Expanded Transcanal Transpromontorial Approach to the Internal Auditory Canal: Pilot Clinical Experience

Livio Presutti, MD[1], Matteo Alicandri-Ciufelli, MD, FEBORL-HNS[1,3], Marco Bonali, MD[1], Alessia Rubini, MD[2], Giacomo Pavesi, MD[3], Alberto Feletti, MD[3], Barbara Masotto, MD[4], Lukas Anschuetz, MD[1,5], Daniele Marchioni, MD[2]

[1]Otolaryngology-Head and Neck Surgery Department, University Hospital of Modena, Modena, Italy

[2]Otolaryngology-Head and Neck Surgery Department, University Hospital of Verona, Verona, Italy

[3]Neurosurgery Department, New Civil Hospital Sant'Agostino-Estense, Baggiovara (MO), Italy

[4]Neurosurgery Department, University Hospital of Verona, Verona, Italy

[5]Otolaryngology-Head and Neck Surgery Department, Inselspital, University Hospital and University of Bern, Bern, Switzerland

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Conflict of Interest

The authors declare no conflict of interest.

Corresponding author

Lukas Anschuetz, MD

Department of Otorhinolaryngology, Head & Neck Surgery, University Hospital of Modena, Via del Pozzo 71, 41100 Modena, Italy

Email: anschuetz.lukas@gmail.com

work: +39-059-4222402, mobile: +39-3483895474, fax: +39-059-4222454

ABSTRACT

Objective: The aim of this study is to describe and evaluate the feasibility of an expanded transcanal transpromontorial approach, developed from the exclusive endoscopic transcanal transpromontorial approach.

Study Design: Retrospective case series.

Methods: Retrospective chart review of 10 patients operated by an expanded transcanal transpromontorial approach in two tertiary referral centers (University Hospital of Modena and University Hospital of Verona, Italy). Data from charts and video documentation were collected and analyzed.

Results: Between April 2015 and January 2016, 10 patients underwent an expanded transcanal transpromontorial approach for vestibular schwannoma Koos Stage I or II and were enrolled in the study. The size of the tumors ranged from 7 to 19 millimeters in maximum diameter. A gross total resection was achieved in all cases. One subject experienced postoperative CSF otorhinorrhea and three subjects experiences temporary postoperative facial weakness all of which resolved. The mean follow-up was 5 months.

Conclusion: The expanded transcanal transpromontorial approach allowed bimanual dissection using a microscopic technique for the treatment of pathologies of the internal auditory canal and cerebellopontine angle. This novel approach resulted in minimal morbidity and comparable facial nerve preservation rates to the traditional approaches to the internal auditory canal. The expanded transpromontorial approach to the internal auditory canal holds promise for addressing pathology in this region of the temporal bone from the external auditory canal.

Key Words: inner ear; internal auditory canal; transcanal approach; endoscopic ear surgery; cerebellopontine angle

Level of Evidence: 4

INTRODUCTION

The classical surgical corridors to the internal auditory canal (IAC) and the cerebellopontine angle (CPA) are indirect approaches. In the retrosigmoid and transmastoid-translabyrinthine approach the pathology is reached posteriorly, while the middle cranial fossa approach gains access to the IAC superiorly. The advantages, disadvantages, clinical indications, morbidity and mortality have been carefully described[1] and therefore, these approaches are routinely used. However, the retrosigmoid and the middle cranial fossa approach require a craniotomy and the transmastoid-translabyrinthine depends on a subtotal petrosectomy to access the pathology.[1] Moreover, the retrosigmoid approach needs intradural drilling of the posterior aspect of the petrous bone to reach the pathology at the fundus of the IAC. In order to minimize the drilling of the posterior bony lining of the IAC, the endoscope was introduced two decades ago. After conventional access to the CPA, the endoscope was used to gain access and enhance visibility at the fundus of the IAC.[2]

