Endoscopic versus Microscopic approach in the treatment of atelectatic otitis media

Giannicola Iannella[1], Annalisa Pace[1], Antonio Greco[1], Armando De Virgilio[1], Lodovica Gatti[1], Antonino Maniaci[2], Jerome R. Lechien[3], Rémi Hervochon[4], Ali Faramarzi[5], Quentin Mat[6], Maryana Cherkes[7], Matthias Koiner-Graupp[7], Paolo Boscolo-Rizzo[8], Luigi Angelo Vaira[9], Giuseppe Magliulo[1]

Running Head: atelectasis otitis media

[1]Department of 'Organi di Senso', University "Sapienza", Rome, Italy
[2]Department of Otolaryngology, Kore University, Enna, Italy
[3]EpiCURA Hospital & University of Mons, Mons, Belgium
[4]Service d'ORL et Chirurgie Cervico-Faciale, Pitié-Salpêtrière Hospital, APHP (Greater Paris University Hospitals), Paris
[5]Otolaryngology Research Center, Department of Otolaryngology, Shiraz University of Medical Sciences, Shiraz, Iran
[6]Department of Otorhinolaryngology, C.H.U. Charleroi, Charleroi, Belgium
[7]Department of Otolaryngology and Head&Neck Surgery Medical University of Graz. Austria
[8]Department of Medical, Surgical and Health Sciences, Section of Otolaryngology, University of Trieste, Trieste, Italy.
[9]Maxillofacial Surgery Operative Unit, Department of Medical, Surgical and Experimental Sciences, University of Sassari, Sassari, Italy.

Corresponding author:
Annalisa Pace, M.D., Viale Università 33, Rome 00183, Italy;
Telephone number: +392387893753 Fax number: +390649976817
annalisa.pace@uniroma1.it

ABSTRACT

BACKGROUND: endoscopic ear surgery in patients Chronic Otitis Media(COM) media with eardrum atelectasis.
OBJECTIVE: to compare the postoperative outcomes and audiological results of the endoscopic approach versus the microscopic approach for treatment of COM media with eardrum atelectasis, using a randomized prospective model.
METHODS: Sixty patients were consecutively enrolled in the study and randomized into two groups: Group A 32 patients underwent canal wall up tympanoplasty (CWA); Group B 28 patients underwent tympanoplasty with an exclusive trans-meatal endoscopic approach. Audiological results and preoperative, intraoperative and postoperative outcomes were evaluated.

RESULTS: No statistical difference emerged between distribution of middle ear atelectasis patients grade 3 and 4 between the two surgical groups ($p>0.05$). The group B appeared to have shorter surgical times than group A (69.8min vs. 88.9min). The graft success rate was estimated in 90.6% and 92.8% in group A and B respectively, without statistical differences between groups ($p=1$). The Overall success rate was therefore calculated in 87.5% and 92.8% for both groups.

CONCLUSION AND SIGNIFICANCE: Endoscopic ear surgery could be a suitable approach for treating COM media with eardrum atelectasis with similar results compared with the Microscopic surgery.

Keywords: middle ear atelectasis; tympanic membrane retraction; endoscopic ear surgery; middle ear endoscopy

INTRODUCTION

Chronic Otitis Media (COM) with middle ear atelectasis which occurs when tympanic membrane becomes retracted towards the promontory and the ossicles of the middle ear [1-3]. There are several classifications of middle ear atelectasis (Sadè, Tos, Charachon and ERASMUS) developed to report this disease [4]. Each system differently describes the progression of middle ear atelectasis and guides treatment based on its severity. The most widespread and used classification actually remains the Sadè classification. This distinguish different grades of middle ear atelectasis: Grade I correspond to a mild retraction of the tympanic membrane, while in the Grade IV the tympanic membrane is adherent to the promontory [5-7].

In COM media with eardrum atelectasis and Adhesive otitis media (AOM) conditions the retraction of the tympanic membrane may lead to erosion of the long process of the incus and the stapes superstructures with a possible conductive hearing loss. Usually, COM media with eardrum atelectasis affects patients of any age [1-3].

