We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

6,900
Open access books available

186,000
International authors and editors

200M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Minimally Invasive Transcanal Endoscopic Ear Surgery

Lela Migirov and Michael Wolf

Additional information is available at the end of the chapter

Abstract

Endoscopes have rapidly become widely accepted in the performance of ear surgery. Current chapter describes surgical technique and benefits and limitations for endoscopic eradication of cholesteatoma, endoscopic tympanoplasty, endoscopic stapedotomy and endoscopic cochlear implantation.

Minimally invasive endoscopic and endoscope-assisted surgical techniques are increasingly being employed in the surgical management of cholesteatoma. Endoscopic surgeries distinctly reduced residual cholesteatomas and the indications of later tympanotomy thanks to the good visualization of residual cholesteatoma sites, such as the anterior and posterior epitympanic spaces, sinus tympani, facial recess, and hypotympanum. Minimally invasive transcanal endoscopic approach can be applied as for primary cholesteatomas as well as for revision of CWU cases, when residual/recurrent cholesteatoma is confined to the middle ear, and in CWD or radical cavities, when residual/recurrent disease is hidden in the supratubal recess, sinus tympani or under pseudo-membrane in the large mastoid cavities.

The use of endoscopes in myringoplasty is especially helpful in patients with narrow external canals, anterior defects and bone overhang, when perforation's margins are barely, if at all, visible under a microscope.

The transcanal endoscopic stapedotomy can be beneficial in improving the visibility and accessibility of the stapes and the oval window niche, avoiding manipulation of the chorda tympani nerve and blind fracture of the stapedial crurae.

An endoscopic cochlear implantation involves entering the middle ear by means of endoscopic transcanal tympanotomy and insertion of the electrode array into the scala tympani via the round window under direct endoscopic control. The main benefits of the endoscopic transcanal approach to cochlear implant are improving the visibility

and accessibility of the round window membrane, obviating the need to divide the chorda tympani nerve in order to obtain adequate exposure of the middle ear structures, and eliminating the risk of the facial nerve injury since it is not in the direction of drilling.

1. Introduction

The introduction of endoscopes completely changed the surgical approach to the middle ear pathologies. Management of cholesteatoma continues to pose a surgical challenge, and the choice of surgical technique depends on the extension of the disease, the surgeon's own experience and skills, published data, and the patient's socioeconomic circumstances. Minimally invasive endoscopic and endoscope-assisted surgical techniques are increasingly being employed in the surgical management of cholesteatoma.

2. Endoscopic surgery for cholesteatoma

Exclusive transcanal endoscopic approach (TEA) can be used for the resection of a primary cholesteatoma or for endoscopic revision of an accessible residual/recurrent cholesteatoma in the post-mastoidectomy cavity. In endoscope-assisted ear surgery (EAES), the endoscopes are introduced intraoperatively for completion of surgery performed under a microscope.

Endoscopic ear surgery (EES) and EAES distinctly reduced residual cholesteatomas and the indications of later tympanotomy thanks to the good visualization of residual cholesteatoma sites, such as the anterior and posterior epitympanic spaces, sinus tympani, facial recess, eustachian tube and hypotympanum [1-10]. Moreover, it was found that retraction pockets extending into the facial recess may be more readily removed by using endoscopes than by converting to an intact canal wall mastoidectomy with a facial recess approach [10,11].

The vast majority of cholesteatomas starts to develop in the middle ear and its extensions, and only later involves the mastoid cavity. Thus, the most logical access to a cholesteatoma has not yet advanced to the mastoid is the transcanal approach. However, the endoscopic approach depends on the experience and skills of the surgeon. In addition, otosurgeons are accustomed to using both hands at surgery while in the EES one hand is occupied with the endoscope and the other performs the manipulations for the eradication of the pathology, suctioning, hemostasis and subsequent reconstructions [10].

A cholesteatoma is defined as being accessible with TEA when it does not extend beyond the level of the lateral semicircular canal [11]. In case of cholesteatoma inaccessible even with

angled instruments under direct vision of angled endoscopes traditional mastoidectomy is performed. The optimal surgical approach to residual/recurrent cholesteatoma is a controversial issue since residual lesions can be missed and cholesteatoma tends to recur despite the variety of surgical options. The common sites of residual lesions and recurrences are sinus tympani, attic, anterior epitympanic space, facial recess and the supratubal region, and they can all be visualized and accessed using the TEA [3,5-7,12-26].

Preoperative assessment includes otoscopy and pure tone audiometry in all patients. Recent studies have shown that 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 [27-31]. The size of lesion determined by the non-EPI DW images correlated well with intra-operative findings, with error margins lying within 1 mm [28-31]. Non-EPI DW MRI can distinguish cholesteatoma from other tissues and from mucosal reactions in the middle ear (ME) and mastoid, and it can also demonstrate the extent of the lesion [27-31]. Thus, we prefer performing the non-EPI DWI MRI prior to primary cholesteatoma surgery as well as before revision procedures [31]. Non-EPI DW images allow avoiding the irradiation, and this point is extremely important for all patients, especially children [32]. The choice of approach as in primary as well as in revision surgery depends on the extent of disease and on the preoperative otoscopic and radiological findings (Figures 1-8). We already found that cholesteatoma < 8 mm in size and confined to the ME or its extensions can be eradicated with a minimally invasive TEA, while endoscope-assisted retroauricular mastoidectomy is the preferable procedure for larger lesions [31].

Many primary and some residual/recurrent lesions can be accessed with endoscopes. However, prior to undergoing the intervention, all the patients are informed of the possibility of extending their surgery to a transmastoid approach in the event that the cholesteatoma could not be satisfactorily eradicated by the transcanal endoscopic approach.

2.1. Surgical technique

The operating room setup, instrumentation and surgical technique were similar to those proposed by Tarabichi [11-14]. Rigid 3-mm diameter, 0°, 30° and 45° endoscopes, angled picks and forceps and routine otologic micro-instruments are used for all the TEA procedures (the list of the instruments can be seen in the web site of the International Working Group on Endoscopic Ear Surgery). A wide posterior tympanomeatal flap was elevated via the external auditory canal and then transposed inferiorly in cases of cholesteatoma situated in the middle ear (ME) under a closed or perforated tympanic membrane (TM). If needed, the scutum was removed with a bone curette until the cholesteatoma extension and the mastoid antrum could be visualized. The malleus and incus are removed when they are involved in the cholesteatoma or when they limit access to cholesteatoma in the anterior or posterior epitympanic space. When present, the stapes is left intact and meticulously and gently cleaned when it is involved with the cholesteatoma. Scutumplasty is done with tragal cartilage, and TM defects are reconstructed with the palisade technique and perichondrium in the relevant cases. In certain cases, cholesteatoma can be assessed and removed using the endoscopes directly from the radical cavity or from the mastoid cavity remaining after a canal-wall-down (CWD) procedure.

