Surgical Anatomy of Cerebellopontine Cistern

Ricardo Ramina, Gustavo Simiano Jung, Erasmo Barros da Silva Jr, and Rogerio S. Clemente

1 Introduction

Subarachnoid cisterns are compartments of the subarachnoid space filled with cerebrospinal fluid (CSF), separating the arachnoid membrane and the pia mater. These spaces contain fibers and many trabeculae [1]. The subarachnoid cisterns are interconnected, and their patency is important for CSF circulation. Cranial nerves, arteries, and veins pass through them. Knowledge of the anatomy of their neural and vascular structures is important in planning and performing intracranial surgery. Opening basal cisterns to release CSF reduces the intracranial pressure allowing better identification of the anatomic structures. The subarachnoid cisterns are divided into two groups: supratentorial and infratentorial. The posterior fossa cisterns are unpaired and paired. Unpaired are the following cisterns: interpeduncular, prepontine, premedullary, quadrigeminal, and the *cisterna magna*. Paired cisterns are the cerebellopontine and cerebellomedullary (Figs. 1 and 2) [2].

This chapter will discuss the surgical anatomy, radiologic findings of the cerebellopontine cistern, and the surgical approaches to different pathologies encountered in this region.

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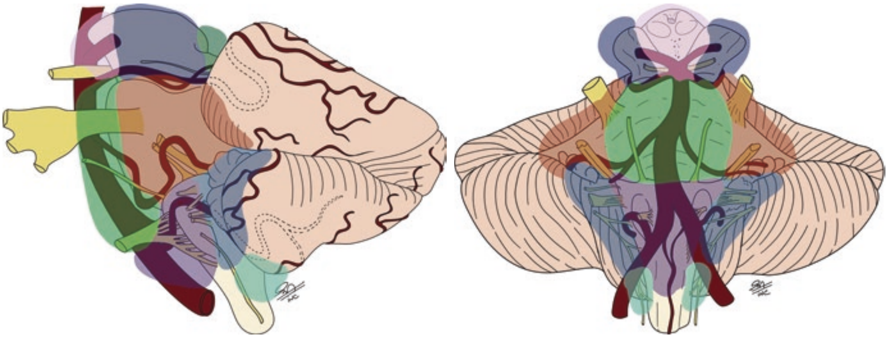


Fig. 1 Drawings showing the cerebellopontine cisterns (brawn), the prepontine cistern (green), and the cerebellomedullary cisterns (gray)

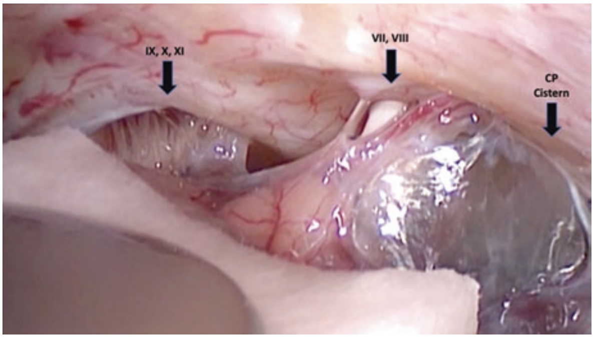


Fig. 2 Surgical picture showing the cerebellopontine cistern filled with CSF and the cranial nerves VII and VII at the internal auditory meatus. The cranial nerves IX, X, and XI at the jugular foramen

2 History

Key and Retzius first studied the anatomy of the subarachnoid cistern in 1875 [3]. In 1959, the neuroradiologist Liliequist described the cistern based on pneumographs and anatomical studies [4]. Other studies were made by Lewtas NA [5], Amundsen P [6], Yasargil MG [1], and Matsuno H [2].

The first successful complete cerebellopontine angle tumor removal is credited to Charles Ballance in 1894. The tumor was removed with the finger, and the patient recovered from surgery and was alive at least 18 years after surgery [7]. Victor Horsley, Fedor Krause, Harvey Cushing, Walter Dandy, and other pioneers contributed to the CPA surgery [8]. In 1939, Olivecrona presented a rate of facial nerve preservation of 65% in the surgical treatment of vestibular schwannomas; this result was extraordinary for that time [9]. William House using the surgical microscope and microsurgical techniques through the translabyrinthine approach, reported excellent facial nerve preservation rates and low operative mortality rate [10–13]. In 1965, Rand and Kurze, using the suboccipital transmeatal approach and microdissection, removed vestibular schwannomas totally with a high rate of preservation of facial, vestibular, and cochlear nerves [14]. More recently, Madjid Samii, in a large series of patients submitted to vestibular schwannoma removal, showed rates of anatomical facial preservation of approximately 93% (100% in smaller tumors) and improved rates of hearing preservation with minimal mortality rates (below 1%) [15, 16].

3 Surgical Anatomy

The cerebellopontine cistern is on the posterior portion of the petrous bone between the anterolateral surface of the pons and the cerebellum (Figs. 2 and 3). The pontomesencephalic membrane splits this cistern superiorly from the ambient cistern. The pontomesencephalic membrane is attached to the brainstem and intersects the oculomotor nerve anteriorly. Inferiorly, the cerebellopontine cistern is separated from the cerebellomedullary cistern by the lateral pontomedullary membrane, which lies between the cranial nerves VII, VIII, and IX. The anterior pontine membrane separates the cerebellopontine cistern medially from the prepontine cistern through the anterior pontine membrane. Laterally, the cerebellopontine cistern extends to the edge of the cerebellar surface [2, 17].

The cranial nerves running through the cerebellopontine cistern are the trigeminal nerve, the abducens nerve, the facial nerve, and vestibulocochlear nerve (Fig. 4). The trigeminal nerve originates about halfway between the lower and upper lateral portion of the pons and runs in the superolateral part of the cerebellopontine cistern. This nerve has two roots: the larger one is the sensory root located laterally and a narrow motor root located superior and medially to the sensory root. The *abducens* nerve originates in the pontomedullary junction and passes anterior to the pontine membrane. The facial and vestibulocochlear nerves originate in the pontomedullary junction running in the inferior part of the cerebellopontine cistern (Figs. 5 and 6).

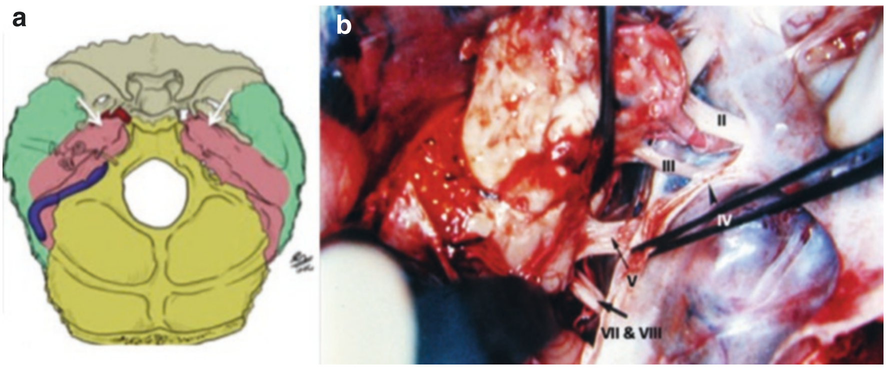


Fig. 3 (**a**) Drawing showing the relationship of the posterior portion of the petrous bone (brawn) and the structures of the internal auditory canal. (**b**) Anatomical preparation with the cranial nerves V, VII and VIII in the cerebellopontine angle

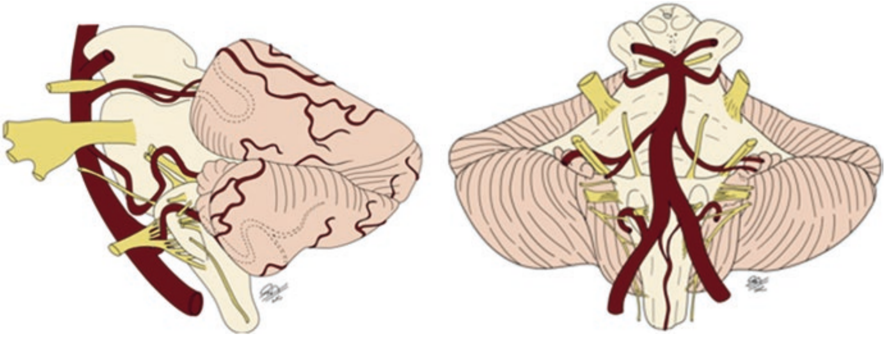
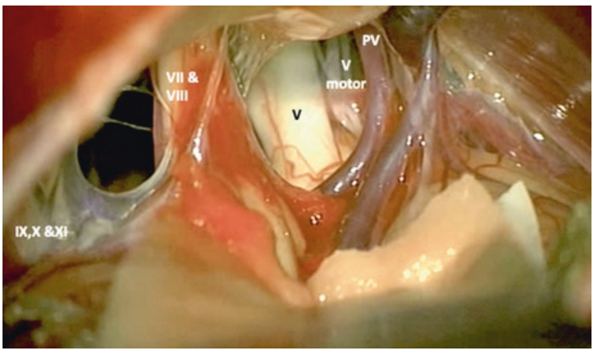


Fig. 4 Drawing showing the cranial nerves at the cerebellopontine angle

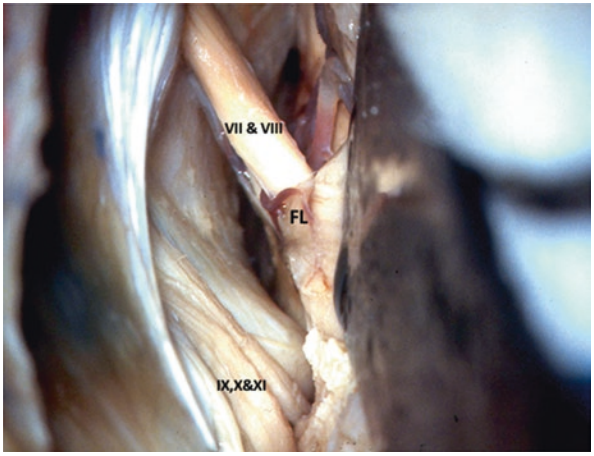
Fig. 5 Drawings showing the cranial nerves V, VII, and VII in the cerebellopontine angle and the basilar artery with its branches (AICA, SCA, and PCA)

