Endoscopic Versus Microscopic Canal Wall Up Surgery for Cholesteatoma: A Diffusion-Weighted Magnetic Resonance Imaging Post-Operative Study

Mohamed Kamal Mobashir[1], Atef Hamed Ali[1], Mostafa Hasan Hassan[1], Inas Mohamed Abdel-Aziz El Fiki[2], Ahmed Nagy Hadhoud*[1], Mohammed Elsayed Elmaghawry[3]

Departments of [1]Otorhinolaryngology, [2]Radiology, Faculty of Medicine Zagazig University, Egypt

[3] Fellow of Otorhinolaryngology, Zagazig University Hospitals, Egypt

***Corresponding Author**: Ahmed Nagy Hadhoud, **Mobile:** (+20)1006708797**, E-mail:** A7me_ed@hotmail.com

ABSTRACT

Background: Cholesteatoma is a surgical disease for which the primary universally accepted goal is total eradication of cholesteatoma to obtain a safe and dry ear. The second objective is restoration or maintaining the hearing.

Objective: This study was aimed to solve the problem of residual cholesteatoma and decrease the problem of large mastoid cavities and to increase the learning curve of endoscopic ear surgery.

Patients and Methods: non-randomized controlled trial study performed in Otolaryngology, Head and Neck Surgery Departments, Zagazig University Hospitals in the period from February 2018 to February 2021 on 30 patients suffering from middle ear cholesteatoma. Otoendoscopic evaluation were used for detection of the presence of attic perforation, posterosuperior perforation, aural polyps and, whitish shadow behind intact tympanic membrane. All patients were operated under general anesthesia with controlled hypotensive technique.

Results: After 1 year of follow-up in 15 patients using endoscopic approach and 15 patients using microscopic approach, the recidivistic cholesteatoma was found in 6.7% in endoscopic group while it was 20% in microscopic group.

Conclusions: It could be concluded that the use of an endoscope provided important benefits to patients with middle ear cholesteatoma and offer superior visualization than microscope.

Keywords: Endoscopic, Cholesteatoma, Microscopic, Ear surgery

INTRODUCTION

Residual cholesteatoma, in which uncleared remnants of keratinizing squamous epithelium survive after incomplete surgical clearance occurs in as many as 35% of patients[(1)]**.** Canal wall down surgery exenterates potential hidden places for matrix remnants, but residual disease still occur, in several reputable series as frequently as with intact canal wall surgery. Removal of the canal wall therefore does not seem justifiable for the prevention of residual disease, pose a life-long burden and poor hearing outcomes. Intact canal wall can lead to conditions favorable to the introduction of the water into the external auditory meatus, and primary ossicular chain reconstruction [(2,3)]**.**Since the introduction operative endoscopy in the 1990s, the concept of a minimally invasive approach in middle ear surgery is changing. Endoscopic middle ear surgery can offer some advantages compared to the traditional microscopic technique, guaranteeing excellent visualization of mesotympanic structures, direct visual control of hidden areas such as anterior epitympanic spaces, retrotympanum, protympanum [(4)]**.**

Use of endoscope during cholesteatoma surgery should allow for more frequent preservation of the posterior canal wall, as well as lower rates of residual cholesteatoma and thus less need for second-look operations for residual [(5)]**.**

Non-echo planar (non-EPI) diffusion-weighted (DW) magnetic resonance imaging (MRI) can accurately predict the presence and extent of cholesteatoma in both primary and residual cases [(6)]**.** Non-EPI DW MRI can distinguish cholesteatoma from other tissues asgranulation tissue and mucosal reactions in the middle ear and mastoid. One of the greatest challenges in the past decade has been the question whether MRI could replace second look surgery [(7,8)].

The aim of the current work was to solve the problem of residual cholesteatoma and decrease the problem of large mastoid cavities and to increase the learning curve of endoscopic ear surgery**.**

PATIENTS AND METHODS

This non-randomized controlled trial study included a total of 30 patients suffering from middle ear cholesteatoma, unilateral or bilateral disease, attending at Otolaryngology, Head and Neck Surgery Departments, Zagazig University Hospitals. This study was conducted between February 2018 to February 2021.

***Ethical Consideration*:**

Written Informed consent was taken from the patient to participate in the study. Approval for performing the study was obtained from Otorhinolaryngology Departments, Zagazig University Hospitals after taking Institutional Review Board (IRB) approval. The work has been carried out in accordance with the code of ethics of the world medical association (Decleration of Helsinki) for studies involving humans.