An operating microscope is used when the surgeon needs both hands to complete the removal of the cholesteatoma from the facial nerve or stapes footplate, and occasionally for ossicular chain reconstruction (OCR). Operative time depends on the extension of the disease, ossicular involvement in cholesteatoma and whether OCR is required.

Post-operative follow-up recommendations included repeated clinical examinations, and all the patients are encouraged to perform non-EPI DWI MRI at approximately one year following surgery. Second-look procedures or secondary OCRs usually are planned according to the clinical and MRI findings and the postoperative audiometric results. Whatever the etiology of cholesteatoma, scutumplasty with cartilage yielded good results in terms of prevention of postoperative retraction pockets.

EES has several advantages as compared to traditional mastoidectomy. This is a minimally invasive surgical approach in terms of incision, bleeding, drilling, postoperative pain and healing, and it is curative in terms of the radical eradication of the pathology including hidden areas poorly accessible and thus overlooked by a microscope. In the TEA, bony work can be circumvented leading to a decrease of possible intraoperative complications. This is functional surgery since scutumplasty and reconstruction of the tympanic membrane lead to conditions favorable to the introduction of the water into the external auditory meatus, and primary ossicular chain reconstruction can be done at the same setting. The patient can be discharged on the same day or on the day after surgery, and the hospital stay can be shortened compared to at least 2 days postoperative admission for uneventful retroauricular mastoidectomy. In contrast to mastoidectomy, the EES can be performed under local anaesthesia, and there is no need for postoperative wound care. Post-EES healing time is usually painless and is shorter compared to mastoidectomy. The set-up time and costs of the endoscopic procedure are comparable with mastoidectomy and even less since there is no need in drilling, cotton material and cauterization for hemostasis, suturing of the wound, bandage and postoperative wound care. The endoscopes and video-cameras are in routine use for endoscopic sinus surgery and thus are already available in most departments. The routine otologic micro-sets should be completed with some angled picks and forceps.

Although mastoidectomy is a procedure that is familiar to all otosurgeons, it can be compli-cated by accidental trauma to middle cranial fossa dura, dural exposure in the tegmen and sinodural angle, and brain herniation into the mastoid cavity. Dural and tegmen defect due to dural tears and cerebrospinal fluid leakage may result in pneumocephalus, brain herniation, subdural empyema, epidural or brain abscess [33-39]. In addition to primary cholesteatoma cases, minimally invasive TEA can be applied for revision of canal-wall-up (CWU) cases, when residual/recurrent cholesteatoma is confined to the middle ear, and in CWD or radical cavities, when residual/recurrent disease is hidden in the supratubal recess, sinus tympani or under pseudo-membrane in the large mastoid cavities, when access to cholesteatoma via external ear canal is difficult using the operating microscope due to the limited axis of work [24]. The TEA can be one of the options for eradication of residual/recurrent lesions in addition to traditional CWU and CWD techniques. The TEA avoids drilling in the mastoid region, thereby obviating the risk of dural injury and postoperative intracranial complications. Pre-operative non-EPI DWI MRI can predict cholesteatoma extension and is essential in planning revision surgery

for residual/recurrent lesions. Screening with non-EPI DWI MRI at one year postoperatively is highly recommended to rule out residual disease, especially in patients who underwent CWU mastoidectomies.

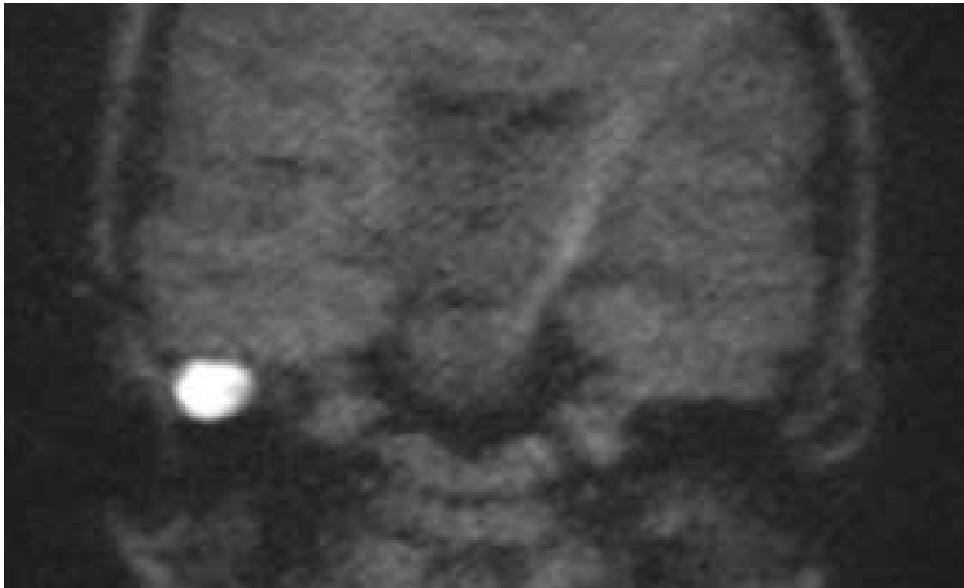**Figure 1.** A view (with a 0° endoscope) of a left ear primary retraction pocket cholesteatoma.

Figure 2. Non-EPI DW coronal images of the same patient presented in Figure 2 shows a 7-mm hyperintense lesion in the left attic (it was managed with TEA).

Figure 3. Endoscopic view of right ear primary retraction pocket cholesteatoma extended to the mastoid cavity.

Figure 4. Non-EPI DW coronal images of the same patient presented in Figure 3 shows a hyperintense lesion occupied whole mastoid cavity (it was managed with CWD mastoidectomy).