Fig. 6 Surgical view of the CPA after opening the arachnoid of the cerebellopontine cistern. PV, petrosal vein; V cranial nerve with its motor portion, VII and VIII cranial nerves and caudal cranial nerves (IX, X, and XI) covered by arachnoid



The facial nerve is usually hidden by the choroid plexus and the flocculus (Fig. 7). This portion of the facial nerve (subpial) is the point of vascular conflict of hemifacial spasm. The facial nerve arises 2–3 mm anterior to the root entry zone of the vestibulocochlear nerve. The lateral recess of the fourth ventricle (foramen of Luschka) is inferior and posterior to the root entry zones of the facial and vestibulocochlear nerve. In the cerebellopontine cistern, the facial nerve is located anteromedially, and the vestibulocochlear nerve is posterolateral. The outer arachnoid membrane goes into the internal auditory canal around the VII and VIII cranial nerves. Behind these nerves is the *flocculus*, which covers the aperture of the lateral recess of the fourth ventricle. The facial nerve is anterosuperior in the internal auditory canal, the cochlear nerve anteroinferior, the superior vestibular nerve is posterosuperior, and the inferior vestibular nerve is posteroinferior (Fig. 8).

Fig. 7 Anatomical preparation showing the cranial nerves VII and VIII hidden by the flocculus



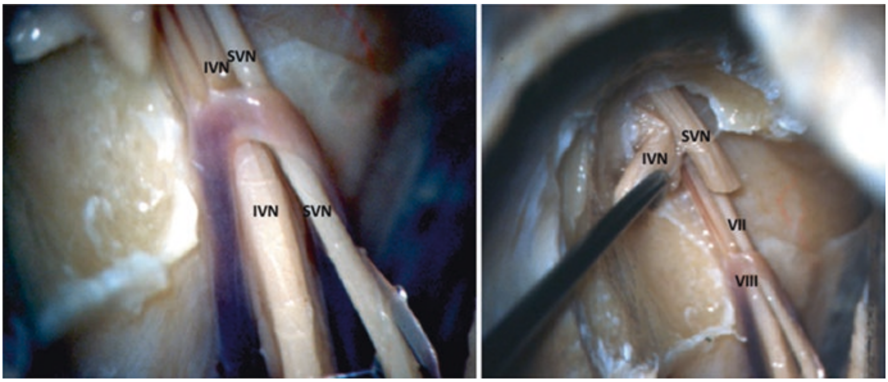


Fig. 8 Anatomical preparation. Left: Inferior (IVN) and superior (SVN) vestibular nerves in the CPA and in the internal auditory canal. Right: The IVN and the SVN are cut exposing the VII and VIII cranial nerves

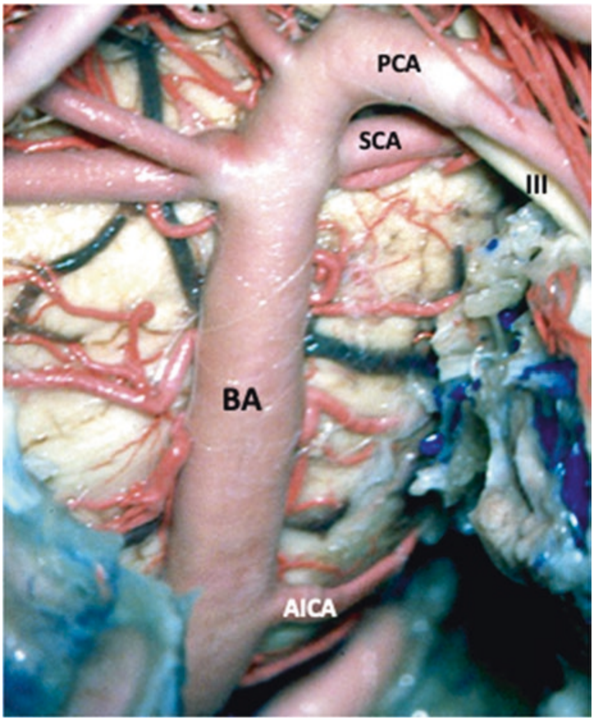


Fig. 9 Anatomical preparation showing the main arteries coursing in the CPA. PCA, posterior cerebral artery; SCA, superior cerebellar artery; AICA, anterior inferior cerebellar artery; BA, basilar artery and its perforator branches. III- oculomotor nerve

The main arteries coursing through the cerebellopontine cistern are the superior cerebellar artery (SCA) and the anterior inferior cerebellar artery (AICA) (Fig. 9). The SCA arises from the basilar SCA runs through the junction of the oculomotor nerve and the pontine membrane, above the trigeminal nerve, and below the trochlear nerve. The SCA supplies the tentorial surface of the cerebellum, lateral to the vermis. The AICA originates from the basilar artery at the pontine level in most cases, and in some cases, it arises from the vertebral artery. It enters the cerebellopontine cistern inferiorly through the anterior pontine membrane, close to the cranial nerves VII and VIII (usually inferior to these nerves) to reach the middle cerebellar peduncle supplying the petrosal surface of the cerebellum. The AICA may form a vascular loop close to the internal auditory meatus where two major branches are identified: the subarcuate and the labyrinthine arteries (Fig. 10).

The major veins crossing this cistern are the transverse pontine veins, the veins of the cerebellopontine fissure, pontomedullary sulcus, and middle cerebellar peduncle [2]. The transverse pontine veins join the tributaries of the superior petrosal *sinus* at the cerebellopontine cistern (Figs. 4 and 6). The superior petrosal vein (Dandy's vein) is formed by veins draining the cerebellum and brainstem into the superior petrosal sinus posterior to the trigeminal nerve.

The cerebellopontine angle (CPA) has the brainstem's medial boundary, the *cerebellum* as the posterior boundary, and its roof. Laterally is limited by the temporal bone, and its floor is formed by the cranial nerves IX, X, and XI. This space is filled with CSF. The cranial nerves 4th to the 11th are within the CPA [18] (Fig. 6).

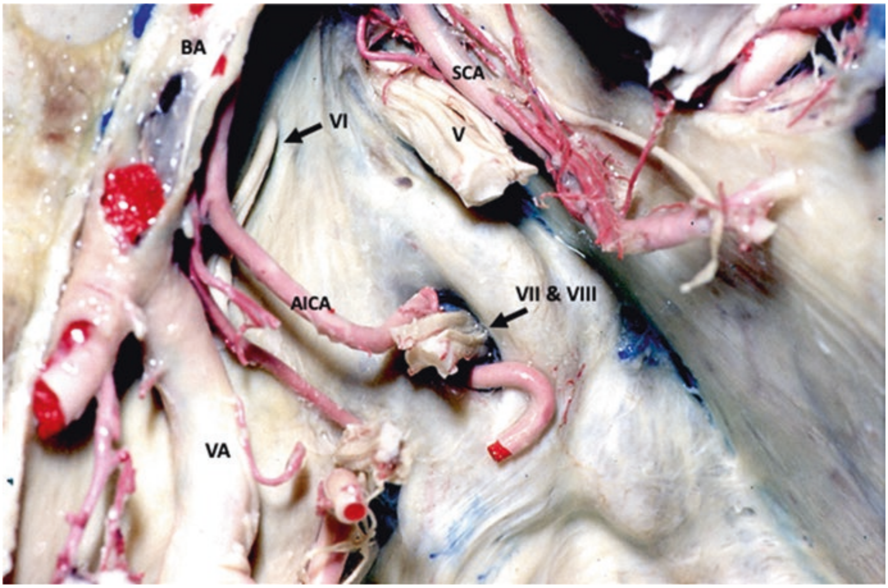


Fig. 10 Anatomical specimen demonstrating the relationship of the main CPA arteries (SCA, AICA) and the cranial nerves

4 Pathologies and Clinical Symptoms

Cerebellopontine angle tumors account for 5% to 10% of all intracranial neoplasms. Most CPA tumors are benign and vestibular schwannomas (acoustic neuromas) account for over 80%. Meningiomas are the second more common (3–10%), followed by epidermoid cysts (2–4%) and other rarer tumors: chordomas, chondrosarcomas, arachnoid or neuroenteric cysts, metastases, schwannomas of the trigeminal, facial, and caudal cranial nerves. Brainstem gliomas, ependymomas, medulloblastomas, tumors of the endolymphatic sac, and papillomas of the choroid plexus may involve the CPA secondarily. Aneurysms, brainstem cavernomas, and arteriovenous malformations are the vascular lesion encountered in this region. The presenting symptoms may be vague and nonspecific. Benign lesions usually present progressive and long-standing symptoms so that they may remain undetected for long periods. Patients with malignant lesions typically offer a short history of pain and multiple cranial nerves. Cranial compression nerves by arteries and veins (trigeminal neuralgia, hemifacial spasm, and glossopharyngeal neuralgia) are surgical pathologies found in the CPA [19–22]. Clinical symptoms are related to the etiology, involvement of cranial nerves, mass effect, and compression of the brainstem. High-frequency hearing loss and tinnitus are the most frequent symptoms in patients with vestibular schwannomas.

5 Radiological Diagnosis

Radiological diagnosis requires analysis of precise location, site of origin, extensions and margins, density, signal intensity, contrast enhancement, identification of cranial nerves, vessels, jugular bulb, and bone abnormalities. Evaluation of the temporal bone with standard radiography includes Towne and Stenver's views and polytomography. Accurate diagnosis is, however, only possible with CT scanning and MRI. Usually, both studies are required for more definitive diagnosis elucidation.