The Eustachian tube dysfunction (ETD) has been indicated as the main cause of COM media with eardrum atelectasis [8-12]. ETD leads to the imbalance of the middle ear pressure system and the tympanic cavity acquires a continuous negative pressure state, resulting in invagination of the tympanic membrane under the effect of this middle ear negative pressure [13,14]. However, there are some patients suffered from COM media with eardrum atelectasis that showed a normal function of the ET [15-16]. Marchioni et al.[17] have hypothesized an alteration in the ventilation routes of the middle ear as a cause of pathological processes of Tympanic Membrane (TM) retraction. The presence of a tympanic isthmus blockage associated with a possible complete tensor fold could exclude the anterior epitympanic recess from the posterior epitympanic space and the protympanum. The blockage of the tympanic isthmus could create a selective negative pressure in the attic-mastoid spaces; this chronic lack of aeration could be the cause to the reduction of the pressure level and consequently the development of a retraction pocket [2,3,17].

The management of COM media with eardrum atelectasis is one of the most challenging for otologist[10,11]. The difficulty in the management of these patients lies not only in which patients to treat and which not, but in choosing the best type of surgical approach. Microscopic ear surgery (MES), using a trans-canal or retro-auricular approach (canal wall up tympanoplasty ± mastoidectomy), are usually used to treat this kind of pathologies[13,14,18]. The

advent of endoscopes in the last years changed the therapeutic approach to several middle ear diseases and different authors have proposed the exclusive transcanal endoscopic ear surgery (ESS) as an effective and safe surgical technique for its surgical treatments[17,19].

A wider and clearer view of the surgical field, middle ear fold and a better visibility of the hidden structures (tympanic isthmus and complete tensor fold) are some of the clearly recognized advantages of the endoscope. These features of exclusive oto-endoscopy could be useful during the surgical treatment of adhesive otitis media to better visualize a possible ventilation routes blockage. However, an exclusive middle ear endoscopic surgery does have some possible limitations linked to single-handed work, limited surgical space, the lack of a stereoscopic view and, last but not the least, a potentially long surgical learning curve[17,19,20]. Therefore, in consideration of these advantages and limitation, it is logical to ask if ESS is superior to MES in the treatment of adhesive otitis media.

In this study, we have attempted to compare the postoperative outcomes and audiological results of the endoscopic approach versus the microscopic approach for treatment of COM media with eardrum atelectasis, using a randomized prospective model.

Materials and methods

Trial design

The study protocol was a single-center controlled prospective randomized trial with two prospective arms: patients with COM media with eardrum atelectasis treated with a canal wall up tympanoplasty with a microscopic approach vs patients with COM media with eardrum atelectasis treated using an exclusively endoscopic surgical approach. Figure 1 shows the flow-chart of the trial design.

Prospective patients' enrollment

All patients aged between 16 and 65 years with a diagnosis of COM media with eardrum atelectasis consecutively referred to the 'Organi di Senso' Department of "Sapienza" University in Rome, from January 2019 to January 2022, to surgery consult, were initially considered as possible candidates for the study inclusion. Baseline assessment of all enrolled patients was performed: full medical history, otomicroscopic evaluation and a high-resolution middle ear and mastoid CT scan + auditory tests were performed. All patients were classified according to the Classification of tympanic membrane atelectasis proposed by Sadé (Tab1). This is still the main classification system used to describe COM media with eardrum atelectasis in adults. Only patients with otomicroscopic findings corresponding to a grade 3 (Fig. 2 A and fig.4 A) and 4 (Fig. 3 A) of the Sadè classification were considered surgical candidates and enrolled in the study[1-10]. Patients with normal hearing or an air-bone-gap (ABG) < 10 dB and Patients with inadequate follow-up were excluded from the study. Patients with otomicroscopic examination or CT scan evidence of epitympanic or mesotympanic cholesteatomas as cases of revision surgery were excluded to the study. Eligibility for the study inclusion according to Sadè classification and other well-defined inclusion / exclusion criteria have been summarized in table 1.

