INVITED REVIEWS

Enlarged Middle Fossa Surgery: Indications, Advantages, and Surgical Technique

Mislav Gjurić, MD, PhD

From the Department of
Otorhinolaryngology, Head & Neck
Surgery, KBC Šalata,
University of Zagreb, Croatia

Correspondence
Prof. Mislav Gjurić, MD
Department of
Otorhinolaryngology, Head & Neck
Surgery
Šalata 4, 10000 Zagreb, Croatia

Phone: +385 1 492 2051
Fax: +385 1 492 2051
E-mail: mgjuric@kbc-zagreb.hr

In this article, the indications for, advantages of, and technique for performing surgery of the temporal bone and cerebellopontine angle via the enlarged middle cranial fossa approach are reviewed. Nine hundred sixty-two patients who underwent that procedure between 1979-1997 in a tertiary referral center were studied. Performing enlarged middle cranial fossa surgery, which is a demanding procedure, requires extensive training. That approach, however, is irreplaceable in the treatment of a variety of diseases (facial nerve disorders, vestibular schwannomas, other neoplastic and inflammatory temporal bone diseases) and in vestibular neurectomy for patients with Meniere´s disease.

Although Parry was the first to approach the internal auditory canal (IAC) through the middle fossa in 1904[1], that technique did not become a standard procedure in the armamentarium of otologic and skull base surgeons until 1961[2]. Exposure of the internal auditory canal through the middle cranial fossa enables the complete removal of an intrameatal lesion while preserving facial nerve function and hearing. That approach was subsequently used for a variety of indications such as facial nerve decompression or nerve repair, as well as in vestibular nerve section for patients with Meniere´s disease. Rosomoff[3] reported on the subtemporal-transtentorial approach to the cerebellopontine angle (CPA), in which an intradural retraction of the temporal lobe was used. Bochenek and Kukwa[4] and Kanzaki and colleagues[5] described an extended middle cranial fossa approach; they obtained better exposure by cutting the tentorium and removing the labyrinth. An obvious limitation of that approach was the patient's loss of residual hearing.

In 1982, Wigand and colleagues[6] described the enlarged middle cranial fossa approach (EMFA), which is a modification of the middle fossa approach described by House in 1961[2]. Although the middle fossa approach is limited to the unroofing of the internal auditory canal, the EMFA provides additional exposure by extensive extradural temporal bone removal from the petrous apex anteriorly to the superior semicircular canal posteriorly. Inner ear structures thereby remain intact. The IAC is exposed entirely, from the meatal foramen at the fundus down to the porus. In the cerebellopontine angle, the entire course of the facial and the vestibulocochlear nerves is visualized to their exit zones at the brainstem. Flexible extension into the petrous apex, the protympanum, and the middle ear is tailored according to the individual pathologic condition.

The EMFA, which is primarily an otologic procedure, is indicated for the treatment of a variety of diseases such as temporal bone fractures, extensive cholesteatoma of the temporal bone and petrous apex, other petrous apex lesions (cholesterol granuloma, mucocele, meningioma, etc), intractable tinnitus,

hemifacial spasm, or sensorineural hearing loss, as well as in vestibular nerve section and neurovascular decompression at the brainstem for patients with Meniere´s disease. Facial nerve decompression or grafting from the CPA to the intratympanic portion of the facial canal can be readily accomplished via the EMFA, which provides the best exposure of the labyrinthine portion of the facial nerve and the geniculate ganglion. Repair of dural tears and brain herniation can also be safely performed. Lesions of the petrous internal carotid artery can be approached through the middle fossa in a single procedure or as a part of a combined craniocervical approach.

The most frequent indications for the EMFA are intracanalicular vestibular schwannomas or tumors with limited extension into the CPA in patients with preserved hearing[7-9]. Technical modifications that have been developed since the EMFA was first used in the late 1970s and published 1982 enable the safe removal of tumors extending 2 cm into the CPA and have proved to be advantageous in preserving hearing.

