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Combined Lateral Microscopic/Endoscopic Approaches to Petrous Apex Lesions: Pilot Clinical Experiences

Livio Presutti, MD[1], Matteo Alicandri-Ciufelli, MD[1], Alessia Rubini, MD[1], Federico Maria Gioacchini, MD[1], and Daniele Marchioni, MD[1]

Abstract

Background: Surgical treatment of lesions involving the temporal bone, petrous apex, or internal auditory canal is usually performed using the classical microscopic approach that necessitates wide external incisions and soft tissue dissection. At present, the main application of endoscopic surgery is in the surgical treatment of middle ear cholesteatoma, but with the natural evolution of the technique, there will be an increasing number of applications in lateral skull base surgery.

Objective: This study aimed to describe the pilot clinical experiences of our institution with combined microscopic/endoscopic-assisted approaches to the lateral skull base.

Methods: A retrospective chart review was performed on patients undergoing an operation between July 2005 and September 2011 for lateral skull base pathology using the endoscope-assisted technique.

Results: Nine patients (7 female, 2 male; mean age = 57.4 years) were reviewed and included in the present study. In all cases, the petrous apex lesion of each patient was unilateral: 6 cases had cholesteatoma of the petrous bone; 2 cases had cholesterinic granuloma of the petrous apex; and 1 case had a low-grade chondrosarcoma of the petrous apex. Overall, after a mean follow-up of 30.7 months, no residual disease has been found in our series up to the present time in the cholesteatoma group. In the cholesterinic granuloma group, only a partial success was obtained in the patient who underwent the infracochlear approach, since the most medial part of the pathology was not accessed and still persisted at neuroradiologic examinations made postoperatively.

Conclusion: In our case series, lateral combined microscopic/endoscopic procedures have proved to be effective in the treatment of petrous apex lesions, allowing less destructive approaches compared to exclusive microscopic procedures.

Keywords
combined approaches, petrous apex

Introduction

Endoscopic instrumentation, techniques, and knowledge are rapidly improving, and in the future, endoscopic surgery may gain increasing importance in otology. Most of the spaces traditionally considered to be difficult to access with the exclusive use of a microscope could be easily explored with an endoscope, used either in combination with a microscope[1] or exclusively.[2] Recently, new physiological,[3] anatomical,[4] and surgical concepts[2,5-8] have been introduced thanks to application of the endoscope in middle ear surgery.

At present, the main application of endoscopic surgery is in the surgical treatment of middle ear cholesteatoma, but with the natural evolution of the technique, there will be an increasing number of applications in lateral skull base surgery. In fact, based on the increasing experience of the present authors in endoscopic ear surgery, it has gradually been noted that the internal ear,[9] the petrous apex, and virtually the entire temporal bone could be accessed more easily in an endoscopic-assisted fashion. Due to the vital structure contained in the petrous bone, codification of the landmarks

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Table 1. Patients' Preoperative Assessment.

Patient No.	Age, y	Pathology	Preoperative Symptoms	Preoperative Radiologic Study
1	52	Middle ear and petrous apex cholesteatoma	Right sensorineural hearing loss	Middle ear CT; cerebellopontine angle MRI
2	71	Petrous bone cholesterinic granuloma	Right anacusis	Middle ear CT; cerebellopontine angle MRI
3	33	Petrous apex cholesterinic granuloma	Left tinnitus	Angiography; middle ear CT; cerebellopontine angle MRI
4	59	Petrous bone cholesteatoma	Left sensorineural hearing loss	Middle ear CT; cerebellopontine angle MRI
5	43	Petrous apex low grade chondrosarcoma	Occasional vertigo; right hemifacial spasms	Middle ear CT; cerebellopontine angle MRI
6	58	Petrous bone cholesteatoma	Right tinnitus; right sensorineural hearing loss	Middle ear CT; cerebellopontine angle MRI
7	72	Petrous bone cholesteatoma	Left sensorineural hearing loss	Middle ear CT; cerebellopontine angle MRI
8	79	Large middle ear cholesteatoma with supralabyrinthine extension	Bilateral sensorineural hearing loss	Middle ear CT; cerebellopontine angle MRI
9	50	Petrous bone and pontocerebellar angle cholesteatoma	Left sensorineural hearing loss	Middle ear CT; cerebellopontine angle MRI

Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

and procedures and their integration into classical microscopic approaches are, in the authors' opinion, the first steps in the possible future evolution of application of the endoscopic technique to the lateral skull base. At present, some experience of endoscopic ear surgery of the lateral skull base has already been gained both in cadaveric dissections[9] and in patients.

In fact, all of the classical microscopic approaches to the temporal bone, petrous apex, or internal auditory canal (IAC) necessitate wide external incisions and soft tissue dissection—in some cases, craniotomy (retrosigmoid, middle cranial fossa), extensive temporal bone drilling, healthy tissue removal (translabyrinthine, transotic, transcochlear, infralabyrinthine), cerebellopontine angle exposure by cerebellar retraction (retrosigmoid), and temporal lobe retraction (middle cranial fossa)—and cannot really be considered to be minimally invasive. Moreover, in some of those approaches, the labyrinth must be destroyed (transcochlear, transotic) or the facial nerve rerouted (transcochlear, infralabyrinthine), and this is done to gain room to access, visualize, and operate in the most inaccessible spaces of that region.

The aim of the present article is to describe the pilot clinical experiences of our institution with combined microscopic/endoscopic-assisted approaches to the lateral skull base. Although it represents an initial experience, it could help those undertaking this kind of surgery to introduce the endoscope in some surgical steps during pathology removal, with the aim of limiting tissue destruction and improving visualization of hidden areas, sparing, whenever indicated, as many structures as possible.