All patients selected for the surgery previously underwent a ventilation tube insertion (T-tube SPIGGLE & THEIS) at the initial stages of the pathology in order to improve the atelectasis of the tympanic membrane. In no case was this treatment effective. At the end of the patients' enrollment 60 patients were considered candidates to the randomization process of this study

Randomization

Sixty patients were randomized into two groups of treatment:

- Group A – canal wall up tympanoplasty + mastoidectomy with a retroauricular microscopic approach

- Group B – tympanoplasty with an exclusive trans-meatal endoscopic approach

For each patient randomization was conducted by picking a piece of paper with a treatment order written on it out of a box (group A vs group B). The chances of picking group 1 or group 2 were 50/50. After randomization patients were casually distributed into two groups of study according to the following distribution: Group A with 32 patients; group B with 28 patients

Surgery

Microscopic surgeries were performed using a Leica M620 F20. Differently, for EES, rigid endoscopes with an angulation of 0, 30 and 45°, a length of 14-cm and an outer diameter of 3 mm and 4 mm (Storz, Germany) were used: they were connected to a camera head (Storz, Germany) and a high definition monitor positioned in front of the surgeon.

The steps of EES consisted of:

a) creation of the tympanomeatal flap in the posterosuperior and posteroinferior portions of the external auditory canal;

b) access to the middle ear and preservation of the chorda tympani; removal of the thinned tympanic membrane adhered to the promontory or incus/stapes (Fig 2 B-C and fig.3 B-C) ,

d) a small atticotomy in order to explore the epitympanic region if necessary (Fig. 5 A-B)

e) identification of the oval and round windows, the tympanic segment of the Fallopian canal, the cochleariform process and horizontal semicircular canal (Fig.3 C and fig 5 A-B);

f) removal of any eroded ossicles (incus and the head of malleus) (Fig. 3C and Fig. 5 A-B);

g) opening of the tympanic isthmus or tensor fold if these were identified blocked (fig 5A-B);

i) Graft with tragus cartilage + pericondrium by underlay technique (Fig. 2 D and fig. 3D):

k) repositioning of the tympanomeatal flap in its original position (Fig. 2 D)

Patients undergoing tympanoplasty through MES performed a classic canal wall-up tympanoplasty technique with mastoidectomy in all cases. Mastoidectomy with epitympanotomy was performed in all these cases in order to evaluate a possible block in the antrum or isthmus and re-ventilate the epitympanic region (Fig. 4 B and Fig 5 C-D). No mastoid obliteration was performed. Like to the EES the thinned tympanic membrane adherent to the promontory was raised and eroded ossicles was removed (Fig 4 C-D-E). A Graft with temporalis fascia and a small piece of conchal cartilage were performed using an underlay technique (Fig 4 F). All surgeries were performed to the same senior otologic surgeon.

Preoperative and intraoperative evaluation

In all patients enrolled in the study in addition to the Sadè classification, were collected preoperative clinical symptoms (ear fullness sensation, otorrhea, vertigo/dizziness). The presence of facial nerve dehiscence was investigated on CT images (absence of the osseous wall of the facial nerve canal), and subsequently compared to the corresponding intraoperative findings. Any intraoperative observations of Fallopian canal erosion made using either an operating microscope or an endoscope and confirmed by palpation during the surgery were considered as dehiscence.

The intraoperative ossicles erosion was investigated in all patients enrolled in the study. Finally, operating times for both groups were collected.

Postoperative evaluation

Hearing was assessed preoperatively and at 1 month, 3 months and 6 months after surgery in both groups. Final hearing recovery at six-month follow-up was evaluated and classified according to the draft AAO-HNS hearing classification system[1-10]. These included pure-tone audiometry (frequencies ranging from 0.5 to 8 kHz) with measurement of air conduction, and bone conduction thresholds. All patients enrolled in the study were asked to evaluate the severity of post- operative pain. This was classified using three grades: almost no pain, mild pain requiring no analgesic drugs and pain requiring analgesic drugs[15-20]. Taste abnormalities were investigated as: presence or absence of a subjective abnormal taste sensation. Healing time was investigated by a physical examination and otomicroscopic investigation. It was determined as the number of days between surgery and successful tympanic grafting with complete eardrum repair and the patient's return to his/her normal activities. Otomicroscopic follow-up was performed approximately every 15 days for the first 3 months after surgery and then once every 3 months.

Statistical Analysis and Ethical statement

To test the differences between the groups, Fisher's exact test was applied to categorical data, while Student's t test was used for continuous data. ANOVA and MANOVA tests were used as appropriate. Probability values lower than 0.05 were considered statistically significant. All analyses were performed using the STATA 12.1 software (Stata Corp., College Station, TX, USA). The local Ethics Committee of Sapienza University approved the study and all patients signed an informed consent for inclusion in the study before their enrollment.