Temporal lobe deficiency and suppurative otitis media are relative contraindications for middle fossa surgery, which is not limited by the age of the patient. We have used the EMFA without complications in patients older than 70 years.

EMFA: Surgical Technique

Between 1979-1997 in the department of otorhinolaryngology, University of Erlangen, Germany, nine hundred sixty-two patients were treated using the enlarged middle fossa approach. The indications were sporadic unilateral vestibular schwannoma (759 patients), facial nerve tumor and meningeoma (28), rare cerebellopontine angle tumors (17), vestibular nerve section (99), cholesteatoma of the petrous bone (22), facial nerve decompression or reconstruction (32), and cerebrospinal fluid leak[5].

The patient who is to undergo surgery via the EMFA is placed in the supine position with the face turned to the opposite side. No external head fixation is used. The surgeon is seated at the head of the table and has a reverse view of the patient's skull (Figure 1).

Presurgical preparation includes shaving the temporal area, placing the electrodes for continuous intraoperative facial nerve and brainstem response monitoring, preparing the skin, and injecting the incision area with Lidocain 1% with epinephrine 1:200.000.
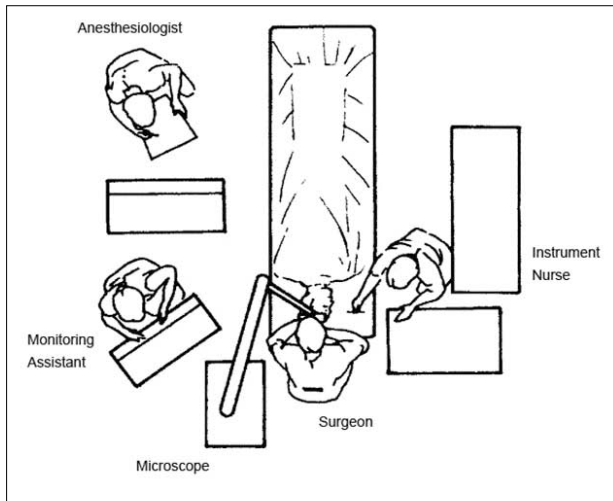

Figure 1: The operating theater for enlarged middle fossa surgery.

A vertical skin incision made in the pretragal area at the superior tragal rim is extended above the auricle and is curved anteriorly to stay within the hairline to a total extension of 8 to 10 cm (Figure 2). The branches of the superficial temporal artery are ligated. A piece of temporalis fascia and a small strip of muscle are harvested for later closure of bony defects within the temporal bone and are preserved in wet gauze. The temporalis muscle is incised with electrocautery in a vertical direction, which exposes the temporal squama and the root of the zygoma. Frontal branches of the facial nerve are preserved. A 4- x 5-cm trapezoid-form osteoplastic craniotomy is placed just above the root of the zygoma and is designed so that its inferior margin is cut wider than the superior, which enables a better view of the middle fossa floor (Figure 3). Two-thirds of the craniotomy opening is centered anterior to the root of the zygoma and one-third is centered posterior to the zygomatic root. Craniotomy is performed either with the craniotome after 1 burr hole has been placed
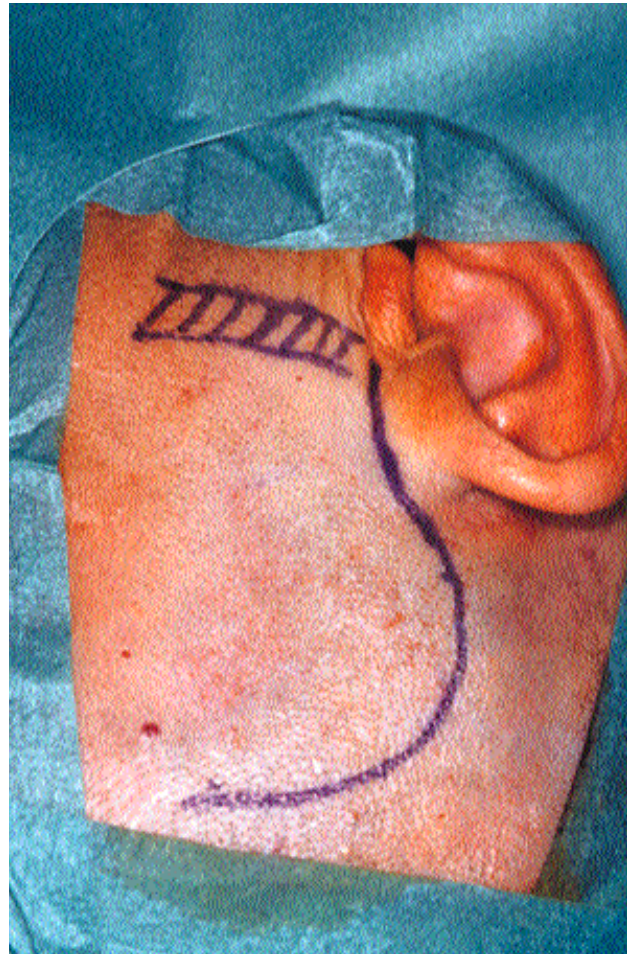