CT scans with bone window with thin slices show bone changes of the internal auditory canal (IAC), petrous bone, mastoid emissary veins, and calcifications [23]. Bone erosion with smooth margins suggests the presence of a slow-growing benign lesion. Infections and aggressive tumors may present osteolytic lesions with ill-defined margins and moth-eaten patterns. The IAC is eroded or widened in over 70% of vestibular schwannomas cases. A high-resolution CT scan is performed to delineate labyrinthine air cells, the relationship between the semicircular canals and the internal auditory meatus. Meningiomas may present hyperostosis of the petrous apex or temporal bone.

MRI is the diagnostic method of choice for all CPA tumors. Contrast enhancing lesions usually are schwannomas, meningiomas, chordomas, paragangliomas, chondrosarcomas, hemangioblastomas, metastases, and medulloblastomas. Non-enhancing tumors are the epidermoid cysts, arachnoid and neuroenteric cysts, low-grade gliomas, and other less frequent lesions [24]. Vestibular schwannomas are isointense on T1-weighted sequences and hyperintense on T2-weighted sequences. They enhance intensely and may present cystic portions. Vestibular schwannomas usually extend into the IAC. Meningiomas on T1-weighted are frequently isointense or hypointense to the brain parenchyma and hyperintense on T2-weighted MRI studies. Meningiomas have broad contact with the petrous bone, tentorium, or clivus. Invasion of the IAC is rare, and meningiomas arising primarily within the IAC are very rare. The "dural tail signal" (enhancement along the dura) is not pathognomonic of meningiomas but is frequently observed. Calcifications and hyperostosis may be present in meningiomas and are very rare in schwannomas. Chordomas and chondrosarcomas are heterogeneous, and bone erosion is observed [25, 26]. Paragangliomas enhance intensely and extend into the ear, jugular bulb, jugular vein, and neck [27, 28]. A precise radiological diagnosis is essential for surgical planning.

Digital angiography is performed when an aneurysm is suspected and for preoperative embolization (e.g., paragangliomas and other highly vascularized tumors).

6 Surgical Approaches

Careful preoperative evaluation is critical in minimizing intraoperative and postoperative complications. Preoperative imaging studies may define the exact size and location of the lesion.

Different surgical approaches may be used to treat tumors and other lesions in the CPA, and each has its advantages and disadvantages [29]. Selection of surgical technique is based on several factors: patient's age, general clinical and neurological status, type of lesion, tumor size and extensions (posterior fossa, middle fossa, IAC, and cavernous sinus), site of origin, and surgeon's experience. The surgical approach should provide sufficient exposure to the CPA and its related structures. It should permit adequate pathology exposure with no or very low morbidity, protect the neural and vascular structures, and permit adequate reconstruction of the dura and skull base. The CPA may be surgically approached through the posterior cranial fossa, through the petrous bone, through the middle fossa, or with a combination of approaches. Continuous neurophysiological monitoring is performed throughout the surgery, from the positioning of the patient to the skin closure. Somatosensory evoked potentials, electromyography of the facial nerve, monitoring of the brainstem auditory evoked potentials, oculomotor, trochlear, *abducens*, and caudal cranial nerves are used according to tumor extension and clinical presentation. During surgery, continuous exchange between the neurosurgeon and the neurophysiologist is of fundamental importance.

The main operative approaches are the retrosigmoid, translabyrinthine, presigmoid, retrolabyrinthine petrosectomy, total petrosectomy, transcochlear, and middle fossa.

The retrosigmoid approach introduced by Fedor Krause (1903) is one of the most frequently used approaches (Fig. 11). It is simple, safe, fast, and associated with a very low procedure-related morbidity rate [30–32]. The patient may be placed in a semi-sitting position, lateral or park-bench position, or supine position

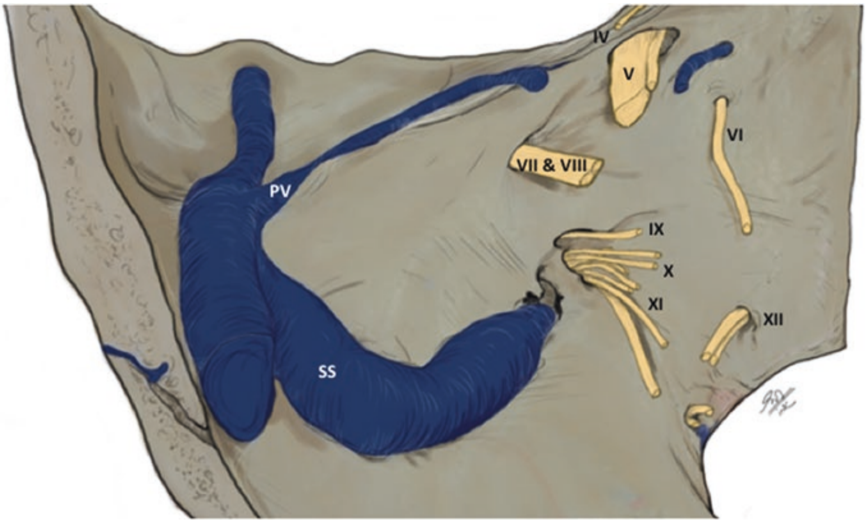


Fig. 11 Drawing showing the Sigmoid sinus (SS), the petrosal vein (PV) and the cranial nerves IV, V, VI, VII, and VIII in the CPA, as well as the cranial nerves IX, X, and XI in the jugular foramen and the XII cranial nerve

[33]. Every surgical position has pros and cons (Fig. 12). The semi-sitting position has the risk of venous air embolism, paradoxical air embolism, tension pneumocephalus, and circulatory instability. However, experienced anesthesiologists can minimize these risks using transesophageal echocardiography or the combined monitoring of end-tidal carbon dioxide and precordial Doppler [34–36]. Patients placed in a semi-sitting position should have their legs raised to or above the level of the heart, this will increase the venous pressure, and the risk of air embolism is reduced. In the last 20 years, we have been using the supine position in all surgeries through the retrosigmoid approach (Fig. 13) [33]. The retrosigmoid approach provides access to all levels of the CPA and neighboring regions. Meckel's cave and posterior portion of the middle cranial fossa and posterior part of the cavernous sinus may be accessed by opening the tentorium and removing the suprameatal tubercle [37]. All sizes of vestibular schwannomas may be removed through the retrosigmoid/transmeatal approach. It offers very good control of the neurovascular structures of the posterior fossa, preservation of hearing, and, if necessary,

Fig. 12 Drawing of retrosigmoid approach (right side) exposing the anatomical structures in the CPA region

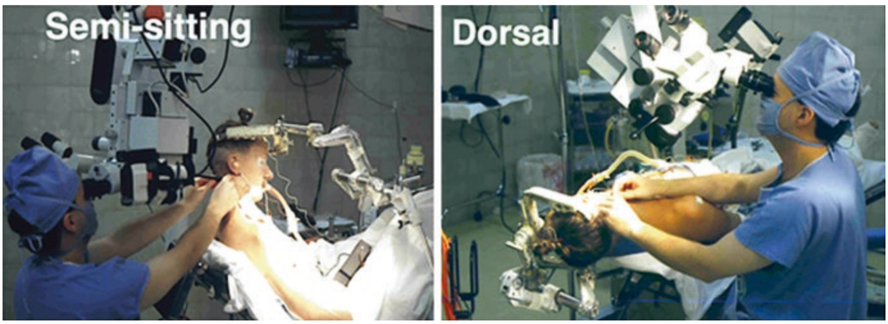


Fig. 13 Surgical pictures of patient positioning for retrosigmoid approach. Semi-sitting and dorsal (supine)

reconstruction of the facial nerve. Meningiomas, epidermoid cysts, vascular decompression of cranial nerves, and other pathologies may be adequately addressed by this approach. Endoscopy is very useful for removing small intracanalicular or intralabyrinthine tumors (Fig. 14), identifying cranial nerves and vessels, closing opened mastoid cells during drilling of the IAC, and checking vascular structures compressing cranial nerves (Figs. 15, 16, 17 and 18).

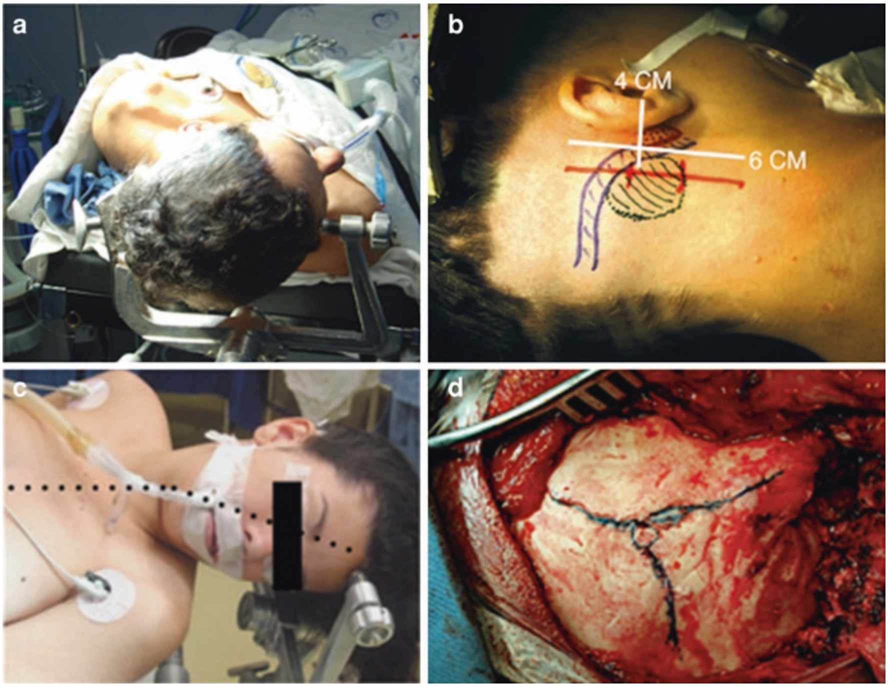
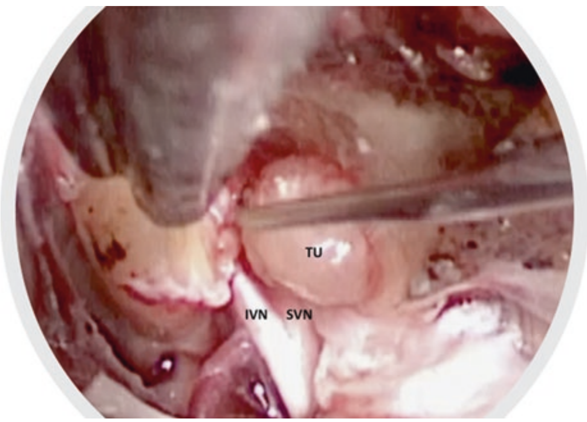