Methods

A retrospective chart review was performed on patients undergoing an operation for lateral skull base pathology by the endoscope-assisted technique. All patient charts were obtained to gather clinical information about preoperative symptoms, preoperative examination and radiology, surgical reports, and postoperative course. Patients available and not lost at follow-up were contacted to undertake a control visit, during which facial nerve function was assessed by means of the House-Brackmann grading system, and when necessary, an audiometric evaluation was performed.

Results

Nine patients (7 female, 2 male; mean age = 57.4 years) undergoing an operation between July 2005 and September 2011 were reviewed and included in the present study. In all cases, the petrous apex lesion of each patient was unilateral: 6 cases had cholesteatoma of the petrous bone; 2 cases had cholesterinic granuloma of the petrous apex; and 1 case had a low-grade chondrosarcoma of the petrous apex.

The preoperative symptoms were analyzed for each patient (Table 1). Unilateral hearing loss on the side of the lesion was the most common symptom (found in 6 out of 9 cases); good hearing function was present in 2 cases (1 patient with cholesterinic granuloma and 1 patient with petrous apex chondrosarcoma); preoperative dizziness was reported in 1 case; facial muscle fasciculations were present in 1 case; and preoperative tinnitus was present in 1 case.

Based on the characteristics of the lesion, on the hearing function, and on the extent of the pathology to the inner ear and petrous apex, 2 different approaches were selected. In cases with hearing loss or poor hearing function, a *transotic endoscopic-assisted approach* was chosen. In cases with lesions extending into the petrous bone without labyrinthine or cochlear involvement and in patients with good hearing function, preservation of hearing was attempted by performing an *infracochlear endoscopic-assisted approach* or an *infralabyrinthine endoscopic-assisted approach*.

Transotic Endoscopic-Assisted Approach

Under microscopic visualization, an incision was made roughly 2 to 3 cm from the retroauricular groove, and tissues covering the mastoid were raised. The skin of the external auditory canal and the tympanic membrane were removed, and the malleus and incus were identified and removed. A mastoidectomy was performed by a canal wall-down technique, by identifying the classical landmarks such as the middle cranial fossa dura, which was skeletonized posteriorly to the sinodural angle, and the sigmoid sinus, lying posteriorly and inferiorly. The posterior cranial fossa dura was identified and followed medially toward the bony labyrinth and endolymphatic sac. When required, a skeletonization of the jugular bulb was performed. The tympanic tract of the facial nerve was then exposed and skeletonized until the geniculate ganglion was exposed superiorly to the cochleariform process. During this procedure, a thin bony layer of the Fallopian canal was maintained to protect the nerve. Based on the extent of the pathology, the following surgical procedures were then adopted:

- In the case of IAC involvement by pathology or infralabyrinthine extent, a labyrinthectomy was performed until the dura of the IAC was identified, so as to adequately reach the disease.
- When required, drilling at the retrofacial recess was also performed, creating a communication between the cochlear region and the tympanic cavity.
- If the lesion extended anteriorly involving the internal carotid artery, a wide skeletonization of the vertical tract of the carotid artery was performed. In some cases, drilling was extended anteriorly to the carotid itself toward the tubaric region, so as to isolate that vessel circumferentially.
- In cases where the lesion involved the cochlea, the stapes was removed and the vestibule was identified; the promontory was drilled out until the cochlea was completely open. If necessary, based on the extent of the pathology, further drilling of the cochlea was performed, until the IAC fundus was visualized.

After all of the above-mentioned microscopic steps, the endoscopic procedure followed based on the extent of the pathology.

In the case of carotid involvement when the pathology involved the petrous apex, going toward the most medial and anterior part of the carotid artery, an endoscope was inserted into the mastoid cavity, allowing magnification of the protympanum and the surrounding anatomical structures such as the carotid artery and Eustachian tube (Figure 1). A 45-degree endoscope, 15 cm in length and 4 mm in diameter, was used to perform this step. The position of the carotid artery was detected, and when required, extensive drilling was performed at the pericarotic level under endoscopic view, reaching anteriorly and medially to the vertical tract of the carotid artery, and inferiorly to the horizontal carotid artery without extensive manipulation of the vessel itself. During this surgical procedure, the main surgical landmarks considered were the cochlea, the vertical tract of the carotid artery, the tensor tympani muscle and geniculate ganglion, and the jugular bulb (if protruding into the tympanic cavity). When a wide endoscopic access to the supratubaric region was required, the cochleariform process with the tensor tympani muscle was removed. The greater petrosal nerve was identified by following the geniculate ganglion anteriorly under endoscopic view. This anatomical structure can be considered to be the superior limit of the dissection, representing an important landmark for the internal carotid artery in its horizontal portion. In fact, during the endoscopic approach to the carotid artery, the search for the greater petrosal nerve could indicate where the horizontal tract of the carotid artery was located.

Then, drilling of the area including the vertical tract of the carotid artery anteriorly, the cochlea posteriorly, the greater petrosal nerve superiorly, and the jugular bulb inferiorly was performed. When required, drilling of the bony wall of the vertical tract of the carotid artery was performed under endoscopic view, allowing opening of the paraclival air cells anteriorly with respect to the vertical tract. In these cases, drilling was carried out medially to the internal carotid artery, until the air cells of the petrous apex and clivus were reached. Based on the extent of the pathology, the horizontal tract was identified endoscopically and followed medially and anteriorly to the anterior carotid foramen. Once the air cells lying inferiorly to the carotid and around the carotid had been drilled, the pathology was removed using curved dissectors and suction.