Figure 2: The curved temporal skin incision (note blue-lining).
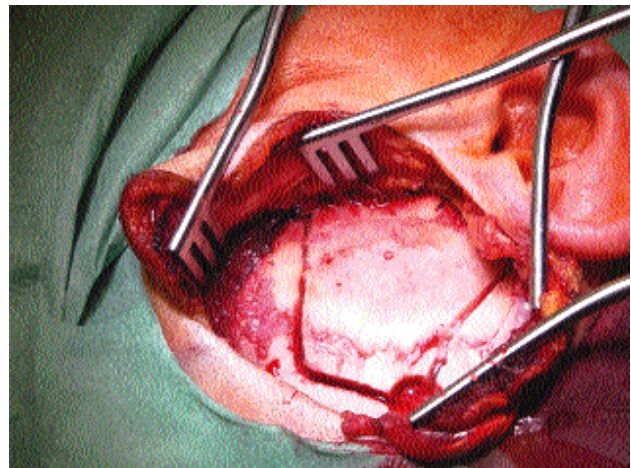

Figure 3: A 4- x 5-cm trapezoid-form osteoplastic craniotomy just above the root of the zygoma. The inferior margin is cut wider than the superior margin. Craniotomy is performed with the craniotome after 1 burr hole has been placed at the posterosuperior aspect of the craniotomy opening.

at the posterosuperior aspect of the future craniotomy opening or with the cutting drill.

The temporal dura is mobilized gradually from the bony middle fossa floor in a posterior-to-anterior direction and then from the posterior petrous ridge to the foramen ovale. Bleeding from the craniotomy margins or disrupted dural adhesions at the petrosquamous fissure is controlled with bone wax, Surgicel packing (Ethicon, Switzerland), or a diamond drill. The self-retaining dura retractor is introduced just after sufficient mobilization of the dura and is then gradually retracted. The superficial petrosal nerves are found close to the geniculate ganglion, which is usually coved by bone (Figure 4). Early recognition of a dehiscent geniculate ganglion is essential to prevent facial nerve injury at this step. The nerves adhere tightly to the dura, from which they are separated by sharp dissection to avoid traction. The direction of dissection is again from posterior to anterior. Bleeding from nourishing vessels is controlled with packing. The bone over the internal carotid artery may be very thin or dehiscent. Resection of the middle meningeal artery and release of the cerebrospinal fluid (CSF) from the middle fossa through a 1-mm incision just above the superior petrosal sinus contributes significantly to lowering the pressure on the temporal lobe. The middle meningeal artery is cauterized and transected, and the foramen spinosum is packed with bone wax and Surgicel (Ethicon) (Figure 5).