. Patients were 18 male and 12 female, their ages ranged from 11 to 56 years with mean age (30.9 ± 9.7). They underwent endoscopic ear surgery (**Group A)** 15 cases and microscopic ear surgery (**Group B)** 15 cases.

Received: 24/4/2021
Accepted: 20/6/2021

Inclusion criteria: Age 11-60 years. Chronic Suppurative Otitis Media with Cholesteatoma. Unilateral or Bilateral disease.

Exclusion criteria: Revision Mastoid surgeries. Patient with intracranial complications of cholesteatoma. Patients with external and middle ear abnormalities (congenital or acquired). Medically and surgically unfit patients.

Pre-operative evaluation:

- Thorough history taking with special emphasis on: hearing loss and its duration, tinnitus, otorrhea, otalgia, ear pressure, vertigo, dizziness, or muscle weakness on one side of the face.
- The physical exam included a full head and neck exam including inspection of the head, eyes, nose, oral cavity, oropharynx, neck and most importantly ears.
- Otoendoscopic evaluation for detection of presence of attic perforation, posterosuperior perforation, aural polyps and whitish shadow behind intact tympanic membrane.
- Audiological assessment by audiometry prior to surgery to establish a baseline.
- High resolution computerized tomography (HRCT) of the temporal bone. Images analysis was performed by one radiologist and one otoneurologist.

Surgical techniques:

Group (A): As regard patients with limited attic cholesteatoma they were operated with TTEES in the following steps:

All patients were operated under general anesthesia with controlled hypotensive technique. Skin disinfection was done with povidone iodine 10%. Injection; this was done by 1/200000 adrenalin lidocain solution injected in the external auditory canal under posterior meatal wall skin, at 6th O'clock and 12th O'clock. Incision and elevation of the flap: Using the 0 degree endoscope, wide tympanomeatal flap was designed to extend from 6 o'clock inferiorly to1 o'clock superiorly in right ear and 11 o'clock in the left ear and to be about 5 millimeters from the annulus. It was performed with the round knife and haemostasis during this step achieved with aid of cottonoids soaked with adrenalin solution and with the aid of the round knife with suction tip. Elevation of the flap till reaching the annulus and identification of the chorda tympani and then transposing it inferiorly to expose the superior and posterior portion of the medial part of the external auditory canal were performed. Entry to the middle ear and continuous careful dissection of the tympanic membrane from the posterior malleolar ligament and then from the handle of malleus till the umbo then separating the flap from it with sharp scissor as the tympanic membrane was adherent to the malleus at that point. A clear view of the protympanum and eustachian tube region was possible after transposing the flap inferiorly. The scutum was totally removed with sharp curette or burr until the anterior bony wall of the epitympanic space was explorable representing the anterior limit of the dissection. Right angle curette was useful in completion of this step. Then, dissection of the cholesteatoma was performed from the anterior bony wall of the anterior epitympanic space (AES) to the posterior epitympanic space (PES) toward the antrum and the periantral mastoid cells maintaining the integrity of the sac whenever possible. Ossicular chain was preserved as much as possible, but the malleus and incus were removed when they were involved in the cholesteatoma or when they limit access to cholesteatoma in the anterior or posterior epitympanic space. When present, the stapes was left intact and meticulously and gently cleaned when it is involved with the cholesteatoma. Removal of the most superior and posterior bony wall of the medial portion of the external auditory canal was done to reach the antrum and the periantral mastoid cells. At the end of this procedure, a sort of small open cavity was created. This procedure allowed us to isolate the most posterior extension of the cholesteatoma sac removing en bloc the disease and maintaining the integrity of the sac whenever possible.

Work with angled endoscopes; After these surgical steps, a 45° or 30° endoscope was used to check the retrotympanic spaces removing cholesteatoma sac from them. Curved instruments and suction tips were mandatory in dissection in these sites. When located, mesotympanic and hypotympanic cholesteatoma fragments were removed. Ensure patency of the area of isthmus and division of the tensor fold to provide adequate attic ventilation.

Ossicular chain reconstruction; when necessary, an ossicular chain reconstruction was performed by a remodeled autologous incus or by prosthesis.

Attic reconstruction: the attic defect was reconstructed with composite chondroperichondrial tragal graft with excess porichondrium.