In the case of labyrinthine facial nerve and IAC involvement by pathological tissue, the following steps were performed. A 45-degree endoscope, 14 cm in length and 4 mm in diameter, was inserted into the mastoid cavity, and the geniculate ganglion region and labyrinthine tract of the facial nerve with its relationship to the vestibule were endoscopically detected. The anatomic areas lying medially and anteriorly to

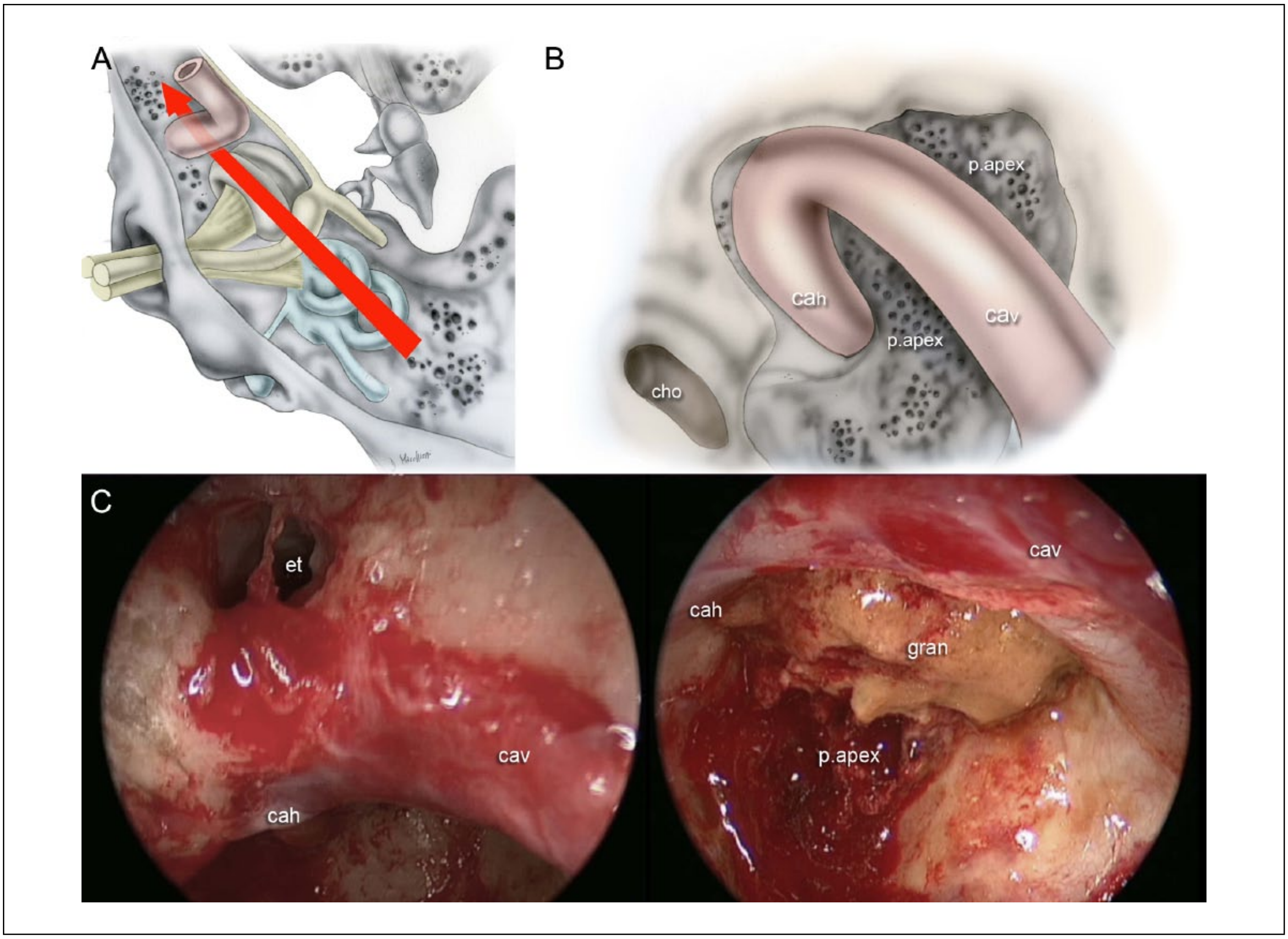

Figure 1. Cholesterinic granuloma of the petrous apex. (A) Temporal bone from above: schematic drawing representing the transotic approach (red arrow). (B) Endoscopic view of the carotid artery; the vertical and horizontal portions of the carotid artery are detected endoscopically, and the petrous apex is exposed lying medially with respect to this vascular structure. (C) Clinical case; right ear: after the microscopic steps, the endoscope permitted the exposure of the lesion lying medially and anteriorly with respect to the carotid artery. cah, horizontal tract of the carotid artery; cav, vertical tract of the carotid artery; cho, cochlea; et, Eustachian tube; gran, cholesterinic granuloma; p.apex, petrous apex cells.

the labyrinthine facial nerve were exposed endoscopically and the nerve was followed in its anterior and posterior, and lateral to medial directions as far as the IAC. The pathological tissue was detected and removed from the labyrinthine tract of the facial nerve and surrounding structures, avoiding the rerouting of the facial nerve and reducing manipulation of the nerve as much as possible (Figure 2).

