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Middle ear surgery: why and how to switch from microscope to endoscope

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Abstract. *Middle ear surgery: why and how to switch from microscope to endoscope*. *Rationale:* Endoscopic-controlled middle ear surgery is a controversial topic in the ENT field. It was introduced in the past few years as an innovative alternative to microscopic-controlled surgery. It offers better visualization of the middle ear and is associated with lower morbidity, but with the same functional results.
Study design: This retrospective study evaluated our recent experiences with this technique, focusing on 70 cases of endoscopic type I tympanoplasty and 42 other cases of middle ear surgery performed under exclusive endoscopic control. The student's t-test was used for statistical analysis.
Results: There was a tympanic perforation closure rate of 95.7%, with a statistically significant improvement in hearing thresholds and closure of air-bone gaps. We also describe our initial experience, learning curve, and the lessons learned.
Conclusions: We believe endoscopic-controlled middle ear surgery is an effective technique with good anatomical and functional results, offering excellent visualization. Thus, the endoscope is a valid alternative to the microscope. It is a one-handed technique that must be performed step-by-step; therefore, there is a learning curve of several months. Further studies should evaluate the lower morbidity associated with this technique.

Introduction

In the field of otorhinolaryngology, endoscopic surgery has been used for many years and is a standard procedure in the daily ENT surgical practice. It has been used almost exclusively in sinus and larynx surgery.[1,2] The use of the endoscope in otologic surgery was described by Tarabichi, the pioneer of ear and mastoid endoscopic surgery, in the 1990s. Initially, the endoscope was considered an adjunct to the microscope.[3] Its role was limited to visualizing the residual epidermis after cholesteatoma surgery or the anterior angle during tympanoplasty.[4,6] It has progressively become the exclusive means for visualizing many types of middle ear interventions, as a valid alternative to the microscope.[7,9] The endoscopic approach has improved otologic surgical procedures by providing greater access and has strongly improved the visualization of previously hidden areas of the middle ear, such as the retrotympanum, the anterior epitympanum, and the earfolds.[10,12] Furthermore, the endoscopic view provides a better understanding of the anatomy of the middle ear because the light source and camera are directly guided inside it. The use of the endoscope enables micro-invasive surgery of the middle ear, with minimum damage to surrounding tissues. In this retrospective study, we report our preliminary observations with this technique, describe some lessons learned during our initial experience, and evaluate the first functional results. We focused our study on the 70 type I tympanoplasty interventions and 42 other types of middle ear procedures we performed under exclusive endoscopic control. Based on the preliminary functional results, we discuss how to progressively expand the indications for endoscopic surgery and improve the surgeon's confidence.

Material and methods

This was a retrospective study including 112 consecutive patients of all ages (4 to 70 years old) who underwent endoscopic middle ear surgery between October 2014 and September 2016 at the Centre Hospitalier Régional de la Citadelle in Liège, Belgium. The 70 patients who underwent type I tympanoplasty were included in the statistical analysis of our primary outcome (the functional results). The 42 patients undergoing other interventions were not included in the statistical analysis in this study because of the smaller number,

but they were included when discussing our learning curve, which is our secondary outcome. Two surgeons began developing this technique in 2014 and performed all of the interventions, either together or individually. They both had several years of experience in microscope-assisted ear surgery as well as in endoscopic sinus and skull base surgery.

Inclusion criteria were patients who underwent surgery for middle ear disease under exclusive endoscopic control. All the tympanic membrane perforation patients that consulted with the surgeons and needed type I tympanoplasty were operated endoscopically. No patient was refused or referred to microscopic surgery because of size or location; therefore, there was no bias in the selection. Exclusion criteria were patients that were lost after surgery and had incomplete audiometric follow-up. All patients had a pre-operative consultation using a microscopic otoscopy and an audiometric analysis evaluating hearing thresholds and air-bone gaps (AC 40 interacoustics). All patients benefited from post-operative consultations at 1, 2, and 4 weeks after surgery, and were then seen 2 and 5 months after surgery. A post-operative audiometric analysis was performed 4 weeks after surgery. All patients applied auricular drops, a solution of ciprofloxacin (3 mg/mL) daily for 1 week, following surgery. Finally, all patients had a post-operative follow-up at a minimum of 5 months after surgery.