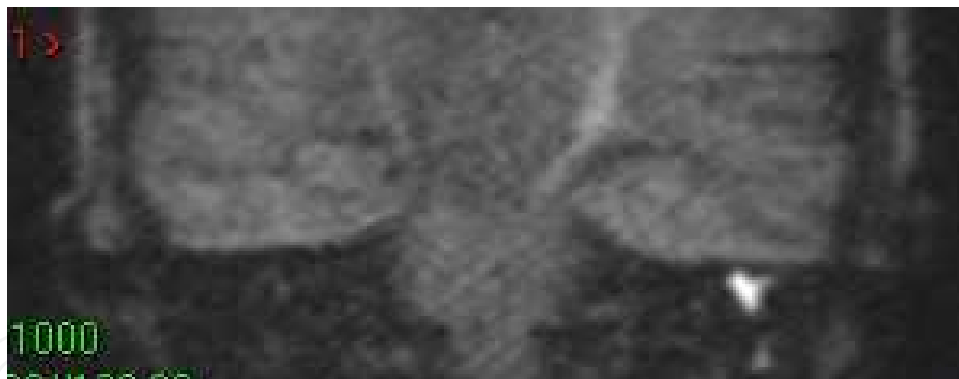**Figure 5.** Endoscopic view of right ear residual cholesteatoma presented 1 year after CWU mastoidectomy.
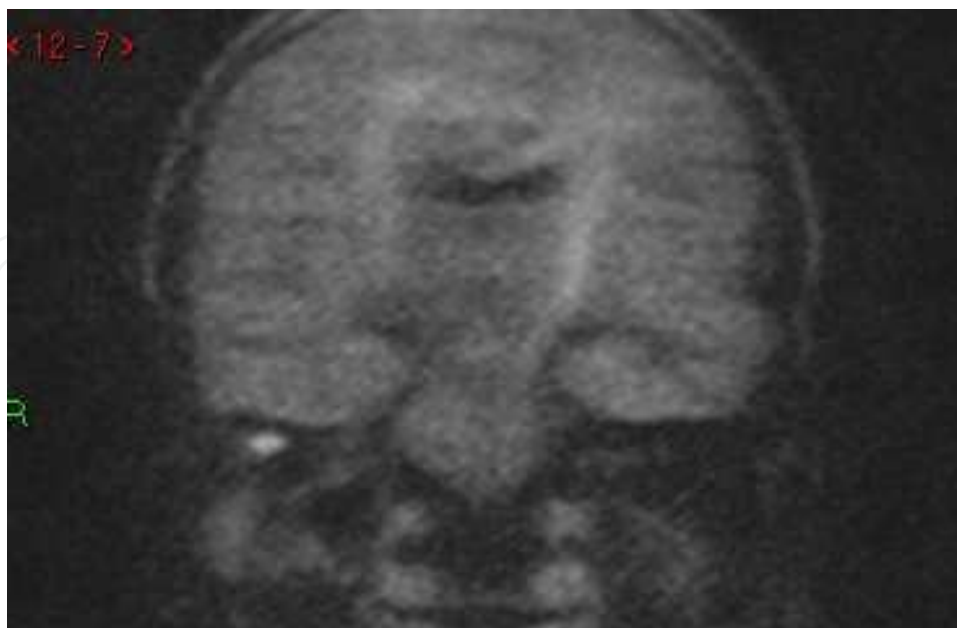
Figure 6. Non-EPI DW coronal images of the same patient presented in Figure 5 shows a 6-mm hyperintense lesion in the right attic (it was managed with TEA).

Figure 7. Endoscopic view of left ear recurrent cholesteatoma presented 2.5 years after CWD mastoidectomy.

Figure 8. Non-EPI DW coronal images of the same patient presented in Figure 7 shows a 9-mm hyperintense lesion in the left middle ear with an extension to the mastoid (it was managed with TEA).

3. Endoscopic myringoplasty

Recently, different endoscopes have been used in the performance of ear surgery in general and myringoplasty in particular, and the surgical success of endoscope-assisted myringoplasty ranges between 80 and 100 % [40-46]. Myringoplasty can be technically difficult, especially in pediatric patients, due to the narrowness of the external auditory canal and the generally small

size of the ear [46]. Moreover, temporalis fascia grafts and myringoplasties for anterior perforations are more likely to fail in children [40-43,47,48]. Surgical management of anterior perforations requires total exposure of the anterior angle, but a microscope may fail to provide a view of the anterior edge in 73 % of perforations that can, however, be entirely exposed with an endoscope [44]. As a result, drilling of the anterior part of an external auditory canal is usually unavoidable for the repair of anterior perforations when only a microscopic approach is employed [47].

3.1. Surgical technique

Transcanal endoscopic myringoplasties are performed under local or general anesthesia with a chondro-perichondrial graft that is harvested from the tragus and placed medial to the tympanic membrane remnants, utilizing the underlay technique and 14-mm length, 3-mm diameter, 0° and 30° endoscopes (Figures 9 and 10). Tympanomeatal flap is elevated using the 0° endoscope in all the cases, and the 30° endoscope can be utilized for better visualization of anterior perforations. The margins of perforations are freshened using the 0° or 30°endoscopes. A microscope is used for removal of the sclerotic plaques and releasing adhesions surrounding the ossicles when bimanual manipulations are needed.
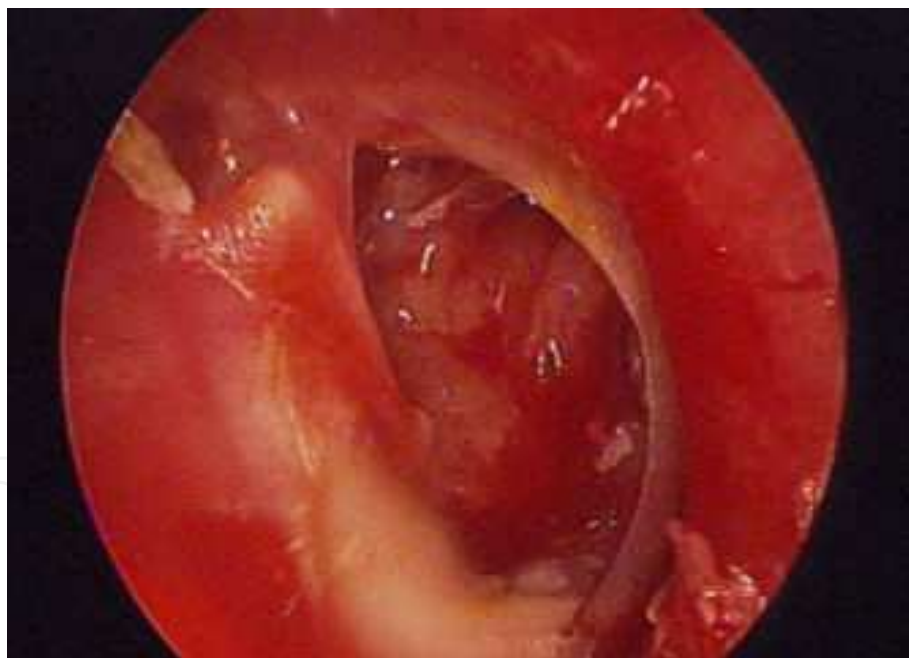
Figure 9. Endoscopic view of a large anterior perforation in the right tympanic membrane.

We found that an endoscope is very effective in ensuring satisfactory approximation of graft material to the perforation margins in small, medium-sized, large and subtotal perforations as well. The transcanal endoscopic myringoplasty had, in our hands, a 100% rate of surgical success for closure of tympanic membrane defects. This technique is especially helpful in patients with narrow external canals, anterior defects and bone overhang, when perforation's

