EXPANDED TRANSCANAL TRANSPROMONTORIAL APPROACH TO INTERNAL AUDITORY CANAL AND CEREBELLOPONTINE ANGLE: A CADAVERIC STUDY

Livio Presutti, MD[1]; Marco Bonali, MD[1]; Daniele Marchioni, MD[2]; Giacomo Pavesi, MD[3]; Alberto Feletti, MD[3]; Lukas Anschuetz, MD[1,4]; Matteo Alicandri-Ciufelli, MD, FEBORL-HNS[1,3].

[1]Otolaryngology-Head and Neck Surgery Department, University Hospital of Modena, Via del Pozzo 71, 41100 Modena, Italy

[2]Otolaryngology-Head and Neck Surgery Department, University Hospital of Verona, Piazzale Ludovico Antonio Scuro, 10 37100 Verona, Italy

[3]Neurosurgery Department, New Civil Hospital Sant'Agostino-Estense, Stradello Baggiovara 53, 41126 Baggiovara (MO), Italy

[4]Otolaryngology-Head and Neck Surgery Department, Inselspital, University Hospital and University of Bern, 3010 Bern, Switzerland

Short running title: Extended Transcanal Approach to the Lateral Skull Base

Corresponding Author

Dr. med. Lukas Anschuetz

Department of Otorhinolaryngology, Head & Neck Surgery, University Hospital of Modena, Modena, Italy

Via del Pozzo 71, 41100 Modena, Italy

Email: anschuetz.lukas@gmail.com

work: +390594222402

mobile: +393483895474

fax: +390594222454

Conflicts of interest

None.

Financial Disclosures

LA holds a scholarship by the Bangerter-Rhyner Foundation, Bern, Switzerland and by Karl Storz GmbH, Tuttlingen, Germany. The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

Abstract

Objective: The aim of this paper is to describe and evaluate the feasibility of an expanded endoscopic transcanal transpromotorial approach (ExpTTA) to the internal auditory canal and the cerebellopontine angle.

Study design: Experimental anatomical study

Methods: In September 2015 we performed a cadaveric dissection study. In totally 2 heads (4 sides) were dissected focusing on anatomical landmarks and surgical feasibility. Data from dissections were reviewed and analyzed for further considerations.

Results: In all 4 sides of the cadavers the procedure was feasible. In all cadavers it was necessary to extensively drill the temporo-mandibular joint and to calibrate the external ear canal to allow adequate room to manoeuver the instruments and optics and to access comfortably to the cerebellopontine angle. Also thorough skeletonization of the carotid artery and the jugular bulb were necessary for the same purpose.

Conclusions: The ExpTTA appeared to be successful for accessing the internal auditory canal and cerebellopontine angle region. Potential extensive and routinely application of this kind of approach in lateral skull base surgery will depend on the development of technology and surgical refinements and on the diffusion of skull base endoscopic skills among the otolaryngologist and neurosurgical community.

Keywords

Cerebellopontine angle; endoscopic ear surgery; inner ear; internal auditory canal; transcanal approach

Level of evidence: NA (Basic research)

Introduction

Surgical approaches to the internal auditory canal (IAC) are widely known and extensively recorded, the most popular being classified as retrosigmoid, transmastoid-translabyrinthine, and middle cranial fossa approach. Clinical indications, advantages, disadvantages, and risks in terms of mortality and morbidity have been carefully described[1] A common factor in all of the methods described to date is, that they are all indirect approaches to the inner ear, since the retrosigmoid and translabyrinthine methods approach the pathology from posteriorly, while through the middle cranial fossa approach the pathology from superiorly. To access the internal auditory canal (IAC) and cerebellopontine angle (CPA), all of these approaches require wide external incisions, and a variable degree of bone removal[1].

The first introduction of the endoscopic technique in IAC surgery has been in combination with the retrosigmoid approach[2]. After removal of the CPA portion of the neoplasm, the intracanalicular extension was removed under endoscopic control, trying to avoid extensive drilling of the posterior aspect of the petrous bone. In the surgical treatment of the middle ear the endoscope has been introduced in the 1990s[3] as an additive tool to visualize hidden areas[4]. During the last years technical improvements and growing expertise in the handling of the endoscope allowed to introduce the exclusive endoscopic approach to the middle ear[5,6] and to the lateral skull base[7,8]. The development of these endoscopic techniques required several cadaver dissections[9], to better understand the anatomy and to define appropriate instruments for this purpose. During these dissections, some advances were made in exploring the internal ear, from the labyrinth to the IAC, until an appropriate procedure was recorded, and was ready to be applied clinically.