Figure 4: The superficial petrosal nerves adhere tightly to the dura, from which they are separated by sharp dissection to avoid traction.
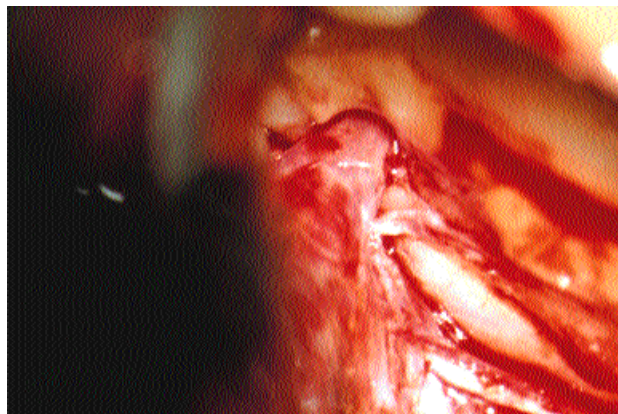

Figure 5: The middle meningeal artery is found at the foramen spinosum and is transected

Preservation of the middle meningeal artery does not improve the control of bleeding, which is almost always of venous origin and is readily controlled with packing. Mobilization of the temporal dura over the larger surface reduces the pressure on the temporal lobe more effectively than does minimal dissection of the dura directly over the IAC. The only exception to the use of this strategy occurs when limited exposure is required in patients with certain pathologic conditions in the lateral aspect of the temporal bone. Adequate dura mobilization and release of the CSF enables the curved blade of the middle fossa retractor to be advanced over the posterior petrous ridge, thus bisecting the angle formed by the greater superficial petrosal nerve and the arcuate eminence. Inadequate exposure of the ridge and the presence of dural folds left over the bone result in incomplete bone removal and hinder the exposure of the cerebellopontine angle.

Blue-lining the superior semicircular canal (SSC) is the first step in bone excision and the most important landmark of the inner ear position [10]. The position of the IAC will correspond with the line bisecting the angle formed by the SSC and the petrosal nerves. Maximum exposure and the preservation of important structures are achieved by positive identification of landmarks early in the course of surgery. The position of the SSC does not always correspond well with the visible arcuate eminence. The surgeon must use a diamond drill to search for the canal and must look for the dense, whitish bone of the otic capsule. The

direction of drilling should be parallel to the expected axis of the SSC that is perpendicular to the posterior petrous ridge. The surgeon must account for the various degrees of mastoid pneumatization that necessitate the removal of varying amounts of bone. Alternative landmarks enabling proper orientation within the floor of the middle fossa are the greater superficial petrosal nerve and the tegmen tympani. Following the nerve retrograde by unroofing of the nerve canal leads to the geniculate ganglion. This procedure, however, renders the facial nerve more vulnerable to surgical trauma. The opening of the tegmen tympani enables the positive identification of middle ear structures but requires precise wound closure to prevent disturbances of middle ear mechanisms, postoperative CSF leak, or brain herniation.

After having blue-lined the SSC, the surgeon initiates bone removal in the suprameatal plane 1 mm anterior to the SSC. The IAC is identified medially at the level of the porus, and the bone around it is reduced to at least two-thirds of the depth of the meatus. The petrous bone posterior and anterior to the IAC and anteromedial to the cochlea is removed. Venous bleeding from the bone marrow at the petrous apex is readily controlled with bone wax. The removal of the petrous ridge anteromedial and posteromedial to the labyrinth gradually exposes the dura of the posterior fossa deep to the superior petrosal sinus (Figure 6). The superior petrosal sinus is resected only in patients
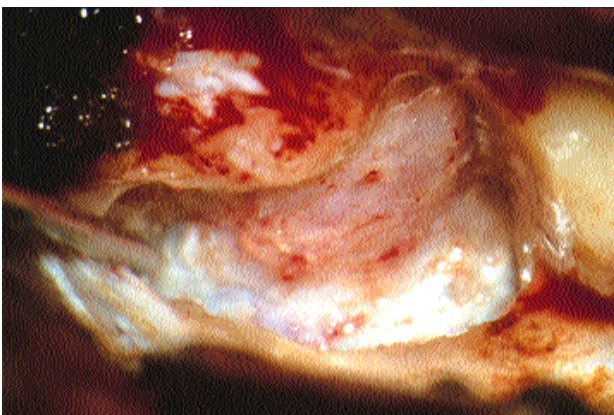