RESULTS

Preoperative and intraoperative outcomes

The preoperative and intraoperative data for patients enrolled in the study are summarized in Table 2.

There were no differences in the patients' characteristics (patient age and sex) and preoperative symptoms (Ear Fullness sensation, Otorrhea episodes, Facial palsy, Vertigo/Dizziness otorrhea) between the group A and B, indicating an homogeneous selection of patients that provided a good comparison of the outcomes between the two groups ($p>0.05$ in all variables analyzed). In the MES group 11 patients were preoperatively classified as grade 3 and 21 as grade 4 of the Sadè's classification. Similarly, in the ESS group 9 were classified as grade 3 and 19 as grade 4 (AOM). No statistical difference emerged between distribution of middle ear atelectasis patients grade 3 and 4 between the two surgical groups ($p>0.05$). During surgery none pearl of cholesteatoma was identified in the atelectasis TM surgical confirming the Sadè preoperative classification. Erosion of the ossicular chain did not appear statistically different between the two groups ($p>0.05$): intraoperatively incus erosion was observed in 53.1% of MES and 53.5% of ESS, differently Incus + stapes superstructures erosion was observed in 9.3% and 7.1% of MES and ESS respectively. The same no difference between the groups was found in the erosion of the ossicular chain sub classify patients according to the Sade classification (See table 2). A difference between MES and ESS emerged in the identification and opening of airway pathways blockages. A blocked tympanic isthmus emerged in 31.2% of the MES group and 42.8% of the EES group; a complete tensor fold was visible in 21.8% of the MES group and 53.5% of the MES group. The blocked airways were reopened in all cases. The CWU tympanoplasty with the EES approach appeared to have shorter surgical times than CWD + mastoidectomy via MES (69.8min vs. 88.9min). Despite this short time no statistical difference between the two groups emerged ($p=0.1$)

Postoperative outcomes (table 3)

The postoperative follow-up period ranged from 26 to 49 months (mean: 36.1 months).

The analysis of the postoperative pain showed that 78.5% of the patients of the endoscopic group and 34.3% of patients who underwent microscopic reported 'no pain' after surgery. A statistical difference, on behalf of the ESS group, emerged ($p<0.05$). Postoperative dizziness that was reported in 16% of MES group and 13.3% of EES group ($p=1$). In all cases this disappeared after in the 15 days post-surgery. A transient abnormal taste sensation occurred in 25% and 10.7% of the microscopic and endoscopic groups respectively. Despite this apparent difference there was no statistical difference between the two groups (0.1). In three MES patients, no attachment of the temporalis muscle fascia graft was observed, while in ESS group one patient showed a tragus cartilage displacement to the promontory and one had cartilage necrosis. The graft success rate was estimated in 90.6% and 92.8% in MES and ESS groups respectively, without statistical differences between groups ($p=1$). Besides, no differences emerged in the recurrence of middle ear diseases (middle ear atelectasis, TM perforation or middle ear cholesteatoma) at the mean follow-up of 15.8 months that was only in one patients of the MES group that showed a TM perforation. The Overall success rate at follow-up was therefore calculated in 87.5% and 92.8% for the MES and ESS groups respectively. Despite a difference in the final success rate between the two groups, no statistical difference emerged ($p=0.6$). The average postoperative air-conduction thresholds of microscopic and endoscopic approaches are reported in table 4, showing no statistical difference between the two groups ($p <0.05$).

No significant differences were observed in postoperative pain, postoperative dizziness, graft success rate, average healing time, recurrence of middle ear disease, or overall success rate during follow-up when comparing Sadè grade 3 and Sadè grade 4 between ESS and MES ($p > 0.05$ for each comparison). Similarly, no differences in hearing recovery were found when comparing patients with Sadè grade 3 and Sadè grade 4 in both the ESS and MES groups.