In the same aim endoscopic techniques were introduced to visualize middle ear pathology during its surgical treatment since the 1990s.[3] In a first phase the endoscope was used during conventional microscopic operations to assist the surgeon in the exploration of hidden recesses due to the wide angle view and the possibility to use angulated scopes.[4] With growing experience the endoscopic technique was used as the main tool in the surgical treatment of middle ear cholesteatoma, using the microscope complimentary in case of mastoid involvement of the pathology.[5,6] Technical and surgical refinements allowed to introduce the advantages of the endoscopic middle ear surgery in novel endoscopic approaches to the lateral skull base.[7,8]

With ongoing investigations, the authors developed techniques to directly access the inner ear through the external auditory canal (EAC), either choosing an endoscopic assisted microscopic or even an exclusive endoscopic technique. These advances in developing a novel surgical technique required thorough understanding of the anatomy and identification of appropriate instruments, which was achieved during several cadaver dissections, prior to a clinical application.[9]

The first clinical implication of the exclusive endoscopic approach to the IAC was realized in March 2012. For the first time a cochlear schwannoma (CS) involving the IAC was removed using a direct transpromontorial approach through the external to the internal auditory canal, without any external incision.[10] Other lateral skull base applications have been described by our team during the last 2 years.[7,8] The first case series using an exclusive endoscopic transcanal transpromontorial approach (EndoTTA) to remove vestibular schwannomas (VS) involving the IAC has recently been published.[11] However, the treatment of Koos I VS is still a matter of debate,[12] in selected cases a new surgical approach may offer a valuable alternative.

The transpromontorial removal of larger tumors (Koos II) with limited extension to the CPA would require bimanual dissection of the tumor and intracranial vessels. The straight and direct access to the IAC as described by the EndoTTA may also be promising for a microscopic approach. However, the implementation of a microscope based transpromontorial technique requires an enlarged access route in order to enhance visibility and the surgical freedom. The aim of this study is to describe an expanded transcanal transpromontorial approach (ExpTTA) and report its feasibility in the first case series.

MATERIALS AND METHODS

Between January and February 2016, a retrospective chart review was carried out on patients operated by ExpTTA from March 2015 to January 2016. Data were gathered and summarized for further consideration based on charts, images, videos and surgical reports.

The ExpTTA was indicated in the following cases:

- Growing mass, evaluated during follow-up using magnetic resonance imaging (MRI), tumor growth was defined as an increase in tumor size in two consecutive MRI studies;

- Koos Stage I (mass located in the IAC) or Koos Stage II (IAC involvement and limited extension to the CPA);

- Patients with severe to profound hearing loss (evaluated with pure tone average (PTA) and speech recognition threshold (SRT) at speech audiometry) and/or patients with severe vertigo and concomitant pronounced neurovegetative symptoms such as nausea and vomiting.

All patients were operated by two senior otolaryngologists (DM and LP) in cooperation with senior neurosurgeons. Before implication in patients, the ExpTTA was studied on cadavers in order to determine suitable instruments and to identify the important surgical landmarks as described next.

Approach to the tympanic cavity and identification of the main landmarks (Figures 1 and 2)

The patient lay in the supine position with head slightly extended and rotated to the contralateral side. Intraoperative facial nerve monitoring was mandatory. The surgeon used principally a standard otological microscope and complimentary, when required a 4 mm diameter, 15 cm length, 0° angled endoscope (Karl Storz, Tuttlingen, Germany). The endoscope and the microscope were connected to an AIDA three-chip high-resolution monitor and camera system (Karl Storz, Tuttlingen, Germany). All operations were recorded and stored in a digital archive for documentation and further analyses.

First, the endoscope was introduced through the EAC and a circular incision of the EAC skin was made approximately 1.5 cm from the tympanic annulus. After dissection of a circular tympano-meatal flap, the skin was removed en block with the tympanic membrane. A Shambaugh incision (intercartilaginous incision between helix and tragus) was performed in order to expose the lateral portion of the EAC bone.