margins are barely, if at all, visible under a microscope. The choice of chondro-perichondrial graft material and the meticulous removal of myringosclerotic plaques can enhance the surgical outcome of endoscopic myringoplasty performed by an experienced otologist.
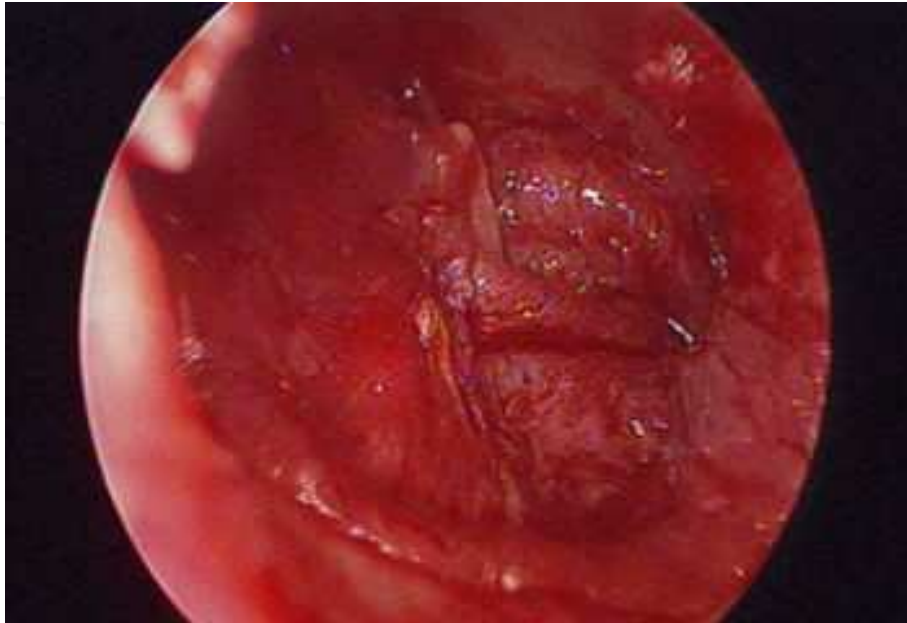
Figure 10. Endoscopic view of the same ear as in Figure 9 at the end of the myringoplasty.

4. Endoscopic stapedotomy

Stapedotomy can be technically difficult and challenging due to anatomic variations in size, configuration, shape or irregularity of the external ear canal. The stapes and oval window niche (OWN) can be obscured by the scutum. Excessive removal of the bone for better visualization of the middle ear (ME) structures can rarely result in subluxation of the incus [49-51]. When the posterior part of the bony annulus is removed to visualize the stapes, the chorda tympani nerve (CTN) can be occasionally touched, stretched, manipulated or transected and result in 20-60% of postoperative taste disorders or tongue symptoms [52-57]. The existing data indicate that the CTN should be preserved whenever possible, especially if surgery is bilateral [53,54,57,58]. Bilateral CTN damage can result in transient or permanent bilateral ageusia of the anterior two-thirds of the tongue, as well as a decreased resting salivary flow rate. In addition, the patients may suffer from transient or persistent, distressing xerostomia or tactile dysguesia [58-60]. However, damage to the CTN and subluxation of the ossicles or stapes fracture significantly decreases in the hands of an experience surgeon.

Endoscopic stapedotomy was introduced in our department with the intent to avoid injury to the CTN when attempting to achieve visibility of the ME structures. The CTN was preserved in all cases, and our preliminary audiometric results were comparable with the others [61-63].

4.1. Surgical technique

The position of the patients is the same as for routine otomicroscopic ear surgeries. The external ear canal is injected with lidocaine 1% with 1:100.000 epinephrine. A fully endoscopic trans-canal procedure was undertaken using rigid endoscopes 3 mm diameter, 14-cm length, 0° and 30°. Angled picks and curved scissors and forceps are used in addition to the routine otologic micro-instruments. A posterior tympanomeatal flap is elevated transmeatally with the 0° endoscope and then transposed anteriorly. All the surgeries are performed with a 0° endoscope, while a 30° endoscope can be required to better visualize the OWN, the anterior crus of the stapes, the tympanic portion of the facial nerve and the pyramidal eminence in some cases due to bony overhang in the posterior tympanum. Stapes fixation is confirmed by gentle testing of ossicular chain mobility. The stapes tendon is cut with curved micro-scissors and the stapes is separated from the incus in the incudo-stapedial joint. The anterior and posterior stapedial crus are carefully fractured and the superstructure is removed. The distance between the footplate and medial surface of the long process of the incus was measured to determine the required prosthesis size. The hole in the footplate is created with a Skeeter microdrill using a 0.5-mm diameter diamond burr. A platinum/fluoroplastic piston prosthesis (0.4-mm diameter, 4.5/4.75-mm length) is placed into this hole and fitted along the long process of the incus (Figures 11-14). The appropriate ossicular chain movement with the replaced stapes is ensured by malleus palpation. The tympano-meatal flap is repositioned, and the external auditory canal is filled with Gelfoam® soaked in ear drops containing antibiotics.
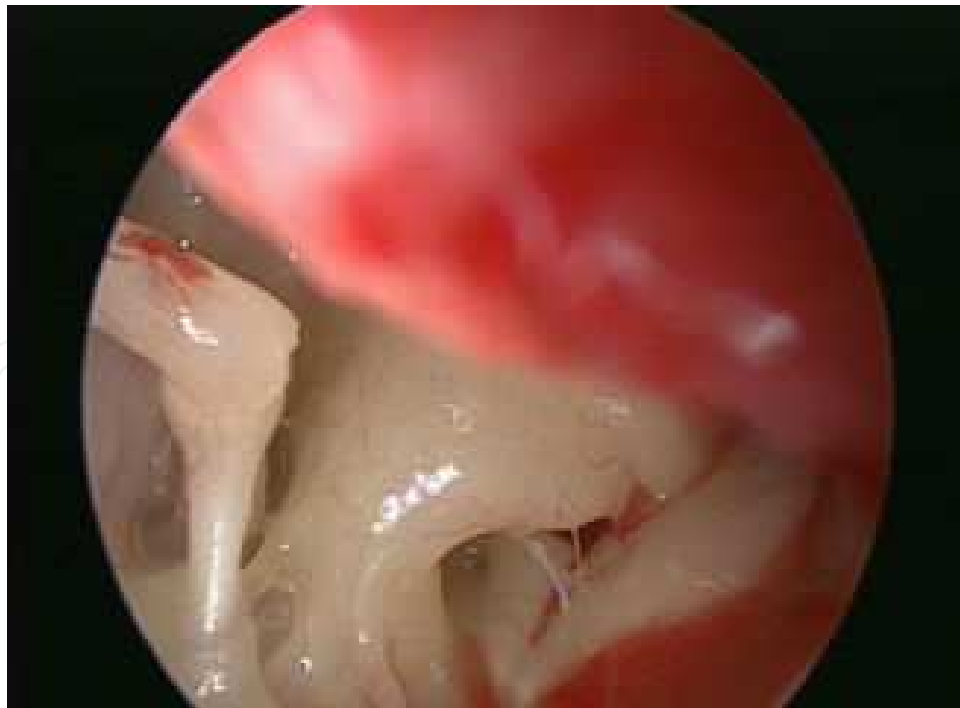
Figure 11. Endoscopic view of the right middle ear after an elevation of the tympano-meatal flap. Good access to the stapes and oval window niche was achieved without removal of the scutum and without touching the chorda tympani nerve.