DISCUSSION

The treatment of COM media with eardrum atelectasis is one of the most challenging for otologists. The difficulty in the management of these patients lies not only in which patients to treat and which not, or in the selection of graft, but also in choosing the best type of surgical approach. Traditional surgical treatment of TM atelectasis is a ventilation tube placement, however, more frequently this type of treatment is not sufficient to resolve the TM atelectasis [1,2]. TM retraction could persist, despite a restoring middle ear aeration, due to redundant TM retraction, fibrous adhesions between the undersurface of the membrane to the bony structure in the middle ear and/or a blockage of the ventilation routes of the middle ear. Therefore, in advanced cases of COM media with eardrum atelectasis with conductive hearing loss, tympanoplasty with TM reconstruction can be the only effective treatment option [3-6]. Microscopic ear surgery (MES), using a trans-canal or retro-auricular approach (canal wall up tympanoplasty ± mastoidectomy), are usually used to treat this kind of pathologies[12-14]. In the last years different authors proposed the use of the exclusive trans-canal endoscopic ear surgery (ESS) as an effective and safe surgical technique for different middle ear diseases such as otosclerosis, chronic otitis media and cholesteatomas[15,16]. The endoscopic approaches to the middle-ear are generally conservative techniques, that in most cases, avoid extensive mastoidectomy due to the possibility of an around-the-corner view of most middle ear spaces (such as the retro-tympanum and anterior epitympanum), structures and folds. Furthermore, exclusive endoscopic surgery is usually

performed with a trans-canal approach rather than retro-auricular, thus avoiding, unlike microscopy techniques, wide tissue elevations and external incisions[17,18]. Just preliminary reports regarding an exclusive endoscopic approach to treat COM media with eardrum atelectasis has been reported in literature[19-21]. A recent clinical retrospective study on the efficacy and safety of endoscopic ear surgery for adhesive otitis media has been published by Guo et al[20]. A total of 17 patients with adhesive otitis were enrolled in this study, including 1 patient with Dornhoffer stage II; 6 patients with stage III; and 10 patients with stage IV. Similarly, Lou et al[21] reported a retrospective case series of an exclusive endoscopic treatment for a TM adhesive perforation. In total, 26 patients with unilateral adhesive perforation associated with chronic otitis media who underwent full-thickness cartilage-perichondrium double graft myringoplasty were included. In this study, we have attempted to compare the postoperative outcomes and audiological results of the endoscopic approach versus the microscopic approach for the treatment of COM media with eardrum atelectasis, using a randomized prospective model. To our knowledge there are no studies in the literature that have compared MES and ESS in the treatment of COM media with eardrum atelectasis through this type of clinical trial. In our study similar results were obtained with endoscopic and microscopic approach regarding the overall success rate (graft attachment or none recurrence of middle ear diseases) that was 87.5% and 92.8% respectively (p=0.6). Both groups of patients showed a postoperative hearing improvement. The average postoperative air-conduction thresholds of microscopic and endoscopic approaches not showed statistical difference between the two groups ($p < 0.05$) with a gap closure <20 dB reported in 37.5% and 42.8 % of MES and ESS groups respectively.

Our results regarding the success rate and hearing recovery appeared very similar to other literature reports. In the study of Lou et al.[21] the graft success rate was 96.15% (25/26) at 12 months and 88.46% (23/26) at 24 months and no middle ear cholesteatoma formation and keratin pearls were found during the period of follow up. Similary, Guo et al[20] reported a well repaired tympanic membrane after the endoscopic ear surgery tympanoplasty, without invaginations or TM perforations in all patients of the study. The mean postoperative air-conduction hearing threshold [49.06±22.15 dB hearing level (dB HL)] and mean air-bone gap (19.94±10.00 dB HL) were significantly improved compared with the preoperative values (65.29±21.53 and 32.53±8.21 dB HL, respectively; $P<0.05$).