After positioning orthostatic retractors, the EAC was drilled circumferentially under microscopic view to widen the surgical field so as to achieve an adequate view and movement of the surgical instruments in the EAC. Drilling of the EAC was continued until the temporo-mandibular joint capsule was exposed, an important anatomical landmark representing the superficial anterior limit. A wide atticotomy was performed to expose the ossicular chain. The incus and malleus were removed to obtain a clear view of the whole tympanic tract of the facial nerve, the geniculate ganglion and its relationship with the cochleariform process.

Identification of the important landmarks for this approach continued with exposure of the middle cranial fossa dura superiorly (by removing the tympanic tegmen), the carotid artery anteriorly below the tympanic tube orifice (in the protympanic space), the jugular bulb inferiorly, and the third tract of the facial nerve posteriorly.

Transpromontorial approach to the IAC (Figures 3 and 4)

As a result of the enlarged EAC as described above, bimanual dissection under microscopic view was easily possible for the following steps. After careful identification of the anatomical landmarks, the surgery proceeded with removal of the stapes from the oval window and exposure of the vestibule and spherical recess in the saccular fossa. This structure looks like a thin cribriform plate separating the vestibule from the fundus of the IAC and represents the site of medial termination of the inferior vestibular nerve fibers. The oval window was enlarged using a microcurette, a burr or by Piezosurgery instrument (Mectron, Carasco/Genova, Italy). Thereafter, we adopted a transpromontorial approach to the IAC, removing the promontorial bone and progressively exposing the basal, middle and apical turn of the cochlea.

Knowledge of the position of the labyrinthine tract of the facial nerve was determined from the previously identified anatomical landmarks, serving as boundaries to the surgical field. An imaginary line from the geniculate ganglion to the spherical recess passing just above the apical turn of the cochlea indicated the route of the facial nerve into the inner ear.

The dura of the IAC was progressively exposed inferiorly and posteriorly from the fundus to the porus of the IAC until reaching the reflection of the dura on the petrous bone. At this point, our limits of dissection were the second tract of the facial nerve superiorly, the vertical tract of the internal carotid artery anteriorly, the jugular bulb inferiorly, the third portion of the facial nerve posteriorly, and the middle cranial fossa dura superiorly. The dura along the IAC was then opened to reach the tumor.

Removal of the pathology was performed from the meatus to the fundus of the IAC using a “piecemeal” technique until a radical removal was obtained. The neoplasm was carefully dissected using traditional microscissors or appropriate elevators. Ultrasound suction was not used because of the lack of room for maneuver with the keyhole approach. Because of the relatively small dimensions of the neoplasm, we believe that conventional instruments are sufficient for dissection of tumors from the facial nerve.

The extension of the neoplasm to the CPA was removed with further bone drilling to enlarge the opening of the IAC meatus, always keeping in mind the anatomical boundaries of the dissection to avoid damage to noble structures, and following the acoustic-facial bundle towards the entry zone.

At the end of tumor excision, the endoscope allowed us to check for complete tumor removal and to gain a wider view of the vascular and nervous structures. Finally, facial nerve function was checked with the intraoperative facial nerve monitoring system.

The transpromontorial defect created was closed with a fat pad harvested from the abdomen and positioned between the inner and middle ear. Thereafter, the graft was covered by fibrin glue. The Eustachian tube was closed with muscle fragments and bone dust to avoid abdominal fat resorption caused by airflow from the rhinopharynx. The final step was cul-de-sac closure of the residual skin of the EAC.

RESULTS

Between April 2015 and January 2016, 10 patients underwent the expanded transcanal transpromontorial approach (ExpTTA) for VS at the Otolaryngology Department of the University Hospital of Modena or at the Otolaryngology Department of the University Hospital of Verona and were included in the present study.

Preoperative assessment (Table 1)

The mean age of our cohort was 53.6 years and the male/female ratio was 3:7. All patients suffered from subjective hearing loss, associated with vertigo in five cases. In addition, one patient presented a hemifacial spasm.