If the lesion did not involve the IAC dura, the dura layer was preserved avoiding cerebrospinal fluid leakage; when dural involvement by pathology was found, an endoscopic dissection and preservation of the facial nerve into the IAC was attempted, removing the lesion from the IAC (Figure 3). The dural defect was closed with a muscular fragment placed on the surgical cavity.

When retrofacial area involvement was found after microscopic posterior retrofacial tympanotomy, a 45-degree endoscope was used permitting complete removal of the pathology from this area, without the necessity for facial nerve rerouting, such as occurs during classical exclusive microscopic transcochlear approaches.

Once both microscopic and endoscopic procedures had been completed, obliteration of the Eustachian tube was made with a temporalis muscle fragment. The surgical cavity was also obliterated with abdominal fat. The procedure was ended by a cul-de-sac closure of the external ear canal skin.

Infralabyrinthine Endoscopic-Assisted Approach

When a lesion extended inferiorly to the labyrinth in a patient with good hearing function, an infralabyrinthine endoscopic-assisted approach was performed.

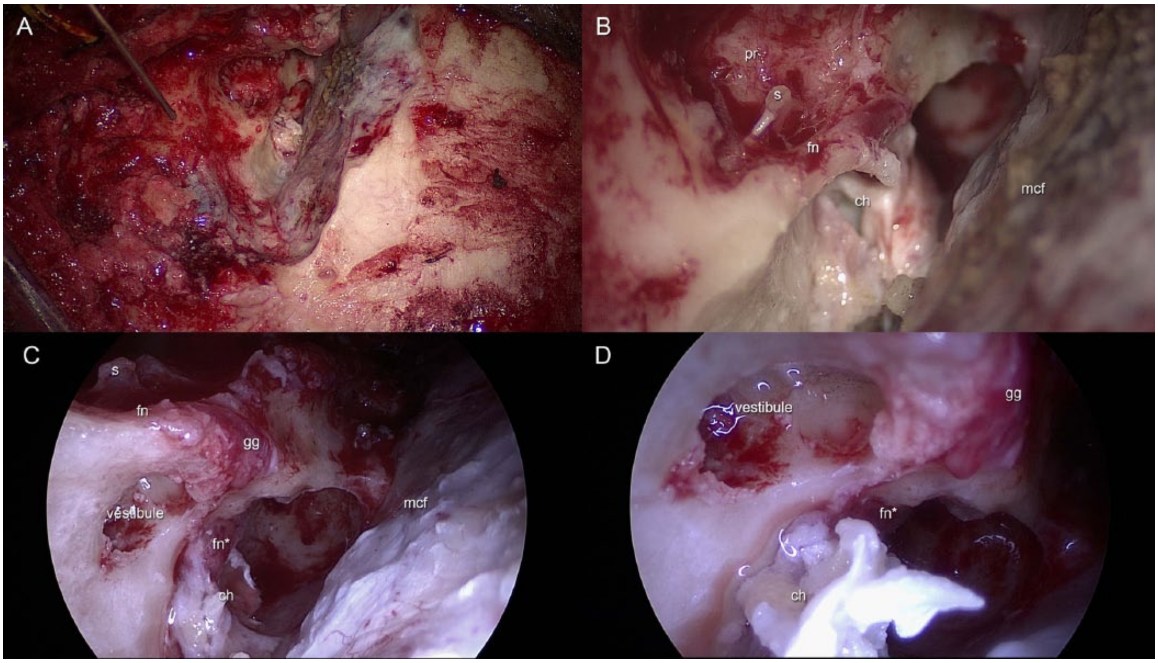

Figure 2. Cholesteatoma of the petrou.s apex. (A) Clinical case; left ear: general microscopic view after the microscopic procedure during the transotic approach. (B) Microscopic view of the tympanic facial nerve and vestibule after labyrinthectomy. (C) The introduction of a 45-degree endoscope allowed better exposure of the vestibule and the labyrinthine facial nerve, exposing the residual cholesteatoma (D). ch, cholesteatoma; fn, tympanic facial nerve; fn*, labyrinthine facial nerve; gg, geniculate ganglion; mcf, middle cranial fossa; pr, promontory; s, stapes.

An incision was made approximately 2 to 3 cm from the retroauricular groove, and tissues covering the mastoid were raised. A mastoidectomy was performed, clearly exposing the middle cranial fossa dura and sigmoid sinus. The jugular bulb was detected inferiorly and the mastoid tract of the facial nerve was identified anteriorly to the digastric ridge. After antrotomy, the otic capsule and fossa incudis were identified. Retrofacial air cells were drilled inferiorly to the posterior and lateral semicircular canal, and medially to the mastoid segment of the facial nerve, creating sufficient room for the introduction of optics.

The anatomic limits considered during this dissection were the labyrinth superiorly, the facial nerve (mastoid tract) anteriorly and laterally, and the posterior cranial fossa dura and sigmoid sinus with jugular bulb posteriorly and inferiorly. A 45-degree endoscope was inserted into the mastoid cavity and under the retrofacial recess, reaching the petrous apex. A preliminary endoscopic exploration was performed to identify the anatomical landmarks, and in cases where erosion of the temporal bone was provoked by the disease eliminating the anatomical structures of the petrous apex, special attention was paid to detect the IAC dura and the carotid artery. Dissection of the pathological tissue was carried out endoscopically, carefully removing this tissue from the vascular structures and IAC. Once the pathology had been removed, a final exploration of the surgical cavity was performed with a 45-degree endoscope to identify any possible residual pathology. At the end of the procedure, the tympanic cavity remained substantially preserved.