For the first time, an exclusive endoscopic approach to the IAC was described in and used to remove a cochlear schwannoma (CS) involving IAC in March 2012. The operation used a direct transcochlear approach from lateral to medial and from external to internal auditory canal, without any external incision[10]. Other lateral skull base applications were described during the last two years by our team[7,8]. The first case series of the exclusive endoscopic transcanal transpromontorial approach (EndoTTA) to remove vestibular schwannomas involving IAC has been recently published[11].

The aim of this paper is to describe an expanded endoscopic transcanal transpromontorial approach (ExpTTA), derived from the EndoTTA, and to discuss feasibility, results and findings of this approach on a cadaver model. Since management of intracanalicular vestibular schwannomas (VSs) is complex and strongly debated[12], this kind of therapeutic option in appropriate and selected cases could modify classic concepts of the management of this pathology, also expanding indications of EndoTTA, at present limited to small vestibular schwannomas of the IAC.

Materials and Methods

In September 2015 two cadaver fresh heads (4 sides) were dissected using an endoscopic technique by the first author (LP). An expanded approach was codified and named expanded transcanal transpromontorial approach (ExpTTA). Video and photographic material were collected, and a retrospective review and analyses of data obtained by this dissection was performed in October 2015.

Surgical technique

The head was slightly extended and rotated contra-laterally, just as in the traditional endoscopic middle ear surgery. The surgeon held a 4 mm diameter, 15 cm length, 0° angled endoscope (Karl Storz Tuttlingen Germany) by the left hand, and the operative instruments by the right hand. The endoscope was connected to AIDA three-chip high-resolution monitor and camera system (Karl Storz, Tuttlingen, Germany).

- Approach to the tympanic cavity and identification of the main landmarks

First step was a circular incision of the external ear canal skin approximately 1.5 cm from the tympanic annulus, under classical traditional endoscopic view, with the endoscope introduced through the external auditory canal (EAC). The skin was then removed “en bloc” with the tympanic membrane. A Shambaugh incision (intercartilaginous skin incision between helix and tragus) was performed to allow the detachment of the lateral portion and the skin of the EAC to expose widely the bony EAC (Figure 1A). After positioning orthostatic retractors, the EAC was drilled circumferentially to allow a better view of the surgical field and to allow accurate movements of the surgical instruments in the canal (Figure 1B and 1C).

The next step was the exposition of the temporo-mandibular joint (TMJ) capsule, an important anatomical landmark for this approach representing the superficial anterior limit (Figure 1D). It was obtained by drilling the anterior wall of the EAC. A wide atticotomy was made to expose the ossicular chain (Figure 2A). Consecutively the incus and the malleus were removed to obtain a clear view of the whole tympanic tract of the facial nerve (Figure 2B), the geniculate ganglion and its relationship with the cochleariform process. The identification of the main landmarks for this approach continued with the exposition of the middle cranial fossa dura superiorly (by drilling the tympanic tegmen), the carotid artery anteriorly under the tympanic tube orifice (in the protympanic space), the jugular bulb inferiorly and the third tract of the facial nerve posteriorly, drilling the posterior aspect of the EAC and the posterior portion of the bony annulus.

- Transpromontorial micro-/endoscopic approach to the IAC

After the clear identification of the anatomical landmarks, the dissection proceeded with the removal of the stapes (Figure 2C) from the oval window and the exposition of the vestibule and the spherical recess in the saccular fossa (Figure 2D). This structure appears 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 enlargement of the oval window was made by a microcurette, a burr or by a Piezosurgery® instrument (Mectron, Carasco/Genova, Italy). At this stage, a transpromontorial approach to the IAC was performed (Figure 3A), drilling the promontorial bone and exposing progressively the basal, middle and apical turns of the cochlea.

The knowledge of the position of the labyrinthine tract of the facial nerve was allowed by the previous identification of all the anatomical structures described that were at the same time boundaries of the surgical field and surgical landmarks. An imaginary line passing from the geniculate ganglion to the spherical recess just above the apical turn of the cochlea indicated the facial nerve route through the inner ear.

The progressive drilling of the IAC was performed until the fundus of the IAC was opened, at the level of the cochlear nerve emergency (Figure 3B). Our limits of dissection at this point 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 (Figure 3C). The dissection kept on until the lateral aspect of the IAC dura was completely exposed. The dura along the IAC was then cut to reach the internal auditory canal.