Fig. 14 (**a, b**) Surgical position for the retrosigmoid approach. (**c**) Surgical incision. (**d**) Asterium as marker for the burr hole

Fig. 15 Endoscopic removal of a small vestibular schwannoma (TU), inferior (IVN), and superior(SVN) vestibular nerves



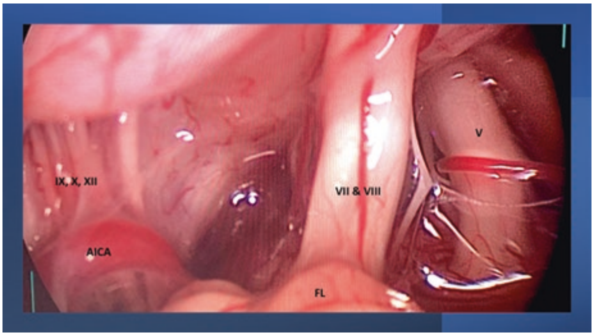


Fig. 16 Endoscopic view of the cranial nerves (V, VII & VIII and IX, X, XI), AICA and flocculus (FL)

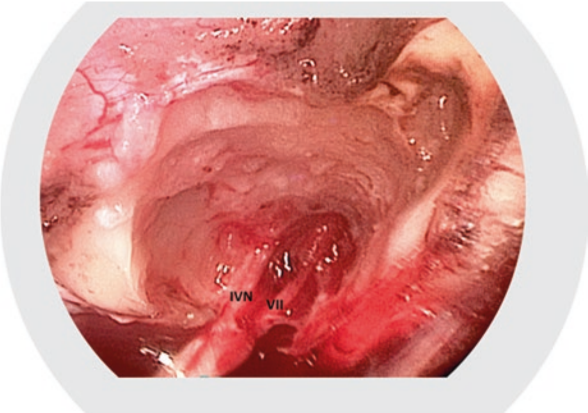


Fig. 17 Endoscopic view within the internal auditory canal after removal of a small vestibular schwannoma from the superior vestibular nerve. Inferior vestibular nerve (IVN) and facial nerve (VII)

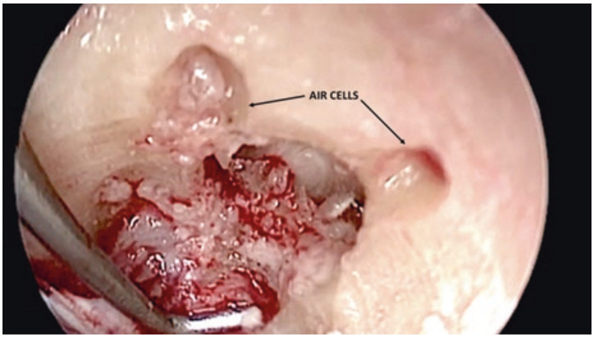


Fig. 18 Endoscopic identification of opened air cells in the internal auditory canal

The translabyrinthine approach introduced by Rudolf Panse in 1904 is used by ENT surgeons and neurosurgeons to remove vestibular schwannomas when preoperative hearing is lost [38–40]. The semicircular canals and the lateral wall of the IAC are removed, allowing wide exposure of the intrameatal and extrameatal tumor parts. This approach may access different pathologies of the petrous bone. It is also used in combination with other approaches to removing cranial base tumors.

Water-tight dura reconstruction is difficult, and an additional abdominal incision is usually needed to remove fat graft to occlude the surgical field and avoid CSF-fistula.

The middle fossa approach (extra of intradural) is utilized in cases of small vestibular schwannomas, trigeminal schwannomas, cysts, and other petrous apex tumors with extensions to the CPA up to the VII & VIII complex [41, 42]. An extended middle fossa approach with resection of the petrous apex behind the horizontal segment of the petrous internal carotid artery medial to the IAC and incision of the *tentorium* (Kawase approach) may be used for larger lesions [43]. This approach exposes the petrous apex intradural and extradural. It lead dissection of the second and third divisions of the trigeminal nerve, the Gasserian ganglion, the petrosal portion of the internal carotid artery, and the meatal and petrosal portions of the facial nerve. Retraction of the temporal lobe is necessary to expose the petrous apex.

Petrous approaches [44–47] with partial or complete resection of the petrous bone has the advantage of shortening the distance to reach the tumor and minimizing brain retraction.

The presigmoid approach allows supra and infratentorial exposure without resection of the labyrinth and preservation of hearing (Fig. 19). It requires, however, more bone drilling increasing the surgical time and may have higher approach-related morbidity.

The hearing may also be preserved by the retrolabyrinthine approach (removal of the bone between the sigmoid sinus and the semicircular canals).

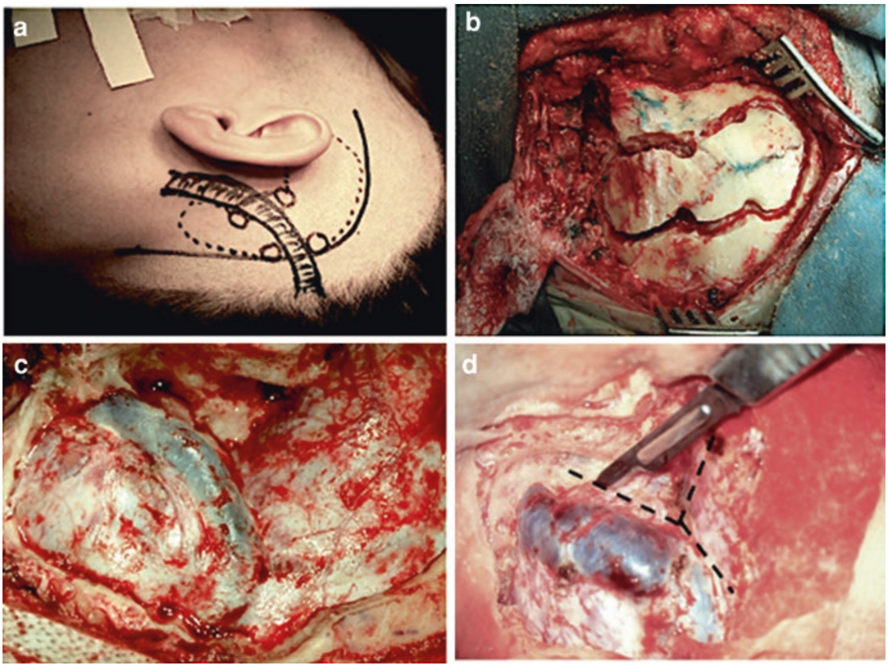


Fig. 19 Presigmoid approach. (**a**) Skin incision and planning the craniotomy. (**b**) Craniotomy. (**c**) Surgical exposure of the sigmoid and transverse sinuses, the middle and posterior fossa dura. (**d**) Dura opening in front of the sigmoid and tranverse sinuses, extending to the middle fossa

Total petrosectomy and the transcochlear approach are used if the hearing is already lost. This surgical access permits a wide exposure of the structures anterior to the IAC and petroclival region [48].

According to our experience, the approaches to CPA should be simple, permit adequate control of the important neurovascular structures of this region, reconstruction of the posterior fossa cranial base, and be associated with no or very-low approach-related morbidity. The retrosigmoid is the more used approach to the CPA. It allows surgical exposure from the Gasserian ganglion and posterior portion of the middle fossa (with removing the suprameatal tubercle and opening of the tentorium) to the cerebellomedullary cistern.

7 Case Studies

7.1 Case 1: Small Vestibular Schwannoma

A 42-year-old patient female was admitted to our hospital with a 3-years history of headaches, tinnitus, and progressive hearing loss on the right ear. MRI showed a small (T2) vestibular schwannoma on the right CPA (Fig. 19). The tumor was radically removed through a right retrosigmoid approach to preserve the facial nerve and hearing (Figs. 20 and 21).