Infracochlear Endoscopic-Assisted Approach

When a lesion extended inferiorly to the cochlea, an infracochlear endoscopic-assisted approach was used. A standard postauricular incision was performed, and a tympanomeatal flap was raised as far as the fibrous annulus. The annulus was then raised, entering the tympanic cavity, while pulling the tympanic membrane superiorly, maintaining the adhesion to the umbo. The endoscope was then introduced through the external auditory canal, and the inferior bony annulus was thus exposed endoscopically; a diamond bur was used to remove the inferior portion of the bony annulus, visualizing the hypotympanum. The round window niche and the inferior prominence of the promontory were detected endoscopically (representing the superior limit of the dissection). The course of the carotid artery anteriorly and the jugular bulb posteriorly was always

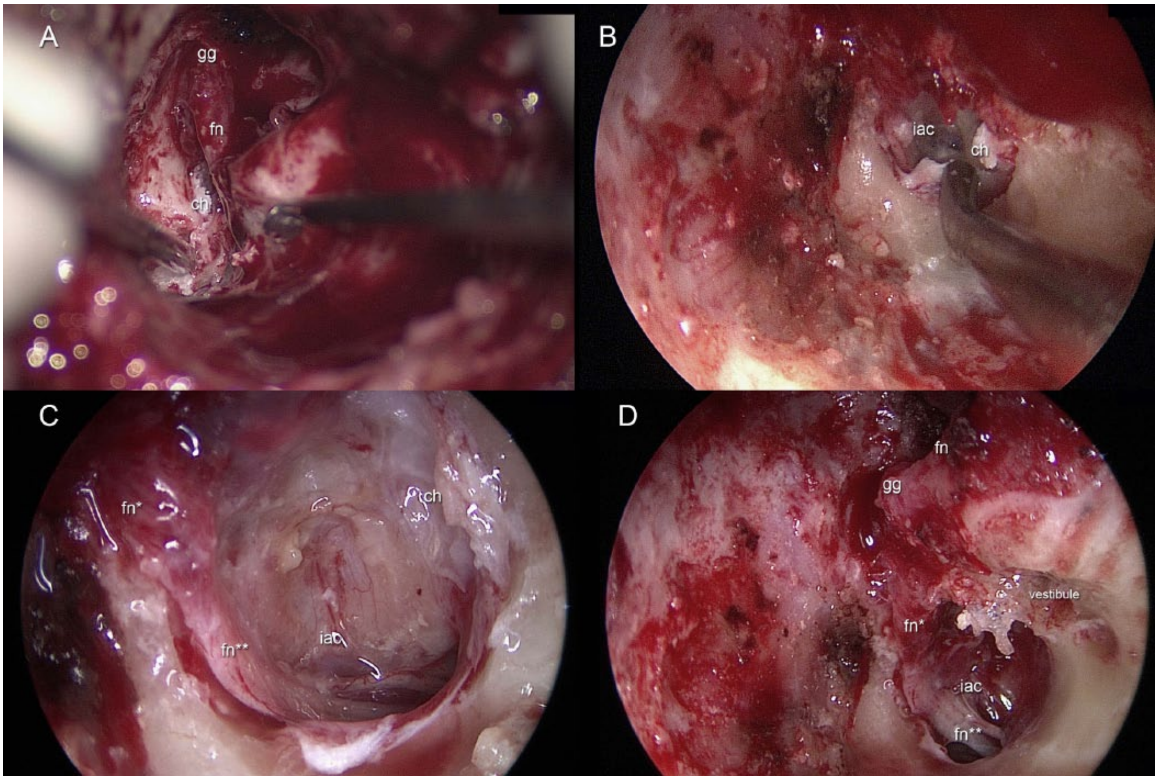

Figure 3. Cholesteatoma of the petrous apex. (A) Clinical case; right ear: general microscopic view after the microscopic procedure. (B) A 45-degree endoscope was used to expose the fundus of the IAC, detecting the residual cholesteatoma. (C) The intrameatal facial nerve was preserved and residual cholesteatoma identified and removed. (D) Final endoscopic view after cholesteatoma removal, showing the entire tract of the inner facial nerve from the geniculate ganglion to the internal auditory canal. ch, cholesteatoma; fn, tympanic facial nerve; fn*, labyrinthine facial nerve; fn**, IAC facial nerve; gg, geniculate ganglion; iac, internal auditory canal.

highlighted and exposed by the diamond bur. These 2 vascular structures were used as landmarks in the dissection, representing, respectively, the anterior and posterior limits of the dissection (Figure 4). The bony cells between the jugular bulb and the carotid artery, below the cochlea, were removed endoscopically, providing exposure of the inferior portion of the petrous apex and allowing the removal of the disease from this anatomical area. The petrous apex was exposed by further introducing the endoscope through the route created, to verify the complete eradication of the pathology.

A Silastic sheet was inserted through the tympanic cavity to guarantee ventilation of the petrous apex, and the eardrum and external ear canal skin were replaced at the end of the procedure.

As mentioned above, on the basis of the extent of the disease, different surgical approaches were used. If a normal hearing function was found (in 2 out of 9 cases), hearing preservation was attempted, selecting a conservative approach: 1 patient underwent an infralabyrinthine endoscopic-assisted approach and 1 patient underwent an infracochlear endoscopic-assisted approach. When preoperative hearing loss was established, a transotic endoscopic-assisted surgery was selected (7 out of 9 cases). Surgical data from our chart review are summarized in Table 2.