Figure 6: Exposed dura over the interior auditory canal and the cerebellopontine angle. The amount of dural exposure depends on the underlying pathologic condition.

with a large tumor. After the porus and the medial aspect of the IAC have been identified, the IAC is unroofed laterally; care must betaken to avoid entering the cochlea or the vestibule. The bone covering the anterior rim of the IAC must be removed very close to the basal turn of the cochlea. Great care must be taken not to enter the dura at this point, because the facial nerve lies directly below. The vertical crest (the Bill's bar) should be identified, thus marking the position of the facial nerve anteriorly and the superior vestibular nerve posteriorly. Precise identification of the nerves at the fundus is an essential step that limits the extension of the dissection laterally (Figure 7). To avoid the unnecessary risk of facial nerve damage, the labyrinthine portion of the facial nerve is not routinely decompressed.
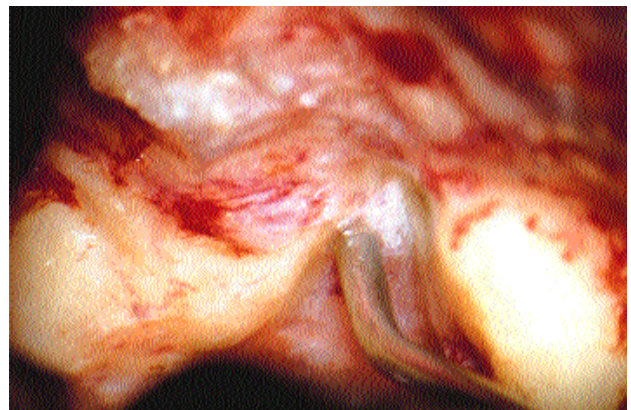

Figure 7: Precise identification of the nerves at the fundus is an essential step that limits the extension of the dissection laterally. The labyrinthine portion of the facial nerve is not routinely decompressed to prevent the unnecessary risk of facial nerve damage.

Dural incision is initiated posteriorly over the superior vestibular nerve at the meatal fundus, and the facial nerve is avoided. The incision is completed in an inverted T-fashion; the short arm of the T is placed just beneath and parallel to the superior petrosal sinus. The 2 dural flaps are glued aside to the bony rims to ensure that they remain open throughout the procedure.

If transection of the superior petrosal sinus is necessary to better expose the cerebellopontine angle (6.4% of the patients in our series), the sinus is incised and is packed on both ends with Surgicel (Ethicon) and

fibrin glue. At the conclusion of the procedure, a separate free muscle graft is used to secure the resected sinus.

At the completion of surgery, the dural flaps are reapproximated and glued together, and the bony defect is filled with free strips of temporalis muscle soaked in fibrin glue. Special care is taken to plug and cover all opened mastoid cells and middle ear spaces that could allow a postoperative CSF leak. The second layer consists of a piece of temporalis fascia covering the middle fossa floor, and the third cover is a piece of resorbable gelatin sponge with fibrin glue. Dural suspension sutures are used only when the risk of bleeding is increased. The craniotomy flap is repositioned and is secured with at least 3 resorbable 2-0 sutures. The wound is closed in 3 layers after the placement of a suction drain under the temporalis muscle. The suction drain is kept in place no longer than 12 hours to obviate a CSF leak. The application of a compression head bandage concludes the surgery.