As regards tumor size, the mean diameter of maximum extent was 12.21 mm (range 7 to 19 mm). Koos classification was used to evaluate the growth pattern of the VS. We staged two cases as Koos Stage I and eight cases as Koos Stage II.

Preoperative hearing was classified using PTA threshold and threshold of perception at speech audiometry. Mean PTA was 66 dB HL. In four subjects, the degree of hearing loss at PTA was moderate but they presented severe vertigo with associated neurovegetative symptoms. The mean SRT was 65.8 dB, with a range from 45 dB to 100 dB. These results were calculated on 6 of the 10 patients in our casuistry, because 4 patients didn't reach this threshold.

Surgical procedures

All 10 ExpTTAs allowed us to remove the VS radically. No intraoperative complications were reported. The average length of surgery was 250 minutes. In all cases, an abdominal fat graft was used to close the transpromontorial defect and a cul-de-sac closure of the external ear canal. In eight cases, a watertight closure of the Eustachian tube was performed using either abdominal fat (n=2) or muscle fragments and bone dust (n=6). In two cases no closure of the Eustachian tube was performed. Since this procedure involves removal of the cochlea, ipsilateral deafness was present after surgery in all patients. The final histologic exam identified VS in all the specimens.

Postoperative assessment (Table 2)

Four patients were admitted postoperatively to the intensive care unit (ICU) for 24–48 hours, this as a safety measure with regard to comorbidities. In six cases, the patients were immediately extubated at the end of the procedure and monitored at the inpatient clinic. A postoperative CT scan was obtained in all patients showing no complications. The mean hospital stay after ExpTTA was 7.5 days (range: 6 to 10 days). No patient required prolonged treatment of vertigo or vestibular rehabilitation after the surgical intervention. The mean follow-up was 5 months.

One patient presented with postoperative CSF otorhinorrhea requiring a surgical revision. During the second surgical procedure, we noticed a complete reabsorption of the abdominal fat graft. The adipose tissue was removed from the temporal bone, and a graft harvested from the temporal muscle was used to repair the defect.

Facial nerve outcome

Intraoperative facial nerve monitoring was always used to detect facial nerve function during identification and removal of the neoplasm. All the patients in this study had a grade 1 (normal) preoperative facial nerve function, evaluated with the House-Brackmann grading system.[13] Immediately after surgery, 3/10 patients (30%) presented a transitory facial palsy grade II with complete recovery during the follow-up period in all cases. The remaining 7/10 (70%) patients had a normal facial nerve function immediately after surgery up to the last follow-up evaluation.

DISCUSSION

The IAC is an anatomical region, which is relatively difficult to access. Outcomes and associated complications of the various approaches with regard to VS surgery are reported in the literature.[14] These data comparisons indicate that the middle cranial fossa approach is superior to the retrosigmoid approach for hearing preservation in patients with tumors <1.5 cm.

As regards postoperative facial nerve dysfunction (House-Brackmann grade III or higher) the results are largely dependent on tumor size, as identified by a large systematic review including more than 5000 patients.[14] Comparing the different approaches the retrosigmoid technique is associated with significantly better results in patients with intracanalicular tumors than the middle cranial fossa technique (4% vs 16.7%, respectively).[14] These results were confirmed by Yamakami et al. who observed no residual facial palsy at last follow up in a cohort of 44 patients undergoing a retrosigmoid approach.[15] For patients with tumors < 1.5 cm, the middle cranial fossa procedure is associated with significantly better results with regard to facial nerve dysfunction compared with the translabyrinthine approach (3.3% vs 11.5%, respectively), and the retrosigmoid approach is the best approach in terms of saving facial nerve function for tumors 1.5–3.0 cm.[14] However, another large study on 1151 reported the middle cranial fossa approach to account for the highest percentage of postoperative facial palsy grade III or higher (32.4%) when compared to the translabyrinthine (13.9%) or retrosigmoid (3.1%) in tumors < 1cm.[16] The retrosigmoid approach is also superior to the translabyrinthine approach for tumors > 3.0 cm (30.2% vs 42.5%, respectively).[14] In our study including Koos Grade I and II VS, we noted the absence of facial nerve dysfunction in all patients at last follow-up. However it is extremely difficult to compare the different reports in literature as the surgical experience, the indications to surgery and even the method to assess tumor size[16] very considerably in literature.

