	27.32 (5-45)	23.94 (0-48.33)
Ost (PORP-TM)	1	55	16.67	3	24.17 (26.67-36.67)	21.11 (15-38.33)
Ofm (TORP-M)	6	27.54 (28.33-56.67)	22.93 (18.33-56.67)	2	27.19 (30-53.33)	21.52 (20-38.33)
Oft (TORP-TM)	7	27.72 (13.33-41.67)	23.44 (13.33-43.33)	1	56.67	63.33

Legend
* On: intact ossicular chain
* Ox: no data available in the chart
* Osi: erosion of incudostapedial joint, repaired with cement
* Osm: missing incus, reconstruction between malleus and stapes head
* Ost: missing incus and malleus, reconstruction between the with cartilage reinforced tympanic membrane and stapes head
* Ofm: missing stapes and incus, reconstruction between malleus and mobile stapes footplate
* Oft: missing stapes, incus and malleus, reconstruction between the with cartilage reinforced tympanic membrane and mobile stapes footplate