The cerebellopontine angle was reached with further bone drilling to enlarge the opening of the IAC meatus, always keeping in mind the anatomical boundaries of the dissection to avoid noble structures injuries, and following the acoustic-facial bundle toward the entry zone**.** At the end of the dissection, the endoscope allowed us to check in a panoramic view the vascular and nervous structures into the IAC and CPA. Finally the obliteration of the internal auditory canal was obtained by abdominal fat (Figure 3D).

Results

In all 4 sides of the cadavers the procedure was feasible, and all the landmarks reported above were identified (Figure 4). In all cadavers it was necessary to extensively drill the TMJ and to calibrate the EAC to allow ad adequate room to maneuver the instruments and optics and to access comfortably to the CPA. Also the wide skeletonization of the carotid artery and the Jugular bulb were necessary for the same purpose.

Discussion

Actually IAC is a very poor accessible anatomical region despite the different approaches chosen. By retrosigmoid approach, a craniotomy and an extensive drilling of the posterior aspect of the petrous bone are required to fully expose the IAC. In most cases the use of endoscopes inside the CPA is required to visualize the fundus of the IAC. By translabyrinthine approach, a subtotal petrosectomy is required to identify the IAC and to properly skeletonize it. Middle cranial fossa approach guarantees less bone work to the petrous bone, but requires a wide craniotomy and temporal lobe retraction[1]. Independently of the approach, the surgery of this region (e.g. VS surgery) is traditionally considered very delicate overall. Post-operative morbidity can be high, due to intraoperative and post-operative complications. Besides this, facial nerve post-operative results are critical for functional and psychological issues and the patient’s quality of life. For those reasons, a general attitude in the management encourage in most cases wait and scan policies, so as to evaluate the growing of the mass during time[13]. In case of documented growing, a therapeutic attempt can be more strongly suggested.

In 2013 our team published the first case of EndoTTA[10]. The approach guaranteed a cochlear schwannoma removal, with IAC extension. Since this first clinical application, the authors started using more frequently the approach for stage I and II (Koos) VSs and in 2015 the first case series of ten patients was published[11]. The EndoTTA gives the possibility of a lateral to medial control of IAC, with a high magnification of every structure inside and outside the IAC, including the facial nerve. The morbidity, based at least on our first results, could be compared to those of a tympanoplasty, rather than to an operation to the CPA. Certainly, the sample size was still small, since at present the indication to EndoTTA for VSs treatment is considered as follows: growing VSs stage I or II (Koos), with class D hearing (AAO-HNS) and whose symptoms does not respond to medical treatment (e.g. intratympanic Gentamicin injections in case of debilitating vertigo). Nonetheless those very strict indications, we deem that EndoTTA is very promising, since potentially differs in terms of morbidity from the classic microscopic approaches. Moreover it guarantees a radical removal of the pathology, with a possible very low morbidity to the facial nerve, due to a direct control and magnification of the whole nerve path thanks to the endoscope. Of course the hearing preservation is not feasible by this approach, and it this for this reason that indication to surgery suggest at present patients with unserviceable hearing.

ExpTTA, as showed in the present article, would potentially expand the anatomical limits of the indication to surgery, for two main reasons. The first one is an obvious enlarged room for maneuvering the surgical instruments, compared to EndoTTA. The second one is, as direct consequence of the increased space for surgical instruments, the possible use of microscope in combination to the endoscope for some delicate steps, for example while dissecting vessels in the most medial portion of the pathology, or toward the CPA. The use of microscope would free one hand during the dissection, facilitating the procedure when necessary.

Morbidity, although it must be proved in living patients, would be at least theoretically similar to the EndoTTA, since it provides only a small skin incision between tragus and Helix (Shambaugh incision), and only a little increase in bone work.

In summary, this approach can be considered a sort of less-invasive translabyrinthine approach, since it demolishes the labyrinth, but it spares the mastoid, most of the temporal bone and avoids large skin incisions and wide soft tissue dissections. Of course clinical experience is necessary to confirm potential benefits, definite feasibility and morbidity of this expanded approach. Risks of the approach must also be underlined: actually, going medially toward CPA the risk of incontrollable bleeding, possibly from branches of the anterior inferior cerebellar artery (AICA) would increase, and the room created could not be enough to control it. Moreover, although EndoTTA has very low risk of complications such as post-operative cerebrospinal fluid leak, or facial nerve palsy, the ExpTTA could have potential higher rates of unfavorable events. Finally, every kind of endoscopic lateral skull base procedure requires a preliminary long training in endoscopic middle ear surgery to acquire enough manual expertize. Also the perfect knowledge of endoscopic landmarks is necessary, to recognize and dissect in the safest way neurovascular structures inside the temporal bone.