Another important postoperative complication during VS surgery is CSF leakage. The incidence of CSF leakage in the literature is significantly greater after the retrosigmoid approach than after either the middle cranial fossa or translabyrinthine approaches (10.3%, 5.3%, 7.1%, respectively).[14] In our study, we observed one case of oto-rhinoliquorrhea due to abdominal fat graft resorption, with complete recovery of CSF leakage after revision surgery. Reported operative mortality rates for middle cranial fossa, retrosigmoid, and translabyrinthine approaches are 0%, 0.3% and 1.3%, respectively.[14] Concerning major neurological complications, the different rates reported in the literature for middle cranial fossa surgery, retrosigmoid approach and translabyrinthine procedure are 2.4%, 1.8% and 2.6%, respectively.[14] Of course, it is very difficult to compare those rates using classical approaches to our results because 10 patients is a very small number from which to draw conclusions. However, the authors believe that the promising results in terms of morbidity, complications and postoperative recovery in our study will be confirmed in larger case series.

Due to the reported intraoperative complications and resulting postoperative morbidity, in most cases a wait-and-scan policy is adopted for VS[17]. However, an alternative includes radiosurgical management of VS. Adequate control of VS by radiosurgery has been documented.[18] Nevertheless, no long-term results or studies which prospectively compare wait-and-scan policy to radiosurgery are available. At present, we do not know exactly what percentage of growth is stopped by radiosurgery and what percentage would have stopped anyway in their natural history, as often occurs. We have to consider that in a young patient, the choice of radiosurgery cannot exclude a possible reoperation in the future, with a higher risk of complications.

This study presents the first case series of patients operated by an ExpTTA for VS treatment. Since the first clinical application in 2013[10] the transpromontorial access was successfully used to treat Koos Stage I and II VS by the EndoTTA[12]. The endoscopic technique offers high magnification of every structure inside and outside the IAC, including the facial nerve. This straight transpromontorial access is now enriched by the present extended approach, which allows bimanual dissection and therefore enhanced control of the tumor and neurovascular structures. In fact, the endoscopic steps are also important in the ExpTTA, for example, in precise drilling of the cochlea, or during identification of the intralabyrinthine portion of the facial nerve.

Despite strict indications for VS surgery, we consider that the ExpTTA is a promising and innovative approach. The direct transpromontorial access allows complete removal of the pathology with a very low morbidity. Indications for EndoTTA and ExpTTA will probably be subject to modification in future, since they are very new techniques and improvements are still being made. At present, we would recommend an EndoTTA in the case of tumors less than 1 cm, involving the most lateral portion of the IAC. In the case of tumors of larger dimensions, exceeding 1 cm or involving the CPA, we would recommend an ExpTTA.

Concerning surgical morbidity, we have to consider that, in part, our favorable results regarding the FN are possibly due to the early stage of the VS. These tumors are less adherent to the FN inside the IAC. In our opinion, access to the intradural compartment through the EAC should not influence the risk of infection, since, in most cases, the middle ear is a sterile cavity. No infections of the surgical site or meningitis have been reported in the present case series or in EndoTTA approaches.[12] Needless to say, that hearing preservation is not feasible with this approach. Due to the removal of the cochlea a concomitant ipsilateral cochlear implantation is not possible. For this reason, the indication must include only patients with poor hearing. However, in our experience it is technically challenging to preserve the cochlear nerve when removing tumors involving the fundus of the IAC.