Facial Nerve Results

In 6 out of 9 patients affected by petrous bone cholesteatoma, an involvement of the IAC and the labyrinthine facial nerve was found (Figure 5). In all of these patients, it was possible to remove the cholesteatoma matrix from the geniculate ganglion and from the medial aspect of the labyrinthine facial nerve endoscopically, and no rerouting of the facial nerve was required in any patient. In 2 out of 6 patients, it was necessary to remove the cholesteatoma matrix from the fundus of the IAC using a 45-degree endoscope, and in these cases, it was possible to remove the cholesteatoma endoscopically, preserving the integrity of the facial nerve into the IAC. In 5 out of 9 patients, a normal preoperative function (House-Brackmann [HB] grade I) of

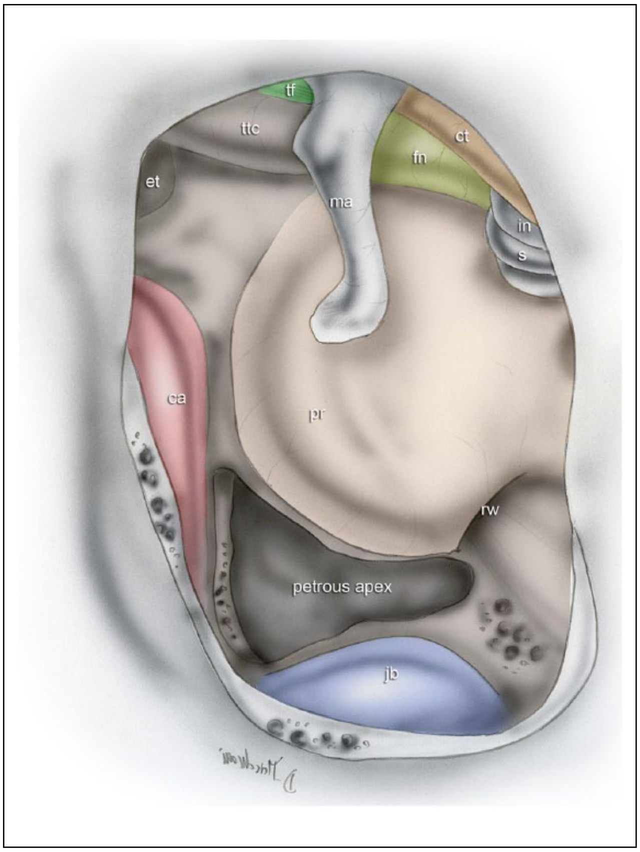

Figure 4. Left ear. Schematic drawing representing the infracochlear approach; the carotid artery and the jugular bulb were exposed; the petrous apex was reached by removal of the bony cells between the vascular structures and the promontory using a diamond bur. ca, carotid artery; ct, chorda tympani; et, Eustachian tube; fn, facial nerve; in, incus; jb, jugular bulb; ma, malleus; pr, promontory; rw, round window; s, stapes; tf, tensor fold; ttc, tensor tendon canal.

the facial nerve was found, and the surgical approach was selected based on the extent of the diseases: 3 patients underwent transotic endoscopic-assisted surgery; 1 patient underwent an infracochlear endoscopic-assisted approach; and 1 patient underwent an infralabyrinthine endoscopic-assisted approach. In the postoperative period, 3 out of 5 patients showed a normal function of the facial nerve (HB grade I), whereas 2 out of 5 patients showed HB grade II facial nerve palsy.

In 4 out of 9 cases, facial nerve function with varying degrees of impairment was found preoperatively. HB grade III-IV was observed in 1 patient; in 3 patients, a severe impairment of facial nerve function (grade V-VI) was observed. Of these, postoperatively, the facial nerve function was as follows: in 2 patients with HB grade V-VI, the facial nerve did not show any improvement after surgery; in 2 patients, an improvement in facial nerve function was observed (in 1 patient, from HB grade III-IV to grade II; in the second patient, from HB grade V-VI to grade IV).

Hearing Function Results

In 2 out of 9 patients, the preoperative hearing test showed a useful hearing function on the affected side (pure tone audiometry [PTA]-air conduction [AC] = 48.75 dB HL and PTA-bone conduction [BC] = 20.62 dB HL) and a preservation of hearing function was attempted. In both patients, it was possible to use a conservative approach, preserving the hearing function (1 infracochlear endoscopic-assisted approach and 1 infralabyrinthine endoscopic-assisted approach) (PTA-AC = 51.25 dB HL and PTA-BC = 29.37 dB HL).

In 6 out of 9 patients, the preoperative hearing test showed an intermediate to severe sensorineural hearing loss in the affected ear (PTA-AC = 85.31 dB HL and PTA-BC = 52.19 dB HL) and a transotic surgical procedure was selected. In all of these patients, a postoperative anacusis was expected and hence observed.

In 1 out of 9 patients, the preoperative hearing test was not performed.

Carotid Artery

In 3 patients where the disease involved the internal carotid artery, during the endoscopic steps, it was possible to visualize the medial surface of the vertical portion of the carotid artery completely, removing the pathological tissue and, when necessary, drilling the cellular tissue of the petrous apex lying anteriorly to the vessel. In patients in whom the horizontal tract of the carotid artery was also involved, during the endoscopic procedure, it was possible to detect the horizontal tract of the carotid artery, removing the disease from this anatomical area without further manipulation or displacement of the artery.

Residual/Recurrence

The mean follow-up of this series was 30.7 months. During the follow-up time, magnetic resonance or computed tomography scans were performed with timing based on clinical issues (type of pathology and eventual onset of new symptoms). In the cholesteatoma group, no residual disease has been found in our series up to the present time (6 out of 6 patients). In the cholesterinic granuloma group (2 patients), only a partial success was obtained in the patient who underwent the infracochlear approach, since the most medial part of the pathology, lying at the most medial and inferior part of the temporal bone, was not accessed and still persisted at neuroradiologic examinations made postoperatively.