Figure 12. Endoscopic view of the right ear: cutting of the stapedius.
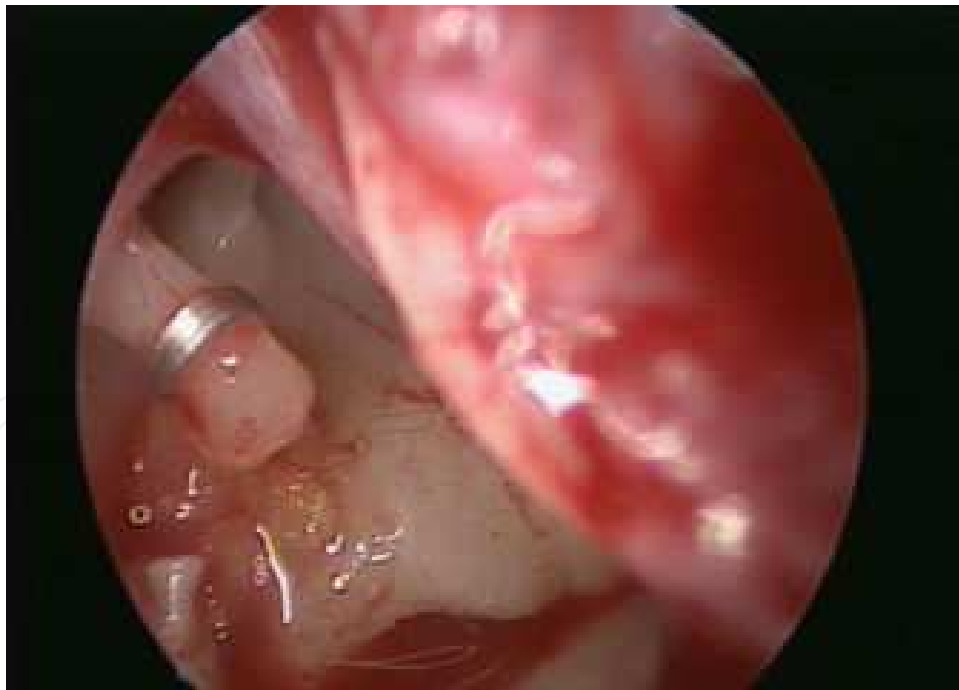
Figure 13. Endoscopic view of piston prosthesis placed in the hole that was created in the footplate and covered with a small piece of fat.

The possible benefits of ES are excellent visibility and accessibility of the stapes and the OWN, and avoiding manipulation of the CTN and blind fracture of the stapedial crurae. Assistance

in using the operating microscope can be required when there is the need for two-hand manipulations for proper placing and coupling of the prosthesis, especially during the surgeon's initial endoscopic procedures. Finally, right-handed surgeon (L.M.) found that the axis of work was initially more comfortable when performing surgery on right ears and that the relative difficulty in creating a hole in the footplate and positioning the prosthesis in left ears could be overcome with more training.

Transcanal fully endoscopic stapedotomy can be utilized in patients with unfavorable external or middle ear anatomy, in candidates for revision or bilateral stapedotomy, in patients with already impaired taste sensation, with food-, smell- or taste-related occupations, and in those for whom the taste of food contributes appreciably to their quality of life.

5. Endoscopic cochlear implantation

Recent developments in cochlear implant electrode array design and modifications of surgical techniques have resulted in improved post-implantation performance by minimizing intra-cochlear damage during implantation [64]. However, electrodes and the surgical procedures used for their insertion still produce intracochlear trauma. An optimal site for cochleostomy in terms of avoiding insertion trauma during cochlear implantation (CI) has not yet been established. Some authors recommend the insertion of the electrode array through the cochleostomy corresponding to the antero-inferior margin of the round window membrane (RWM), while others contend that atraumatic insertion can be achieved directly through the RWM by removing the antero-inferior overhang of the RW niche, drilling down the crista fenestra, and incising the most lateral aspect of the RWM before insertion [64]. Regardless of the site of electrode insertion, the first step is achieving adequate exposure of the RWM in order to facilitate minimally invasive surgery. However, the topographical relationships among the facial nerve (FN), CTN, and RW showed that the widest route of approach through the facial recess (FR) frequently did not point directly towards the RW, but rather towards the basal turn at the promontory [65]. RWM insertion using the FR approach can be more challenging in pediatric patients, with the visibility of the RWM being limited in 11%-22 % of children even after an "optimal" posterior tympanotomy. An extended membranous cochleostomy or conventional bony cochleostomy may be required in some of these cases [66]. Moreover, the access to the RWM may be compromised in an FR approach due to the bony overhangs, abnormal course of the FN, jugular bulb location or abnormalities, anteriorly located sigmoid sinus, narrow FR and an undeveloped mastoid [67-70].

An endoscopic CI involves entering the ME by means of endoscopic transcanal tympanotomy and insertion of the electrode array into the scala tympani via the RW under direct endoscopic control [71,72]. Limited access to the ME structures can result in electrode misplacement, damage to the FN and injury to the CTN when a CI is carried out with an FR approach [73-78]. Indeed, bilateral sacrificing of the CTN due to a narrow FR in bilaterally implanted children can lead to morbidity that has not yet been investigated in depth. One of the reasons for incorrect electrode insertion using the microscopic approach through the FR can be the

presence of a wide subcochlear canaliculus that could be mistaken with the RW niche [72]. Our experience as well as findings of our colleagues showed that the direct visualization of the RWM using a transcanal endoscopic approach permits electrode insertion through the RWM into the scala tympani with less drilling of the niche comparing to the FR technique [72].

5.1. Surgical technique

The procedures are performed with the patients under general anesthesia. The position of the patients, the skin incisions and the drilling of the implant wells are the same as for routine otomicroscopic CI. The external ear canal is injected with lidocaine 1% with 1:100.000 epinephrine. Cortical mastoidectomy until visualization of the incus is performed. A 6 o'clock vertical incision is made in the meatal skin, and a posterior tympano-meatal flap is elevated transmeatally to expose the ME cavity using a rigid 0° endoscope 3 mm in diameter and 14 cm in length held manually, and then transposed anteriorly. The CTN and body of the incus are exposed. Visualization of the incus body serves as a target for drilling and preventing injury to the FN which is located medial to it. The RWM is incised, and the electrodes are passed through the tunnel from the mastoid to epitympanum, medial to the CTN and lateral to the incus into the RW (Figure 15). The tympano-meatal flap is repositioned, and the external auditory canal is filled with Gelfoam® soaked in ear drops containing antibiotics. The surgical procedure can be modified in some procedures as follows: instead of inserting the electrodes through a tunnel that could limit the angle of insertion, an open groove is drilled starting superiorly and laterally to the CTN and ending in the mastoid region. The electrodes are passed through the groove medially to the CTN and laterally to the incus into the scala tympani through the RW, which is then covered with a small piece of temporalis fascia. The groove is filled with bone dust that had been collected during the drilling of the implant well, and covered with a large piece of fascia prior to repositioning of the tympano-meatal flap, aiming to prevent extrusion of the electrode array into the external auditory canal or tracking of the canal skin into the mastoid with cholesteatoma formation. All patients routinely receive intravenous ceftriaxone intra-operatively, followed by a course of oral cephalexin during the first postoperative week.