We wish to emphasize that in this case series, four patients were monitored postoperatively in the ICU as a precautionary measure. They did not present any complications in the immediate postoperative period. Six patients were directly extubated and sent to the inpatient clinic, just as happens in middle ear surgery. Mean hospital stay was approximately 7 days and the operative time was also quite short (approximately 250 minutes). Although the length of postoperative stay could be compared to a classical retrosigmoid or translabyrinthine approach, a further shortening of surgical times and postoperative hospital stay may be expected in the future, since, in most cases, special caution was taken due to the novelty of the technique.

In summary, the ExpTTA can be considered to be a sort of less-invasive translabyrinthine approach, since it removes the cochlea, but spares the mastoid and most of the temporal bone and avoids large skin incisions and wide soft tissue dissections. Of course, further clinical experience is necessary to confirm the potential benefits, feasibility and morbidity of this expanded approach. The risks of the approach must also be underlined: in fact, working medially towards the CPA, the risk of uncontrollable bleeding, possibly from branches of the antero-inferior cerebellar artery (AICA) would increase and the space created may not be large enough to control it. The bleeding concern is particularly true for the largest neoplasms, and for the most medial ones. In fact, in our experience with both EndoTTA and ExpTTA, the smaller masses do not have close relationships with relevant vessels, and they are only sparsely vascularized. We must emphasize that, in the case of uncontrollable bleeding which could not be managed through the EAC, a shift to a retrosigmoid approach would be facilitated by the low intracranial pressure (CSF already drained by the TTA).

Finally, every kind of endoscopic lateral skull base procedure requires a preliminary long training period in endoscopic middle ear surgery to acquire sufficient manual expertise. In addition, excellent knowledge of endoscopic landmarks is necessary, to recognize and dissect neurovascular structures inside the temporal bone in the safest manner.

CONCLUSION

The ExpTTA proved to be successful as a transpromontorial access to the IAC allowing a microscopic technique and therefore bimanual dissection. In the presented case series, we observe successful tumor removal from the cochlea, the fundus of the IAC and the most lateral portion of the CPA with low complication rates. The described approach appears to be safe and less invasive compared to traditional microscopic procedures.

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REFERENCES

1. Bennett M, Haynes DS. Surgical approaches and complications in the removal of vestibular schwannomas. Otolaryngol Clin North Am 2007 Jun;40(3):589–609.
2. Magnan J, Chays A, Lepetre C, Pencroffi E, Locatelli P. Surgical perspectives of endoscopy of the cerebellopontine angle. Am J Otol 1994 May;15(3):366–370.
3. Thomassin JM, Korchia D, Doris JM. Endoscopic guided otosurgery in the prevention of residual cholesteatomas. Laryngoscope 1993;103:939–943.
4. Presutti L, Marchioni D, Mattioli F, Villari D, Alicandri-Ciufelli M. Endoscopic management of acquired cholesteatoma: our experience. J Otolaryngol Head Neck Surg 2008 Aug;37(4):481–487.
5. Marchioni D, Alicandri-Ciufelli M, Molteni G, Genovese E, Presutti L. Endoscopic tympanoplasty in patients with attic retraction pockets. Laryngoscope 2010 Sep;120(9):1847–1855.
6. Tarabichi M. Endoscopic management of limited attic cholesteatoma. Laryngoscope 2004 Jul;114(7):1157–1162.
7. Marchioni D, Alicandri-Ciufelli M, Rubini A, Presutti L. Endoscopic transcanal corridors to the lateral skull base: Initial experiences. Laryngoscope 2015 Sep;125 Suppl 5:S1–S13.
8. Presutti L, Nogueira JF, Alicandri-Ciufelli M, Marchioni D. Beyond the middle ear: endoscopic surgical anatomy and approaches to inner ear and lateral skull base. Otolaryngol Clin North Am 2013 Apr;46(2):189–200.
9. Marchioni D, Alicandri-Ciufelli M, Mattioli F, et al. From external to internal auditory canal: surgical anatomy by an exclusive endoscopic approach. Eur Arch Otorhinolaryngol 2013 Mar;270(4):1267–1275.
10. Presutti L, Alicandri-Ciufelli M, Cigarini E, Marchioni D. Cochlear schwannoma removed through the external auditory canal by a transcanal exclusive endoscopic technique. Laryngoscope 2013 Nov;123(11):2862–2867.