Table 2. Results.

Patient No.	Type of Lesion	Surgical Operation	Follow-Up, mo	Preoperative Grade of Facial Nerve Function[a]	Postoperative Grade of Facial Nerve Function[a]	Preoperative PTA[b]	Postoperative PTA[b]
1	Middle ear and petrous apex cholesteatoma	Transotic endoscopic-assisted approach	86	III	II	Not found	—
2	Petrous bone cholesterinic granuloma	Transotic endoscopic-assisted approach	40	I	I	Right anacusis	—
3	Petrous apex cholesterinic granuloma	Infracochlear endoscopic-assisted approach	63	I	I	Air conduction: 61.25 dB HL; bone conduction: 25 dB HL	Air conduction: 61.25 dB HL; bone conduction: 25 dB HL
4	Petrous bone cholesteatoma	Transotic endoscopic-assisted approach	15	V	IV	Air conduction: 61.25 dB HL; bone conduction: 36.25 dB HL	—
5	Petrous apex low grade chondrosarcoma	Infralabyrinthine endoscopic-assisted approach	13	I	I	Air conduction: 36.25 dB HL; bone conduction: 16.25 dB HL	Air conduction: 41.25 dB HL; bone conduction: 33.75 dB HL
6	Petrous bone cholesteatoma	Transotic endoscopic-assisted approach	12	I	II	Right anacusis	—
7	Petrous bone cholesteatoma	Transotic endoscopic-assisted approach	10	V-VI	V-VI	Air conduction: 83.75 dB HL; bone conduction: 60 dB HL	—
8	Large middle ear cholesteatoma with supralabyrinthine extension	Transotic endoscopic-assisted approach	11	I	II	Air conduction: 76.25 dB HL; bone conduction: 46.25 dB HL	—
9	Petrous bone and pontocerebellar angle cholesteatoma	Transotic endoscopic-assisted approach	26	VI	VI (following facial surgery; actual Grade IV)	Air conduction: 120 dB HL; bone conduction: 66.25 dB HL	—

[a]House-Brackmann grading system.
[b]PTA, pure tone audiometry of the pathological ear obtained by calculating the average between the thresholds of the 500–1000–2000–4000 Hz frequencies.

Discussion

Otoneurosurgical procedures for lesions located in the petrous apex and temporal bone are a real challenge for surgeons. At present, these interventions are based on microscopic procedures, despite the progress made in endoscopic ear surgery. These microscopic procedures have been precisely codified, although in most circumstances, they are extremely aggressive, with extensive demolition of temporal bone structures, and are also variably aggressive toward crucial anatomical structures such as the facial nerve, otic capsule, and carotid arteries.

Based on the extent of the disease and despite the normal functioning of the facial nerve, microscopic transcochlear approaches with posterior rerouting of the facial nerve are required in some cases to reach and remove the pathological tissue, when pathological processes extend to the most anterior portions of the petrous bone: these procedures provoke a poor function of the facial nerve postoperatively, due to the extensive manipulation and devascularization of the facial nerve. In fact, the labyrinthine facial nerve runs from the geniculate ganglion to the IAC anteriorly to posteriorly, and to the fundus of the IAC laterally and medially. The position of the facial nerve makes it difficult to obtain a clear microscopic view of the most anterior portion of the labyrinthine facial nerve, also limiting access to the petrous apex since the nerve and geniculate ganglion cover these portions (Figure 6). So, when pathological tissue such as cholesteatoma involves the labyrinthine facial nerve extending anteriorly with respect to this structure, a traditional transotic procedure is not sufficient to expose the pathological tissue and a hard manipulation or a rerouting of the nerve could be required. In fact, the traditional transotic approach allows removal of disease tissue, maintaining the facial nerve in the Fallopian canal and avoiding rerouting of the nerve. For this reason, in some cases, a transcochlear approach is required to maintain direct control of these anatomical structures and the whole petrous apex.

In the present authors' opinion, the surgical procedure for lesions of the petrous apex and lateral skull base will remain for long microscopic procedures, but from our experience, the introduction of endoscopic surgery has allowed "around the corner" exploration and disease removal from critical anatomical areas around the