Tympanic membrane grafting; the defect was grafted with perichondrium with gelfoam pieces under it. Repositioning of the flap. Packing of the external canal; Filling the external auditory canal with moistened gelfoam then small pack impregnated with antibiotic ointment. Closure of the site of tragal incision.

Group (B): Pure post auricular microscope surgery assisted by angled picks and forceps and routine otologic micro-instruments were used:

1. A postauricular approach
2. Elevation of wide tympanomeatal flap
3. If needed scutum was removed and dealed with cholesteatoma in the middle ear
4. Removal of disease from the retrotympanum was completed under the microscope, assisted by a Buckingham mirror for visualization, or by drilling off bone toward the facial nerve
5. The malleus and incus were removed when they were involved in the cholesteatoma or when they limited access to cholesteatoma in the anterior or posterior

epitympanic space. When present, the stapes was left intact.

6. Defects of the scutum (scutumplasty-for prevention of postoperative retraction pockets) and tympanic membrane were reconstructed with cartilage and perichondrium

Postoperative follow up:

The total follow up period was 12 months. It included: Systemic antibiotics for 2 weeks. Otoscopic and otoendoscopic examinations were done weekly for the first month, then monthly in the first 3 months, then every 3 months afterwards with meticulous removal of any debris or discharge from the external auditory canal. Audiological assessment by audiometry. Pure tone audiometry and DW MRI temporal bone were done 1 year postoperative. The MR images were reevaluated by 2 radiologists blinded to the clinical and surgical information.

Statistic analysis

Recorded data were analyzed using the Statistical Package for Social Sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA) (IBM Corp. Released 2013). Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage. A one-way analysis of variance (ANOVA) was used when comparing between more than two means. Least Significant Difference (LSD) was used for multiple comparisons between different variables. Chi-square (X^2) test of significance was used in order to compare proportions between qualitative parameters. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, P-value <0.001 was considered highly significant.

RESULTS

Table (1) shows that 60% of patients were male and 40% were female, their ages ranged from 11 to 56 years with mean age 30.9 years with standard deviation 9.7. Patients suffered from middle ear cholesteatoma 28 of them (93.3%) were acquired type and 2 patients (6.7%) were congenital type.

Table (1): Demographic data of the studied subjects (N=30).

Demographic data	The studied patients (N=30)	
	No.	%
Gender		
Male	18	60%
Female	12	40%
Age (years)		
Mean ± SD	30.91 ± 9.71	
Median (range)	30 (11 – 56)	
Type of Cholesteatoma		
Acquired	28	93.3%
Congenital	2	6.7%

Table (2) This table shows that there was significant difference between the two groups regarding detection of cholesteatoma in sinus tympani while there was no significant difference between the two groups regarding detection of cholesteatoma in facial recess and anterior epitympanum.

Table (2): Detection of cholesteatoma by Endoscope and Microscope among the studied subjects (N=30).

Endoscope	Microscope		Total	p-value
	Not visible	Visible		
Sinus tympani				
Not detected	19 (63.3%)	0 (0%)	19 (63.3%)	0.016 (S)
Detected	7 (23.3%)	4 (12.3%)	11 (36.7%)	
Total	26 (86.6%)	4 (12.3%)	30 (100%)	
Facial recess				
Not detected	22 (73.3%)	0 (0%)	22 (73.3%)	0.5 (NS)
Detected	2 (6.7%)	6 (20%)	8 (26.7%)	
Total	24 (80%)	6 (20%)	30 (100%)	
Anterior epitympanum				
Not detected	25 (83.3%)	0 (0%)	25 (83.3%)	0.063 (NS)
Detected	5 (16.7%)	0 (0%)	5 (16.7%)	
Total	30 (100%)	0 (0%)	30 (100%)	

‡ McNemar's test.
P-value< 0.05 is significant. Sig.: significance.

Table (3) This table shows that there was significant improvement in symptoms before surgery and one year after surgery regarding discharge, hearing impairment and Tinnitus while no significant difference was found regarding vertigo.

Table (3): Change in symptoms in the studied subjects (N=30).