Vestibular Schwannoma Dissection

The first objective in tumor dissection is to preserve the facial nerve while removing the entire tumor. The facial nerve is identified at the meatal foramen and is followed to the anterosuperior tumor surface, along which it runs medially. If the tumor is small, the nerve can be easily dissected up to the porus by medial-to-lateral dissection. To avoid traction or anterior stretching of the nerve in larger tumors in which the facial nerve is flattened on the tumor surface, only the posterior margin of the nerve is identified. The vestibulofacial anastomosis is cut. In most cases, the superior vestibular nerve is readily identified and is divided at the fundus so that the main bulk of the vestibular schwannoma arises from the inferior vestibular nerve. Safe exposure of the tumor surface is achieved by consequent detachment of its arachnoid sheath, which is thick in the IAC and at the porus but becomes thinner at the brainstem.

Intracapsular tumor debulking is performed with scissors and round knives, and bleeding is controlled with cautery. Extensive debulking allows the tumor

capsule to collapse and renders the tumor margin gradually visible. The posterior aspect of the tumor capsule is developed first. The petrosal vein, which is usually encountered at this step, must be carefully separated from the tumor. The arachnoidal adhesions are dissected in addition to the vessels that do not penetrate the tumor capsule. Only vessels entering the tumor are coagulated and separated. In tumors adherent to the cerebellum or the brain stem, it is crucial to develop the right plane by tedious dissection of the tumor capsule from the surrounding dural adhesions. The loop of the anterior inferior cerebellar artery, which is usually found on the inferior surface of the tumor, must be carefully dissected and spared.

Only after sufficient tumor reduction is the proximal segment of the facial nerve identified near the brainstem. After establishing the plane of the facial nerve proximally and distally, the most difficult part of the dissection at the porus is performed, usually bluntly and in a medial-to-lateral direction. Dissection of the lateral tumor extension is critical and may compromise the blood supply to the cochlea, a complication avoided by minimizing the use of bipolar cautery close to the cochlear nerve. The ball-tipped dissector and the ball hook are used to slowly remove the tumor from the fundus. During this procedure, the tumor is bent along its mediolateral axis so that the cochlear nerve becomes visible on the anteroinferior tumor surface (Figure 8).
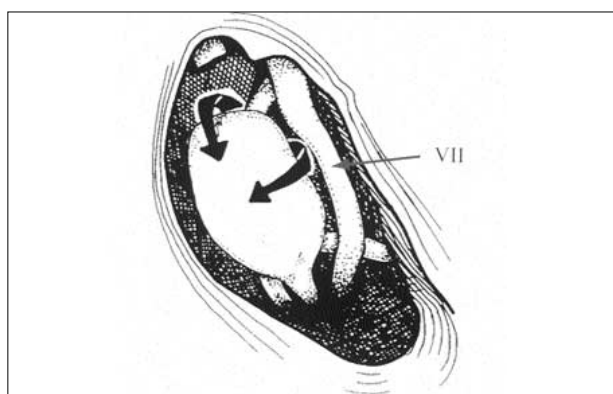

Figure 8: As the tumor is slowly removed from the fundus, it is bent along its mediolateral axis so that the cochlear nerve becomes visible on the anteroinferior tumor surface. Medial traction must be avoided. The nerve is peeled off the tumor surface by dissection perpendicular to the course of the nerve.

Table. Surgical complications in patients in our series who underwent enlarged middle fossa surgery between 1979-1997.

	No. of Patients	
	N = 962	Percent of Patients
Death	3	0.3
CPA hematoma	6	0.6
Temporal lobe contusion	18	1.9
Meningitis	19	2.0
CSF leak requiring revision	21	2.2
Seizures	6	0.6
Transient neurologic deficits	54	5.6

CPA, cerebellopontine angle; CSF, cerebrospinal fluid.

Medial traction must be avoided. The nerve is peeled off the tumor surface in a dissection perpendicular to the course of the nerve. The blood supply to the cochlea usually runs between the facial and cochlear nerves. Noninvolved fibers of the inferior vestibular nerve are left intact to reduce the risk of damage to the very fragile cochlear nerve and its blood supply, although the benefit of doing so to enable postoperative vestibular compensation is questionable. Finally, the proximal segment of the vestibular nerve is identified, and the most medial part of the tumor is resected.