A. Outcomes of the study

The primary outcome of this study was the functional results of the 70 endoscopic type I tympanoplasty surgeries that were performed during the study period. This included the tympanic perforation closure rate, audiometric results (pure tone audiometry and air-bone gap), and peri- and post-operative complications (relapsing perforation, graft infection, facial palsy). We considered the perforation as closed when no relapsing perforation was visible within 5 months following the surgery. The mean hearing thresholds were calculated using air conduction pure tone audiometry on conversational frequencies: 500 - 1000 - 2000 - 4000 Hz. The mean air-bone gaps were calculated based on the same frequencies.

The secondary outcome of this study was to describe and discuss our learning curve and the practice time that was needed before expanding the indications for endoscopic surgery beyond type I tympanoplasty (type II and III tympanoplasty, cholesteatoma surgery). To evaluate our learning curve, we divided the 2 years of the study into four “6-month periods” and analyzed the number and types of interventions performed during each period for the 112 operations evaluated. The third outcome was to evaluate the surgical time of type I tympanoplasty when this information was available. In addition, our experience with learning and improving this technique is detailed in the “Discussion” section. The design of this study was approved by the Institutional Review Board of our institution (number 412). Statistical analysis was performed using statistical tools (Excel). A p-value <0.05 was considered statistically significant in our student’s t-tests.

B. Operating room set-up

The set-up of the operating room is described in Figure 1. The surgeon and the instrumentalist (or the second surgeon) were seated side-by-side in front of the operated ear. The endoscopic tower as well as the anesthesiologist and his machine were on the other side of the patient (Figure 1).

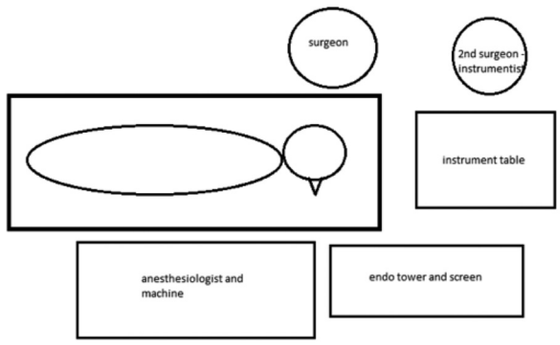


Figure 1
Set-up of the operating room.

C. Preparing the operative field

Before starting any procedure, we installed a foamy armrest in front of the ear. We used dermal iso-Betadine as the defog liquid for the endoscope. We begin the intervention by trimming the hair of the external auditory canal to avoid smudging the lens of the endoscope.

D. Types of endoscopes

We use different Storz rigid endoscopes with lens angulations of 0 or 30° and a length of 6 or 11 cm,

along with a Storz HD camera. All interventions were performed with 2.7 mm diameter endoscopes, which offer more space for the other instruments, avoiding excessive conflicts.

E. Dealing with bleeding

We initially found the major difficulty was bleeding of the tympanomeatal flap. It is useful to discuss with the anesthesiologist the importance of stable and controlled hypotension during the entire procedure, and to place the patient in a slight reverse Trendelenburg position. We performed classic infiltration of the external auditory canal with local anesthetics and adrenaline (lidocaine chlorhydrate 20 mg/mL; adrenaline bitartrate 1:200000) for all patients to reduce the bleeding. During the more hemorrhagic moments during the intervention, we used special instruments with an integrated suction duct. We used cottonoids soaked in a 1/1000 adrenaline solution when needed. At the beginning of our apprenticeship, we did not hesitate to enlist the help of a second person when the bleeding was intense. The second surgeon or assistant used the suction, which allowed us to improve the length of surgery. After gaining experience, each surgeon now performs all interventions alone, without the help of a second surgeon.

F. Type of graft

All tympanic grafts were performed using tragus cartilage perichondrium with or without the tragus cartilage itself. When the cartilage was used along with the perichondrium, we made a triangular notch in the cartilage to apply only the perichondrium on the manubrium of the malleus. We used the cartilage along with the perichondrium in the following cases: when the diameter of the perforation was >4 mm, when the perforation was marginal, or when it was not a first intervention. In the other cases, we used the perichondrium only. The choice of the tragus as a graft was made in accordance with our goal of performing micro-invasive surgery with limited cutaneous incisions. Before our new endoscopic surgical orientation, our first choice graft was fascia temporalis, and we preferred to use the cartilage graft only in second interventions after relapse or in children. Recently, we started using fascia temporalis in our endoscopic procedures by making a hidden incision in the scalp. We do not want to abandon the use of tragus cartilage, which is a very useful graft in some situations such as anterior or large perforations. The replacement of the tympanomeatal flap was secured by placing several pieces of gel foam in the external auditory canal.