Regarding the microscopic tympanoplasty treatment for COM media with eardrum atelectasis, Iacovou et al.[22] performing a systematic review of literature, found a mean cartilage graft integration rate of 92.4% and good temporalis muscle fascia grafting in 84.3% of patients. In the study of Ozbek et al [19] healing of the tympanic membrane was achieved in 91% of ears. Postoperative PTA-ABG was less than 20 dB in 71% of ears. In our studies comparing MES and ESS approaches in COM media with eardrum atelectasis, some differences appeared. Identification and opening of airway pathways blockages looked different between the two surgeries. A blocked tympanic isthmus (figure 5 A-D) emerged in 31.2% of the MES group and 42.8% of the EES group; a complete tensor fold was visible in 21.8% of the MES group and 53.5% of the MES group. Blocked tympanic isthmus appeared more frequently in ESS than in MES, although this finding was not statistically significant (p=0.4), whereas statistical difference appeared in the identification of complete tensor fold (p=0.04). What could be this explained? Although the use of angled endoscopes provides an easier to visualize the tympanic isthmus and the scars/adhesions blocking it, we believe that a correct visualization of it can be achieved through the combined endo-canalar and trans-mastoid views of the microscopic approach. A complete tensor fold is better visualized with angled endoscopes as shown in the different identification rate between MES and ESS and as reported in the studies of Marchioni et al[18]. The analysis of the postoperative pain showed as 78.5% of the patients of the endoscopic group and 34.3% of patients of

microscopic group reported 'no pain' after surgery. A statistical difference between the two groups emerged ($p<0.05$). Less pain observed in the ESS group could be related to the absence of a retro-auricular incision that avoids wide tissue elevations and mastoidectomy [16,17]. However, as reported in our previous study, should be remembered that in case of endaural microscopic approach to middle ear disease, the retro-auricular incision is avoid and similar postoperative pain between ESS and MES could be could be achieved [23,24].

The neovascularization and the superficial cartilage graft got a complete epithelialization within 4-6 weeks in both groups. However, ESS seemed to show a shorter average healing time probably related to the type of graft used (tragal cartilage with perichondrium), the less tissue cutting and manipulation achieved with the trans-canal approach. The same, no difference in healing time emerged in previous studies comparing ESS and MES via endaural approach for attic cholesteatomas surgery. The last differences between the two groups of study appeared in the surgical times, that was shorter in the ESS group. This could be linked to the absence of microscopic steps of the retro-auricular incision and mastoidectomy but need of more participants to be confirmed.

All patients in the MES group underwent canal wall down (CWD) tympanoplasty with mastoidectomy, a well-established approach for treating chronic otitis, with or without atelectasis of the tympanic membrane [12-14,25]. In contrast, the ESS group underwent an exclusively transcanal approach without mastoidectomy. This could be considered a limitation in comparing the study groups. However, in cases of chronic otitis media with eardrum atelectasis or when a mastoid opacity is visible on the CT scan, we prefer to perform mastoidectomy to safely open any scarring in the mastoid antrum, address potential blockages of the tympanic isthmus, and improve ventilation in the epitympanic and middle ear regions.

The microscope is the traditional instrument employed in the otologic surgery, providing excellent vision, depth perception with possibility of magnification with the benefit of a double-hands surgery. Advances of EES are the optimal visualization of the surgical filed, around the corner exploration, absence of external incisions and tissue preservation[18,24]. In contrast, the disadvantage of endoscopic surgery is represented by one-hand surgery, necessity of continuous cleaning of the endoscope and potentially difficulty of the procedure in case of continuous bleeding. Both MES and ESS are effective and sure techniques to treat patients with COM media with eardrum atelectasis. The type of surgical approach should be chosen by the surgeon in accordance with the advantages and disadvantages of each single technique, surgeon's personal experience and extension of the pathology, taking in mind that both options should be available in the armamentarium of the next generation of otologists.

CONCLUSION

Endoscopic ear surgery (EES) and microscopic ear surgery (MES) are both suitable approaches for treating chronic otitis media (COM) with eardrum atelectasis. The potential benefits of EES may include a minimally invasive approach, less tissue trauma, reduced pain, and possibly faster recovery times. However, based on the results of this study, there is no evidence to suggest that EES is superior to MES in terms of surgical outcomes for treating COM with eardrum atelectasis.

Declarations of interest

Ethical considerations: The local Ethics Committee of Sapienza University approved the study

Consent to participate: all patients signed an informed consent for inclusion in the study before their enrollment.

Consent for publication: Not applicable

Declaration of conflicting interest: all authors declared no conflict of interest

Funding statement: None

Data availability statement: on request to the corresponding author

REFERENCES

1. Alanazy S, Kim H, Nam GS, et al. Radiological dimensions of the Eustachian tube in patients with adhesive otitis media. J Laryngol Otol. 2023 May;137(5):520-523.