Fully endoscopic CI with complete electrode insertion via the RW was found more feasible for insertion of Concerto (Medical Electronics, Innsbruck, Austria) electrode followed by HiRes90K (Advanced Bionics Corporation, California, USA) and Nucleus 24 Contour Advance (Cochlear Corporation, Australia) [71].

The main benefits of the TEA to CI are improving the visibility and accessibility of the RWM, obviating the need to divide the CTN in order to obtain adequate exposure of the ME structures, and eliminating the risk of FN injury since the FN is not in the direction of drilling. The open groove technique was used several times in the past by the first author in cases of low-set dura and anteriorly based sigmoid sinus. A follow up of these patients showed that there is no protrusion of the electrode over a period of at least 5 years when the groove is filled with bone dust and is covered with intact skin.

A good knowledge of the endoscopic anatomy of the middle ear and a good practical knowledge of the endoscopic technique are essential to ensure a safe endoscopic CI with good

outcome. An assistance of another surgeon may be required for holding the endoscope during the insertion of the electrode by a right-handed surgeon in the right cochlea and in removal of stylet, when relevant. Moreover, modern electrodes designed for hearing preservation by all companies are very thin and there is the need in bimanual manipulations for their safe and slow insertion requiring the help of an assistant in holding the endoscope. An angle of electrode insertion seems more comfortable in the transcanal approach compared to the epitympanic root of insertion. Right-handed surgeons (e.g. the first author) found that the axis of work was initially more comfortable when performing surgery on left ears and that the relative difficulty in electrode insertion in right ears could be overcome with more training [71]. Complete electrode insertion is achievable into the scala tympani via the round window both in children and adults. This technique can be used as a first surgical option or complementarily to the traditional posterior tympanotomy approach in patients with undeveloped or anomalous mastoid, narrow facial recess, anteriorly based sigmoid sinus, abnormal course of the facial nerve, high jugular bulb, malformed cochlea or distorted anatomy of the middle ear. The main limitation of an endoscopic CI is that it is a difficult one-hand surgery, technically possible only for highly skilled otosurgeons with extensive experience in performing classic aproaches as well as various endoscopic ear procedures. In endoscopic CI, one hand is occupied by the endoscope while the other performs manipulations during endoscopic CI including suctioning, hemostasis and subsequent introduction of the electrode into the cochlea [71]. The lack of stereoscopic vision was not considered to be a drawback by the first author in any surgery.

Figure 14. Wide exposure of the middle ear after elevation of the tympano-meatal flap in an endoscopic transcanal cochlear implantation (left ear).
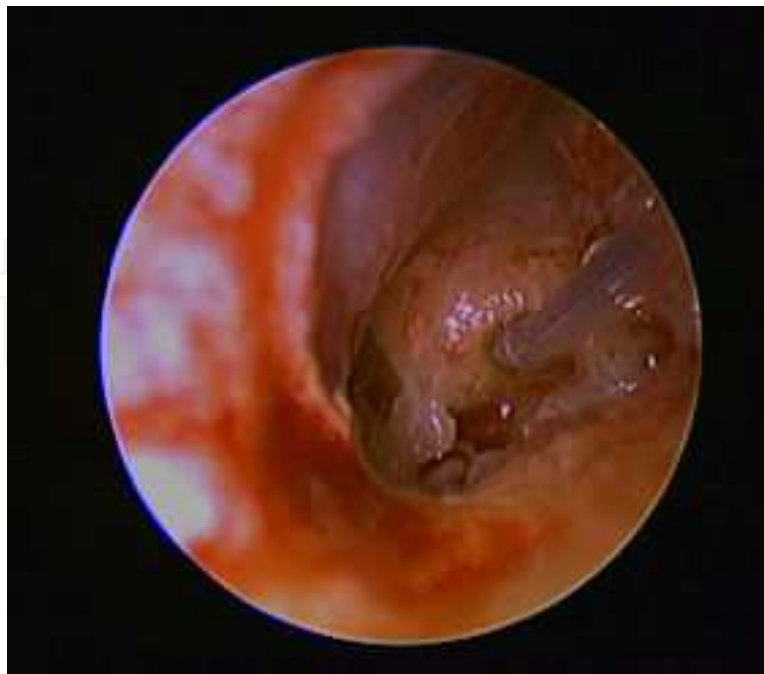
Figure 15. An electrode array passing through the tunnel medial to the chorda tympani nerve and lateral to the incus into the cochlea via the round window in an endoscopic transcanal cochlear implantation (the same ear as in Figure 14).

6. Conclusion

The transcanal endoscopic approach is minimally invasive surgery that can be successfully applied for various ear pathologies. Knowledge on middle ear anatomy, ear radiology and an experience in classic techniques is essential before starting the endoscopic approach. The assistance of an operating microscope may be required when there is the need for two-hand manipulations in dissection of the cholesteatoma from the dehiscent facial nerve, ossicles, stapes footplate, and in some cases of ossicular chain reconstruction, introduction of the electrode array into the cochlea. In inexperienced hands, the endoscopic approach can be associated with complications due to direct trauma from the tip of the endoscope to the facial nerve, the ossicular chain and a low-lying tegmen.

Author details

Lela Migirov* and Michael Wolf

*Address all correspondence to: migirovl@gmail.com

Department of Otolaryngology- Head and Neck Surgery, Sheba Medical Center, affiliated to the Sackler School of Medicine, Tel Aviv University, Israel

References

[1] Thomassin JM, Korchia D, Doris JM. Endoscopic-guided otosurgery in the prevention of residual cholesteatomas. Laryngoscope 1993;103:939-943.

[2] Good GM, Isaacson G. Otoendoscopy for improved pediatric cholesteatoma removal. Ann Otol Rhinol Laryngol 1999;108:893-896.

[3] Badr-El-Dine M. Value of ear endoscopy in cholesteatoma surgery. Otol Neurotol 2002;23:631–635.

[4] 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;129:490-496.

[5] Ayache S, Tramier B, Strunski V. Otoendoscopy in cholesteatoma surgery of the middle ear. What benefits can be expected? Otol Neurotol 2008;29:1085-1090.

[6] Migirov L, Shapira Y, Horowitz Z, Wolf M. Exclusive endoscopic ear surgery for acquired cholesteatoma: preliminary results. Otol Neurotol 2011;32:433-436.

[7] Presutti L, Marchioni D, Mattioli F, Villari D, Alicandri Ciufelli M. Endoscopic management of acquired cholesteatoma: our experience. J Otolaryngol 2008;37:481-487.

[8] Bottrill ID, Poe DS. Endoscope-assisted ear surgery. Am J Otol 1995;16:158-163.

[9] Marchioni D, Mattioli F, Alicandri-Ciufelli M, Presutti L. Transcanal endoscopic approach to the sinus tympani: a clinical report. Otol Neurotol 2009;30:758-765.