11. Thakur JD, Banerjee AD, Khan IS, et al. An update on unilateral sporadic small vestibular schwannoma. Neurosurg Focus 2012 Sep;33(3):E1
12. Marchioni D, Alicandri-Ciufelli M, Rubini A, Masotto B, Pavesi G, Presutti L. Exclusive endoscopic transcanal transpromontorial approach: a new perspective for internal auditory canal vestibular schwannoma treatment. J Neurosurg 2016 Mar;11:1–8.
13. House JW, Brackmann DE. Facial nerve grading system. Otolaryngol Head Neck Surg 93:146–147, 1985
14. Ansari SF, Terry C, Cohen-Gadol AA. Surgery for vestibular schwannomas: a systematic review of complications by approach. Neurosurg Focus 2012 Sep;33(3):E14.
15. Yamakami I, Ito S, Higuchi Y. Retrosigmoid removal of small acoustic neuroma: curative tumor removal with preservation of function. J Neurosurg. 2014 Sep;121(3):554-63.
16. Falcioni M, Fois P, Taibah A, Sanna M. Facial nerve function after vestibular schwannoma surgery. J Neurosurg. 2011 Oct;115(4):820-6.
17. Patnaik U, Prasad SC, Tutar H, Giannuzzi AL, Russo A, Sanna M. The long-term outcomes of wait-and-scan and the role of radiotherapy in the management of vestibular schwannomas. Otol Neurotol 2015 Apr;36(4):638–646.
18. Jacob JT, Pollock BE, Carlson ML, Driscoll CL, Link MJ. Stereotactic radiosurgery in the management of vestibular schwannoma and glomus jugulare: indications, techniques, and results. Otolaryngol Clin North Am 2015 Jun;48(3):515–526.

FIGURE LEGENDS

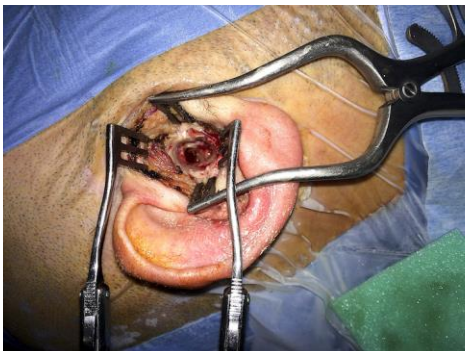

Figure 1: Right ear. External view of the access after incision and superficial soft tissue dissection.

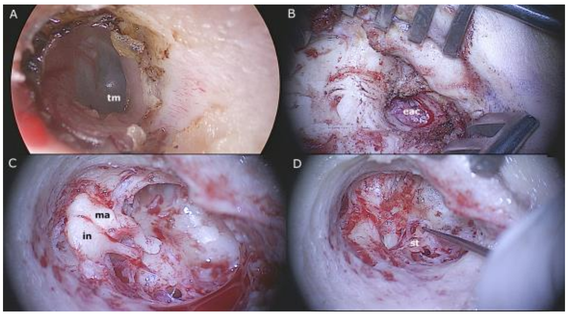

Figure 2: Right ear. Panel A: endoscopic view. Circumferential incision of the skin of the external auditory canal (EAC). Panel B: microscopic view. Shambaugh incision and superficial soft tissue displacement to widely access the bony EAC. Panel C: endoscopic view. Tympanic cavity exploration after calibration of the EAC. Panel D, endoscopic view. Ossicular chain removal.

tm: tympanic membrane, eac: external auditory canal, ma: malleus, in: incus, st: stapes.