2. Ohnishi T, Shirahata Y, Fukami M, Hongo S. The atelectatic ear and its classification. Auris Nasus Larynx. 1985;12 Suppl 1:S211-3.

3. Yoshida S, Seki S, Sugiyama T, et al. Clinical characteristics of atelectatic eardrums and adhesive otitis media in children. Int J Pediatr Otorhinolaryngol. 2022 Aug;159:111188.

4. James AL, Papsin BC, Trimble K, et al. Tympanic membrane retraction: An endoscopic evaluation of staging systems. Laryngoscope. 2012 May;122(5):1115-20.

5. Sadé J. The buffering effect of middle ear negative pressure by retraction of the pars tensa. Am J Otol. 2000 Jan;21(1):20-3.

6. Sadé J. On the function of the pars flaccida: retraction of the pars flaccida and buffering of negative middle ear pressure. Acta Otolaryngol. 1997 Mar;117(2):289-92.

7. Sadé J. Features of retracted (atelectatic) and ballooned (hyperectatic) tympanic membranes. Ear Nose Throat J. 2002 Dec;81(12):815-6.

8. Yoshida S, Seki S, Sugiyama T, et al. Comparative study on adhesive otitis media and pars tensa cholesteatoma in children. Auris Nasus Larynx. 2022 Oct;49(5):790-796.

9. Si Y, Chen Y, Xu G, et al. Cartilage tympanoplasty combined with eustachian tube balloon dilatation in the treatment of adhesive otitis media. Laryngoscope. 2019 Jun;129(6):1462-1467.

10. Deng R, Fang Y, Shen J, et al. Effect of esterified hyaluronic acid as middle ear packing in tympanoplasty for adhesive otitis media. Acta Otolaryngol. 2018 Feb;138(2):105-109.

11. Diacova S, McDonald TJ, Ababii I. Clinical, functional, and surgical findings in chronic bilateral otitis media with effusion in childhood. Ear Nose Throat J. 2016 Aug;95(8):E31-7.

12. Larem A, Haidar H, Alsaadi A, et al. Tympanoplasty in adhesive otitis media: A descriptive study. Laryngoscope. 2016 Dec;126(12):2804-2810.

13. Honnurappa V, Mahajan N, Vijayendra VK, et al. Management of attic retraction pockets. J Laryngol Otol. 2023 Nov;137(11):1272-1276.

14. Noij KS, Noij DP, Borgstein J. Healing of the tympanic membrane after surgical intervention for atelectasis of the middle ear in sixty-two adults. Clin Otolaryngol. 2017 Apr;42(2):450-454. doi: 10.1111/coa.12614. Epub 2016 Feb 18. PMID: 26725586.

15. Iannella G, Angeletti D, Manno A, Pasquariello B, Re M, Magliulo G. Malleostapedotomy in stapes revision surgery: Is an endoscopic approach possible? Laryngoscope. 2018 Nov;128(11):2611-2614

16. Presutti L, Anschuetz L, Rubini A, Ruberto M, Alicandri-Ciufelli M, Dematte M, Caversaccio M, Marchioni D. The Impact of the Transcanal Endoscopic Approach and Mastoid Preservation on Recurrence of Primary Acquired Attic Cholesteatoma. Otol Neurotol. 2018 Apr;39(4):445-450.

17. Iannella G, Marcotullio D, Re M, Manno A, Pasquariello B, Angeletti D, Falasca V, Magliulo G. Endoscopic vs Microscopic Approach in Stapes Surgery: Advantages in the Middle Ear Structures Visualization and Trainee's Point of View. J Int Adv Otol. 2017 Apr;13(1):14-20.

18. Marchioni D, Rubini A, Soloperto D. Endoscopic Ear Surgery: Redefining Middle Ear Anatomy and Physiology. Otolaryngol Clin North Am. 2021 Feb;54(1):25-43.

19. Ozbek C, Ciftçi O, Ozdem C. Long-term anatomic and functional results of cartilage tympanoplasty in atelectatic ears. Eur Arch Otorhinolaryngol. 2010 Apr;267(4):507-13. doi: 10.1007/s00405-009-1084-7. Epub 2009 Sep 2. PMID: 19727785.