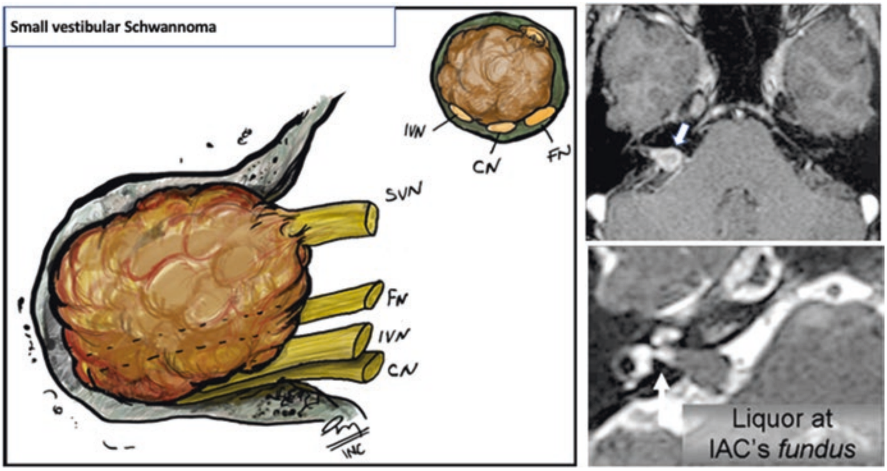


Fig. 20 Case 1. Drawing representing a small vestibular schwannoma that originates from the superior vestibular nerve (SVN). MRI of a right side vestibular schwannoma with the presence of CSF at the fundus of the internal auditory canal

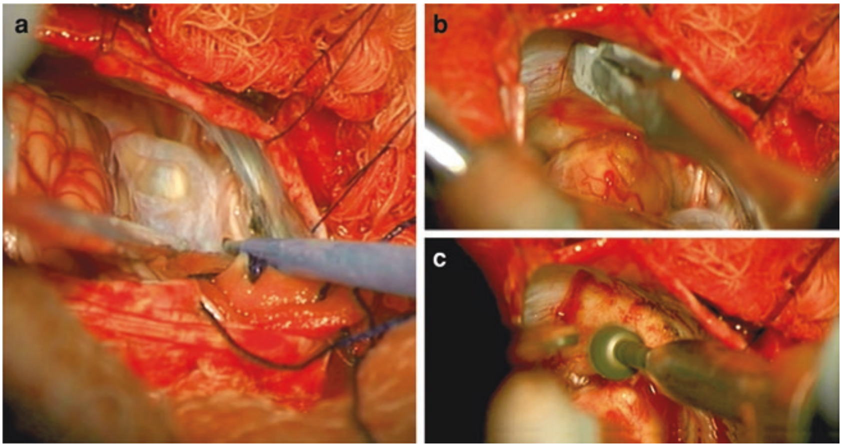


Fig. 21 Case 1. (**a**) Surgical exposition of the right cerebellopontine cistern through the retrosigmoid approach. (**b**) Opening of the dura mater over the internal auditory canal. (**c**) Drilling of the internal auditory canal

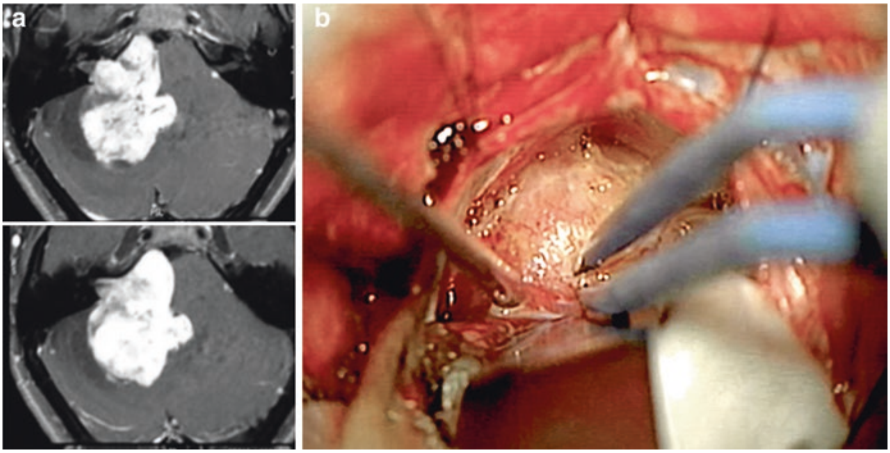


Fig. 22 Case 2. (**a**) MRI (T1-wGd) demonstrating a giant vestibular schwannoma in the right CPA. (**b**) Surgical approach to the tumor through the retrosigmoid approach

7.2 Case 2: Large Vestibular Schwannoma

This 45-year-old female reported a history of progressive hearing loss for 5 years. She became deaf on the right ear 2 years before admission to our department and developed gait difficulty and facial numbness in the last 12 months. An MRI disclosed a very large right-sided vestibular schwannoma (T4B) with compression of the IV ventricle (Fig. 22). Radical tumor removal was accomplished through the retrosigmoid-transmeatal approach with preservation of the facial nerve (Fig. 23).

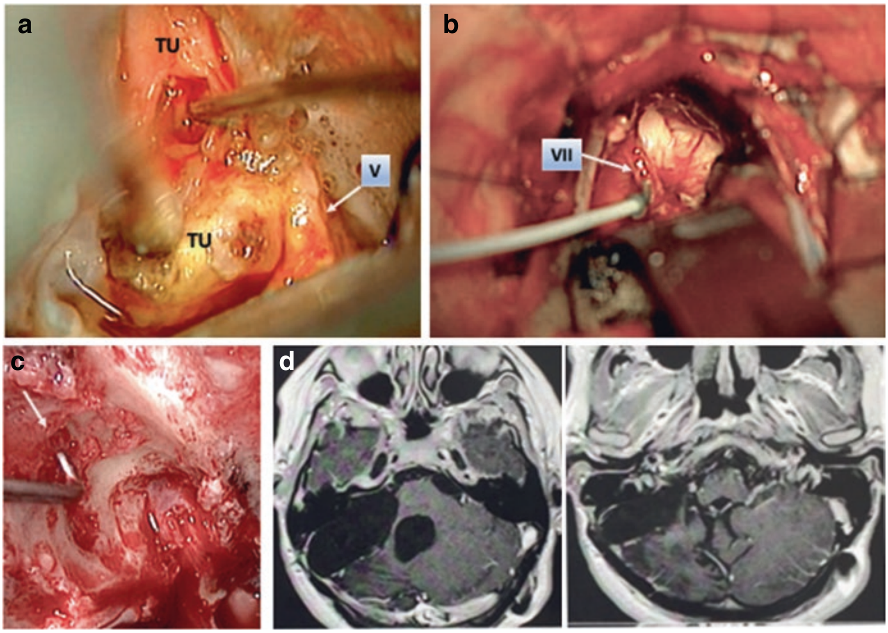


Fig. 23 Case 2. (**a**) Dissection of the trigeminal nerve (V) from tumor capsule (TU). (**b**) Electric stimulation of facial nerve after complete removal of the VS. (**c**) Endoscopic identification of opening air cells (hook). (**d**) Postoperative MRI demonstrating radical removal of the tumor

7.3 Case 3: Cerebellopontine Angle Meningioma

A 55-year-old male was admitted due to hearing loss and tinnitus of the left ear. The hearing was normal. MRI revealed a left side CPA meningioma with extensions into the internal auditory canal (Fig. 24). Total removal of the tumor was possible after opening the internal auditory canal and the jugular foramen. The cranial nerves V, VII, VIII, IX, X, and XI were preserved (Fig. 25).

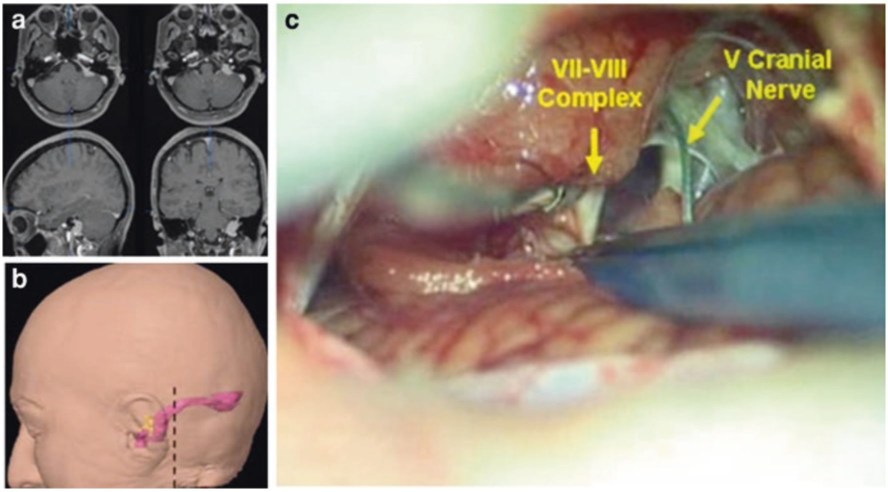


Fig. 24 Case 3. (**a**) MRI (T1-wGd) showing a left-side meningioma in the CPA. (**b**) Planned skin incision for the retrosigmoid approach. (**c**) Surgical view with exposition of cranial nerves V, VII, and VIII

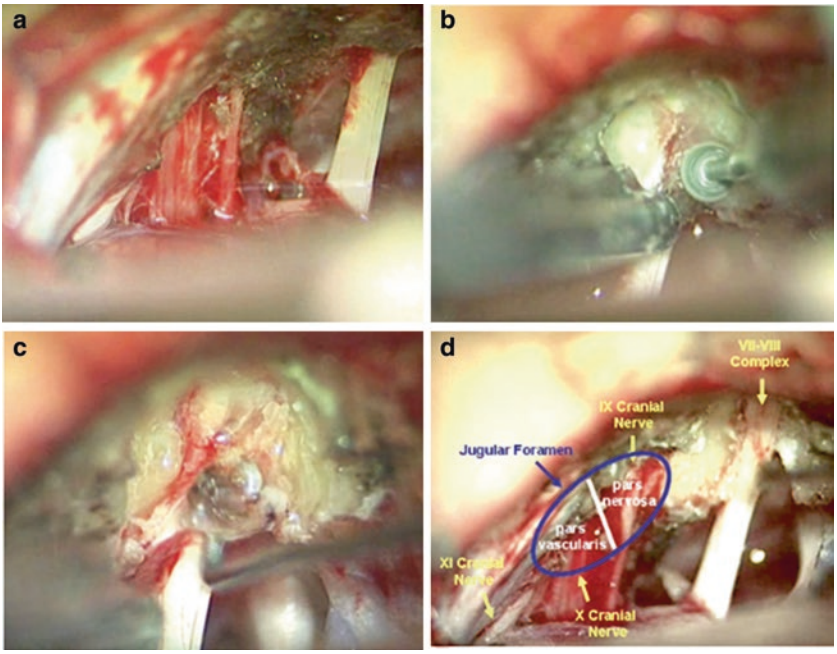


Fig. 25 Case 3. (**a**) Surgical view after radical removal of the intradural portion of the tumor. (**b**) Drilling the internal auditory canal. (**c**) Tumor removal from the intracanalicular portion. (**d**) Radical removal of the meningioma from the CPA, internal auditory canal and jugular foramen

7.4 Case 4: Petroclival Meningioma

Our definition of petroclival meningioma according to its implantation is shown in Fig. 26. These tumors are medial to the cranial nerves and may extend to the middle fossa, cavernous sinus, Meckel's cave, clivus, internal auditory canal, and jugular foramen involving the lower cranial nerves.