Results

A. Functional results of endoscopic type I tympanoplasty

This study included 70 patients who underwent type I tympanoplasty. Seventy-nine patients were initially selected for this study, but nine were excluded because they were lost during the follow-up. Perforations were divided into anterior, central, or posterior and according to their size (< or > 4 mm) (Table 1). All interventions consisted of type I transcanal endoscopic tympanoplasty performed by one or two surgeons (2- or 3-handed). All interventions were performed during one-day hospitalizations, under general anesthesia. All tympanic grafts were performed using tragus cartilage perichondrium with or without the tragus cartilage, according to the underlay technique.

The mean pre-operative hearing threshold was 30.90 decibels Hearing Level (dB HL) (SD 13.77) with a mean air-bone gap of 14.93 dB HL (SD 11.39). The post-operative mean hearing threshold was 24.11 dB HL (SD 14.16) with a mean air-bone gap of 7.52 dB HL (SD 10.82). On average, the hearing threshold was improved by 7.04 dB HL (SD 9.42) ($p<0.05$) and the air-bone gap was reduced by 7.40 dB HL (SD 9.42) ($p<0.05$) (Table 2). We found that 95.7% of tympanic perforations were definitely closed within a follow-up period of 5 to 24 months. The mean follow-up period was 12.69 months (SD 6.03). We did not encounter any peri-operative complication. There were two post-operative graft infections that were treated effectively with local antibiotics (ciprofloxacin 3 mg/mL) for 10 days. We also described three perforation relapses, two were early relapses in the first 3 post-operative months and one was a late relapse 8 months after surgery. All three cases will undergo another surgery using the same technique.

B. Our gain in experience

The number of interventions has been rapidly growing, along with our experience and confidence (Figure 2. During the first 6 months, we performed

Figure 2
Evolution of the number and age of patients over time.

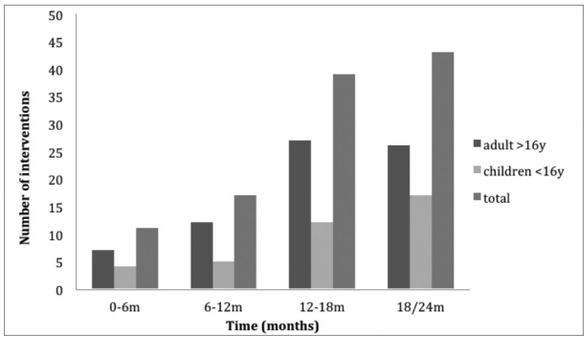
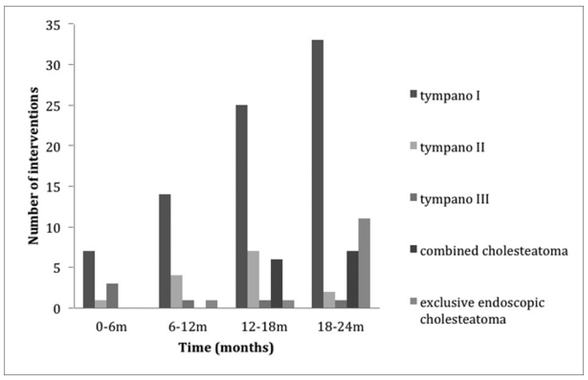


Figure 3
Evolution of our indications over time.



almost exclusively type I tympanoplasties. We began expanding the indications by the second 6-month period to include ossiculoplasties and one endoscopic cholesteatoma at the 9th month. We progressively widened our indications for cholesteatoma procedures, using either purely endoscopic interventions or combining the endoscope with the microscope, according to the extent of the cholesteatoma (Figure 3).

C. Surgical time

The mean operation time of endoscopic type I tympanoplasty, for cases where that information was available (32 patients out of 70), was 86.25 min (SD 26.09). The operation time was progressively reduced as we gained experience (r-value -0.44) (Figure 4).