Symptoms	Preoperative (N=30)	1 year (N=30)	p-value (Sig.)
Discharge			
Absent	1 (3.3%)	28 (93.3%)	0.0001 (HS)
Present	29 (96.7%)	2 (6.7%)	
Hearing impairment			
Absent	0 (0%)	22 (73.3%)	0.008 (S)
Present	30 (100%)	8 (26.7%)	
Vertigo			
Absent	26 (86.7%)	30(100%)	0.12 (NS)
Present	4 (13.3%)	0 (0%)	
Tinnitus			
Absent	9 (30%)	24 (80%)	0.0001 (HS)
Present	21 (70%)	6 (20%)	

‡ McNemar's test.
P-value< 0.05 is significant. Sig.: significance

Table (4) This table shows that recidivistic cholesteatoma in 4 cases (13.3%) among studied group indicating residual cholesteatoma (1 case in endoscope group and 2 cases in microscope group) and recurrent cholesteatoma (1 case in microscope group only).

Table (4): Cholesteatoma recidivism after 12 months of surgery of the studied subjects (N=30).

cholesteatoma recidivism after 12 months of surgery	Endoscope (N=15)	Microscope (N=15)	The studied patients (N=30)
	No. (%)	No. (%)	
Recidivistic cholesteatoma	1 (6.7%)	3 (20%)	4 (13.3%)
Residual cholesteatoma	1 (6.7%)	2 (1.3%)	3 (10%)
Recurrent cholesteatoma	0 (0%)	1 (6.7%)	1 (3.3%)

Figure (1): 12 months postoperative picture of right ear shows successful attic reconstruction.

Figure (2): 12 months postoperative picture of left ear shows tympanic membrane retraction.

Figure (3): 12 months postoperative picture of left ear shows recurrent cholesteatoma with perforation and keratin in the attic**.**

DISCUSSION

The main goals for Cholesteatoma surgery are disease eradication leading to safe and dry ear, hearing preservation and/or restoration, maintenance of temporal bone anatomy, and prevention of recurrence.

Complete resection of cholesteatoma is paramount among these prerequisites[9-11].

The use of the surgical microscope brought advances into the field of otologic surgery because it expands the ability of surgeons to see the limited confines of the temporal bone[12].

Endoscopically assisted surgery and, more recently, total transcanal endoscopic ear surgery (TTEES) procedures have been advocated in the management of middle ear cholesteatoma[13,14].

The newest generation of slim endoscopes and high-definition cameras, as well as dedicated instrument sets, makes these approaches gaining popularity[13,15].

This study was conducted on 30 patients that have middle ear cholesteatoma their age ranged from 11 to 56 years and the mean age was 30.9 years with standard deviation 9.7, and the cholesteatoma were more in males (60%) than females (40%). In agreement with our study, **Vercruysse *et al.*[16]** who found that cholesteatoma was more common in males with an average age of 28.4 years. **Gaurano and Joharjy[17]** found that males were 54.6% and females were 45.4%. While, **El-Meselaty *et al.* [18]** found that (43.9%) were males and (56.1%) were females with a mean age 25.8 years.

In our study there were (93.3%) of cases have acquired cholesteatoma while (6.7%) of them have congenital cholesteatoma. This is in agree with **House and Sheehy[19]** who reported (3.7%) incidence of congenital cholesteatoma.

In this study, the sinus tympani was the most common site that was involved by cholesteatoma in about (36.7%) of cases whereas the facial recess was considered to be the second most common site and represents (26.7%). These results are similar to those reported by **Badr-El-Dine *et al.*[12]**, **Magnan *et al.* [20]** and **Pratt [21]**. It is also similar to results but they reported higher rates of intraoperative residuals in the form of (88.9%) for sinus tympani and (49.3%) for the facial recess.

In our study after 12 months follow up of patients there was improvement in symptoms. The percentage of ear discharge decreased significantly to be (6.7%) after it was (96.7%) ($p=0.0001$) indicating good healing. Also there was significant improvement in hearing as (73.3%) of cases regain normal hearing level (0-20 db) after there were (100%) of cases had hearing impairment ($p=0.008$). Vertigo also improved significantly as there were (13.3%) of cases complaining of it preoperatively and no one complain postoperatively (0%). Also (70%) of cases were complaining of tinnitus preoperatively and this percentage decreased to (20%) which means significant improvement ($p=0.0001$). Recidivistic cholesteatoma was found in 4 cases (13.3%) among the studied group.