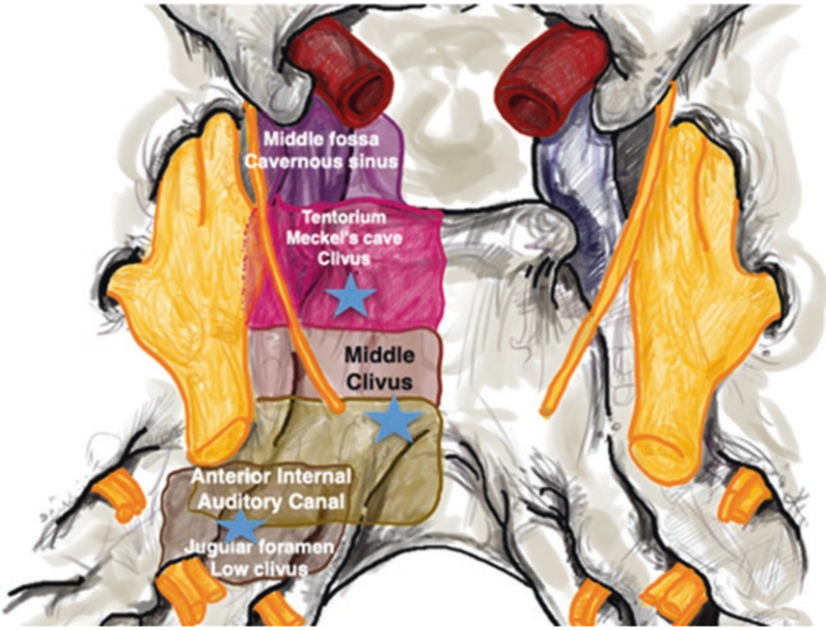


Fig. 26 Drawing showing the areas of implantation and extensions of petroclival meningiomas

The case of a 33-year-old female who complained for 3 years of headache, tinnitus, and decreasing hearing on the left ear is presented. In the last 1½ years, she developed gait difficulty and ataxia. MRI showed a very large left-sided petroclival meningioma (Fig. 27). This tumor was radically removed using a presigmoid approach. Cranial nerves IV, V, VII, and VIII were preserved (Fig. 28).

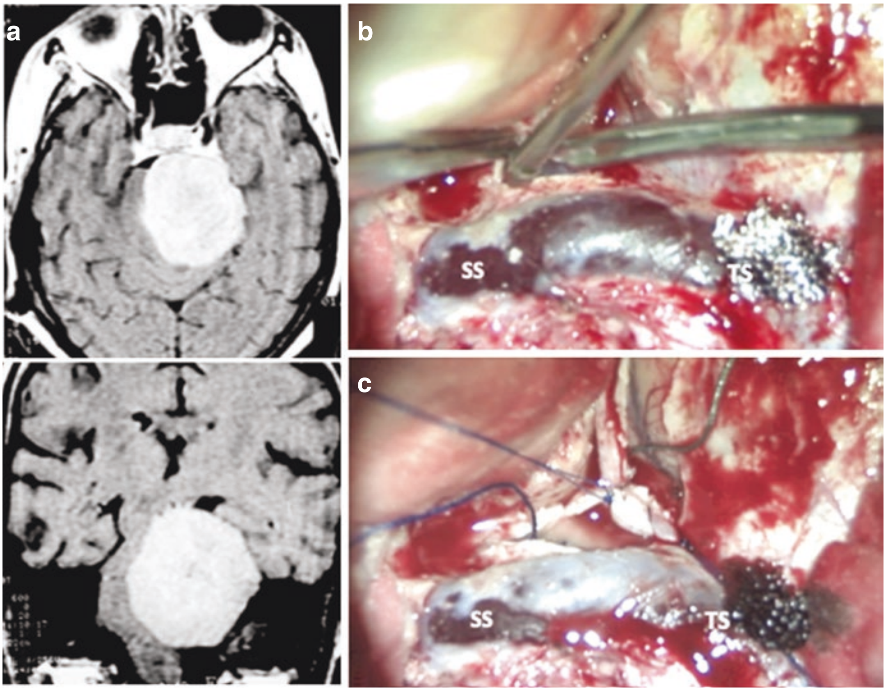


Fig. 27 Case 4. (**a**) MRI (T1-wGd) of a large left side petroclival meningioma. (**b**) Presigmoid approach with exposure of the sigmoid (SS) and transverse sinuses (TS). (**c**) Opening of the dura mater in front of the sigmoid sinus (SS) and in the middle fossa

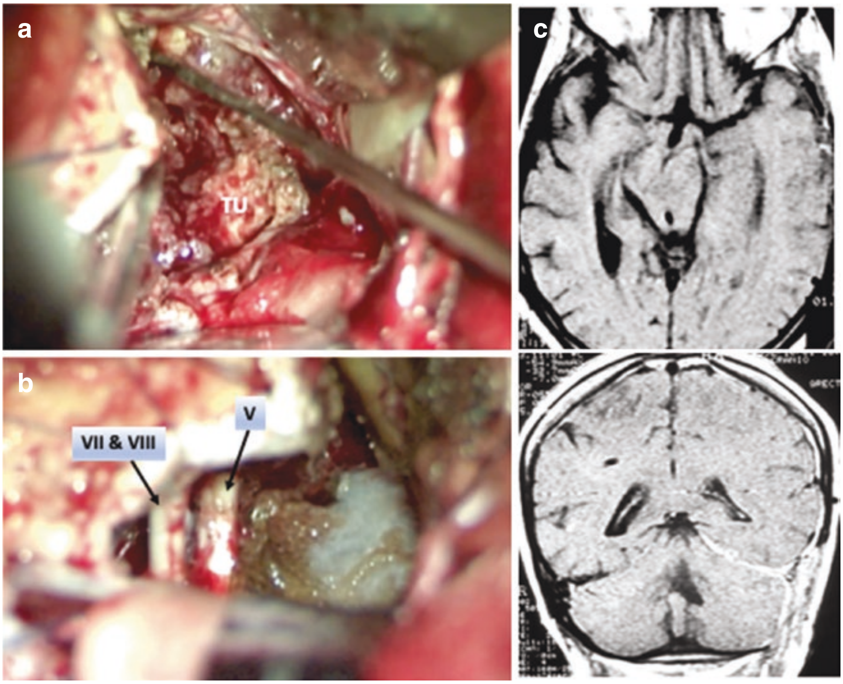


Fig. 28 Case 4. (**a**) Presigmoid approach to the CPA and middle fossa showing the meningioma in the cerebellopontine angle (TU). (**b**) After radical removal of the tumor the cranial nerves V, VII, and VIII are identified. (**c**) Postoperative MRI (T1-wGd) demonstrating radical removal of the tumor

7.5 Case 5: Epidermoid Cyst

This 43-year-old female patient complained of decreased hearing and facial pain on the right side. An MRI disclosed a large epidermoid cyst occupying the whole cerebellopontine cistern (Fig. 29). Radical removal with the cyst capsule was possible through the retrosigmoid approach, and all involved cranial nerves were preserved (Fig. 30).

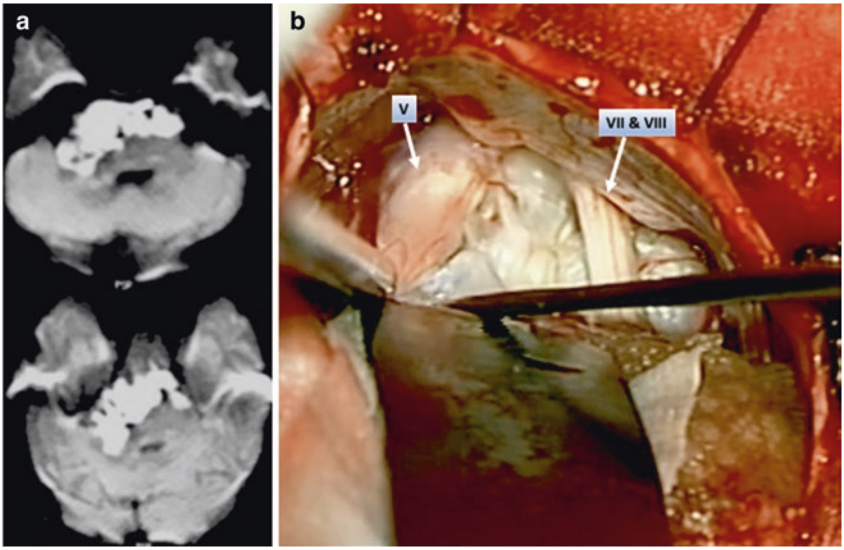


Fig. 29 Case 5. (**a**) MRI (diffusion scan) showing a large epidermoid cyst occupying the CPA and prepontine region. (**b**) Retrosigmoid approach showing epidermoid cyst medial to cranial nerves V, VII, and VIII