Discussion

A. Our functional results

The above results confirm there was a statistically significant improvement in the hearing of our patients after endoscopic type I tympanoplasty, as well as a tympanic perforation closure rate of 95.7%. Those results are anatomically and functionally comparable to those described using the microscope-assisted technique[13,16] and to those described in the literature for endoscopic type I tympanoplasty.[17,19]

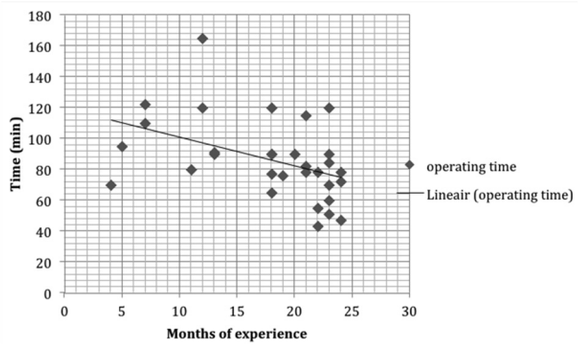
Table 1
Description of the patients undergoing type I tympanoplasty and the outcomes.

Age (years)		28.24 (SD 21.5)
Sex		
	Female	59.70%
	Male	40.30%
Side		
	Left	52.86%
	Right	47.14%
Size of perforation		
	<4 mm	37.70%
	>4 mm	62.30%
Location of perforation		
	anterior	48.60%
	central	24.30%
	posterior	27.10%
Marginal		25.70%
Type of graft		
	cartilage + perichon-drium	92.30%
	perichon-drium	7.70%
RESULTS		
Audiometric results		
	Hearing threshold (dB HL)	-7.04 (9.42)
	ABG (dB HL)	-7.4 (9.42)
Perforation closure rate		95.70%
Complications		
	graft infec-tion	2
	relapsing perforation	3
Intervention time (min)		86.3 (SD 26.1)

B. Advantages of endoscopic middle ear surgery

We have noticed several advantages to this technique, including the quality of the luminosity

Figure 4
Evolution of the surgical time of type I tympanoplasty with experience, R value: -0.44



and image and the access to every region of the middle ear. The endoscope provides a much better view of the different regions of the middle ear than the limited tubular view of the microscope. The avoidance of any retro-auricular incision and suture simplifies the surgical procedure. For the patient, especially the pediatric patient, important aspects of the technique are the absence of post-operative care and the absence of risk of a auricle deformation due to the retro-auricular incision, as all interventions were performed using a transcanal approach.

From a socio-economic point of view, all interventions were performed during a one-day hospitalization. In addition, patients reported very low post-operative pain rates, but this was not analyzed in this study.

There was no report of ossicular damage due to inadvertent contact with the endoscope, especially since we mostly used 0° endoscopes. In our series, the small caliber of the external auditory canal has not been problematic, even in young children. We believe that all type I tympanoplasties can be performed endoscopically with a transcanal approach. Some previous studies discussed the possibility of heat-induced damage.[20,21] We did not find any lesions of middle ear structures, likely because of the regular water irrigation during the intervention. There was no additional surgical material needed as we use the same instruments as for the microscopic technique. Thus, endoscopic type I tympanoplasty is as effective as microscopic type I tympanoplasty, and provides comfort and excellent visualization for the surgeon.

C. Limitations of the endoscopic technique

Although, as discussed above, the endoscopic technique offers several advantages, it also bears some limitations. First, the introduction of a new surgical technique always requires a period of learning and progression, and operations times can be prolonged in the beginning. The surgeon has to learn to work one handedly, without binocular vision. Surgery of all middle ear pathologies is not feasible with this technique, due to the extension of the disease, which will be discussed later. We found the tympanomeatal flap was the hardest time to master, because of the bleeding.