Our results are comparable with results of **Badr-El-Dine *et al.* [12], Tarabichi *et al.* [22]** and **Marchioni *et al.* [23]** but we are not agreeing strongly with other studies like **Neudert *et al.* [24]**, **Marchioni *et al.* [25]**, **Alicandri-Ciufelli *et al.* [26]**, **Hunter *et al.* [27]** and **Cohen *et al.* [28]**. The later studies reported higher rates of recidivism and this explained by different aspects. Firstly, the longer period of follow up in the later studies. Secondly, we depend in our study only on clinical findings and DW MRI which has limited sensitivity for very small lesions. On the other hand, other studies depend mainly on the second look surgery.

From the previous discussion, it becomes clear that endoscopy enables to eradicate the disease with minimal invasive and functional strategy in the form of decreasing the number of mastoidectomies needed to manage limited lesions, decrease the need for CWD approach with its morbidities, giving better chance to the CWU approach to control the disease better without need to posterior tympanotomy and finally it guarantees better middle ear aeration. From these points of view, the term "functional endoscopic ear surgery (FEES)" becomes clear and accepted in the last few years.

Endoscopic ear surgery generally has some limitations: first, the endoscopic approach depends on the experience and skills of the surgeon. In inexperienced hands, the endoscopic approach can be associated with complications caused by direct trauma from the tip of the endoscope to the facial nerve, the ossicular chain, and low-lying tegmen. Second, otosurgeons are accustomed to using both hands at surgery, whereas in the endoscopic ear surgery, one hand is occupied with the endoscope and the other performs the manipulations. Hence, assistance is often required with the operating microscope when there is a need for two-hand manipulations in the dissection of the cholesteatoma from the dehiscent facial nerve, ossicles, and stapes footplate, and in some cases, ossicular reconstruction is very difficult to perform with one hand. Moreover, operating with one handed prevents the ability to simultaneously dissect and suction the operative field but this point is partially resolved by development of new instruments with suction incorporated in it. Third, the endoscopic surgeon watches the monitor in contrast to looking directly into the operated ear through the oculars of the microscope, and this can result in a loss of depth perception that is later compensated with experience. Fourth, fogging and smearing of the tip of the endoscope and the need for frequent cleaning and application of defogging agents affect the operative time. Fifth, the safety of excessive heat dissipation from the endoscope tip is still unclear. Sixth, the mastoid is not accessible by the endoscope, and when the mastoid is involved with the cholesteatoma, a microscopic technique is required. Seventh, as regard length of operation time many admit that although increased familiarity with the equipment and manipulation within the ear, time is negligible between TTEES and microscopic techniques. Eighth, the relatively small number of patients and short follow up period but it is logic for such new technique. Finally, the cost of equipment involved is a disadvantage [11, 22, 23, 29, 30].

CONCLUSION

It could be concluded that the use of an endoscope provided important benefits to patients with middle ear cholesteatoma and offer superior visualization than microscope. Patients who received endoscope surgery had fewer residual lesions and lower recurrence rates than those who received microscope surgery.