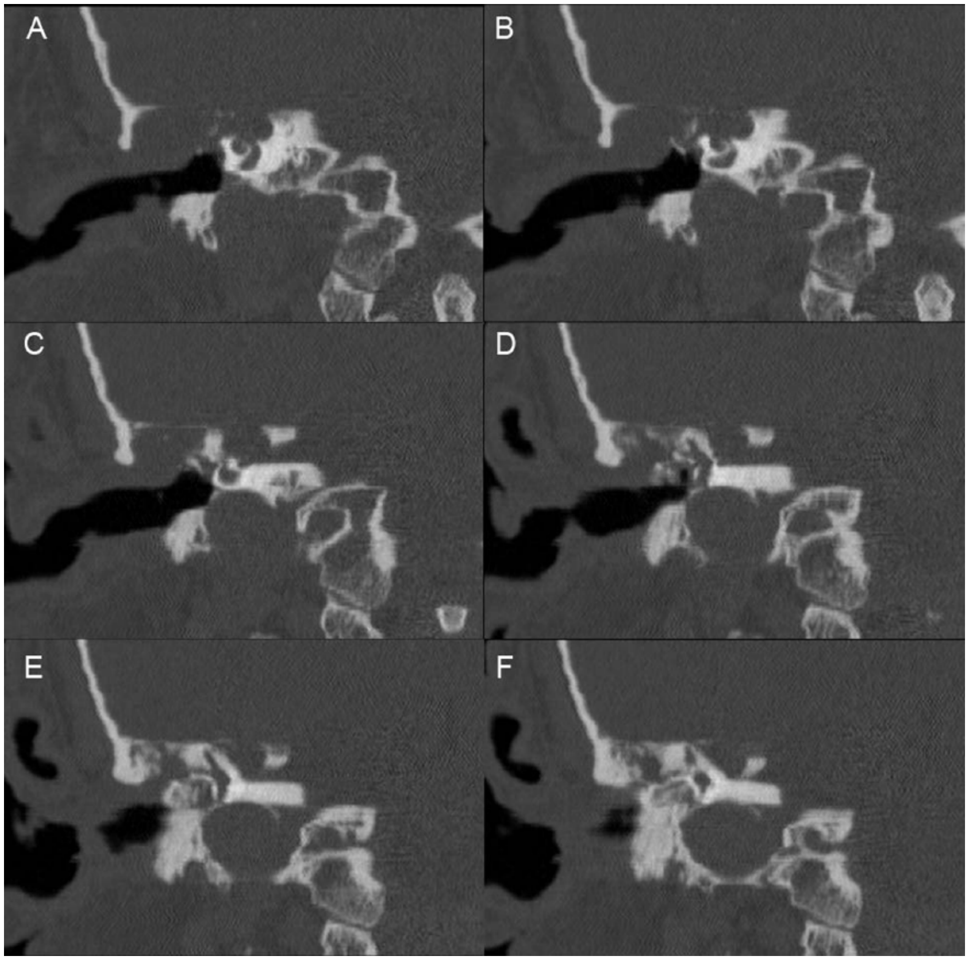

Figure 5. Computed tomography images, coronal slices. (A-B) Supracochlear extension of cholesteatoma with involvement of the geniculate ganglion's area. (C-D) Involvement of the internal auditory canal. (E-F) Labyrinthine fistula.

Fallopian canal, without displacing the structures that lie between the surgeon and the pathology, in particular, the petrous apex and the most anterior portions of the temporal bone. For this reason, transotic endoscopic-assisted surgery might be considered as a conservative approach with respect to the facial nerve but with the same capacity and possibly disease control as the transcochlear microscopic approach.

Endoscopic dissection of the carotid artery was also considered in our study. In 3 patients, the endoscopic-assisted surgery permitted control of both the vertical and horizontal tracts of this vascular structure, reaching the petrous apex medially and anteriorly with respect to this vessel, without rerouting the facial nerve.

The limitations of this study were the low number of patients due to rarity of lesions of the petrous apex, and the short follow-up. Moreover, it must be considered that cholesteatoma is a pathology that presents completely different problems in prognostic terms from cholesterinic granuloma or low grade chondrosarcoma.

Conclusion

Lateral combined microscopic/endoscopic procedures have proved to be effective for petrous apex lesion treatment in the case series reported. In our experience, it allowed less destructive approaches to be used compared to exclusive microscopic procedures, sparing temporal bone tissue as much as possible. In particular, an adequate exposure of the horizontal and vertical tracts of the carotid artery can be obtained, helping to avoiding rerouting of the facial nerve, and the distal and medial spaces of the petrous bone and petrous apex can be visualized with angled optics. Further developments are necessary to be able to draw definite

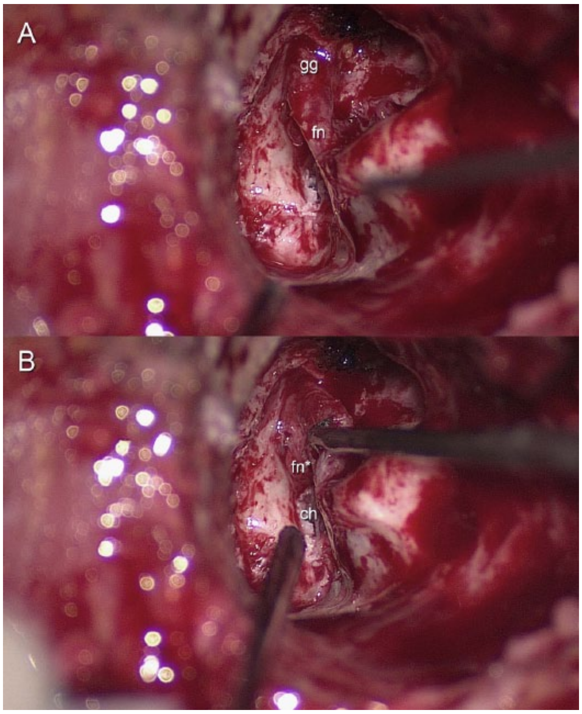

Figure 6. Cholesteatoma of the petrous apex. Right ear: microscopic procedure after the transotic approach. (A) The tympanic segment of the facial nerve was uncovered as far as the geniculate ganglion anteriorly. (B) The labyrinthine segment of the facial nerve is hidden beyond the tympanic segment because of the straight axis of the microscope; a dissector was used to lift the tympanic segment of the facial nerve anteriorly, partially uncovering the labyrinthine segment. ch, cholesteatoma; fn, facial nerve; fn*, labyrinthine facial nerve; gg, geniculate ganglion.

conclusions about the utility of the endoscope on this type of skull base surgery, although our preliminary clinical experiences seem promising.

Declaration of Conflicting Interests

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