D. Lessons learned and experience gained

Type of endoscope

The surgical gesture was performed with a 0° angled endoscope to avoid any damage to the ossicles. The 30° angled endoscope was occasionally used at the end of a cholesteatoma procedure to visualize zones of the middle ear that are unseen with the 0° angled endoscope. This is often also done after microscopic interventions.[22] The length of the endoscopes we used varied according to the number of hands performing the surgery. When two surgeons operate simultaneously, as we sometimes did in the beginning, we prefer 11 cm endoscopes, which offer a better optimization of space and prevent conflicts between the hands of the two surgeons and the endoscope. When the intervention is performed by only one surgeon, we prefer the shorter 6 cm endoscope, which is more comfortable and allows the surgeon to rest their hands on the head of the patient or on the armrest. We do not recommend the use of an endoscope holder because the endoscope is in constant motion during the surgery for optimal visualization and to avoid conflicts with other instruments. Furthermore, if the patient should move unexpectedly during the intervention, the risk of damage to an element of the middle ear anatomy would be high as the endoscope would remain static.

Cholesteatoma surgery: exclusively endoscopic or a combined technique?

As we gained experience, we progressively started performing cholesteatoma surgeries endoscopically. We begin the surgery by endoscopically removing the disease located in the middle ear and we progressively follow it to its distal extension. We have found it possible to remove cholesteatomas under exclusive endoscopic control when the

disease is limited and does not cross the limit of the lateral semi-circular canal. When it does, we use a combined technique and use the microscope for a posterior approach with mastoidectomy. We have found residual cholesteatoma in the mastoid every time the disease crosses the lateral semi-circular canal, and this requires a combined posterior approach. Therefore, we suggest starting endoscopically in the middle ear and following the cholesteatoma to where it leads. If the limit of the lateral semi-circular canal is crossed by the disease, a posterior microscopically-controlled approach must be used because the endoscopic view cannot assure the absence of cholesteatoma beyond it. Thus, we found it necessary to use the microscope whenever a posterior approach is needed. Thus, the endoscope does not completely replace the microscope in all cases of middle ear pathologies.

The necessary learning curve

This technique is a one-handed surgery, as the other hand is busy at all times holding the endoscope. This explains why there is an adaptation and practice needed before completely mastering the technique.[23,24] When we look back at our learning curve, we see that we progressively expanded the indications for endoscopic surgery. During the first trimester, we only performed type I tympanoplasties. Progressively, we selected cases that were more difficult, e.g. those with anterior perforations. Then, we started performing endoscopic ossiculoplasties. For cholesteatoma surgeries, we initially performed combined techniques (using the endoscope and the microscope) and we now perform exclusive endoscopic cholesteatoma surgery when the extension allows it. We believe it takes 3 to 6 months before feeling completely confident performing type I tympanoplasty. It took us approximately 1 year to be able to perform all types of middle ear interventions endoscopically. We recommend taking one or two endoscopic ear surgery courses before starting endoscopic ear surgery in the clinical practice.

During the two years of the study, 90% of the middle ear interventions we performed were under exclusive endoscopic control (except stapes surgery). We found our experience in four-handed skull base surgery very useful and adapted that technique to middle ear surgery. Mastering endoscopic sinus surgery is not a necessary step for endoscopic ear surgery, but we believe that we have gained in our learning curve because rhinologists are used to manipulating the endoscope and to working with one hand in narrow operative fields. We see this with young surgeons who adjust to the technique faster when they already have some experience in sinus surgery. Furthermore, we noticed that the younger generation of surgeons seem more at ease with the manipulation of endoscopes and indirect visualization of their gestures on the screen.

E. Limits of the study

Our study contains some methodological limits inherent to its retrospective nature and the lack of a control group.

Conclusions

Endoscopic type I tympanoplasty is a feasible and effective technique with audiometric results and perforation closure rates that are comparable to those from microscope-controlled tympanoplasty, with similar complication rates. We believe a surgeon has to start with and master type I tympanoplasty when beginning endoscopic middle ear surgery. We have found it takes approximately 6 months to 1 year to master this intervention endoscopically. The endoscope approach has the advantage of better visualization of the middle ear. Furthermore, and although this was not the aim of this study, we believe it offers advantages for the patient such as low pain levels and a rapid return to work or school. These comfort and socio-economic advantages should be evaluated in future studies. This one-handed surgical technique requires some learning time. During the last two years, 90% of the middle ear interventions we performed were done under exclusive endoscopic control. The endoscope is a great tool for low morbidity interventions and is an effective alternative to the microscope, but it cannot replace the microscope in all cases. We believe endoscopic middle ear surgery will greatly be developed in the future and further research is needed on this subject.

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