COMPLICATIONS

In experienced surgical care centers, the mortality rate is low for patients undergoing EMFA. In this series, the mortality rate was 0.3% (Table). Most deaths occurred because of brainstem edema, late meningitis, or complications from anesthesia.

Hematoma of the CPA, which is an exceptional but potentially fatal complication of EMFA that occurred in 0.6% of our patients, is managed by immediate reopening and hemostasis. The control of potentially hazardous CPA hemorrhage is limited by the EMFA, and the retrosigmoid opening is often required for better exposure. Similar symptoms may also be induced by an epidural hematoma, which can be managed by evacuation and hemostasis.

Temporal lobe contusion, which occurred in 1.9% of the patients in our series, was caused by brain retraction or compression of the vein of Labbé and required ventricular shunting and steroid therapy. Delayed recovery and dysphasia, which occurred in 5.6% of the patients in this study, are rare and in our subjects always resolved completely over time. Sometimes, temporary external drainage is necessary. In addition to surgical precautions, brain-protective measures include the administration of mannitol and steroids, as well as the use of moderate hyperventilation (arterial pCO2, 30-35 mm Hg). If the operative time is decreased to 3 to 4 hours on average, the retractor is kept in position for 2 to 3 hours.

Meningitis, which occurred in 2% of the patients in this study, is managed with appropriate antibiotics after the culture and identification of the offending organism. CSF leakage, which developed in 2.2% of our study subjects, is rare after middle fossa surgery as opposed to other approaches. The amount of dural incision and opening of the mastoid cell system is less extensive, and meticulous defect closure ensures an uneventful postoperative course. Routine spinal drainage is unnecessary but may be required if a profuse leak develops. If conservative measures fail to resolve that complication, surgical revision with meticulous closure of the dural defect and mastoid pneumatic system is indicated.

CONCLUSION

Further development and technical refinement of the enlarged middle cranial fossa surgery has made it safe and important procedure. It is an integral part of different approaches performed in a major skull base center. It has an irreplaceable role in the treatment of vestibular schwannomas and a variety of diseases such as facial nerve disorders and other neoplastic and inflammatory temporal bone diseases, as well as in vestibular neurectomy for patients with Meniere´s disease.

REFERENCES

1. Parry RH. A case of tinnitus and vertigo treated by division of the auditory nerve. J Laryngol Otol 1904;19:402.

2. House WF. Surgical exposure of the internal auditory canal and its contents through the middle, cranial fossa. Laryngoscope 1961;71:1363-85.

3. Rosomoff HL. The subtemporal transtentorial approach to the cerebellopontine angle. Laryngoscope 1971;81:1448-54.

4. Bochenek Z, Kukwa A. An extended approach through the middle cranial fossa to the internal auditory meatus and the cerebello-pontine angle. Acta Otolaryngol 1975;80:410-4.

5. Kanzaki J, Kawase T, Sano K, Shiobara R, Toya S. A modified extended middle cranial fossa approach for acoustic tumors. Arch Otorhinolaryngol 1977;217:119-21.

6. Wigand ME, Haid T, Berg M, Rettinger G. The enlarged transtemporal approach to the cerebello-pontine angle. Technique and indications. Acta Otorhinolaryngol Ital 1982;2:571-82.

7. Gjuric M, Wigand ME, Wolf SR. Enlarged middle fossa vestibular schwannoma surgery: experience with 735 cases. Otol Neurotol 2001;22:223-30; discussion 230-1

8. Breuer T, Gjuric M, Wigand ME. Extended middle fossa surgery for meningiomas within or at the internal auditory canal. Am J Otol 2000;21:729-34.

9. Gjuric M, Koester M, Paulus W. Cavernous hemangioma of the internal auditory canal arising from the inferior vestibular nerve: case report and review of the literature. Am J Otol 2000;21:110-4.

10. Fisch U. Transtemporal surgery of the internal auditory canal. Report of 92 cases, technique, indications and results. Adv Otorhinolaryngol 1970;17:203-40.