20. Guo YN, Qian M, Li J, et al. Clinical retrospective study on the efficacy and safety of endoscopic ear surgery for adhesive otitis media. Ann Transl Med. 2022 Nov;10(22):1211.

21. Lou Z. Endoscopic full-thickness cartilage-perichondrium double graft myringoplasty in adhesive perforation: retrospective case series. Acta Otolaryngol. 2021 Jan;141(1):14-18.

22. Iacovou E, Vlastarakos PV, Papacharalampous G, et al. Is cartilage better than temporalis muscle fascia in type I tympanoplasty? Implications for current surgical practice. Eur Arch Otorhinolaryngol. 2013 Nov;270(11):2803-13. doi: 10.1007/s00405-012-2329-4. Epub 2013 Jan 16. PMID: 23321796.

23. Marchioni D, Rubini A, Gazzini L, et al. Complications in Endoscopic Ear Surgery. Otol Neurotol. 2018 Sep;39(8):1012-1017.

24. Iannella G, Pace A, Greco A, et al. Endaural microscopic approach versus endoscopic transcanal approach in treatment of attic cholesteatomas. Am J Otolaryngol. 2023;44(4):103860.

25. Abdel Aziz AAR, Youssef AM, Mostafa MM, et al. Cartilage tympanoplasty in the treatment of adhesive otitis media with and without Eustachian tube balloon dilatation. J Otol. 2022;17(4):226-231.

LEGEND

FIGURE 1: Flow chart of the study protocol

FIGURE 2: Endoscopic ear surgery. Grade III Tympanic membrane atelectasis according to Sadè classification.

A: endoscopic view of atelectasis tympanic membrane.

B, tympanomeatal flap and middle ear access showing TM adherence to the incudo-stapedial joint and promontory.

C: complete removal of adhesions and fibrous tissue with elevation of the tympanic membrane;
D: Tympanic membrane grafting with tragal cartilage + perichondrium.
Tympanic membrane (**tm**), Tympanic membrane retraction (**tm-r**); Tympanic membrane adhesion (**tm- a**); cartilage tympanic membrane reconstruction (**C-R**)

FIGURE 3: Endoscopic ear surgery. Grade IV tympanic membrane atelectasis according to Sadè classification.
A: endoscopic view of atelectasis tympanic membrane adherent to the promontory and head of stapes with a possible incus erosion.
B, tympanomeatal flap and middle ear access showing TM adherence to the stapes superstructures and promontory.
C: complete removal of last fibrous tissue to the head of the stapes
D: Tympanic membrane grafting with tragal cartilage + perichondrium.
Malleus (**m**), Tympanic membrane retraction (**tm-r**); Tympanic membrane adhesion (**tm- a**); facial nerve (**f**), cartilage tympanic membrane reconstruction (**C-R**)

FIGURE 4: Microscopic ear surgery. Grade III tympanic membrane atelectasis according to Sadè classification.
A: microscopic view of atelectasis tympanic membrane adherent to the to the incudo-stapedial joint and promontory.
B, mastoidectomy, epi-tympanotomy

C: tympanomeatal flap and middle ear access showing TM adherence to the stapes superstructures and promontory.
D: complete removal of last fibrous tissue to the incudo-stapedial join
E complete removal of adhesions and fibrous tissue, elevation of the tympanic membrane and verification of ossicular chain integrity

F: Tympanic membrane grafting with temporalis fascia + small piece of conchal cartilage.

Tympanic membrane (**tm**); Malleus (**m**), Tympanic membrane retraction (**tm-r**), Posterior wall (**PW**); mastoid cavity (M); Epi-tympanic recess **(E-R)**. Tympanic membrane adhesion (**tm- a**); facial nerve (**f**), incus (**i**); temporalis fascia and cartilage reconstruction (**TF-C**)

FIGURE 5.
A: Tympanicum isthmus blockage trans-canal endoscopic view

B: Tympanicum isthmus blockage opening by a hook

B and C: Tympanicum isthmus blockage opening achieved through a combined endo-canal and trans-mastoid microscopic view

Tympanicum isthmus (T-I); Malleus (**m**), facial nerve (**f**), Tympanic membrane (**tm**); promontory (**p**); mastoid cavity (M); Epi-tympanic recess **(E-R)**.