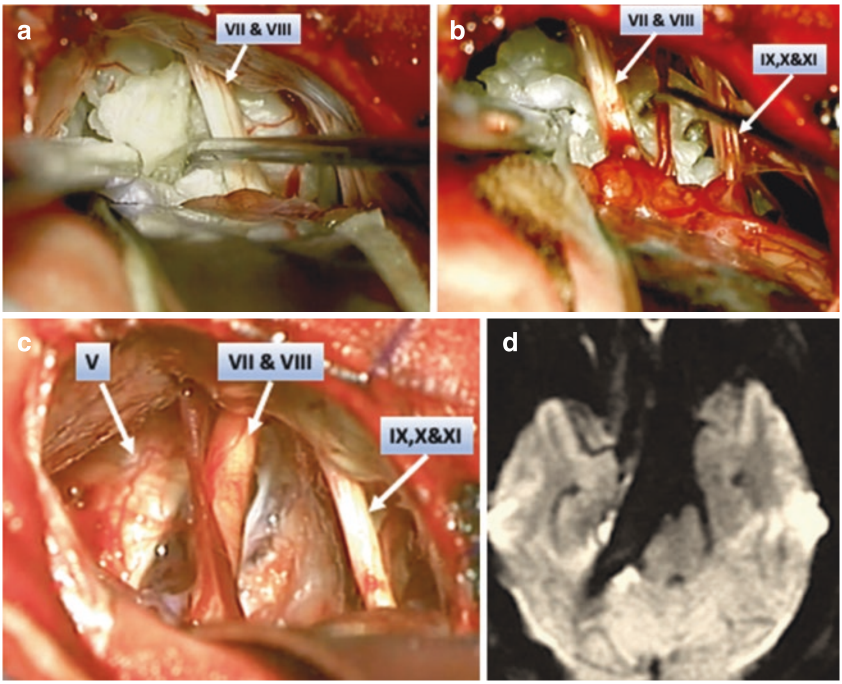


Fig. 30 Case 5. (**a**) Dissection of epidermoid cyst capsule from cranial nerves VII and VIII. (**b**) Epidermoid cyst medial to cranial nerves VII, VII, IX, X, and XI. (**c**) After radical removal the CPA and prepontine region are free from tumor. (**d**) MRI (diffusion scan) demonstrating radical removal of the lesion

7.6 Case 6: Trigeminal Neuralgia

A 63-year-old female presented a history of refractory left side hemifacial pain (V2 division of the trigeminal nerve) that started 4 years before. MRI showed a vascular compression of the trigeminal nerve at its entry zone at the brainstem (Fig. 31). Vascular decompression of the trigeminal nerve with interposition of a Teflon implant was carried out through the retrosigmoid approach (Fig. 32).

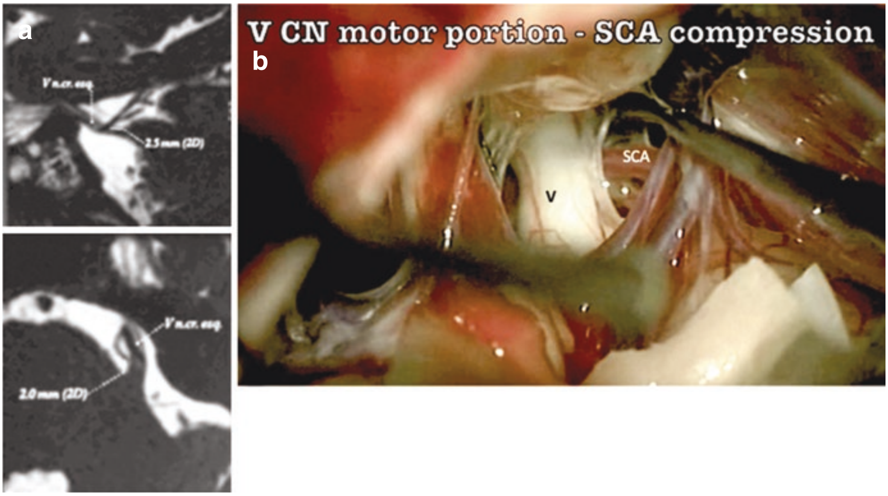


Fig. 31 Case 6. (**a**) MRI (T2-w) of a patient with left side trigeminal neuralgia. The trigeminal nerve (V) is compressed by the superior cerebellar artery. (**b**) Surgical view showing the trigeminal nerve (V) and the superior cerebellar artery (SCA)

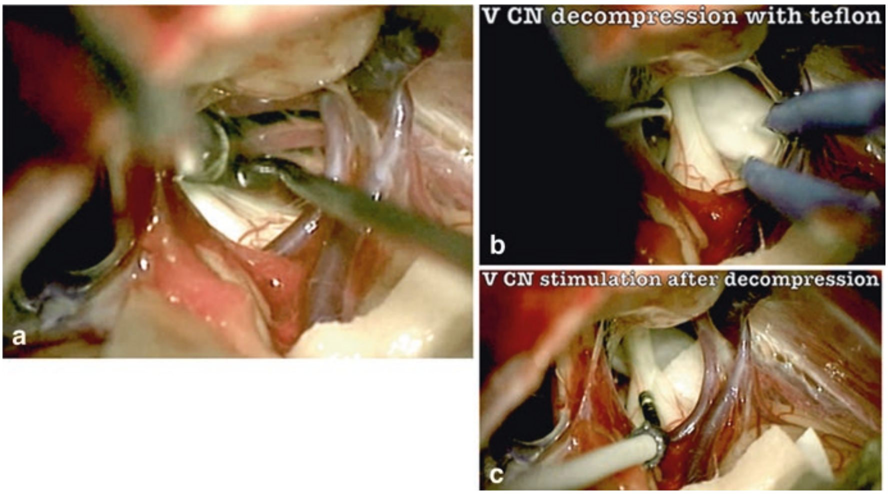


Fig. 32 Case 6. (**a**) The SCA is dissected from the trigeminal nerve at its entry-zone. (**b**) A small piece of Teflon in interposed between the nerve and the artery. (**c**) After vascular decompression, the trigeminal nerve is electric stimulated

8 Complications and How to Avoid

CSF fistula is a common complication after surgical removal of tumors and other pathologies involving the temporal bone and mastoid. It may occur with a frequency of 2% to 25% [49–51]. It may occur through the mastoid cells or externally through the skin (Table 1). Usually, it appears immediately or a few days after surgery, but it may develop in a delayed fashion. CSF fistulas may present a “low-flow” or “high-flow.” A thin-cut CT scan may demonstrate the area of leakage. High-flow CSF fistulas may be associated with pneumocephalus. In these cases, an immediate surgical exploration may be necessary. Endoscopy is very useful for identifying and sealing opened air cells within the internal auditory canal after drilling the internal auditory meatus through the retrosigmoid approach. If postoperative CSF-fistula develops, these opened air cells may be occluded through the mastoid (Table 1).

Dysfunction of cranial nerves is another possible complication after surgery of pathologies in the cerebellopontine cistern. Intraoperative monitoring is of fundamental importance to avoid damage to cranial nerves and brainstem. Postoperative facial nerve palsy after removing vestibular schwannomas or other lesions should be carefully treated with artificial tears and other measures for eye protection. Special care is needed in patients with facial analgesia and corneal reflex absent (trigeminal nerve deficit) to avoid corneal ulceration. In these cases, an early tarsorrhaphy should be performed. Lower cranial nerves neuropathy needs early identification and management. Patients with tumors requiring extensive surgical dissection around the caudal cranial nerves should be extubated in the ICU only after they wake up from anesthesia and a positive swallowing testing. Aspiration pneumonia is a very dangerous complication and may be the cause of postoperative mortality. Modified *barium* or direct laryngoscopy may be used to diagnose deficits of these nerves. Oral intake is allowed only after the normal function of swallowing is observed. Postoperative infection may occur due to intraoperative contamination, previous infection in the mastoid or ear, or postoperative CSF-fistula. Early recognition and adequate management are necessary to avoid meningitis.

Table 1 CSF-fistula types and management

CSF-fistula types	Prevention and management
Through mastoid cells	Prevention: First, water-tight dura closure. Fill all opened pneumatized cells with muscle graft or fat graft or bone wax and fibrin glue
	Management: Lumbar drainage, acetazolamide for 3 days. If it fails, reoperation
Subcutaneous	Prevention: Water-tight dural closure, if not possible, fascia or muscle flap rotation
	Management: Compressive dressing and lumbar drainage. In case of failure, reoperation

9 Pearls and Tips

1. The cerebellopontine region and the CPA have a complex anatomy with the presence of important neurovascular structures. A thorough understanding of this complex anatomy is essential to obtain a successful surgery with minimal complications.
2. Many pathologies may arise in this region requiring different treatment strategies.
3. Clinical examination and careful review of neuroradiological findings will determine the location of pathology, the differential diagnosis and help to delineate the best surgical approach.
4. Selection of the appropriate surgical strategy should be individualized for each case.
5. Surgical approach should be simple, avoid brain retraction and damage to healthy tissues, and preserve neurovascular structures.
6. Choice of surgical approaches depends on many factors according to etiology and extension of the lesion, involvement of cranial nerves, and surgeon's experience.
7. Intraoperative monitoring of cranial nerves and brainstem is very important during surgery in this area.
8. Adequate skull base reconstruction with water-tight dura closure will avoid postoperative CSF leak and achieve good cosmetic result.
9. Anticipating, avoiding, recognizing, and managing early surgical complications will improve outcomes and patients' quality of life.