Conclusion

The ExpTTA is a feasible approach to access the IAC and cerebellopontine area. Potential extensive and routinely application of this kind of approach in lateral and posterior skull base surgery will depend on the development of technology and surgical refinements, and on the diffusion of skull base endoscopic skills among otolaryngologist and neurosurgical community.

References

1. Bennett M, Haynes DS. Surgical approaches and complications in the removal of vestibular schwannomas. Otolaryngol Clin North Am. 2007;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;15(3):366–70.

3. Thomassin JM, Korchia D, Doris JM. Endoscopic guided otosurgery in the prevention of residual cholesteatomas. Laryngoscope. 1993;103:939-43.

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;37(4):481–7.

5. Tarabichi M. Endoscopic management of limited attic cholesteatoma. Laryngoscope. 2004;114(7):1157–62.

6. Marchioni D, Alicandri-Ciufelli M, Molteni G, Genovese E, Presutti L. Endoscopic tympanoplasty in patients with attic retraction pockets. Laryngoscope. 2010;120(9):1847-55

7. Marchioni D, Alicandri-Ciufelli M, Rubini A, Presutti L. Endoscopic transcanal corridors to the lateral skull base: Initial experiences. Laryngoscope. 2015;125 Suppl 5:S1-13

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;46(2):189-200.

9. Marchioni D, Alicandri-Ciufelli M, Mattioli F, Nogeira JF, Tarabichi M, Villari D, Presutti L. From external to internal auditory canal: surgical anatomy by an exclusive endoscopic approach. Eur Arch Otorhinolaryngol. 2013;270(4):1267-75.

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;123(11):2862-7.

11. 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. In press

12. Thakur JD, Banerjee AD, Khan IS, Sonig A, Shorter CD, Gardner GL, Nanda A, Guthikonda B. An update on unilateral sporadic small vestibular schwannoma. Neurosurg Focus. 2012;33(3):E1

13. 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. 2014;36(4):638-46

Figure Legends

Figure 1: Shambaugh incision and removal of the tympanic membrane along with the skin of the external auditory canal (figure A and B); identification of the facial nerve (figure C) and the temporo-mandibular joint (figure D). eac external auditory canal, tc tympanic cavity, sk meatal skin, fn* third tract of the facial nerve, fn** second tract of the facial nerve, in incus, ma malleus, s stapes, rw round window niche, TMJ temporo-mandibular joint.

Figure 2: Removal of the ossicular chain and exposure of the middle cranial fossa dura (figure A and B); removal of the stapes (figure C) and skeletonization of the carotid artery and jugular bulb (figure D). tt tegmen tympani, imj incudo-malleolar joint, fn facial nerve, s stapes, rw round window niche, jn Jacobson nerve, mcf-d middle cranial fossa dura, tmj temporo-mandibular joint, gpn great petrous nerve, ant antrum, lsc lateral semicircular canal, cp cochleariform process, cp* cochleariform process overturned, ttm tensor tympani muscle, et Eustachian tube, ow oval window, gg geniculate ganglion, ca carotid artery, jb jugular bulb.

Figure 3: Approach to the fundus of the IAC and identification of the first tract of the facial nerve. fn facial nerve, fn* facial nerve first tract, fn** facial nerve second tract, fn*** facial nerve third tract, cho cochlea, gg geniculate ganglion, gpn great petrous nerve, sph spherical recess, ca carotid artery, chon cochlear nerve, iac-d internal auditory canal dura, cp cochleariform process, mcf-d middle cranial fossa dura, fat abdominal fat.

Figure 4: (left ear) picture showing the main landmark of the approach. Jb: jugular bulb; ca: carotid artery; pr: promontory; chon: cochlear nerve; fn: facial nerve; fn*: intralabyrinthine facial nerve; fn**: facial nerve on the internal auditory canal; iac: internal auditory canal; rw: round wondow; lsc: lateral semicircular canal; mcf: middle cranial fossa; gg: geniculate ganglion; gpn: greater petrosal nerve.

Acknowledgements

LA holds a scholarship by the Bangerter-Rhyner Foundation, Bern, Switzerland and by Karl Storz GmbH, Tuttlingen, Germany. The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.