[10] Tarabichi M. Endoscopic middle ear surgery. Ann Otol Rhinol Laryngol 1999;108:39-46.

[11] Tarabichi M. Endoscopic management of limited attic cholesteatoma. Laryngoscope 2004;114:1157-1162.

[12] Tarabichi M. Transcanal endoscopic management of cholesteatoma. Otol Neurotol 2010;31:580-588.

[13] Tarabichi M. Endoscopic management of acquired cholesteatoma. Am J Otol 1997;18:544-549.

[14] Tarabichi M. Endoscopic management of cholesteatoma: long-term results. Otolaryngol Head Neck Surg 2000;122:874-881.

[15] Wilson KF, Hoggan RN, Shelton C. Tympanoplasty with intact canal wall mastoidectomy for cholesteatoma: long-term surgical outcomes. Otolaryngol Head Neck Surg 2013;149:292-295.

[16] Tomlin J, Chang D, McCutcheon B, Harris J. Surgical technique and recurrence in cholesteatoma: a meta-analysis. Audiol Neurootol 2013;18:135-142.

[17] Stew BT, Fishpool SJ, Clarke JD, Johnson PM. Can early second-look tympanoplasty reduce the rate of conversion to modified radical mastoidectomy? Acta Otolaryngol 2013;133:590-593.

[18] Stankovic M. The learning curve in revision cholesteatoma surgery. Am J Otolaryngol 2013; 34:65-71.

[19] Drahy A, De Barros A, Lerosey Y, Choussy O, Dehesdin D, Marie JP. Acquired cholesteatoma in children: strategies and medium-term results. Eur Ann Otorhinolaryngol Head Neck Dis 2012; 129:225-229.

[20] Gaillardin L, Lescanne E, Morinière S, Cottier JP, Robier A. Residual cholesteatoma: prevalence and location. Follow-up strategy in adults. Eur Ann Otorhinolaryngol Head Neck Dis 2012;129:136-140.

[21] Minovi A, Venjacob J, Volkenstein S, Dornhoffer J, Dazert S. Functional results after cholesteatoma surgery in an adult population using the retrograde mastoidectomy technique. Eur Arch Otorhinolaryngol 2014;271:495-501.

[22] Osborn AJ, Papsin BC, James AL. Clinical indications for canal wall-down mastoidectomy in a pediatric population. Otolaryngol Head Neck Surg 2012;147:316-322.

[23] Vercruysse JP, De Foer B, Somers T, Casselman JW, Offeciers E. Mastoid and epitympanic bony obliteration in pediatric cholesteatoma. Otol Neurotol 2008;29:953-960.

[24] Migirov L, Yakirevitch A, Wolf M. The utility of minimally invasive transcanal endoscopic approach for removal of residual/recurrent cholesteatoma: preliminary results. Eur Arch Otorhinolaryngol. 2014 Nov 21. [Epub ahead of print]

[25] Marchioni D, Mattioli F, Alicandri-Ciufelli M, Presutti L. Transcanal endoscopic approach to the sinus tympani: a clinical report. Otol Neurotol 2009;30:758-765.

[26] James AL. Endoscopic middle ear surgery in children. Otolaryngol Clin North Am 2013; 46:233-244.

[27] De Foer B, Vercruysse JP, Spaepen M, Somers T, Pouillon M, Offeciers E, Casselman JW. Diffusion-weighted magnetic resonance imaging of the temporal bone. Neuroradiology 2010;52:785-807.

[28] Dhepnorrarat RC, Wood B, Rajan GP. Postoperative non-echo-planar diffusion-weighted magnetic resonance imaging changes after cholesteatoma surgery: implications for cholesteatoma screening. Otol Neurotol 2009;30:54-58.

[29] Profant M, Sláviková K, Kabátová Z, Slezák P, Waczulíková I. Predictive validity of MRI in detecting and following cholesteatoma. Eur Arch Otorhinolaryngol 2012;269:757-765.

[30] Edfeldt L, Strömbäck K, Danckwardt-Lillieström N, Rask-Andersen H, Abdsaleh S, Wikström J Non-echo planar diffusion-weighted MRI increases follow-up accuracy

after one-step step canal wall-down obliteration surgery for cholesteatoma. Acta Oto-laryngol 2013;133:574-583.

[31]   Migirov L, Wolf M, Greenberg G, Eyal A. Non-EPI DW MRI in planning the surgical approach to primary and recurrent cholesteatoma. Otol Neurotol 2014;1:121-125.

[32]   Brenner DJ, Hall EJ. Computed tomography-an increasing source of radiation exposure. N Engl J Med 2007;357:2277-2284.

[33]   Garap JP, Dubey SP. Canal-down mastoidectomy: experience in 81 cases. Otol Neurotol 2001;22:451-456.

[34]   De Corso E, Marchese MR, Scarano E, Paludetti G. Aural acquired cholesteatoma in children: surgical findings, recurrence and functional results. Int J Pediatr Otorhinolaringol 2006;70:1269-1273.

[35]   Wormald PJ, Nilssen EL. Do the complications of mastoid surgery differ from those of the disease? Clin Otolaryngol Allied Sci 1997;22:355-357.

[36]   Wootten CT, Kaylie DM, Warren FM, Jackson CG. Management of brain herniation and cerebrospinal fluid leak in revision chronic ear surgery. Laryngoscope 2005;115:1256-1261.

[37]   Dubey SP, Jacob O, Gandhi M. Postmastoidectomy pneumocephalus: case report. Skull Base 2002;12:167-173.

[38]   Migirov L, Eyal A, Kronenberg J. Intracranial complications following mastoidectomy. Pediatr Neurosurg 2004;40:226-229.

[39]   Moore GF, Nissen AJ, Yonkers AJ. Potential complications of unrecognized cerebrospinal fluid leaks secondary to mastoid surgery. Am J Otol 1984;5:317-323.

[40]   Usami S, Iijima N, Fujita S, Takumi Y: Endoscopic-assisted myringoplasty. ORL J Otorhinolaryngol Relat Spec 2001; 63:287-290.

[41]   Karhuketo TS, Ilomäki JH, Puhakka HJ: Tympanoscope-assisted myringoplasty. ORL J Otorhinolaryngol Relat Spec 2001;63:353-357; discussion 358.

[42]   Konstantinidis I, Malliari H, Tsakiropoulou E, Constantinidis J: Fat myringoplasty outcome analysis with otoendoscopy: who is the suitable patient? Otol Neurotol 2013;34:95-99.

[43]   Yadav SP, Aggarwal N, Julaha M, Goel A: Endoscope-assisted myringoplasty. Singapore Med J 2009;50:510-512.

[44]   Ayache S: Cartilaginous myringoplasty: the endoscopic transcanal procedure. Eur Arch Otorhinolaryngol 2013;270:853-860.

[45]   Raj A, Meher R: Endoscopic transcanal myringoplasty-A study. Indian J Otolaryngol Head Neck Surg 2001;53:47-49.