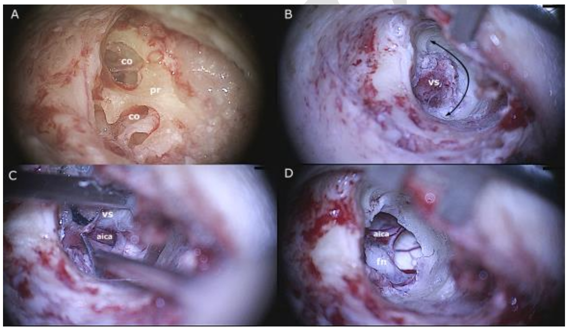

Figure 3: Right ear. Panel A: endoscopic view. Promontory drilling and exposure of the cochlea. Panel B: microscopic view. Drilling of the internal auditory canal (IAC) to expose the vestibular schwannoma (VS). Arrow indicates direction and extent of drilling. Panel C: microscopic view.

Tumor dissection from nerves and vessels. Panel D: microscopic view. AICA and facial nerve are dissected from the pathology.

co: cochlea, pr: promontory, vs: vestibular schwannoma, aica: antero-inferior cerebellar artery, fn: facial nerve

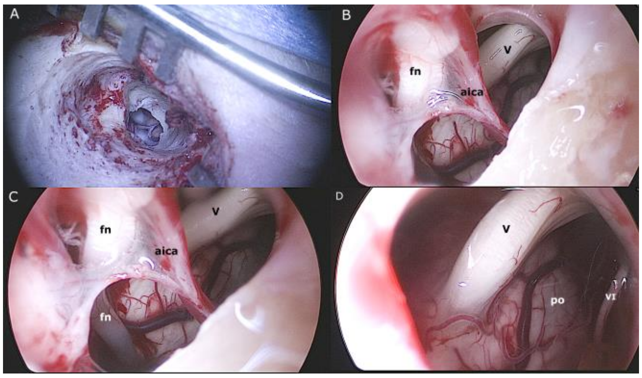

Figure 4: Right ear. Panel A: microscopic view after tumor removal (low magnification). Panel B and C: endoscopic view after tumor removal. Panel D: endoscopic view. Exploration of the CPA.

fn: facial nerve, aica: antero-inferior cerebellar artery, V: trigeminal nerve, VI: abducens nerve, po: pons

TABLE I.
Clinical Data Summary of Preoperative Assessment.

Patient	Age, yr	Sex	Disease	Symptoms	Size (Maximum Diameter), mm	Size (Koos Classification)	Hearing (PTA), dB	Hearing (SRT), dB	Institution	Main Indications to Surgery
C.C.	71	F	VS	Subjective hearing loss, vertigo	9.5	II	70	Not reached	MO	Vertigo
D.P.D.	43	M	VS	Subjective hearing loss, vertigo	17	II	65	65	MO	Vertigo
G.M.	23	F	VS	Subjective hearing loss	7	I	75	Not reached	MO	Tumour growth
A.M.	71	F	VS	Subjective hearing loss, vertigo with severe autonomic symptoms	12	II	35	45	MO	Vertigo, autonomic symptoms, patient preference
M.L.	66	F	VS	Subjective hearing loss, vertigo; tinnitus	19	II	45	50 dB	MO	Vertigo, patient preference
C.E.	49	M	VS	Subjective hearing loss	11.3	II	38.7	65 dB	VR	Tumor growth
F.L.	55	F	VS	Subjective hearing loss	14	II	97.5	Not reached	VR	Tumor growth
G.R.M.	56	F	VS	Subjective hearing loss, tinnitus, hemifacial spasm	9.6	I	113.7	Not reached	VR	Hemifacial spasm
T.E.	41	F	VS	Subjective hearing loss, vertigo	12.2	II	47.5	70 dB	VR	Vertigo
B.A.	61	M	VS	Subjective hearing loss	10.5	II	75	100 dB	VR	Tumor growth

F = female; M = male; PTA = pure-tone average; SRT = speech recognition threshold; MO = Modena; VR = Verona VS = vestibular schwannoma.