References

1. Yasargil MG, Kasdaglis K, Jain KK, Weber HP. Anatomical observations of the subarachnoid cisterns of the brain during surgery. J Neurosurg. 1976;44(3):298–302.
2. Matsuno H, Rhoton AL Jr, Peace D. Microsurgical anatomy of the posterior fossa cisterns. Neurosurgery. 1988;23(1):58–80.
3. Key A, Retzius G. Studien in der Anatomie des Nervensystems und des Bindegewebes. Stockholm: Samson & Wallin; 1875.
4. Liliequist B. The subarachnoid cisterns. An anatomic and roentgenologic study. Acta Radiol Suppl. 1959;185:1–108.
5. Lewtas NA, Jefferson AA. The carotid cistern. A source of diagnostic difficulties with suprasellar extensions of pituitary adenomata. Acta Radiol Diagn (Stockh). 1966;5:675–90.
6. Amundsen P, Newton TH. Subarachnoid cisterns. In: Newton TH, Potts DG, editors. Radiology of the skull and brain, Ventricles and cisterns, vol. 4. Great Neck, NY: MediBooks; 1978. p. 3588–711.
7. Ballance CA. Some points in the surgery of the brain and its membranes. 2nd ed. London: Macmillan; 1908.

8. Koerbel A, Gharabaghi A, Safavi-Abbasi S, Tatagiba M, Samii M. Evolution of vestibular schwannoma surgery: the long journey to current success. Neurosurg Focus. 2005;18(4):e10.
9. Olivecrona H. Acoustic tumors. In: Winther K, Krabbe K, editors. III Congrès Neurologique International, Copenhague, 21/8–25/8 1939. Comptes Rendus des Séances. Copenhague: Einar Munksgaard; 1939. p. 761–71.
10. Crabtree JA, House WF. Transtemporal bone microsurgical removal of acoustic neuromas X-ray diagnosis of acoustic neuromas. Arch Otolaryngol. 1964;80:695–7.
11. Hitselberger WE, Raney AA. Transtemporal bone microsurgical removal of acoustic neuromas. Neurosurgical thoughts comparing suboccipital and tranlabyrinthine approaches. Arch Otolaryngol. 1964;80:754–6.
12. House WF, Hitselberger WE, Knouf EG. Transtemporal bone microsurgical removal of acoustic neuromas. Postoperative complications. Arch Otolaryngol. 1964;80:742–5.
13. House WF. Transtemporal bone microsurgical removal of acoustic neuromas. Evolution of transtemporal bone removal of acoustic tumors. Arch Otolaryngol. 1964;80:731–42.
14. Rand RW, Kurze T. Preservation of vestibular, cochlear, and facial nerves during microsurgical removal of acoustic tumors. Report of two cases. J Neurosurg. 1968;28(2):158–61.
15. Samii M, Gerganov VM, Samii A. Functional outcome after complete surgical removal of giant vestibular schwannomas. J Neurosurg. 2010;112(4):860–7.
16. Samii M, Gerganov V, Samii A. Improved preservation of hearing and facial nerve function in vestibular schwannoma surgery via the retrosigmoid approach in a series of 200 patients. J Neurosurg. 2006;105(4):527–35.
17. Rhoton AL Jr. The cerebellopontine angle and posterior fossa cranial nerves by the retrosigmoid approach. Neurosurgery. 2000;47(3 Suppl):S93–129.
18. Rhoton AL Jr. The posterior cranial fossa: microsurgical anatomy and surgical approaches. Neurosurgery. 2000;47(3 Suppl):S5–6.
19. Brackmann DE, Bartels LJ. Rare tumors of the cerebellopontine angle. Otolaryngol Head Neck Surg (1979). 1980;88(5):555–9.
20. Hitselberger WE, House WF. Tumors of the cerebellopontine angle. Tumors of the cerebellopontine angle. Arch Otolaryngol. 1964;80(6):720–31.
21. Mattei TA, Goulart CR, Lima JS, Ramina R. Differential diagnosis and surgical management of cerebellopontine angle cystic lesions. J Bras Neurocirurg. 2011;22(3):66–71.
22. Ramina R, Mattei TA, Sória MG, da Silva EB Jr, Leal AG, Neto MC, et al. Surgical management of trigeminal schwannomas. Neurosurg Focus. 2008;25(6):E6.
23. Roser F, Ebner FH, Ernemann U, Tatagiba M, Ramina K. Improved CT imaging for mastoid emissary vein visualization prior to posterior fossa approaches. J Neurol Surg A Cent Eur Neurosurg. 2016;77(6):511–4.
24. Moura da Silva LF Jr, Buffon VA, Coelho Neto M, Ramina R. Non-schwannomatosis lesions of the internal acoustic meatus-a diagnostic challenge and management: a series report of nine cases. Neurosurg Rev. 2015;38(4):641–8.
25. Bonneville F, Savatovsky J, Chiras J. Imaging of cerebellopontine angle lesions: an update. Part 1: enhancing extra-axial lesions. Eur Radiol. 2007;17(10):2472–82.
26. Bonneville F, Savatovsky J, Chiras J. Imaging of cerebellopontine angle lesions: an update. Part 2: intra-axial lesions, skull base lesions that may invade the CPA region, and non-enhancing extra-axial lesions. Eur Radiol. 2007;17(11):2908–20.
27. Ramina R, Maniglia JJ, Fernandes YB, Paschoal JR, Pfeilsticker LN, Coelho NM. Tumors of the jugular foramen: diagnosis and management. Neurosurgery. 2005;57(1 Suppl):59–68.
28. Ramina R, Tatagiba MS. Radiological diagnosis. In: Ramina R, Tatagiba MS, editors. Tumors of the jugular foramen. Cham: Springer International Publishing; 2017. p. 51–62.

29. Samii M, Gerganov V. Approaches to the cerebellopontine angle. In: Samii M, Gerganov V, editors. Surgery of Cerebellopontine lesions. Berlin: Springer-Verlag; 2013. p. 115–45.
30. Lang J Jr, Samii A. Retrosigmoidal approach to the posterior cranial fossa. An anatomical study. Acta Neurochir. 1991;111(3–4):147–53.
31. Ojemann RG. Retrosigmoid approach to acoustic neuroma (vestibular schwannoma). Neurosurgery. 2001;48(3):553–8.
32. Ramina R, Constanzo F, da Silva EB Jr, Coelho Neto M. Retrosigmoid transmeatal approach with 360-degree drilling of the internal auditory canal for the resection of intracanalicular meningioma. J Neurol Surg B Skull Base. 2019;80(Suppl 3):S311.
33. Cardoso AC, Fernandes YB, Ramina R, Borges G. Acoustic neuroma (vestibular schwannoma): surgical results on 240 patients operated on dorsal decubitus position. Arq Neuropsiquiatr. 2007;65(3A):605–9.
34. Engelhardt M, Folkers W, Brenke C, Scholz M, Harders A, Fidorra H, et al. Neurosurgical operations with the patient in sitting position: analysis of risk factors using transcranial doppler sonography. Br J Anaesth. 2006;96(4):467–72.
35. Gildenberg PL, O’Brien RP, Britt WJ, Frost EA. The efficacy of doppler monitoring for the detection of venous air embolism. J Neurosurg. 1981;54(1):75–8.
36. Porter JM, Pidgeon C, Cunningham AJ. The sitting position in neurosurgery: a critical appraisal. Br J Anaesth. 1999;82(1):117–28.
37. Samii M, Tatagiba M, Carvalho GA. Retrosigmoid intradural suprameatal approach to Meckel’s cave and the middle fossa: surgical technique and outcome. J Neurosurg. 2000;92(2):235–41.
38. Brackmann DE, Green JD Jr. Translabyrinthine approach for acoustic tumor removal. Neurosurg Clin N Am. 2008;19(2):251–64.
39. Briggs RJ, Luxford WM, Atkins JS Jr, Hitselberger WE. Translabyrinthine removal of large acoustic neuromas. Neurosurgery. 1994;34(5):785–90.
40. House WF. Translabyrinthine approach. In: House WF, Luetje CM, editors. Acoustic tumors, Management, vol. 2. Baltimore: University Park Press; 1979. p. 43–87.
41. House WF, Hitselberger WE, Horn KL. The middle fossa transpetrous approach to the anterior-superior cerebellopontine angle. Am J Otol. 1986;7(1):1–4.
42. House WF, Shelton C. Middle fossa approach for acoustic tumor removal. 1992. Neurosurg Clin N Am. 2008;19(2):279–88.
43. Kawase T, Shiobara R, Toya S. Middle fossa transpetrosal-transtentorial approaches for petroclival meningiomas. Selective pyramid resection and radicality. Acta Neurochir. 1994;129(3–4):113–20.
44. Brackmann DE. Translabyrinthine/transcochlear approaches. In: Sekhar LN, Janecka IP, editors. Surgery of cranial base tumors. New York: Raven Press; 1993. p. 351–65.
45. Ramina R, Neto C, Nogueira GF, da Silva EB Jr. Tumors of the petrous apex. In: Hanna EY, DeMonte F, editors. Comprehensive management of skull base tumors. 2nd ed. New York: Springer; 2021. p. 393–419.
46. Rhoton AL Jr. The temporal bone and transtemporal approaches. Neurosurgery. 2000;47(3 Suppl):S211–65.
47. Sekhar LN, Schessel DA, Bucur SD, Raso JL, Wright DC. Partial labyrinthectomy petrous apicectomy approach to neoplastic and vascular lesions of the petroclival area. Neurosurgery. 1999;44(3):537–50.
48. House WF, Hitselberger WE. The transcochlear approach to the skull base. Arch Otolaryngol. 1976;102(6):334–42.
49. Fayad JN, Schwartz MS, Slattery WH, Brackmann DE. Prevention and treatment of cerebrospinal fluid leak after translabyrinthine acoustic tumor removal. Otol Neurotol. 2007;28(3):387–90.

50. Sampath P, Rini D, Long DM. Microanatomical variations in the cerebellopontine angle associated with vestibular schwannomas (acoustic neuromas): a retrospective study of 1006 consecutive cases. J Neurosurg. 2000;92(1):70–8.
51. Stieglitz LH, Giordano M, Gerganov VM, Samii A, Samii M, Lüdemann WO. How obliteration of petrosal air cells by vestibular schwannoma influences the risk of postoperative CSF fistula. Clin Neurol Neurosurg. 2011;113(9):746–51.