REFERENCES

1. **Wilson K, Hoggan R, Shelton C (2013):** Tympanoplasty with intact canal wall mastoidectomy for cholesteatoma: Long-term surgical outcomes. Otolaryngol Head Neck Surg., 149:292–295.
2. **James A, Cushing S, Papsin B (2016)**: Residual cholesteatoma after endoscope-guided surgery in children. Otol Neurotol., 37:196-201.
3. **Osborn A, Papsin B, James A (2012):** Clinical indications for canal wall-down mastoidectomy in a pediatric population. Otolaryngol Head Neck Surg., 147:316–322.
4. **Hanna B, Kivekas I, Wu Y *et al.* (2014):** Minimally invasive functional approach for cholesteatoma surgery. Laryngoscope, 124:2386–2392.
5. **Hu Y, Teh B, Hurtado G *et al.* (2020):** Can endoscopic ear surgery replace microscopic surgery in the treatment of acquired cholesteatoma? A contemporary review. International Journal of Pediatric Otorhinolaryngology, 131: 109872-78.
6. **Horn R, Gratama J, van der Zaag-Loonen H *et al.* (2019):** Negative predictive value of non-echo-planar diffusion weighted MR imaging for the detection of residual cholesteatoma done at 9 months after primary surgery is not high enough to omit second look surgery. Otology & Neurotology, 40(7): 911-919.
7. **Mansour S, Magnan J, Nicolas K *et al.* (2018):** Cholesteatoma. In Middle Ear Diseases. Springer, Cham. Pp. 311-381. https://www.springer.com/gp/book/9783319729619
8. **Cimsit N, Cimsit C, Baysal B *et al.* (2010):** Diffusion-weighted MR imaging in postoperative followup: reliability for detection of recurrent cholesteatoma. Eur J Radiol., 74:121–123.
9. **Gupta N, Lal M, Gupta R (2019):** Evaluating the role of otoendoscope in cholesteatoma surgery. International Journal of Otorhinolaryngology and Head and Neck Surgery, 5(3): 764-68.
10. **Sarcu D, Isaacson G (2016):** Long-term results of endoscopically assisted pediatric cholesteatoma surgery. Otolaryngol Head Neck Surg., 154:535-539.
11. **Presutti L, Marchioni D, Mattioli F *et al.* (2014):** Endoscopic management of acquired cholesteatoma: our experience. J Otolaryngol Head Neck Surg., 37(4):481–487.
12. **Badr-El-Dine M, James A, Panetti G *et al.*, (2013)**: Instrumentation and technologies in endoscopic ear surgery. Otolaryngol Clin North Am., 46:211-225.
13. **El-Bahrawy A, Sorour S, El-Dine M *et al.* (2018):** Evaluation of Endoscopic Surgery for Middle Ear Cholesteatoma. Zagazig University Medical Journal, 23:283–300.
14. **Isaacson G (2014):** Endoscopic anatomy of the pediatric middle ear. Otolaryngol Head Neck Surg., 150:6-15.
15. **Pothier D (2013)**: Introducing endoscopic ear surgery into practice. Otolaryngol Clin North Am., 46:245-255.
16. **Vercruysse J, De Foer B, Pouillon M *et al.* (2006):** The value of diffusion-weighted MR imaging in the diagnosis of primary acquired and residual cholesteatoma: a surgical verified study of 100 patients. European Journal of Radiology, 16:1461- 1467.
17. **Gaurano J, Joharjy I (2004):** Middle ear cholesteatoma: characteristic CT findings in 64 patients. Annals of Saudi Medicine, 24(6):442-447.
18. **El-Meselaty K, Badr-El-Dine M, Mandour M *et al.* (2003)**: Endoscope affects decision making in cholesteatoma surgery. Otolaryngol Head Neck Surg., 129: 490-496.
19. **House J, Sheehy J (1980):** Cholesteatoma with intact tympanic membrane: a report of 41 cases. Laryngoscope, 90:70-76.
20. **Magnan J, Chays A, Lepetre C *et al.* (1994):** Surgical perspectives of endoscopy of the cerebellopontine angle. Am J Otol., 15:366–370.
21. **Pratt L (1983)**: Complications associated with the surgical treatment of cholesteatoma. Laryngoscope, 93:289–291.
22. **Tarabichi M (2004):** Endoscopic management of limited attic cholesteatoma. Laryngoscope, 114:1157–1162.
23. **Marchioni D, Piccinini A, Alicandri-Ciufelli M *et al.* (2013)**: Endoscopic Anatomy and Ventilation of the Epitympanum. Otolaryngol Clin N Am., 46:165–178.
24. **Neudert M, Lailach S, Lasurashvili N *et al.* (2014)**: Cholesteatoma recidivism: comparison of three different surgical techniques. Otol Neurotol., 35:1801–1808.
25. **Marchioni D, Bonali M, Presutti L (2015)**: Endoscopic Middle Ear Anatomy. Current Otorhinolaryngology Reports, 3:200-208.
26. **Alicandri-Ciufelli M, Marchioni D, Kakehata S *et al.* (2016)**: Endoscopic Management of Attic Cholesteatoma Long-Term Results. Otolaryngol Clin N Am., 49:1265–1270.
27. **Hunter J, Zuniga M, Sweeney A *et al.* (2016)**: Pediatric endoscopic cholesteatoma surgery. Otolaryngol Head Neck Surg., 154:1121-1127.
28. **Cohen M, Basonbul R, Barber S *et al.* (2017):** Residual cholesteatoma during second-look procedures following primary pediatric endoscopic ear surgery. Otolaryngol Head Neck Surg., 157(6):1034-1040.
29. **Dundar R, Bulut H, Guler O *et al.*, (2015)**: Oval window temperature changes in an endoscopic stapedectomy. Craniofac Surg., 26:1704-1708.
30. **Kozin E, Lehmann A, Carter M *et al.* (2014)**: Thermal effects of endoscopy in a human temporal bone model: Implications for endoscopic ear surgery. Laryngoscope, 124: 332–339.