[46] Mohindra S, Panda NK: Ear surgery without microscope; is it possible. Indian J Otolaryngol Head Neck Surg 2010; 62:138-141.

[47] Halim A, Borgstein J: Pediatric myringoplasty: postaural versus transmeatal approach. Int J Pediatr Otorhinolaryngol 2009;73:1580-1583.

[48] Castro O, Pérez-Carro AM, Ibarra I, Hamdan M, Meléndez JM, Araujo A, Espiña G: Myringoplasties in children: our results. Acta Otorrinolaringol Esp 2013; 64: 87-91. [Article in English, Spanish]

[49] Gołabek W, Szymański M, Siwiec H, Morshed K. Incus subluxation and luxation during stapedectomy. Ann Univ Mariae Curie Sklodowska Med 2003;58:302-305.

[50] Lesinski SG. Causes of conductive hearing loss after stapedectomy or stapedotomy: a prospective study of 279 consecutive surgical revisions. Otol Neurotol 2002; 23:281-288.

[51] Malafronte G, Filosa B. Fisch's reversal steps stapedotomy: when to use it? Otol Neurotol 2009; 30:1128-1130.

[52] Miuchi S, Sakagami M, Tsuzuki K, Noguchi K, Mishiro Y, Katsura H. Taste disturbance after stapes surgery--clinical and experimental study. Acta Otolaryngol Suppl 2009;562:71-78.

[53] Guder E, Böttcher A, Pau HW, Just T. Taste function after stapes surgery. Auris Nasus Larynx 2012;39:562-566.

[54] Clark MP, O'Malley S. Chorda tympani nerve function after middle ear surgery. Otol Neurotol 2007;28:335-340.

[55] Michael P, Raut V. Chorda tympani injury: operative findings and postoperative symptoms. Otolaryngol Head Neck Surg 2007;136:978-981.

[56] Saito T, Manabe Y, Shibamori Y, Yamagishi T, Igawa H, Tokuriki M, et al. Long-term follow-up results of electrogustometry and subjective taste disorder after middle ear surgery. Laryngoscope 2001;111(11 Pt 1):2064-2070.

[57] Yung M, Smith P, Hausler R, Martin C, Offeciers E, Pytel J, et al. International Common Otology Database: taste disturbance after stapes surgery. Otol Neurotol 2008;29:661-665.

[58] Guinand N, Just T, Stow NW, Van HC, Landis BN. Cutting the chorda tympani: not just a matter of taste. J Laryngol Otol 2010;124:999-1002.

[59] Chen JM, Bodmer D, Khetani JD, Lin VV. Tactile dysgeusia: a new clinical observation of middle ear and skull base surgery. Laryngoscope 2008; 118:99-103.

[60] Mandel L. Hyposalivation after undergoing stapedectomy. J Am Dent Assoc 2012;143:39-42.

[61] Migirov L, Wolf M. Endoscopic transcanal stapedotomy: how I do it. Eur Arch Oto-rhinolaryngol. 2013;270:1547-1549.

[62] Poe DS. Laser-assisted endoscopic stapedectomy: a prospective study. Laryngoscope 2000;110 (5 Pt 2 Suppl 95):1-37.

[63] Nogueira Júnior JF, Martins MJ, Aguiar CV, Pinheiro AI. Fully endoscopic stapes surgery (stapedotomy): technique and preliminary results. Braz J Otorhinolaryngol 2011;77:721-727 [Article in English, Portuguese].

[64] Skarzynski H, Lorens A, Matusiak M, Porowski M, Skarzynski PH, James CJ. Partial deafness treatment with the nucleus straight research array cochlear implant. Audiol Neurootol 2012;17:82-91.

[65] Hamamoto M, Murakami G, Kataura A. Topographical relationships among the fa-cial nerve, chorda tympani nerve and round window with special reference to the approach route for cochlear implant surgery. Clin Anat 2000;13:251-256.

[66] Leong AC, Jiang D, Agger A, Fitzgerald-O'Connor A. Evaluation of round window accessibility to cochlear implant insertion. Eur Arch Otorhinolaryngol 2013;270:1237-1242.

[67] Song JJ, Park JH, Jang JH, Lee JH, Oh SH, Chang SO, Kim CS. Facial nerve aberra-tions encountered during cochlear implantation. Acta Otolaryngol 2012;132:788-794.

[68] Leung R, Briggs RJ. Indications for and outcomes of mastoid obliteration in cochlear implantation. Otol Neurotol 2007;28:330-334.

[69] Kuhn MA, Friedmann DR, Winata LS, Eubig J, Pramanik BK, Kveton J, Kohan D, Merchant SN, Lalwani AK. Large jugular bulb abnormalities involving the middle ear. Otol Neurotol 2012;33:1201-1206.

[70] Jang JH, Song JJ, Yoo JC, Lee JH, Oh SH, Chang SO. An alternative procedure for cochlear implantation: transcanal approach. Acta Otolaryngol 2012;132:845-849.

[71] Migirov L, Shapira Y, Wolf M. The feasibility of endoscopic transcanal approach for insertion of various cochlear electrodes: a pilot study. Eur Arch Otorhinolaryngol. 2014 Mar 12. [Epub ahead of print]

[72] Marchioni D, Grammatica A, Alicandri-Ciufelli M, Genovese E, Presutti L. Endo-scopic cochlear implant procedure. Eur Arch Otorhinolaryngol 2014;271:959-966.

[73] Orús Dotú C, Venegas Pizarro Mdel P, De Juan Beltrán J, De Juan Delago M. [Cochle-ar reimplantation in the same ear: findings, peculiarities of the surgical technique and complications]. Acta Otorrinolaringol Esp 2010;61:106-117. [Article in Spanish]

[74] Mouzali A, Ouennoughi K, Haraoubia MS, Zemirli O, Triglia JM. Cochlear implant electrode array misplaced in Hyrtl's fissure. Int J Pediatr Otorhinolaryngol 2011;75:1459-1462.

[75] Nevoux J, Loundon N, Leboulanger N, Roger G, Ducou Le Pointe H, Garabédian EN. Cochlear implant in the carotid canal. Case report and literature review. Int J Pediatr Otorhinolaryngol 2010;74:701-703.

[76] Hara M, Takahashi H, Kanda Y. The usefulness of reconstructed 3D images in surgical planning for cochlear implantation in a malformed ear with an abnormal course of the facial nerve. Clin Exp Otorhinolaryngol 2012;5 Suppl 1:S48-52.

[77] Wagner JH, Basta D, Wagner F, Seidl RO, Ernst A, Todt I. Vestibular and taste disorders after bilateral cochlear implantation. Eur Arch Otorhinolaryngol 2010;267:1849-1854.

[78] Brito R, Monteiro TA, Leal AF, Tsuji RK, Pinna MH, Bento RF. Surgical complications in 550 consecutive cochlear implantation. Braz J Otorhinolaryngol 2012;78:80-85. [Article in English, Portuguese]